THE ECONOMICS OF FARM WASTE DISPOSAL


Submitted in fulfilment for the degree of Doctor of Philosophy at the University of Surrey, 1973.
SUMMARY

Pollution is in vogue and this thesis deals with some aspects of pollution as well as waste management. The background and causes of today's problems are examined and the legal situation discussed. The nature of the material under discussion and its effects on the environment are established. Chapters 4 to 7 deal, in detail, with the methods for disposal and/or treatment and/or use of the material.

Chapter 8 attempts to delimit the size of the problem and Chapter 9 examines the consequences of bad or no management. The perspective of agricultural wastes in the Agricultural environment and in the National environment is then ascertained in Chapters 10 and 11. These latter two Chapters may, perhaps, be the most important as personal, subjective opinion from various sources is introduced. The facts established in the previous Chapters are used to determine the seriousness of the problems under discussion and the remedial actions that are available are examined from a cost/benefit basis. The benefits are subjective.

The final Chapter is simply labeled "The Future" and contains the inherent dangers of prediction.

Agriculture deals with natural resources and re-cycling of wastes is essential to the industry's success. Depletion of a resource may produce problems, as may an imbalance. This thesis concerns an imbalance; it is easy to ignore the situation as if it didn't exist.
"A bright idea came into Alice's head. 'Is that the reason so many tea-things are put here?' she asked.

'Yes, that's it,' said the Hatter with a sigh: 'it's always tea-time and we've no time to wash the things between whiles.'

'Then you keep moving round, I suppose?' said Alice.

'Exactly so,' said the Hatter: 'as things get used up.'

'But what happens when you come to the beginning again?' Alice ventured to ask.

'Suppose we change the subject,' the March Hare interrupted, yawning."

(Alice's Adventures in Wonderland, Lewis Carroll)
ACKNOWLEDGEMENTS

.........to Marie for typing, to Dr. Mike Burstall for three years of personal supervision, to Dr. David Reisman for help in preparation of the final draft, to Cedrick Nielsen and Charles Riley (both MAFF) for friendship and expert guidance, to Dr. Chris Bell and Dr. Dave Firth for the occasional suggestion, to numerous Institutions, Organisations, Establishments, and Universities for making available essential information to my wife for the incentive, to the Science Research Council and Social Science Research Council for their financial support, to my friends who have helped me, to my colleagues at work, and to my parents who made me at all possible in the first place.........

My sincere thanks
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td>(i)</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>(iii)</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>(iv)</td>
</tr>
<tr>
<td>PREAMBLE</td>
<td>(xiii)</td>
</tr>
<tr>
<td><strong>Chapter 1 - INTRODUCTION</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Definitions and Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 The Nature of the Changes</td>
<td>3</td>
</tr>
<tr>
<td>1.3 The Extent of the Changes</td>
<td>3</td>
</tr>
<tr>
<td>1.3.1 - Increase in Numbers</td>
<td>3</td>
</tr>
<tr>
<td>1.3.2 - Migration of Enterprises</td>
<td>3</td>
</tr>
<tr>
<td>1.3.3 - Distribution of Holdings</td>
<td>6</td>
</tr>
<tr>
<td>1.4 The Causes of the Changes</td>
<td>9</td>
</tr>
<tr>
<td>1.4.1 - Rising Farm Costs</td>
<td>10</td>
</tr>
<tr>
<td>1.4.2 - Decreasing Labour Force</td>
<td>10</td>
</tr>
<tr>
<td>1.4.3 - Decreasing Land Available</td>
<td>11</td>
</tr>
<tr>
<td>1.5 Summary</td>
<td>13</td>
</tr>
<tr>
<td><strong>Chapter 2 - THE LEGAL ASPECTS</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>14</td>
</tr>
<tr>
<td>2.2 Common Law</td>
<td>14</td>
</tr>
<tr>
<td>2.3 Statute Law</td>
<td>17</td>
</tr>
<tr>
<td>2.3.1 - River Pollution</td>
<td>17</td>
</tr>
<tr>
<td>2.3.2 - Disposal to Sewer</td>
<td>25</td>
</tr>
<tr>
<td>2.3.3 - Nuisances</td>
<td>25</td>
</tr>
<tr>
<td>2.4 The Applications of the Law</td>
<td>27</td>
</tr>
<tr>
<td>2.5 Comparative Legislation</td>
<td>31</td>
</tr>
<tr>
<td>2.5.1 - Belgium</td>
<td>31</td>
</tr>
<tr>
<td>2.5.2 - Denmark</td>
<td>34</td>
</tr>
<tr>
<td>2.5.3 - France</td>
<td>36</td>
</tr>
<tr>
<td>2.5.4 - Germany</td>
<td>37</td>
</tr>
<tr>
<td>2.5.5 - Netherlands</td>
<td>37</td>
</tr>
<tr>
<td>2.5.6 - Sweden</td>
<td>38</td>
</tr>
<tr>
<td>2.6 Summary</td>
<td>38</td>
</tr>
</tbody>
</table>
Chapter 3 - CHARACTERISTICS OF FARM WASTES

3.1 Introduction .................................. 40
3.2 Amounts of Farm Wastes ....................... 40
3.3 Physical Characteristics of Farm Wastes .... 43
   3.3.1 - B.O.D. .................................. 43
   3.3.2 - P.V. ..................................... 44
   3.3.3 - C.O.D. .................................. 44
   3.3.4 - U.O.D. .................................. 44
   3.3.5 - Pitts P.V. ................................ 45
   3.3.6 - S.S. ..................................... 45
   3.3.7 - % Water .................................. 45
   3.3.8 - P.E. ..................................... 46
   3.3.9 - N.P.K .................................... 46
   3.3.10 - % Protein ................................ 46
   3.3.11 - Measured Values ......................... 46
3.4 Effects of Manure Usage ....................... 55
   3.4.1 - Odour .................................... 55
      3.4.1.a - Prevention of Odour Production .... 56
      3.4.1.b - Destruction of Odours .. ............ 58
      3.4.1.c - Masking Agents ...................... 59
   3.4.2 - Toxic Trace Elements ..................... 60
   3.4.3 - Nutrient Imbalance ....................... 61
   3.4.4 - Effect on Soils ............................ 63
   3.4.5 - Disease Risks ............................. 64
3.5 Summary ....................................... 65

Chapter 4 - CLEANING, HANDLING, AND STORAGE

4.1 Introduction .................................. 67
4.2 Housing Methods ................................ 68
4.3 Cleaning Methods ................................ 71
   4.3.1 - Manual Cleaning ........................... 71
   4.3.2 - Manual/Mechanical Cleaning ............. 73
   4.3.3 - Automatic Cleaning ....................... 76
4.4 Handling Methods ................................ 80
   4.4.1 - Forks and Rakes ........................... 81
   4.4.2 - Grabs .................................... 81
   4.4.3 - Buckets .................................. 81
   4.4.4 - Bucket and Chain Elevators ............. 82
   4.4.5 - Auger Elevators ........................... 82
4.4.6 - Free Flow Channels ............... 83
4.4.7 - Pumps .................................. 83
4.5 Storage Methods .............................. 85
  4.5.1 - Compounds ......................... 85
  4.5.2 - Pits .................................. 87
  4.5.3 - Tanks .................................. 88
4.6 Comparison of Collection/Storage Systems 89
  4.6.1 - Dairy Enterprises ................. 90
  4.6.2 - Poultry Enterprises ............... 95
  4.6.3 - Piggery Enterprises.............. 96
4.7 Summary ..................................... 122

Chapter 5 - MANURE AS A FERTILISER

  5.1 Introduction .................................. 123
  5.2 Use of Synthetic, Inorganic Fertilisers ............ 123
  5.3 Use of Manure as Fertiliser ..................... 127
  5.4 Spreading of Manure ............................ 130
    5.4.1 - Solids Spreaders ........................ 131
    5.4.2 - Slurry Spreaders ....................... 131
    5.4.3 - Irrigation ................................ 134
  5.5 Costs of Spreading ............................. 134
  5.6 Summary ..................................... 137

Chapter 6 - TREATMENT OF FARM WASTES

  6.1 Introduction .................................. 138
  6.2 Separation of Liquids and Solids ............. 138
    6.2.1 - Screens .................................. 138
      6.2.1.a - Bar Screens ....................... 138
      6.2.1.b - Band Screens ..................... 139
      6.2.1.c - Rotary Screens .................... 139
      6.2.1.d - Parkwood Screens ................. 139
    6.2.2 - Presses .................................. 140
    6.2.3 - Centrifuges ................................ 140
    6.2.4 - Co-agulation ............................. 142
    6.2.5 - Flotation ................................ 142
    6.2.6 - Bales .................................... 143
6.6.2 - Roughing Treatment
6.6.2.a - Anaerobic Lagoons
6.6.2.b - Aerobic Lagoons
6.6.2.c - Anaerobic Digestors
6.6.2.d - Oxidation Ditch
6.6.2.e - Barrier Ditches

6.6.3 - Polishing Treatment
6.6.3.a - Plastic Modules
6.6.3.b - Bio-Discs
6.6.3.c - Charcoal

6.6.4 - Package Deals, Complete Treatment
6.6.4.a - Composting
6.6.4.b - Incineration
6.6.4.c - Zimpro
6.6.4.d - Boreholes
6.6.4.e - Halmarl

6.7 - Summary

Chapter 7 - DRYING AND OTHER USES

7.1 - Introduction

7.2 - Odour Problems

7.2.1 - Recirculation
7.2.2 - Scrubbing
7.2.3 - After Burners
7.2.4 - Ozonisation
7.2.5 - U.V. Irradiation

7.3 - The Dryers

7.3.1 - Flash Dryers
7.3.1.a - Raymond Flash
7.3.1.b - Scolari
7.3.1.c - Douglas Rowson

7.3.2 - Drum Dryers
7.3.2.a - Colman
7.3.2.b - Haro
7.3.2.c - Jones
7.3.2.d - M.F.E.
7.3.2.e - Orm
7.3.2.f - Sturtevant
11.3.1 - Background ........................................ 291
11.3.2 - Rivers Survey ........................................ 292
11.3.3 - C.B.I. Survey ........................................ 297

11.4 - Effects of Pollution .................................... 299
  11.4.1 - Fishing ............................................... 299
  11.4.2 - Boating ............................................... 300
  11.4.3 - Swimming ............................................. 301
  11.4.4 - Drinking Water Supply ................................ 301

11.5 - Methods and Costs of N and P removal .................. 302
  11.5.1 - Phosphorus .......................................... 303
  11.5.2 - Nitrogen ............................................. 304

11.6 - Summary .................................................. 305

Chapter 12 - THE FUTURE

12.1 - Introduction ............................................. 308
12.2 - External Factors ......................................... 308
12.3 - Internal Factors ......................................... 314
12.4 - Short-term Future ....................................... 315
12.5 - Long-term Future ........................................ 316
12.6 - Conclusions ............................................. 317

BIBLIOGRAPHY

APPENDIX 1 - Pitts P.V. Test
APPENDIX 2 - Two Pits, One Pump, No Problem
APPENDIX 3 - Pilot Questionnaire
APPENDIX 4 - Final Questionnaire
APPENDIX 5 - Coded Questionnaire
APPENDIX 6 - River Pollution Survey.
PREAMBLE

Throughout this thesis it has been necessary to bring cost data to a common basis. This has required certain assumptions and a standardisation of calculations. Therefore, although the source of any quoted costs is given, the quoted costs may be different from those of that source owing to the author's inflation, deflation, or re-calculation. The common base year is 1970 and all costs are at this level.

The Discounted Cash Flow (D.C.F.) method has been used to calculate annual capital charges. A 10% internal rate of return has been assumed (10% interest) and a lifetime of either 5 or 10 years depending upon manufacturers' estimates for new equipment or actual farm experience for existing equipment. The D.C.F. method has several theoretical attractions and advantages, not the least being that annual costs are brought to a here-and-now basis owing to the incorporation of the value of money in the future being less than at present. (Merret and Sykes, 1966).

For an initial capital sum £C borrowed at interest r for n years then repayments in each year are:

Year 1 - C1 + Cr
Year 2 - C2 + (C - C1)r
Year 3 - C3 + (C - (C1 + C2))r
Year n - Cn + (C - (C1 + C2 + ... + Cn))r
For equal payments each year:

\[ C_1 + Cr = C_2 + (C - C_1)r = C_3 + (C - (C_1 + C_2))r \text{ etc.} \]

Whence

\[ C_1 = \frac{C_2}{(1 + r)^{n-1}}; \quad C_2 = \frac{C_3}{(1 + r)^{n-2}}; \quad C_{n-1} = \frac{C_n}{(1 + r)} \]

But \( C = C_1 + C_2 \cdots + C_n \)

\[ = C_n \left\{ \frac{1}{(1 + r)^{n-1}} + \frac{1}{(1 + r)^{n-2}} \cdots + \frac{1}{(1 + r)} + 1 \right\} \]

\[ = C_n \left\{ \frac{1 - \frac{1}{(1+r)^n}}{1 - \frac{1}{(1+r)}} \right\} \quad \text{(Sum of series)} \]

\[ \therefore C_n = \frac{C\left(1 - \frac{1}{(1+r)}\right)}{\left(1 - \frac{1}{(1+r)^n}\right)} \]

Whence repayments = \( C_n + rC_n \)

\[ = C_n \left(1 + r\right) \]

\[ = \frac{Cr}{\left\{1 - \frac{1}{(1+r)^n}\right\}} \]
Certain costs have been inflated to 1970 prices and the following were used depending on the materials or products considered (Annual Abstract of Statistics, wholesale price indexes, 1963 = 100):

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<td>General Chemicals</td>
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<td>98.9</td>
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<td>Iron Castings</td>
<td>313/3,313/4</td>
<td>105.9</td>
<td>111.0</td>
<td>112.3</td>
<td>113.5</td>
<td>117.5</td>
<td>128.9</td>
</tr>
<tr>
<td>Agricultural Machinery</td>
<td>331</td>
<td>104.7</td>
<td>106.9</td>
<td>108.1</td>
<td>112.4</td>
<td>116.5</td>
<td>126.7</td>
</tr>
<tr>
<td>Common Building Bricks</td>
<td>461/2</td>
<td>112.4</td>
<td>114.2</td>
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<td>469/2</td>
<td>106.4</td>
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*Standard Industrial Classification.

Other price indices used were as follows (Annual Abstract of Statistics, Average 1964/65 – 1966/67 = 100):

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<tr>
<td>Barley</td>
<td>97.9</td>
<td>102.9</td>
<td>99.2</td>
<td>98.5</td>
<td>103.0</td>
<td>102.7</td>
</tr>
<tr>
<td>Oats</td>
<td>96.3</td>
<td>101.2</td>
<td>102.5</td>
<td>93.2</td>
<td>96.7</td>
<td>95.9</td>
</tr>
<tr>
<td>Fertilisers</td>
<td>96.0</td>
<td>99.8</td>
<td>104.2</td>
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<td>118.5</td>
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<td>Lime</td>
<td>90.6</td>
<td>105.8</td>
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<td>96.7</td>
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</tr>
<tr>
<td>Labour</td>
<td>92.6</td>
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<td>112.8</td>
<td>120.8</td>
<td>132.7</td>
</tr>
</tbody>
</table>
INTRODUCTION

1.1 DEFINITIONS AND BACKGROUND

According to Webster's Third New International Dictionary waste is 'thrown away or aside as worthless, defective, or of no further use during or at the end of a process'. In this context it is difficult to define farm wastes since the agricultural industry is one of the most efficient reclamation and re-cycling enterprises. With the changing structure of agriculture, however, the traditional outlets for some on-farm arisings are blocked and these products then become classed as wastes. Perhaps a better definition of farm waste is as a product for which its owner has no further use; it may have residual or reclamation value, but the individual or business producing the waste does not consider the process viable or desirable.

The most obvious, and by far the greatest, of farm wastes is that of animal manure. Farmyard manure (FYM) has, in the past, been considered as an invaluable asset having a vital part to play in maintaining the productivity of the soil, indeed the cornerstone of soil fertility. FYM is still important in many farming systems, although with the introduction of large-scale applications of inorganic fertilisers it is no longer the primary supply of plant nutrients, and has consequently become more of an embarrassment than an asset in many instances. This is due not to any change in the animals themselves, but to changes in the way they are housed and managed along with the ever increasing number of animals needed to satisfy the food demands of the human population. These reasons will become more apparent in the following sections.

It is as well firstly to look at the traditional image of a British mixed farm and its systems used for waste disposal, before examining the way the situation has changed and why past disposal
The small pre-War farm unit was a mixed enterprise using a handful of semi-skilled labourers. These labourers undertook the responsibilities in animal husbandry and crop husbandry; feeding, bedding and cleaning, planting, hoeing and harvesting. Animals and crops were interdependent, each providing the other with food, and requiring only semi-skilled labour to transport and spread muck onto the land or to distribute grain and food to the livestock. Cattle, pigs, and poultry were all free range and muck was evenly distributed over the pastures which, in turn, provided not only a vast sink to absorb the muck but also the required food for the livestock. Only when the animals were collected together did the muck need to be cleaned up and stored for use as a fertiliser - the milking parlour, the farrowing house, or the laying pens provided the collection points.

This mixed interdependent farm changed after the War and became more specialised dealing only in livestock or only in crops, and then in one type of animal or crop, eventually progressing into a monoculture enterprise specialising the production of, say, broiler chickens, bacon pigs, or winter cauliflowers. These trends led to the present-day enterprises or businesses where animals are housed throughout the year and therefore have to be cleaned out and the manure disposed of elsewhere.

Simultaneously, specialisation was accompanied by intensification; that is to say, not only were monocultures set up, but these monocultures also became very intensive and dairy herd size rose from 30 to 500, broiler flocks from 20,000 to 500,000, and pigs from hundreds to thousands on the same land area. Intensive units may buy in feed from outside and have no need for arable or pasture land. The animal are now housed throughout the year on some enterprises, under the supervision of a highly skilled husbandry manager. The highly skilled worker is reluctant to clean the manure from the animals,
1.2. THE NATURE OF THE CHANGES

Recent trends in farming patterns have resulted in more animals occupying less land and under less supervision. Herd sizes have changed in favour of larger units by less producers and there has been a migration of cattle, the largest waste producers, to the western regions of Britain. Cereal fields have become larger in the eastern regions.

The overall numbers of animals on British farms has increased and the overall agricultural acreage decreased.

1.3. THE EXTENT OF THE CHANGES

1.3.1 INCREASE IN NUMBERS

The primary reason for the increase in animal populations is the demand for food by the human population. Fig 1(1) illustrates the steady rise of the de facto or home population of the U.K. and hence the rising demand for food.

Figs. 1(2) - 1(4) illustrate the corresponding increases in cattle, pig, and poultry numbers respectively. Production of pigs has risen by about 300% since 1946 and fowls by about 100%. This reflects the relative ease of confining these animals to intensive units for breeding purposes. Cattle numbers have increased by about 29% and this smaller increase is due, in part, to the difficulties encountered during intensive beef or dairy operations. A further contributory factor in the rapid increase in pig production is the relatively short gestation period of 3 months allowing an easy response to market demands and prices. Cattle are naturally, slower to respond.

1.3.2 MIGRATION OF ENTERPRISES

Fig. 1(5) shows the change in distribution and numbers of cattle. The highest densities per 1,000 acres of agricultural

Source: Annual Abstract of Statistics, HMSO.
FIG. 1(2)

Total Cows, Calves, Heifers, and Bulls for Service in UK. [at June each year]

Source: Annual Abstract of Statistics, HMSO.

CATTLE in millions

YEAR

50 54 58 62 66 70

46 50 54 58 62 66 70
FIG 1(3)  Total pigs, sows, and boars in U.K.
(at June each year)

Source: Annual Abstract of Statistics, HMSO:
Cattle per 1,000 acres of agricultural land,
1875.

Cattle per 1,000 acres,
1938.

Cattle per 1,000 acres,
1966.
land are found in Cheshire and the adjoining counties, with an extension into Leicestershire. The other major centres are Somerset, with an extension into Dorset, and Cornwall, Pembroke, and Anglesey. The lowest densities appear in the hill counties and in East Anglia. The main Scottish concentrations have remained on the west coast from Renfrew to Galloway (dairy); and in Aberdeen, Fife, and the Orkneys (beef). These areas have maintained a tradition of cattle rearing throughout the past century.

Geographical reasons are the primary ones for the western movement of cattle. Cornwall has the longest grazing season for grass, which is the cheapest food for livestock. The warm, wet, western regions of Britain provide lush pastures that are ideal for outdoor grazing or for mowing to provide feed for zero-grazing units.

Fig. 1 shows the development of the regions providing grass for mowing. These are closely related to the cattle concentrations.

Fig. 1 shows the pigs development and distribution in Gt. Britain. Apart from the very large increases in numbers, a distinct move to the eastern regions is seen, along with concentrations in Cornwall and in Lancashire. The rearing and fattening of pigs for pork or bacon is no longer closely related to climate or soil type, since most pigs are now kept indoors. The location of the industry seems to have been determined partly by tradition, partly by the availability of feed, and partly by the proximity to large towns and hence markets. Cornwall and Lancashire, for example, will have extensive supplies of feed in the form of skimmed milk owing to the dairy industry being abundant in these areas, as was shown previously.
Acres of grass for mowing per 100 acres of crops and grass, 1875.

Grass per 100 acres, 1938.

Grass per 100 acres, 1966.
Pigs per 1,000 acres of agricultural land, 1875.

Pigs per 1,000 acres, 1938.

Pigs per 1,000 acres, 1966.
Fig. 1(8) indicates the areas that have built up fowls as an industry. Poultry lend themselves very easily to intensive methods of production. In 1884, the base year for this set of maps, in the absence of figures for 1875, the distribution of fowls was remarkably uniform in Britain. Only five English counties had less than 250 birds per 1,000 acres of agricultural land, (Dorset, Wiltshire, Westmorland, Cumberland and Northumberland), and only two counties had more than 500 per 1,000 acres (Cheshire and Lancashire). This almost accidental concentration of fowls in Cheshire and Lancashire became accentuated in the 1930's when the Fylde (lowland region between the estuaries of the Wyre and the Ribble) became the centre of industry. Concentrations also began to appear in the South-East, Cornwall, and the Orkneys. However, with the move away from small or part-time poultry holdings to intensive management on larger holdings, the industry, being totally independent of soil type and climate, naturally preferred sites not too far from the principal markets. Lancashire retained its lead and concentrations built up in Worcester, supplying the West Midland conurbation, and the South-East. Norfolk and Lincolnshire have also developed their traditionally intensive poultry industry.

About 94% of the total poultry in Britain are fowls (56.5% laying, 38.5% table birds, 5.0% breeding) with only 4.2% turkeys, 1.6% ducks, and 0.2% geese (MAFF, June 1972 Census). Therefore fowls are the largest contributors in terms of manure disposal problems; turkeys, ducks and geese traditionally having seasonal markets and so limited intensive enterprises are involved.

(Figs. 1(5) - 1(8) reproduced with permission of HMSO)
Fowls per 1,000 acres of agricultural land, 1884.

Fowls per 1,000 acres, 1938.

Fowls per 1,000 acres, 1966.
1.3.3 DISTRIBUTION OF HOLDINGS

There has been a divergence of the specialist enterprises. Animal units have become intensive and crop units extensive. Figs (1(9) - l(12) show how herd and flock sizes have changed from 1960 - 1968 together with the producers. All these livestock units are tending towards the larger herd or flock and these are being handled by less producers. These are the intensive units, larger herds occupying the same land and using less labour.

Along with the increased demand for food (Fig 1(1)) resulting in more animals (Figs 1(2) - 1(4)), there has been a less tangible demand - one for a better quality food. The emergence of intensive farming units has enabled stricter control over product quality along with the capacity for increased production.

During the period 1960 - 1968 the total number of agricultural holdings in England and Wales has fallen from 328,800 to 284,200. These holdings accommodate the increased animal numbers. (MAFF, The Changing Structure of Agriculture 1970).

Fig 1(13) demonstrates the trend to extensive wheat production with the average field increasing from 26 acres to 46 acres. This is generally paralleled by other cereals.

It is recognised that cattle, pigs and poultry produce the largest waste disposal problems in terms of livestock enterprises, and cereals in terms of crop enterprises. However, turkeys, sheep, and rabbits, although presenting little problem at present may show trends to intensification and specialisation similar to other livestock. These will be a source of waste and may present problems.
Percentage Distribution of Dairy Cow Producers:
[England and Wales]

Total '60 - 140,100
'68 - 96,800

- June 1960
- June 1968

Average herd:
'60 - 19
'68 - 28

Source: The Changing Structure of Agriculture, HMSO.
Percentage Distribution of Breeding Pig Producers.

[England and Wales]

Total '60 - 81,800
'68 - 51,700

- June 1960

Average herd:
'60 - 7
'68 - 14

- June 1968

Source: The Changing Structure of Agriculture, HMSO.
Percentage Distribution of Laying Fowl Producers

[England and Wales]

FIG I(i)

Total '60-216,500
'68-113,800

- June 1960
- June 1968

Flock size: 1,000-4,999 5,000-9,999 > 10,000

Percentage Distribution of Laying Fowls

[England and Wales]

Total '60-34.1m
'68-41.5m

- June 1960
- June 1968

Average flock:
'60-158
'68-364

Flock size: 1,000-4,999 5,000-9,999 > 10,000

Source: The Changing Structure of Agriculture, HMSO.
Percentage Distribution of Broiler Producers

[England and Wales]

Total: 1960 - 5.73m
1968 - 3.05m

Average Flock:
1960 - 2,262
1968 - 11,422

Source: The Changing Structure of Agriculture, HMSO.
Percentage Distribution of Wheat Producers

[England and Wales]

Total: '60-77,700 '68-50,600

Percentage Distribution of Wheat Acreage

[England and Wales]

Total: '60-200m acres '68-2.33m acres

Average field:
'60-26 acres '68-46 acres

Source: The Changing Structure of Agriculture, HMSO.
The turkey industry has experienced irregular growth from 5 million to 15 million poults in the past decade, the rates ranging from 1% to 28% per annum. (Morgan, M.C. 1972). The production is falling into fewer hands; from 7,000 to 4,000 producers in the last ten years with about a dozen holdings accounting for 80% of all turkeys produced, and these operate in units of over 5,000 birds.

85% of the poults supplied for fattening in England and Wales come from three master breeders with 60 or 70 subsidiaries. About 125 breeders account for the remainder of production concentrating on breeding their own strains in flocks of 50 to 60 hens. (Morgan, M.C. 1972).

This situation represents intensivisation of the industry on a large scale. As far as specialisation is concerned, the turkey has become almost unable to reproduce itself because the breast width makes it difficult for the male bird to mate. As a result, the major breeding organisations, without exception, use artificial insemination as standard practice.

The traditional market for turkeys is now expanding away from Christmas sales only and the main sales in 1971 were as follows (Morgan, M.C. 1972):

- Easter: 1,500,000
- Whitsun: 500,000
- Mid-Summer weekends: 300,000
- Weekends: 1,500,000
- Catering trade: 2,000,000
- Christmas: 7,000,000

Mr. Bernard Matthews, Chairman of the British Turkey Federation, forecasts nearly 50 million turkeys for 1993. This will add to the poultry industry's muck problems, but can be treated as being very similar to that of fowl production units.
Sheep

As yet, sheep are extensively bred out of doors on the large acreage hill farms and naturally deposit manure directly onto the land. The total number of sheep in Britain is virtually the same now as it was in 1867 — about 29 million (M.A.F.F. Century of Agricultural Statistics 1968). The concentration of sheep in the uplands is of comparatively recent origins. A map of 1875 would show densities on the clay lowlands of the Midlands, nearly as high as those in the uplands, while throughout the arable counties densities would exceed 50 sheep per 100 acres (Coppock, J.T. Agricultural Atlas of England and Wales, 1964). By 1938 the densities in most of Wales were higher than in any English county, making use of mountain land which was previously not farmed. Westmorland and Hereford are the highest stocked English counties, and in Scotland the concentration of sheep in the Border counties has been maintained throughout the century accounting for about 29% of all sheep in Great Britain in 1966 (M.A.F.F. A Century of Agricultural Statistics).

The extensive nature of sheep production has produced no needs for waste management at all. In-wintering of flocks is, however, becoming common and some units are experimenting with permanent housing for sheep. These systems of farming necessarily collect the manure into one place and this obviously calls for removal and disposal. If sheep production does become intensive to any large degree then waste management must be of prime consideration.

Rabbits

Rabbit production during the two World Wars was encouraged to convert kitchen and garden waste into protein, but no attempt was made to produce intensive farm enterprises. Since myxamatosis
in Britain in 1953 considerable interest has been shown in producing domestic, white-fleshed, rapidly-growing rabbits with a high meat-to-bone ratio. As yet intensive production has met with little success due to the bulk of the breedingstock being unable to withstand the rigours of large numbers in confined spaces (Parkin, R.J. 1972). Little genetic improvement of this breedingstock has occurred because of the lack of research in this infant industry.

The most favoured housing system at the moment is that of rows of raised cages of galvanised welded wire allowing faeces and urine to fall through onto the floor beneath the cages. This enables periodic cleaning and collection of the waste.

The size of the rabbit industry at present is uncertain as rabbits are not included in the M.A.F.F. yearly census. The Commercial Rabbit Association and the Agricultural Development and Advisory Service (ADAS) estimate that there are 100,000 breeding does in Britain owned by some 2,500 producers with 14 of these having over 200 does (Parkin R.J. 1972). The market demand for rabbit in Britain exceeds the supply, and in 1970 205,514 cwt of rabbit meat costing £2,649,000 was imported, mainly from China. The highest demand is in autumn and early winter, but domestic rabbits are difficult to mate during this period. However, with improved storage facilities and when the prejudice against rabbit meat caused by myxomatosis has been overcome, there would seem to be a good future for intensive rabbit production. This will bring the need for waste management.

1.4 THE CAUSES OF THE CHANGES

It is difficult to separate cause from effect in discussing the changes in the agricultural industry outlined above. Whether
a decreased labour force has resulted in or from intensive animal management is a matter for conjecture. However, whether causes or effects certain factors have paralleled the changes and these will be labelled as causes for the purpose of this thesis.

1.4.1 RISING FARM COSTS

Fig 1(14) depicts the net U.K. expenditure on farm rents and farm labour. Both show an upward trend but the expenditure on farm labour is somewhat irregular due to Government intervention via the Agricultural Wages Board established in 1940. The rising costs, particularly for rent and interest, will lead to a movement towards intensification using less land for the same amount of livestock. Rising costs for labour, although not as great as rent, will stimulate a movement towards less hired workers where possible.

Economies of scale are not difficult to detect and, generally speaking, each additional unit, whether it is a cow or an acre of wheat, costs less to maintain than the average unit. Thus a trend to intensive livestock or extensive crop production causes decreasing unit costs but increasing net overall costs.

1.4.2 DECREASING LABOUR FORCE

Fig 1(15) depicts the fall in the agricultural work force and fig 1(16) may illustrate the reason. Despite the increasing bill for farm labour (fig. 1 (14)), the wages paid to agricultural workers have not kept pace with the increase in wages paid to all manual workers. Real wages were only just maintained in the immediate post-war period and actually decreased from
FIG 1(14)

Sources: Annual Abstract of Statistics, HMSO,
Estimated net UK Expenditure on
Farm Rents and Interest. [at May]

Estimated net UK Expenditure on
Farm Labour. [at May]
FIG(115)

Numbers of Regular whole-time, Part-time, Seasonal, and Casual Agricultural Workers in Great Britain.

Source: A Century of Agricultural Statistics, HMSO.
Average weekly earnings of:

- whole-time agricultural men at Sept. [- at March]
- all manual workers at April [- at Oct.]

Sources: Annual Abstract of Statistics, HMSO.
A Century of Agricultural Statistics, HMSO.
1949-1955. Since 1955 a real increase in wages, although adding to the farm's wage bill, has not been as great as for other workers outside agriculture. There is no wage structure which allows for advancement with age, skill, or training and the maximum wage is paid at the age of twenty. (Cowling, et al 1970).

The real increase in the cost of agricultural labour stemming from or resulting in a decrease in the labour force will tend to promote intensivisation where less labour is required.

1.4.3 DECREASING LAND AVAILABLE

The rising population, as depicted in Fig. 1 (l), requires housing, factories for employment, and areas of roads for transport and communications. This demand of the human population for more of the available land in Britain is termed "urbanisation". The British Nation views its land with sentiment and self-delusion; living in cities and dreaming of the country green and unspoiled as Constable saw it. The reality of urbanisation is now becoming apparent. It is unlikely that much urban development will take place on land used for rough grazing, for deer forests, for afforestation, or other non-agricultural purposes, since the greater portion of such land is unsuitable or undesirable for building. Most urbanisation will encroach upon arable and permanent grassland (Stone, P.A. 1970) the total area being about 27 million acres in England and Wales (M.A.F. F. June 1972 Census) with a further 3 million acres in Scotland and Northern Ireland (Annual Abstract of Statistics, 1971).

Less than half the 6,000 acres of good farmland excavated
for minerals each year can be restored to their original use (Personal communication, Council for the Protection of Rural England). It has been estimated (Council for the Protection of Rural England) that British agriculture loses 100,000 acres of land every year - an area the size of Rutland - 38,000 acres to urban development, 50,000 acres to afforestation, and 3,000 acres to roads and services. This is loss of good farmland, apart from the 130,000 acres of derelict land which is increasing by 3,500 acres per year.

At the beginning of this century 5% or 2 million acres, of Britain had been built on and today the figure is 10%. This is likely to be 15% by the end of this century but this land could be made good in two years by an increase in agricultural yield of 1.28% p.a. (Stone, P.A., 1970). The yields per acre of wheat, barley, and oats since 1946 are plotted in Fig 1 (17), and using these as an index of increased agricultural yields it is seen that a 1.28% p.a. increase can be comfortably expected. It seems, therefore, that agriculture can "afford" to lose land at its present rate to urbanisation.

However, the long-run trend in agricultural output per acre has been increasing for three reasons: improved methods of husbandry, better use of the land available by way of reduction in waste land and land improvements, and the use of a higher proportion of land for the most valuable types of production. Implicit in these three reasons is the formation of the specialist and/or intensive unit with its associated problems of waste disposal. Furthermore, in the past some of
FIG. 17. Estimated Yield per acre of:

- Wheat
- Barley
- Oats: in Great Britain[* in U.K.]

Sources: A Century of Agricultural Statistics, HMSO.
Annual Abstract of Statistics, HMSO.
MAFF Press Notices [Whitehall].
best agricultural land has been taken for development and such land produces about three times as much per acre as average land, and yields appear to be rising faster on the better land (Stone, P.A. - 1970).

Thus it can be seen that, although agriculture may be able to repair its losses to urbanisation, it may be important to steer urban development away from the better land. This will then reduce the losses that need to be made good by agriculture. The losses of land will also reduce the areas available to receive animal manures, though this loss may, as yet, be insignificant.

1.5 SUMMARY

This introduction has served to illustrate the changes that have occurred in the agricultural industry in the past two decades and have contributed to waste disposal problems on the farm.

The nature and extent of the changes have been discussed and their causes or consequences noted. The trends, if continued, will aggravate the waste disposal problems of the farm, and the trends seem likely to continue.

This thesis will examine the legal position of farms in terms of waste disposal and then outline past, current and possible future methods of waste management and treatment. The causes and the extent of the problems, as illustrated in this chapter, are an essential background.
CHAPTER 2
THE LEGAL ASPECTS

2.1 INTRODUCTION

The laws relating to farm waste disposal in the U.K. are covered on those specific Acts of Parliament which include articles on Water Pollution. The legislation is complex due partly to the coverage by common law and statute law, and partly to the differences existing between the legislation in England and Wales, Scotland, and Northern Ireland. In addition, statute law governs water pollution via many subjects such as public health, fisheries protection, radioactive waste disposal, harbours, water resources, as well as water pollution itself.

2.2 COMMON LAW

Under Common law the owner of land bordering on a river or stream has certain rights in respect of natural water courses running through his land. In John Young and Co. vs Bankier Distillery Co., these rights have been summarised as "Every riparian proprietor is thus entitled to the water of his stream, in its natural flow, without sensible diminution or increase and without sensible alteration in its character or quality. Any invasion of this right causing actual damage or calculated to found a claim which may ripen into an adverse right entitles the party injured to the intervention of the court". (W.H.O. 1967, Gowan, D. 1972).

Apart from discharges made under statute consent of the River Authority, no-one has any right whatever to introduce or direct into a stream anything but the water he has abstracted for domestic or agricultural use, and then only if the returned
water is not increased, diminished, or changed. Any person introducing effluent into a river without consent is at Common Law a prima facie wrongdoer.

Of course, if all riparian owners insisted on receiving water in its natural state major changes would be required in the methods of treating and disposing of polluting discharges. The operation of the Common Law was considered by the Armer Committee (Trade Effluents Sub-Committee of the Central Advisory Water Committee) in 1960 which recommended that no change be made. It is left to the good sense of the Courts to interpret Common Law so as to prevent injunctions suddenly closing down the activities of effluent-producing industries.

It is of interest that no definition of the term "pollution" is given anywhere in the U.K. legislation. Various Countries have attempted to define it and some examples are quoted (W.H.O. 1967).

1) Swiss Federal Law of 1955 - "Measures necessary to control the pollution or other deterioration of surface water and ground water shall be taken so that the health of man and of animals is protected, that groundwater and springwater is fit to drink, that surface water may be treated to render it fit for consumption and for industrial use, ........, that fish may live in it, ......., and that the countryside is not disfigured". These provisions constitute an indirect definition of water pollution. It is interesting to note that fish are used as an indicator of pollution, and they probably serve best as a visual means of assessing the state of a river.

2) French Law, 1964 - the provisions of this law aimed at "discharges, drainage, wastes, the storage, whether directly or indirectly, of materials of any kind, and more generally to anything liable to cause or increase the deterioration in quality
of waters, whether surface water, groundwater, or maritime territorial waters, by changing their physical, chemical, biological, or bacteriological characteristics".

3) Finnish Water Law, 1961 - pollution is defined as "the discharge of dirt, waste, liquids, gas, bark or other materials into watercourses in such a way that, directly or indirectly, a harmful blocking up of the watercourse, a harmful alteration in the water quality, obvious harm to fish, an appreciable decrease in the pleasantness of the surroundings, a danger to health, or any other injury to private or public interests, is caused". This resembles the Swiss definition in terms of the interference with the use of water rather than the French in terms of the harmful effects of pollution.

4) A more explicit definition is given in Belgian Law, 1950, making it illegal to discharge into waters anything that "is capable of harming the waters by making them either malodorous or putrescible, or harmful to the natural, or cultivated, or reared aquatic fauna and flora, or rendering them unsuitable for the watering of animals, the irrigation of land, or for industrial or domestic use."

In the absence of any corresponding U.K. definition the following have been held by the courts to constitute pollution under the Common Law:

1) rendering water unfit for domestic and agricultural purposes.
2) fouling a river so as to kill or drive away fish.
3) rendering water unsuitable for sheep washing or cattle drinking.
4) raising the temperature of water
5) adding hard water to a soft water stream
6) causing canal water to become offensive
7) fouling a stream by discharging sewage or trade waste into it.
8) throwing noxious refuse into a river (Wisdom, A.S. 1956)

Apart from the Common Law rights of riparian owners, it is Statute Law that comprises the bulk of the legislation.

2.3 STATUTE LAW

2.3.1 RIVER POLLUTION

The earliest reference to water pollution (Spiller, J.L. Chemistry and Industry 1963) appeared in 1388 prohibiting the throwing of dung, filth, garbage, etc. into ditches, rivers or other waters and places within about, or nigh to any cities, boroughs, or towns. A number of laws appeared in the 16th Century empowering Crown commissioners to penalise the casting of dung into the River Thames, or the unloading of ballast, rubbish, gravel or filth from vessels within a haven, road, channel, or river flowing to a port or town. It was not until the 19th century, when the water-carriage system of sewage disposal transferred the filth from the streets to the rivers, and the industrial revolution brought its consequent volumes of polluted liquids and solids, that water pollution was seriously considered. The 16th century acts were short lived and many of them local in their effects (W.H.O. 1967).

A number of acts appeared in 1847 with the aim of preventing the fouling of inland waters, and the first public health act was passed in 1848. This established local boards of health responsible for all sewers, their clearing, cleaning, and emptying,
so as to maintain them in a state that would not be a nuisance or injurious to health. The Act led to the formation in 1857 of a Commission to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses; in 1862 of a Select Committee of the House of Commons, to inquire into the best means of utilising the sewage of cities and towns in England, with a view to the reduction of local taxation and the benefit of Agriculture; in 1864 of a Select Committee to inquire into any plans for dealing with the sewage of the Metropolis and other large towns, with a view to its utilisation for agricultural purposes; in 1865 and 1868 of Commissions on river pollution prevention; and in 1869, 1875, and 1882 of Commissions studying sewage disposal. It is clear from the reports of the Commissions and Committees that agricultural land was thought the best place to deposit human sewage sludges in controlled areas of operation.

The work of the 1865 and 1868 Commissions led to the first legislation limiting the pollution of rivers by sewage and industrial wastes. This was the Rivers Pollution Prevention Act of 1876 with its amendments of 1893 and 1898 remaining in force until 1951. However, not only was Agriculture not mentioned as a polluting industry as such, but Agricultural land was also expected to absorb some of the other wastes to lighten the load on rivers. The Pollution Prevention Act prevented solid matter or liquid sewage being discharged into rivers, and also obliged local authorities to accept trade wastes into their sewerage system provided that the sewers were not thereby adversely affected and were large enough to receive them.
This Act provided the basis for further pollution legislation. Remembering the Common Law rights of riparian proprietors to abstract river water for agricultural purposes, and the absence of any specific definition of pollution, some guidelines of limits for upstream discharges became necessary. These were included in the establishment in 1898 of the Royal Commission on Treating and Disposing of Sewage (including any liquid from any factory or manufacturing process). This body remained in existence until 1915 and issued 10 reports under its chairman Lord Iddesleigh. These reports dealt very fully with the treatment and disposal methods for sewage and advised certain standards with which effluents should comply before being allowed to discharge into rivers. The "Royal Commission standards" taken from this report have become accepted as indicating acceptable quality for discharges, though these standards, or any others, have not been prescribed by Statute Law in the U.K.

The eighth report deals with the standards, and stated that channel experiments led the Commission to believe that 100,000 cubic centimetres of river water taking up not more than 0.4 gram of dissolved oxygen in 5 days is ordinarily free from pollution. This is more conventionally expressed as biological oxygen demand (BOD) of 4 parts per million (ppm), and the limiting 4 ppm served as the foundation for the Commission's standards. Temperature was noted to be important and 65°F (18.3°C) was adopted as the standard. The dissolved oxygen uptake test was to be applied where a river received and mingled with a discharge, and the quality of the receiving water was
defined thus:

<table>
<thead>
<tr>
<th>Description</th>
<th>BOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very clean</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Clean</td>
<td>2 &quot;</td>
</tr>
<tr>
<td>Fairly clean</td>
<td>3 &quot;</td>
</tr>
<tr>
<td>Doubtful</td>
<td>5 &quot;</td>
</tr>
<tr>
<td>Bad</td>
<td>10 &quot;</td>
</tr>
</tbody>
</table>

It is obvious that river water already at 4 ppm cannot be used for dilution purposes. The Commission used the 2 ppm as the average state of river water under ordinary conditions, and recommended a standard of 20 ppm be set for effluent discharges. A clean river dilution of 8 times would result in a river of 4 ppm BOD. The dilution factor of 8 was safely assumed since "the great majority of effluents are diluted by more than 8 times their volume of river water".

Similarly, suspended solids (SS) content of effluents was said in the fifth report (Cd. 4278. HMSO 1908) to be not more than 30 ppm after normal treatment.

Thus the standards recommended for effluents discharging into rivers was taken as 20/30, or 20 ppm BOD and 30 ppm SS maximums. Sewage authorities could consistently reach these standards but as population increased and discharges into rivers consequently increased, these standards became harder to attain due to overloading of sewage works and also because increased discharge volumes decrease the useful dilution factor. Agricultural wastes, such as manures, have very high BOD and SS contents and discharge to rivers untreated is thus not compatible with these standards.

The final report in 1915 recommended the establishment of the Water Pollution Research Laboratory (WPRL) which now has extensive interests in farm waste disposal.
More recently, the Salmon and Freshwater Fisheries Act, 1923, provides in Part 1, Section 8, that "No person shall cause or knowingly permit to flow, or put or knowingly permit to be put, into any waters containing fish, or into any tributaries thereof, any liquid or solid matter to such an extent as to cause the waters to be poisonous or injurious to fish or the spawning grounds, spawn or food of fish....". The penalties are a fine not exceeding £50 for the first offence and not more than £5 every day during which the offence is continued after conviction. A third conviction also renders the offender liable to imprisonment with or without hard labour for not more than three months in lieu of any fine to which he is liable.

In 1937 the Central Advisory Water Committee's findings led to the Public Health (Drainage of Trade Premises) Act which did not include agriculture as an industry.

Perhaps the most notable Act as far as the farming community is concerned is the Rivers (Prevention of Pollution) Act, 1951, which applies only to England and Wales. The corresponding Act for Scotland is the Rivers (Prevention of Pollution) (Scotland) Act 1951, differing only in certain aspects of legal procedure. In Northern Ireland the Rivers Pollution Prevention Act, 1876, discussed earlier, remains in force (WHO 1967).

Sub-section 1 of Section 2 lays down that a person commits a punishable offence -

a) if he causes or knowingly permits to enter a stream any poisonous, noxious, or polluting matter.

b) if he causes or knowingly permits to enter a stream any matter so as to tend either directly or in combination
with similar acts (whether his own or another's) to impede the proper flow of the water of the stream in a manner leading or likely to lead to a substantial aggravation of pollution due to other causes or of its consequences.

The offence is punishable by a fine not exceeding £200 and £50 for summary conviction, and if shown to be a repetition or continuation of an earlier offence imprisonment for not more than 6 months.

However, no definition of the terms poisonous, noxious, or polluting appear in the Act. It has been said (Klein, L. 1962), that "these three words must have separate meanings; "poisonous" implies destruction of life, human or animal; "noxious" is lower in degree and signifies some injury, but not of necessity immediately dangerous to life; "polluting" will include both the other qualities and also what is foul and offensive to the senses"

Of interest to the Agricultural industry is the definition of "trade effluent" in Section 11 as "any liquid (either with or without particles of matter in suspension therein) which is discharged from premises used for carrying on any trade or industry, other than surface water and domestic sewage, and for the purposes of this definition any land or premises wholly or mainly used (whether for profit or not) for agricultural or horticultural purposes or for scientific research or experiment shall be deemed to be premises used for carrying on a trade or industry". This inclusion of agricultural land as trade or industrial premises has great bearing on future pollution legislation and limits the discharges from farms to come into line with other trade effluents, and presumably the Royal Commission standards will apply.
However, part of this Act applied only to new discharges and pre-1951 discharges were specifically exempted from Section 7 which made new discharges illegal unless consent from the river board was granted. The exemption was lost if the previous discharge was substantially altered. The position has since been altered in the Rivers (Prevention of Pollution) Act 1961 which controls pre-1951 discharges.

Thus all discharges into rivers and tributaries made after 27th July 1961 required consent of the appropriate river board. Farm effluents also came into the provisions laid down for trade effluents in the Public Health Act 1961, and implicitly the Public Health (Drainage of Trade Premises) Act 1937.

A major organisational change was brought about by the Water Resources Act 1963 which dissolved the 32 river boards and established 27 river authorities in England and Wales, and a Water Resources Board empowered to bring to the notice of the river authorities any inland water that needed to be improved and could be improved through exercising the powers of the Rivers (Prevention of Pollution) Acts 1951 and 1961. Whilst not changing existing legislation concerning prevention of pollution, the 1963 Act does make provision for protection of groundwater, and Section 72 makes it unlawful to "discharge into any underground strata within a river authority area -

(a) any trade effluent or sewage effluent, or

(b) any poisonous, noxious or polluting mater not falling within the preceding paragraph, except with the consent of the river authority.....and subject to any conditions imposed by the river authority......."
These conditions may relate to:
"(a) the nature, composition and volume of the effluent or other matter to be discharged;
(b) the strata into which it may be discharged;
(c) measures to be taken for protecting water contained in other underground strata through which any well, borehole or pipe containing the effluent or other matter will pass;
(d) the provision of facilities for inspection, including the provision, maintenance and use of observation wells and boreholes".

The penalty for illegal discharge or inability to meet the river authority's standards is a fine not exceeding £100. The river authorities reserve the right to enter and inspect trade premises for the purposes of taking away samples of effluents passing into -
"(a) any inland water in the river authority area, or

(d) any underground strata in that area"

The inclusion of underground water supplies in the legislative framework is of great importance to farmers. Spreading manure on the land or the use of storage heaps or soakaway ditches can directly lead to the leaching of polluting matter into underlying aquifers and render the farmer liable to prosecution.

The Rivers (Prevention of Pollution) (Scotland) Act of 1965 amended the Act of 1951 of the same title to bring Scottish legislation into line with that for England and Wales.
2.3.2 DISPOSAL TO SEWER

The Public Health Act, 1961 placing farms in the category of the trade premises, gave farmers the right to require the public health authority to receive the farm's wastes into the public sewer, and gave the authority the right to lay down conditions including charges, for such acceptance of wastes. These provisions apply to about 4,000 farmers (Gowan, D. 1972).

The costs to farmers of a local authority's acceptance can take two forms (Gowan, D. 1972). A "headage" basis can be applied where £5 per cow or £8 per pig (based on W.P.R.L. information) may be charged or an equitable basis may be adopted. The latter basis is used by most river authorities in the form of a "modified Mogden formula" using a treatability factor of x2 (i.e. farm effluents are twice as difficult to treat as human sewage) and taking into account the BOD and SS.

The former costs are probably the higher and act as a disincentive to farmers intending to discharge into sewers. The latter costs may vary from 1p to £1 or more per 1,000 gal (4,500 litres) (Jeger Report, 1970).

The Jeger Report recommended that farm wastes be kept out of the sewage system altogether (paragraphs 351 and 379), and Gowan (1972) estimates that a national expenditure of £150,000 p.a. is the current level for reception and treatment of farm wastes by local authorities.

2.3.3 NUISANCES

Statutory nuisances covered by the Public Health Act, 1936 are set out in Section 92 to include:

"(a) any premises in such a state as to be prejudicial to health or a nuisance;"
(b) any animal kept in such a place or manner as to be prejudicial to health or a nuisance;

(c) any accumulation or deposit which is prejudicial to health or a nuisance;

(d) any dust or effluvia caused by a trade, business, manufacture or process and being prejudicial to the health of, or a nuisance to, the inhabitants of the neighbourhood;

(e) ......

(f) ....""

In connection with (c) and (d), Section 93 makes it a defence to prove that the best practical means have been taken to avoid the occurrence of the statutory nuisance.

Section 37 requires all new buildings, and Section 39 all existing buildings, to have satisfactory drainage for foul water. Section 50 empowers the local authority to take action in respect of an overflowing or leaking cesspool. Section 80 empowers borough or urban district councils, and many rural district councils, to execute the removal of manures from a farm.

Section 259 requires the clearance of any pond, pool, ditch, gutter or watercourse which is foul or in a state prejudicial to health or a nuisance.

Certain Subsidiary acts are also of concern to farmers as regards general nuisance. The Prevention of Damage by Pests Act, 1949 deals with rat and mice infestations and repeals the Rats and Mice (Destruction) Act, 1919. The Noise Abatement Act, 1960 brings certain levels of noise and vibration into the statutory nuisance category, and the Clean Air Act, 1956 deals
with smoke emissions.

This latter Act is of particular relevance to the arable farmers who find it cheaper to burn straw after the harvesting of a cereal crop than to bale it. It is also of relevance to those operators of chicken manure driers.

The production of smells encountered whilst spreading farmyard manures seems to be covered under Common Law only, presumably due to the subjective nature of assessing smells.

Disease risks are covered by the Public Health Acts.

2.4 THE APPLICATIONS OF THE LAW

Having discussed the actual legal framework of pollution relating to farm wastes, to sewerage, and to nuisance, the applications and workings of the law can now be studied.

A consideration of the Iddesleigh Eighth Report reveals some interesting contradictions, sometimes in successive paragraphs. Since the Report lays down recommendations and not legislation these may not be of great importance, but for a River Authority working to the recommendations it must afford a certain degree of confusion. On the subject of the receiving water the Commission had this to report:

Paragraph 15 (c): "Quality and quantity of river water are, however, highly important local conditions of which account should be taken....."

Paragraph 16: ".....variations in the quality of the diluting water should not be taken into account...."

Paragraph 17: ".....the quality of the diluting water should be assumed to be constant.... " this being represented as
requiring 20 ppm dissolved oxygen in 5 days.

Paragraph 23: this paragraph insists that smaller than 8:1 dilution requires more stringent standards and greater dilution more relaxed standards. Again the Commission takes into account the receiving water.

These contradictions as to whether or not the receiving waters should be considered when setting standards for the effluent must confuse their actual applications.

The difficulties in laying down general conditions by law were recognised in the 1961 Rivers (Prevention of Pollution) Act. This repealed Section 7, Subsections (5), (6), (10), (11), and (17) of the 1951 Act which attempted to formulate general consent conditions. The favoured approach is now to consider individual cases and to set the standard accordingly.

The validity of the 5 day BOD test may itself be questioned as it was originally chosen to "...reflect....the observed conditions of the streams". (8th Report, Paragraph 9 (1)). However, a very small sample placed motionless in an incubator kept in the dark for 5 days barely represents the actual conditions of a flowing stream.

Somewhere in the history of the legislation and standards the temperature of the BOD test has risen from 18.3°C (65°F) to 20°C as laid down in the Ministry of Housing's Methods of Chemical Analysis as Applied to Sewage and Sewage Effluents (1956) under Determination of BOD (p55). The temperature quotient for bacterial activity, Q10, is about 2 for every 10 degree centigrade rise in temperature (Dixon, M. & Webb, E.C. 1966) and so the actual standard of 20 ppm at 18.3°C becomes 23.4 ppm at 20°C. Thus the 20/30 limit of today is slightly
more relaxed than that of the original Commission. This, however, is a very minor point, but taking the previous observations into account there may be a case for abandoning the Royal Commission standards as a working policy.

This point is raised in the Ministry of Housing's report on technical problems associated with complying with the Royal Commission's standards (HMSO 1966), and is dismissed by considering that river boards have used BOD tests and 20/30 standards as guidelines since their formation in 1948. There is also, apparently, a feeling of guilt or shame if local authorities release effluents not complying with the 20/30 standard. The real problems arise, apparently, when the 20/30 standard is insufficiently restrictive. The actual limits applied must be decided by the river authority and BOD and SS are still very much in wide use.

The Ministry of Housing's Report (1966) recommends that, as far as BOD is concerned, 15 ppm should be the next limit to 20 ppm. This is based on the inaccuracy and non-reproducibility of the 5-day test, it being considered that to set a limit of 12 ppm or 13 ppm is almost meaningless. The next limit would, then, be 10 ppm and more stringent limits are not advised on BOD grounds again due to the failings of the test. The report also recommends that bottom deposits, re-aeration phenomena, dilution factors, and rate of flow be taken into account before any limit is set. However, the end results of these considerations are inevitably subjective.

Greater emphasis is placed on the removal of SS as this in itself will also reduce the BOD as some of the solids will exert an oxygen demand, and many methods of reducing SS are discussed
in the report. Most of the methods can be dismissed from farm waste applications on the grounds of cost.

The BOD/SS standards are still in frequent use, but are gradually being complemented by, and in some cases replaced by, the concentrations of ammoniacal nitrogen, nitrate nitrogen, phosphorus, and potassium as standards for effluents. These will be discussed later under the Section on eutrophication.

It is obviously very difficult to monitor the discharges from farm premises as these will rarely be point discharges and will not be continuous. The River Authorities in England tend to take this into consideration when imposing standards and each case is discussed separately. The Avon and Dorset River Authority, for example, prefer to "impose realistic conditions such as 300/300 that can be enforced rather than ideal conditions such as 20/30 that the farmer hasn't a hope in hell of achieving" (Personal communication, 24/3/72). The same River Authority occasionally has to prosecute mainly for "accidental" discharges of silage liquor, but find that negotiation gives better co-operation than punitive measures.

The National Farmers' Union (NFU) is also of the opinion that silage liquor discharges constitute the bulk of the prosecutions (Personal communication, 14/3/72). The N.F.U. are aware that River Authorities are "taking a co-operative and helpful line over discharges of farm effluent and certainly very few cases come to us for attention".

In mid-1969 131,171 known discharges from farm to river were recorded; 2.65% were legal, 22.29% were pending consent, and 75.06% were illegal (Gowan, D. 1972). The N.F.U. estimate
there are about 12 successful prosecutions per year for these discharges, probably because the lack of mobile staff at River Authorities necessitates only serious pollution cases being prosecuted (Personal communication, 14/3/72).

In conclusion it can be seen that the laws applicable in Britain make it illegal to pollute water, but do not attempt to define pollution. Lord Iddesleigh's Commission attempted to lay down realistic standards as guidelines for operation, but in many cases farm wastes are allowed to be discharged above these limits. It will be apparent in later sections that farm wastes have particularly high BOD and SS levels making them difficult to purify to the 20/30 standard. However, the Royal Commission's guidelines have served well in the field of domestic sewage treatment, but River Authorities are loth to apply them to agricultural effluents often expressing both leniency and sympathy.

2.5 COMPARATIVE LEGISLATION

Having discussed both the actual laws and the applications of the laws in Britain, this Section will compare the situation in other European Countries. Their laws are not dealt with in depth, and only the restrictions on effluents are considered so as to establish their strictness or laxity compared with British standards.

2.5.1 BELGIUM

The Law of 11th March 1950 divides surface waters into three categories and delimits the effluents to be accepted by each.

Class 1: Waters used for drinking.

(i) The temperature of the receiving water as a result of accepting a discharge must not exceed 25°C.
(iii) the dissolved oxygen content must remain above 70% saturation.

(iv) SS contents of the effluent must not exceed 0.5 ppm as measured by a 2 hour settling period. (this was increased to 1.5 ppm by an Order of 3rd December, 1963).

(v) the SS content of the receiving water must not be increased by more than 60 ppm by all the effluents discharging into it.

(vi) the concentration of toxic substances of a water supply must not exceed the individual standards laid down by the Minister of Public Health and the Family.

(vii) all pathogens must be disinfected out of effluents.

(viii) the BOD (20°C, 48 hour) of supply water must not exceed 4 ppm.

Class 2: Waters used for the watering of animals and for fisheries purposes.

(i) the temperature of receiving water must not exceed 20°C in salmon stretches, 23°C in "mixed" stretches, and 25°C in carp stretches.

(ii) the pH must remain between 6.5 and 8.7.

(iii) the dissolved oxygen content in salmon and mixed stretches must not be less than 90% saturation, and carp stretches 70% saturation.

(iv) SS content of the effluent must not exceed 0.5 ppm in 2 hours (1.5 ppm after 3/12/63).

(v) SS content of the receiving water must not be increased by more than 60 ppm.

(vi) toxic substances entering the water must not render it unfit for industrial or agricultural use, exceed any stipulated maximum permissible level, or exceed any stipulated minimum lethal dose.
(vii) no malignant anthrax, symptomatic anthrax, tuberculosis, typhoid, or paratyphoid must enter the water.

**Class 3:** Waters used mainly for industrial purposes.

(i) the temperature of the receiving water must not exceed 30°C.

(ii) the pH must remain between 6.5 and 8.7.

(iii) the dissolved oxygen must not fall below 3 ppm.

(iv) the SS content of the effluent must not exceed 0.5 ppm (1.5 ppm after 3/12/63).

(v) the SS content of the receiving water must not be increased by more than 100 ppm.

(vi) no chemical compound may be introduced so as to render the water unfit for industrial or agricultural use.

The Crown Order of 3rd December, 1963 also introduced **Class 4:** Waters not suitable for uses previously mentioned, inter alia, those of drains, ditches, and pipelines of the public road system. The discharge of effluents containing faecal matter or wastes of industrial or agricultural origin into such drains is prohibited.

The laws in Belgium thus appear to be comprehensive as far as permissible effluent standards are concerned. Moreover, agricultural effluents are isolated in the 1963 Order and the following conditions are applicable:

(a) the effluents must not emit objectionable odours.

(b) the temperature of the effluents must not exceed 35°C.

(c) the pH must not be less than 6.

(d) the SS must not exceed 1.5 ppm over 2 hours.

(e) neither SS nor dissolved solids should produce objectionable or unhealthy emanations, nor should they produce any deterioration in the receiving water.
(f) the effluents must not contain fuel or lubricating oils, or petrol.

(g) the effluents must not contain pathogens.

(h) if faecal matter is present then the contents of a 150 ml glass flask, filled with the effluent, to which 0.4 ml of a 0.058% solution of methylene blue has been added, stoppered and stored at 20°C for 3 days, must not decolour the methylene blue dye.

(Methylene blue is a dye which can serve as an electron acceptor in the oxidation pathway of organisms. Under anaerobic conditions methylene blue undergoes this reduction to its colourless hydrogenated state) (Stannier, R.Y., Doudoroff, M., and Adelberg, E.A. 1966). Thus the Belgian law requires agricultural effluents to be in an aerobic state. (Anaerobiosis is associated with the production of odouriferous gases, and this will subsequently be discussed).

This comprehensive piece of legislation applicable to Belgium is apparently still far from satisfactory (WHO 1967).

2.5.2 DENMARK

The law still in force in Copenhagen is that of 30th November, 1857 which prohibits the depositing of "refuse, manure, slaughterhouse wastes, old rags, bones, etc. within 125 metres of....... and sludge from cesspits 315 metres of...." lakes, reservoirs, or open conduits belonging to the Water Board.

For the rest of Denmark a Law passed on 11th April, 1949 is in force. Section 5 (1) prohibits the introduction into watercourses of"....soil....sand, fertilisers....carcasses of animals....effluents from silos and liquid manure pits...."
Section 5 (2) prohibits discharge into watercourse or sea of "Effluents originating from...dairies...slaughterhouses, cow-sheds....."

These laws seem more general than the Belgian ones, but the Danish Engineers' Association drew up Standards in 1946, which act similarly to Britain's Royal Commission Standards in that they are only recommendations:

(a) the receiving waters must be capable of breaking down any organic matter in the effluent.

(b) the effluent must not be poisonous to fish.

(c) 5 day BOD of the receiving water must not exceed 10% of that of the effluent, and in any case 30-40 ppm.

(d) SS must not exceed 0.5 ppm after 2 hours.

(e) the biological state of drains used for conveying effluents must be in the $\alpha-\beta$ mesosaprobic zone.

(The saprobic classification of organisms relates to the observation that different species of animals occupy distinctly separate parts of organically polluted rivers. There are four categories:

1) Polysaprobic - highly polluted
2) $\alpha$-mesosaprobic
3) $\beta$-mesosaprobic
4) Oligosaprobic - little polluted

The category of the river is ascertained by identifying the type of organisms present and relating these to the four classes above, (Kolkwitz, R. and Marsson, M. 1908).

Section 11 deals more particularly with agricultural installations:

".....stables, cow-sheds, piggeries, liquid manure pits,
manure dumps...must be at least 15 metres distance from wells for domestic use. Covered drains and open channels for the discharge of waste waters must be sited more than 15 metres from wells...."

Section 13 empowers the Health Board to survey all likely pollution causing activities around public water supplies and remedy any adverse situations.

Thus, Denmark parallels Britain more closely than Belgium in that individual effluent discharges are allowed subject to the watchful eye of the Authorities rather than strict standards applicable to general situations.

2.5.3 FRANCE

Section 28 of the Law of 15th February 1902 prohibited "...the carcasses of animals, offal, dung, faecal matter... animal wastes to enter faults, swallow-holes, sinkholes, excavations of any kind, spring water, fountain water, wells, cisterns, conduits, aqueducts or reservoirs.

The Decree of 28th May, 1953 laid down the following conditions for "troublesome establishments":

(i) the pH must be between 5.5 and 8.5.
(ii) the temperature must not exceed 30°C.
(iii) the discharge of cyclic hydroxyl compounds and their halogen derivatives is prohibited.
(iv) the discharge of substances liable to give rise to abnormal smells, tastes, or colour.

In addition: (i) an industrial effluent discharged into a moderately polluted system must not exceed 1 ppm SS.
(ii) an industrial effluent discharged into a highly polluted system must not exceed 500 ppm SS.

(iii) the BOD of the effluent must not exceed 500 ppm.

Other standards are recommended for discharges into salmon reaches or shellfish beds and nitrogen content is accountable both as elemental and ammoniacal.

2.5.4 GERMANY

The law of 1st March, 1960 deals with groundwater pollution by liquids in Section 34 (1) and by solids in Section 34 (2). No conditions are laid down, but all discharges must have consent from the relevant Authority. Incidentally, Germany appears to be more concerned with pollution from radioactive wastes (Law of 23rd December, 1959) and detergents (Law of 5th September, 1961).

2.5.5 NETHERLANDS

The absence of any legislation at the National level on water pollution makes the position of the Netherlands somewhat unusual. The position is made more extraordinary by the high population density, high degree of industrialisation, and the fact that the major rivers crossing the Country have already been polluted to a considerable extent upstream (WHO Survey, 1967, p.83).

Each province has advisory committees and these liaise with industrial concerns in order to establish internal works regulations to limit pollution. The manufacturers of dairy products have an office in Arnhem which advises on agricultural effluents and the establishment of the Netherlands Association for Effluent Treatment promoted technical courses for the personnel of treatment plants.

The Netherlands relies on voluntary restrictions of pollution excepting radioactive wastes (Law on Nuclear Energy of 21st February, 1963).
2.5.6 SWEDEN

The basic legislation in Sweden is the Water Law of 28th June, 1918 and its subsequent amendments.

Notification of the establishment of any new dairies must be given to the Water Tribunal and any dairies already in existence wishing to alter their effluent disposal methods must first seek permission of the Water Protection Service. These two bodies may impose such restrictions or limits as they see fit.

2.6 SUMMARY

Where Countries have imposed certain standards for effluents, agriculture is normally treated separately as its wastes are unusually high in BOD and SS. The difficulties in complying with any limits are recognised and individual cases receive independent advice and help so as not to impose conditions that are technically or financially unattainable. Although the actual laws for each Country differ, the applications seem to be similar in that most laws are based on early 1900's Acts and their limitations are recognised.

Pollution is not satisfactorily defined in any of the laws and this omission obviously aggravates the task of applying them necessitating consideration of each individual situation separately.

It seems, therefore, that farm wastes should wherever possible be kept out of public sewage systems as any realistic limits are difficult to attain. It will become evident later that much technology is devoted to putting manure back to the land and assessing its value once there.
One of the difficulties in applying the law relating to farm wastes is that very few infringements will be from point discharges. Hence, farm wastes causing river pollution will be difficult to identify if a diffuse source is responsible. It is interesting that Britain's two legal frameworks, viz Common and Statute Law, operate for two different ends. Common Law protects individuals and is concerned with persons causing a direct nuisance to other persons. As such, the cases are proveable. However, Statute Law deals with offences to large masses and are extremely difficult to prove. It is virtually impossible, say, to prove that an industry releasing noxious or poisonous gases into the whole atmosphere is responsible for the death of a single person. Similarly, it is difficult to prove which farm out of hundreds may be discharging waste, perhaps unwittingly, into a river.

Despite the difficulties of operating Statute Law, the Agricultural industry in Britain does seem to be treated leniently.
CHAPTER 3

CHARACTERISTICS OF FARM WASTES

3.1 INTRODUCTION

This chapter will discuss the properties and effects of farm wastes. The properties will include easily measurable parameters that are inherent in the product's constitution and these properties often serve as yardsticks in assessing or identifying farm wastes. On the other hand, the effects to be discussed will be less tangible and more qualitative, but nevertheless important, effects of farm wastes on their immediate environment. To clarify this, an example of a manure's property is the percentage amount of water, whilst its effects would include how this water acts on, say, the soil where it is spread.

3.2 AMOUNTS OF FARM WASTES

Before discussing the inherent properties of farm wastes it is important to grasp an idea of how much material is being considered. Unfortunately there exists much contradictory information on this subject and difficulties also arise due to different feeding regimes, water availability, and the animals' state of health. A pig fed on whey mixed with water will obviously produce more waste, and a more liquid waste, than a pig fed on cereal-meal and concentrates.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Amount quoted expressed/day</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gals</td>
<td>m³</td>
</tr>
<tr>
<td>Dairy Cow</td>
<td>99 lb/day</td>
<td>9.9</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>44 &quot;</td>
<td>4.4</td>
</tr>
<tr>
<td>Sow</td>
<td>26 &quot;</td>
<td>2.6</td>
</tr>
<tr>
<td>Fat Pig</td>
<td>11 &quot;</td>
<td>1.1</td>
</tr>
<tr>
<td>Poultry (1)</td>
<td>0.2 &quot;</td>
<td>0.02</td>
</tr>
<tr>
<td>Animal</td>
<td>Amount quoted expressed/day</td>
<td>Equivalent</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>Gals</td>
<td>m³</td>
</tr>
<tr>
<td>100 lb pig: Van Slyke</td>
<td>8.4 lb/day</td>
<td>0.84</td>
</tr>
<tr>
<td>pig: Salter</td>
<td>9.5 lb/day</td>
<td>0.95</td>
</tr>
<tr>
<td>100 lb pig: Hart</td>
<td>2.8 lb/day</td>
<td>0.28</td>
</tr>
<tr>
<td>pig: Jeffrey</td>
<td>9.3 lb/day</td>
<td>0.93</td>
</tr>
<tr>
<td>100 lb pig: Taiganides</td>
<td>5.0 lb/day</td>
<td>0.50</td>
</tr>
<tr>
<td>100 lb pig: Schmid Lipper</td>
<td>9.0 lb/day</td>
<td>0.90</td>
</tr>
<tr>
<td>pig: Scheltinga</td>
<td>8.8 lb/day</td>
<td>0.88</td>
</tr>
<tr>
<td>pig: Scheltinga</td>
<td>6.85 lb/day</td>
<td>0.69</td>
</tr>
<tr>
<td>pig: Baxter et al</td>
<td>21.0 lb/day</td>
<td>2.10</td>
</tr>
<tr>
<td>96-103.6 lb pig: Robinson et al</td>
<td>9.55 lb/day</td>
<td>0.96</td>
</tr>
<tr>
<td>1,000 laying hens</td>
<td>0.14 ton/day</td>
<td>32</td>
</tr>
<tr>
<td>Cows (1100-1250 lb)</td>
<td>9 gal/day</td>
<td>-</td>
</tr>
<tr>
<td>Pigs (150 lb)</td>
<td>1 &quot;</td>
<td>-</td>
</tr>
<tr>
<td>1,000 laying hens</td>
<td>0.14 ton/day</td>
<td>-</td>
</tr>
<tr>
<td>Poultry (1000 birds)</td>
<td>57.1 gals/day</td>
<td>-</td>
</tr>
<tr>
<td>Pigs (fatteners)</td>
<td>2.7 gals/day</td>
<td>-</td>
</tr>
<tr>
<td>Cattle</td>
<td>15.1 gals/day</td>
<td>-</td>
</tr>
<tr>
<td>Dairy Cow (Typical)</td>
<td>12.0 gal/day</td>
<td>-</td>
</tr>
<tr>
<td>(1,000 lb)</td>
<td>8.0 gal/day</td>
<td>-</td>
</tr>
<tr>
<td>Calf</td>
<td>6.3 gal/day</td>
<td>-</td>
</tr>
<tr>
<td>Pig (Typical)</td>
<td>1.4 &quot;</td>
<td>-</td>
</tr>
<tr>
<td>(130 lb)</td>
<td>1.6 &quot;</td>
<td>-</td>
</tr>
<tr>
<td>Poultry (100 lb)</td>
<td>2.5 &quot;</td>
<td>-</td>
</tr>
<tr>
<td>Cow (450 kg)</td>
<td>35.7 lites/day</td>
<td>7.9</td>
</tr>
<tr>
<td>(550 kg)</td>
<td>54.3 &quot;</td>
<td>12.1</td>
</tr>
<tr>
<td>Calf (3 month)</td>
<td>28.6 &quot;</td>
<td>6.3</td>
</tr>
<tr>
<td>Pig (Porker)</td>
<td>5.4 &quot;</td>
<td>1.2</td>
</tr>
<tr>
<td>(Baconer)</td>
<td>7.3 &quot;</td>
<td>1.6</td>
</tr>
<tr>
<td>(Wet-fed)</td>
<td>14.3 &quot;</td>
<td>3.2</td>
</tr>
<tr>
<td>(Farrow Sow)</td>
<td>10.7 &quot;</td>
<td>2.3</td>
</tr>
<tr>
<td>Poultry (Adult layer)</td>
<td>0.74 &quot;</td>
<td>0.2</td>
</tr>
</tbody>
</table>
### TABLE 3(1) cont.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Amount quoted expressed/day</th>
<th>Gals</th>
<th>m³</th>
<th>lb.</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Cattle (900 lb) (7)</td>
<td>60 lbs/day</td>
<td>6</td>
<td>0.0270</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Cow Dairy (1000 lb)</td>
<td>1½ cuft/day</td>
<td>9.38</td>
<td>0.0420</td>
<td>93.8</td>
<td>42</td>
</tr>
<tr>
<td>Cow Beef (1000 lb)</td>
<td>1 &quot;</td>
<td>6.25</td>
<td>0.0280</td>
<td>62.5</td>
<td>28</td>
</tr>
<tr>
<td>Pig (250 lb)</td>
<td>0.35 &quot;</td>
<td>2.06</td>
<td>0.0093</td>
<td>20.6</td>
<td>9.3</td>
</tr>
<tr>
<td>1,000 layers @ 5 lb (8)</td>
<td>3 &quot;</td>
<td>18.75</td>
<td>0.0840</td>
<td>187.5</td>
<td>84</td>
</tr>
<tr>
<td>Cow (1,000 lb)</td>
<td>12.5 gal/day</td>
<td>-</td>
<td>0.0568</td>
<td>125</td>
<td>56</td>
</tr>
<tr>
<td>Calf (550 lb)</td>
<td>6.25 gal/day</td>
<td>-</td>
<td>0.0284</td>
<td>62.5</td>
<td>28</td>
</tr>
<tr>
<td>Pig (150 lb)</td>
<td>1.0 gal/day</td>
<td>-</td>
<td>0.0045</td>
<td>10</td>
<td>4.5</td>
</tr>
<tr>
<td>Hen (4.4 lb) (9)</td>
<td>0.03 gal/day</td>
<td>-</td>
<td>0.0001</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Cow (1100-1250 lb)</td>
<td>9 gal/day</td>
<td>-</td>
<td>0.0400</td>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td>Pig (150 lb) (dry fed)</td>
<td>1 gal/day</td>
<td>-</td>
<td>0.0045</td>
<td>10</td>
<td>4.5</td>
</tr>
<tr>
<td>Pig (150 lb) (wet fed)</td>
<td>1.5 gal/day</td>
<td>-</td>
<td>0.0067</td>
<td>15</td>
<td>6.7</td>
</tr>
<tr>
<td>1,000 layers</td>
<td>.14 ton/day</td>
<td>32</td>
<td>0.1440</td>
<td>320</td>
<td>144</td>
</tr>
<tr>
<td>1,000 broilers (from day old to 9 wks)</td>
<td>2.5 tons/9 wks = 88.8 lb/day</td>
<td>8.8</td>
<td>0.0400</td>
<td>88.8</td>
<td>40</td>
</tr>
</tbody>
</table>

(1) - Gowan, 1972 Slurry and Farm Waste Disposal

(2) - O'Callaghan, 1971 Characterisation of Waste Treatment

(3) - Jones, 1970 Symposium, Newcastle upon Tyne

(4) - Bartrop, 1970 "

(5) - Simpson, 1970 "

(6) - Weller, 1970

(7) - Loehr, 1967 Cattle Wastes - Pollution & Potential Treatment.

(8) - Wisconsin University, 1969 - Conference Proceedings.

(9) - Wheatland, 1970 Treatment, Use, and Disposal of Wastes from Modern Agriculture.

(10) - Planned Waste Management, July, 1970. (Distributed at Royal Agricultural Show, Kenilworth, 1970)
Table 3(i) shows the range of values cited in the literature for amounts per day.

As can be seen, therefore, a great discrepancy exists in the literature over manure production from individual animals. For the purposes of this thesis the MAAF figures quoted in Short Term Leaflet 67 will be used viz. Adult cow - 9 gals/day, adult pig - 1/gal/day, 1,000 hens - 1 ton/week.

In June 1972 there were 9,649,000 cattle, 6,862,000 pigs, and 106,450 poultry in England and Wales. The total amount of excreta produced by these animals is therefore somewhere in the region of 5,400 million gals (24 million cu.m.) per year. This does not include Scotland and Northern Ireland.

3.3 PHYSICAL CHARACTERISTICS OF FARM WASTES

As with the amounts produced, the physical and chemical properties of manures attract a lot of discrepancies in the literature. Before giving the values cited, some idea of the parameters in question will be discussed.

3.3.1 B.O.D.

This, as explained earlier, reflects a measurement of the oxygen demand at 20°C in 5 days. The demand is created by bacteria and other micro-organisms which use organic and inorganic matter in the water as a source of nutrients and requiring oxygen to efficiently respire these foods. This test is said to represent the actual state of affairs in a water course more closely than the other oxygen demand tests.

For the growth of a population of micro-organisms a carbon and nitrogen source is essential for the synthesis of the protoplasm of the cells, an energy source is necessary, and many inorganic trace elements are required. All of these factors will be shown to be present in manures and therefore capable of sustaining
biological growth.

Simple organic molecules such as glucose are completely oxidised in 5 days but more complex molecules found in sewage may only be 40% oxidised (Tebbut, 1971). The BOD test is assumed to follow first order kinetics for carbonaceous oxidation, and nitrification is presumed not to occur until 8-10 days have elapsed using raw wastes. However, using treated effluents the nitrogenous oxidation will become important and exert a high BOD. These factors are dismissed and the 5 day test is kept in preference to respirometer tests and the like which are probably too complicated for general usage (Tebbut, 1971).

3.3.2 P.V.

This is the permanganate value of the material and represents the oxygen absorbed from N/80 acidified permanganate in 4 hours at 27°C. This type of oxygen demand is exerted by easily chemically oxidisable material and is no reflection on the actual oxygen demand by living organisms. The main disadvantage of this test is the fact that it does only distinguish the easily oxidisable matter.

3.3.3 C.O.D.

This test uses acidified potassium dichromate (N/10) and is boiled for 2 hours. The strong oxidising conditions also measures the chemical oxygen demand (C.O.D.) of that material which is usually more resistant to both P.V. and B.O.D. tests. C.O.D. values are, therefore, generally higher than B.O.D. values for a sample as the oxidising conditions are capable of acting on a greater range of matter.

3.3.4 U.O.D.

The ultimate oxygen demand is the oxygen required over many
months at ambient temperature. This test is very rarely used due to the obvious time disadvantage.

3.3.5 PITTS P.V.

During the course of research the author and a colleague (C. Bell) recognised the need for a quick and easy oxygen demand test that could be carried out under field conditions. The above tests suffer from the need for long incubation times and the access to water baths and titration equipment. For on-farm testing these are unsuitable.

The simple test devised is appended as a reprint from Effluent and Water Treatment Journal (Vol. 12, No. 7, July, 1972 p 363-364) where it was first published. The name Pitts was given after the farmer who has now been monitoring his waste treatment system (described later) throughout the summer months of 1972. (Appendix 1 and 2).

The Pitts test has been shown to function as it was intended. It is extremely simple to operate out-doors and requires no skill with burettes or pipettes. Fig 3 (1) illustrates the apparatus required and the simple colour changes occuring during titration from the hypodermic syringe. The results are sufficiently reproducible by different people and present a farmer with an approximate idea of the amount of easily oxidisable material he is dealing with in his system.

3.3.6 S.S.

This, as described, earlier is a measure of the suspended solids content of material.

3.3.7 % WATER

The moisture content of manures is an important parameter for determining its suitability for solids/liquids separation, for drying, and also gives some indication as to its flow characteristics. This latter point is of obvious import when considering storage or distribution or transport of the material.
The apparatus.

Titration colour changes.
Fig 3 (2) shows some of the characteristics associated with different moisture contents. (This is modified from J.B. Weller's paper of the Newcastle Symposium).

3.3.8 P.E.

The population equivalent of an animal is usually a measure of the treatability of that animal's manure as compared to human sewage. It is not a widely used parameter as animal manures are very rarely treated in sewage works. However, it does give an indication of the size of the problems involved.

3.3.9 N.P.K.

The three basic plant nutrients found in fertilisers are nitrogen, phosphorus, and potassium. Nitrogen is usually measured and expressed as atomic nitrogen, phosphorus and phosphorus pentoxide $P_2O_5$, and potassium as potash $K_2O$. The values are usually given as % or as units. 1 unit is 1% of 1 cwt. (fertilisers are sold in 1 cwt bags) and is therefore 1.12 lbs weight. (0.51 kg).

There is a distinction between total NPK and available NPK which will become apparent subsequently.

3.3.10 % PROTEIN

This becomes an important parameter when considering the use of dried manures as an animal feed. Usually poultry manure is quoted as this has proved easier to dry due to its lower moisture content than cow or pig manure.

3.3.11. MEASURED VALUES

Having discussed the measurements taken and their uses, the values of these parameters are now presented. Again, the literature has provided a range of values from which to choose. Some of the more often quoted values are used here.

Table 3 (2) shows those parameters commonly in use in sewage engineering and compares sewage in the analysis along with
FIG. 3(2)

<table>
<thead>
<tr>
<th>Characterisation by moisture content.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRY MATTER</td>
</tr>
<tr>
<td>MATERIAL</td>
</tr>
<tr>
<td>ESCRIPTION</td>
</tr>
<tr>
<td>FLUIDITY</td>
</tr>
<tr>
<td>NORMAL HANDLING</td>
</tr>
<tr>
<td>METHODS</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>NORMAL EDGING</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>IN-SITU STORAGE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>XTTERNAL STORAGE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>DILUTION</td>
</tr>
</tbody>
</table>
some values for silage liquor and various washings which will be discussed in a later chapter.

It can be seen that domestic sewage is relatively innocuous. Although the B.O.D. and SS of man's personal excrement is high the large dilution afforded by flushing water, washing water, and trade wastes reduces the loads at the sewage works. The Jeger Report (1970) puts man's daily flushing and washing at 22 gallons per head. The apparent size of the problem Nationally can be illustrated by assuming 3 million cows, 9 million other cattle, 7 million pigs, and 130 million poultry exert P.E's of 30 m., 50 m., 17m., and 13m. respectively. This is equivalent to 110 million P.E's - twice the present population of U.K.

**TABLE 3 (2)**

<table>
<thead>
<tr>
<th>WASTE</th>
<th>C.O.D. ppm</th>
<th>B.O.D. ppm</th>
<th>P.V. ppm</th>
<th>S.S. ppm</th>
<th>% H2O</th>
<th>P.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dairy Cow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) typical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 1,000 lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) 1,100 lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Unspecified</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beef Cow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Unspecified</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Calf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) 900 lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>550 lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste</td>
<td>C.O.D. ppm</td>
<td>B.O.D. ppm</td>
<td>P.V. ppm</td>
<td>S.S. ppm</td>
<td>% H2O</td>
<td>P.E.</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
<td>----------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Pig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) typical</td>
<td>70,000(2)</td>
<td>27,000-33,000(2)</td>
<td></td>
<td></td>
<td></td>
<td>2.3(1)</td>
</tr>
<tr>
<td>150 lb</td>
<td></td>
<td>30,000(5)</td>
<td></td>
<td></td>
<td>85(6)</td>
<td></td>
</tr>
<tr>
<td>(b) 130 lb</td>
<td></td>
<td>27,500(1)</td>
<td></td>
<td></td>
<td></td>
<td>3.4(1)</td>
</tr>
<tr>
<td>(c) floor fed</td>
<td>71,949(4)</td>
<td>21,482(4)</td>
<td>3-5,000(10)</td>
<td>8,500(10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) pipeline water:meal 2.5:1</td>
<td>75,153(4)</td>
<td>21,992(4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) pipeline water:meal 4:1</td>
<td>47,134(4)</td>
<td>16,697(4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) 100 lb. liveweight</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,600(1)</td>
<td>2.6(1)</td>
</tr>
<tr>
<td>(b) Unspecified</td>
<td>170,000(2)</td>
<td>24,000(2)</td>
<td>66,667(5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) 1,000 hens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75(6)</td>
<td></td>
</tr>
<tr>
<td>Broiler litter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32(8)</td>
<td></td>
</tr>
<tr>
<td>Cage layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66(8)</td>
<td></td>
</tr>
<tr>
<td>Litter layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32(8)</td>
<td></td>
</tr>
<tr>
<td>Duck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95(8)</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55(8)</td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Domestic Sewage</td>
<td>400-100-300(2)</td>
<td></td>
<td></td>
<td>350(11)</td>
<td>350(11)</td>
<td>1</td>
</tr>
<tr>
<td>(b) Personal (undiluted)</td>
<td>43,000(1)</td>
<td>48,500(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot washings</td>
<td>2,800(7)</td>
<td></td>
<td></td>
<td></td>
<td>600(7)</td>
<td></td>
</tr>
<tr>
<td>Potato washings</td>
<td>1,100(7)</td>
<td>2,200(7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beetroot</td>
<td>1,600(7)</td>
<td>400(7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>1,200(7)</td>
<td>800(7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Celery</td>
<td>700(7)</td>
<td>600(7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage liquor</td>
<td>60,000(11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(1) Simpson, J.R. Newcastle Symposium 1970
(2) Miner & Willrich, Agricultural Practices and Water Quality. (Willrich & Smith Eds.) Ch. 16.
(6) Jones, Newcastle Symposium, 1970
(7) Barret, Newcastle Symposium, 1970
(8) Riley, Newcastle Symposium, 1970
(9) Wheatland, A.B. Sunningdale Conference, 1968 (MAFF)
(10) Gowan, D. 1972, Abstracted from Appendix 3.
The principles of sewage engineering work quite adequately when applied to farm wastes provided the dilution is sufficiently high. However, the costs of installing and maintaining sewage equipment on farms is prohibitive, and the vast quantities of water that would be necessary are unavailable. The Jeger report states (p.2) that about 60 gals water per head per day are discharged to the sewers and this amounts to some 3,100 million gallons per day total. To afford 60 gals diluting water per one P.E. to Agriculture would require a further 6,600 million gallons per day (60 gals x 110 m. P.E.). This demand would clearly not be possible to meet considering that the Second Annual Report of the Water Resources Board (HMSO, London, 1965) is of the opinion that readily accessible water supplies will soon be fully exploited. One-third of Britain's water is supplied by inland lakes, one-third by underground supplies, and one-third by rivers. (Downing, A.L., 1968)

To dilute and treat agricultural wastes by conventional sewage methods is not only impractical but probably undesirable. This is due to the NPK content of manures making them suitable as crop fertilisers. Table 3.3 shows the NPK contents most frequently quoted for the various classes of wastes as a % and expressed as units/ton of raw waste.
<table>
<thead>
<tr>
<th>Waste</th>
<th>N</th>
<th>P_2O_5</th>
<th>K_2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry (litter)</td>
<td>1.9</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Cows (manure)</td>
<td>0.53</td>
<td>0.26</td>
<td>0.53</td>
</tr>
<tr>
<td>Pigs (manure)</td>
<td>0.53</td>
<td>0.53</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Poultry (litter) 1.9 42* 1.8 40* 1.2 26*  
Cows (manure) 0.53 12* 0.26 6* 0.53 12*  
Pigs (manure) 0.53 12* 0.53 12* 0.36 8*  

Poultry 1.7* 38.0 1.4* 31.3 0.7* 15.6  
Cow 0.5* 11.2 0.2* 4.5 0.6* 13.4  
Pig 0.4* 8.9 0.2* 4.5 0.2* 4.5  

Layer (cate) 1.5* 33.5 1.2* 26.8 0.7* 15.6  
Layer (litter) 1.7* 38.0 2.1* 47.0 1.3* 29.0  
Broiler (litter) 2.3* 49.0 2.0* 44.7 1.3* 29.0  
Duck (Slurry) 0.6* 13.1 0.6* 13.1 0.1* 2.2  
Turkey 1.8* 40.0 1.4* 31.3 0.9* 20.0  

(1) MAAF, S.T.L. 67 1969  
(2) Berryman, C. Newcastle Symposium, 1970  
* - figures quoted, others calculated.  

Table 3 (4) is constructed as an average from several sources and was originally published by Willetts, S.L. (The Economics of Farm Waste Disposal, University of Surrey, 1971)  

<table>
<thead>
<tr>
<th>Material</th>
<th>%N</th>
<th>%P</th>
<th>%K</th>
<th>% H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Sulphate</td>
<td>21.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superphosphate</td>
<td></td>
<td>19.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium Chloride</td>
<td></td>
<td></td>
<td>60.0</td>
<td></td>
</tr>
<tr>
<td>Farm yard manure</td>
<td>0.6</td>
<td>0.3</td>
<td>0.6</td>
<td>76</td>
</tr>
<tr>
<td>Broiler manure</td>
<td>2.3-2.8</td>
<td>2.0-3.1</td>
<td>1.3-1.9</td>
<td>32</td>
</tr>
<tr>
<td>Deep-litter manure</td>
<td>1.7-2.2</td>
<td>2.0-2.4</td>
<td>1.3-1.6</td>
<td>32</td>
</tr>
<tr>
<td>Fresh poultry manure</td>
<td>1.2-1.5</td>
<td>1.0-2.1</td>
<td>0.6-0.7</td>
<td>73</td>
</tr>
</tbody>
</table>
(This table gives only the ranges of the most common manures. Full coverage is given in N.A.A.S. Advisory Papers No. 2. For the purposes of this thesis, however, only an indication of NPK content is required).

<table>
<thead>
<tr>
<th>Material</th>
<th>%N</th>
<th>%P</th>
<th>%K</th>
<th>% H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air dried droppings</td>
<td>3.5</td>
<td>2.5</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Slurry</td>
<td>0.6</td>
<td>0.3</td>
<td>0.2</td>
<td>94</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>1.0</td>
<td>0.8</td>
<td>0.2</td>
<td>55</td>
</tr>
</tbody>
</table>

It can be seen that the poultry manures have the more useful NPK values in terms of fertiliser use. Cow and pig slurries have low NPK contents, being about the same as domestic sludge. Storage of manures leads to a reduction in N and K content by leaching due to rain if uncovered, and to loss of N as ammonia even if covered.

Bernyman, C. (Newcastle Symposium, 1970) states that for cattle and pig slurries about 2/3 N, 3/4 P, and all K is available to the crops in the first year, and for poultry manures 4/5 N, 3/4 P, and all K is available. The residual nitrogen (1/3 N for pigs and cattle, 1/5 N for poultry) is resistant to bacterial breakdown and hence release to the crops and only one half of this becomes available again in the second year. The readily available nitrogen is in the form of urea and this may be almost completely lost if the slurry is applied before a rainfall. Alternate wetting and drying of a soil may lead to 26% loss of nitrogen as ammonia.

Much of the phosphorus in slurries is bound to organic molecules in the faecal matter and is slowly liberated throughout the growing seasons.
About 65% of potassium is present in the urine content of slurry and because it is highly water soluble most of it is immediately available to crops. (Berryman, FWD 8).

Table 3.(5) uses Berryman's data to compare nutrient availability in the first year:

**TABLE 3(5)**

<table>
<thead>
<tr>
<th>Manure</th>
<th>Available N %</th>
<th>Available N Units/ton</th>
<th>Available P2O5 %</th>
<th>Available P2O5 Units/ton</th>
<th>Available K2O %</th>
<th>Available K2O Units/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry</td>
<td>1.3</td>
<td>28</td>
<td>0.9</td>
<td>20</td>
<td>0.9</td>
<td>20</td>
</tr>
<tr>
<td>Cows</td>
<td>0.4</td>
<td>8</td>
<td>0.1</td>
<td>3</td>
<td>0.4</td>
<td>9</td>
</tr>
<tr>
<td>Pigs</td>
<td>0.4</td>
<td>8</td>
<td>0.3</td>
<td>6</td>
<td>0.3</td>
<td>6</td>
</tr>
</tbody>
</table>

Using these figures the equivalent cost of synthetic fertilisers can be derived. This puts a crude monetary value on the various manures as compared with replacement by synthetic NPK sources, but does not take into account the value of other constituents such as trace elements and humus. The humus content will be discussed at length in a subsequent Chapter. Table 3(6) gives values/ton.

**TABLE 3(6)**

<table>
<thead>
<tr>
<th>Manure</th>
<th>Ref</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry</td>
<td></td>
<td>£2.11</td>
<td>£1.98</td>
<td>£2.63</td>
</tr>
<tr>
<td>Cows</td>
<td></td>
<td>£0.58</td>
<td>£0.54</td>
<td>-</td>
</tr>
<tr>
<td>Pigs</td>
<td></td>
<td>£0.63</td>
<td>£0.58</td>
<td>-</td>
</tr>
</tbody>
</table>

(1) - MAFF S.T.L. 67
(2) - Muckmem 25. Internal publication of MAAF authored by C. Berryman, Bury St. Edmunds, 1965 using 3 pence per unit N, 2½ pence
Taking conservative estimates of the nutrient value of manures being £2.00/ton, £0.50/ton, and £0.50/ton for poultry, cows, and pigs respectively then the value of manure produced in England and Wales is about £65 Million/year. (10 million cattle, 7 million pigs, 110 million poultry producing 95 million tons, 10 million tons, 6 million tons per year worth £47.5 million, £5 million, £12 million respectively at 1970 prices).

It has been estimated that 80% of farm waste is put back to the land (C.T. Riley, personal communication) and 20% is deliberately treated in one form or another. The 30 million acres of agricultural land in England and Wales would absorb this 80% of manure at something like 2.95 tons/acre/ and all of the manure at 3.70 tons/acre. As will be shown later this is by no means an excessive amount.

The present problem does not therefore seem to be the availability of land on which to spread the manure, which is of obvious value to the crops or grass, but more the fact that manure is sometimes in the wrong place for its adequate disposal. The maps in Chapter 1 showing geographical distribution of animals will show the areas of the Country where manure is in excess, and subsequent chapters will show the areas of the Country where there is a heavy dependence on synthetic fertilisers.

**Protein Content**

The protein content of manures, poultry manure in particular, will be discussed fully in the Chapter dealing with the re-cycling of manures as an animal feed. (Chapter 7)

Having discussed the inherent properties of manures it can be seen that there are four distinct methods of disposal open to the farmer. These methods are, of course, subject to the legal
restrictions laid down in Chapter 2.

(1) NPK content used as plant nutrient by way of fertiliser.
(2) BOD load reduced in some way to enable more manure to be spread onto limited land or to allow complete discharge from the farm premises.
(3) Protein content used as an animal feed.
(4) Other uses of manure or manure by-products.

Before discussing these in detail it is important to study some of the limitations of the disposal methods. Thus the effects of manure on the environment are now discussed.

3.4 EFFECTS OF MANURE USAGE

3.4.1 ODOUR

The malodourous gases produced in farm wastes occur during storage and are due to anaerobic decomposition leading to the formation of hydrogen sulphide, ammonia, and mercaptans. (Peakin, F.H., A.R.C. Conference, Glasgow, September, 1972). Carbon dioxide, methane, ethylene, and nitrous oxide are also produced on storing farm wastes. The nuisance of odour is apparent at the point of delivery rather than the point of production and human habitation forms the area for most concern. The delivery of malodours over distances depend largely on topography and meteorology, and the effect of the delivery is difficult to estimate.

Smell and taste are referred to as the "chemical senses" and are relatively undeveloped in man. To illustrate this point, a 30% change in intensity is required for a just noticeable change in perception of odour (Hanson, S.W.F. Sunningdale Conference 1968) whereas hearing detects 10%, touch 0.5% and vision 1% changes in intensity. However, the relatively crude discrimination in intensity by the chemical senses is balanced by a higher appreciation
of "quality" and aesthetic association. The effect of an odour on the brain leads to a highly personalised and subjective emotion and this leads to the difficulty in determining or even measuring "acceptable levels of smell". As the Urban population gradually move into rural areas the complaints about smells naturally increase and farm wastes’ contribution to nuisances is highlighted.

The control of odours is attempted by three general methods; preventing odour production, destruction of the odour, or masking of the odour.

3.4.1(a) PREVENTION OF ODOUR PRODUCTION

(1) Aeration. Aeration is probably the simplest and cheapest method of preventing odour production. Wastes under aerated storage conditions do not have a chance to build up an anaerobic fauna and so the products of digestion are not in the reduced and hence malodourous state. The costs incurred during aeration are not very well documented as most research is directed to oxygen transfer characteristics and the economics are not considered in these pilot scale developments. However, costs may reasonably be expected to be high as the Electricity Council Research Centre at Capenhurst are experimenting with vertical shaft and Venturi aerators with a view to providing a "potentially attractive load for the Electricity Supply Industry".

The actual efficiencies of aerators is in the sphere of the Mechanical Engineer at present and some of the aerators commercially available will be briefly discussed in a later chapter.

As to the efficiency in odour prevention, the MAFF has conducted a series of trials to investigate the aeration of farm wastes in storage. The findings of the committee have not been published but the investigation has proven to be thorough
and costs have been considered in this project.

(2) Chemicals The use of certain chemicals to prevent the formation of malodour is in the experimental stage. Formaldehyde, potassium-hydroxy-methane-sulphonate, and ammonium persulphate have all showed promise in delaying the onset of putrefaction in waste storage. The costs of using chemicals, the required amounts, the length of time they remain active, and the effects of spreading or using wastes containing these additions are all being investigated in this country and in Sweden.

In the States, disinfection by addition of lime (calcium hydroxide) or chlorine (calcium or sodium hypochlorite) has been investigated. Hammond, Day, and Hansen reported on the efficiencies of these disinfectors to prevent anaerobic growth. Lime is said to raise the pH in sufficient quantities to about 11 and this inhibits any potential anaerobiosis while chlorine, a potent oxidising agent, destroys the bacteria responsible for malodour production. Calcium hypochlorite powder has 70% available chlorine and sodium hypochlorite liquid has 15% available chlorine, but the latter was used due to ease of mixing with the waste.

Chlorine treatment proved to be an effective deterrent of ammonia, hydrogen sulphide, methane, and carbon dioxide production and lime reduced hydrogen sulphide (not as efficiently as chlorine) but not ammonia.

| Gasses from Untreated and Treated Manure, Per cent by volume except NH3 |
|-----------------|-----------------|-----------------|
|                 | Untreated       | Lime-treated    | Chlorine-treated |
| pH              | 6.0             | 10              | 5.8             |
| NH3             | \(10.8 \times 10^{-5}\) g/l | \(8.5 \times 10^{-5}\) g/l | trace |
| CO2             | 4.25            | 0.47            | 0.60            |
| O2              | 16.93           | 19.40           | 20.60           |
| N2              | 78.78           | 79.90           | 78.80           |
| CH4             | 0.12            | 0.23            | 0.00            |
The relative costs of the treatments were documented as 62 ø per hog per 6 months for lime and $6.40 per hog per 6 months for chlorine. Both treatments also controlled maggots and rodents around the storage area.

3.4.1 (b) DESTRUCTION OF ODOURS

Removal of odour by destruction of malodourous particles is difficult because of the low concentration gradients and the non-linear relationship between odorant concentration and perceived intensity. This point was illustrated by Hanson (Sunningdale Conference 1968) with reference to a water-scrubber designed to produce a "97% reduction in malodour". Although the scrubber indeed achieved a 97% reduction in malodourous material the threshold of perception required a 99.9% reduction in malodourous material before a noticeable change is determined by the nose. Thus, a 97% reduction in malodourous material does not lead to a 97% reduction in malodour. The use of scrubbers therefore seems limited.

Destruction of the malodour by oxidation, chlorination, ozonation, incineration, and treatment with ultra-violet light and chlorine dioxide have all been investigated. Incineration or catalytic combustion appears to be the cheapest of these methods and this is only viable when connected to large installations with a profitable end product such as dried manure.

An enzyme preparation of fungi marketed as "Odourquell" in America has met with little success in this country. The author was present at its English trials in 1971 and there seems little future for this product. The makers claim widespread acceptance
in America and the action is believed to lie in the enzymes' destruction of both anerobic bacteria and malodourous products.

3.4.1 (c) MASKING AGENTS

The final alternative in odour control is that of masking the malodour so the "nose and brain add two smells and neutralise them", or a perfume that completely masks the original odour. Certain substances when submitted to the nostrils simultaneously result in the perception of neither one, such as cedarwood and rubber and camphor and juniper oil. (Hanson, Sunningdale Conference, 1968). Commercial odour-counterants are available, "Odourquell" also having this property. However, to be fully effective the two odours must not separate out when travelling over large distances and this is very dependent on weather conditions.

Thus, odour masks may not appear to be very successful. A further problem arises in that any mask may produce an odour that is itself objectionable to certain people.

The Penetone Co. Ltd. (Bassington Industrial Estate, Cramlington, Northumberland) market "Nodor" claimed to control odours in lagoons and effluent pits by combining the above activities. It inhibits growth and activity of sulphide-producing organisms, prevents fungal growth and hence decomposition of the waste and consequent putrefaction, and masks the odours. As this is a new product it has not been fully tested but is claimed to selectively act on malodour producing organisms whilst allowing normal decomposition of the waste odour-free.
3.4.2 TOXIC TRACE ELEMENTS

Spreading manure onto pastures may cause a build up of trace elements to levels either toxic to the crops or toxic to the animals that graze them. Little published work is available concerning these trace elements. Riley (Newcastle Symposium 1970) quotes some values for minerals and these figures have been calculated from them:

<table>
<thead>
<tr>
<th>Minerals as p.p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Hen manure:</td>
</tr>
</tbody>
</table>

Evans (Sunningdale Conference, 1968) quotes figures upon which the following are based:

<table>
<thead>
<tr>
<th>Minerals in p.p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry manure: Calcium</td>
</tr>
<tr>
<td>45,000</td>
</tr>
<tr>
<td>Sodium</td>
</tr>
<tr>
<td>4,000</td>
</tr>
</tbody>
</table>

The following figures are abstracted from NAAS Advisory Papers No. 2:

<table>
<thead>
<tr>
<th>Minerals in p.p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Cattle slurry:</td>
</tr>
<tr>
<td>Pig slurry:</td>
</tr>
<tr>
<td>Dried poultry manure:</td>
</tr>
</tbody>
</table>

The principal interests are centered around copper and arsenic levels. Copper is fed to pigs as a growth stimulant and brass nipple drinkers lead to copper being injected by young calves and pigs alike. At the levels indicated no problems
are foreseen but continuous application of pig slurry, sometimes with as much as 200 ppm copper, to the same fields may eventually result in toxicity problems in the plants (Berryman, C. 1970)

Ruminants grazing on grass drenched with a high copper pig slurry may be in danger since they are particularly susceptible to copper poisoning. Venn (Newcastle Symposium, 1970) has reported occasional cases of copper poisoning in sheep. The biggest danger is to housed lambs fed on hay grown in acid soils contaminated with pig slurry since acid soils result in an increased level of copper in the herbage.

Arsenical poisoning of stock may occur from feeding poultry manure containing arsenic. Arsenic was formerly given to poultry to control intestinal fauna so as to produce the highest possible feed conversion. Its use has now been banned, though some enterprises are said to still use it (Nielsen, V.C. personal communication, 1971)

Hypomagnesia is a disease characterised by low serum magnesium levels and may be relevant to stock grazing pastures that have received high dressings of nitrate and potash but no extra magnesium. The continuous use of slurries as fertilisers would point to a need to monitor magnesium levels to enable administration in cases of magnesium imbalance.

Lead poisoning is not considered a danger since lead levels are low (0.6 ppm in cattle slurry) and relatively high levels of 200 - 400 ppm are required before toxicity occurs in calves up to four months old (Allcroft, R.A. 1951).

3.4.3 NUTRIENT IMBALANCE

The heavy spreading of manures onto pastures and crops as a means of disposal may lead to nutrient balance problems.
Firstly, there is an obvious risk of nutrient overloading and the consequent change in botanical composition leading to coarser grasses and unproductive species such as nettles and thistles (Quick, Newcastle Symposium 1970, and Nielsen, V.C. personal communication).

Secondly there is the problem of the variable composition of the manures. The production of arable crops requires a fixed fertiliser regime for maximum efficiency and this will be discussed in a later chapter. Certain crops have specific nutrient requirements and the use of manure as a fertiliser is impractical for these arable crops since the nutrients may not be in the required ratio and may not be even known. Manures are certainly variable in composition and rigid fertilising practice cannot be achieved with a non-constant product. This limits the use of manures to grassland where nutrient requirements are less specific, and growth and harvest not as competitive or as husbanded as are arable crops.

The palatability of grass sprayed with slurry is also affected. Stock will refuse to graze pastures sprayed with slurries for periods of up to a month (Quick, Newcastle Symposium, 1970) and Quick has reported the suggestion that this is due to lowered sugar content in the herbage resulting from a high-nitrogen low-phosphorus fertiliser. Pastures can be made acceptable by spraying with sugar or molasses, but this is impractical in terms of time and money.

Spreading slurries onto pastures also acts as a transmitter of weed seeds.
3.4.4 EFFECTS ON SOILS

Spreading slurries onto soils may lead to a number of problems if the dressings are particularly high.

The sealing of the surface of the soil by slurries is termed "ponding" and prohibits the free transfer of gases from the atmosphere to the soil spaces and vice-versa. This leads to anaerobiosis in the soil pores and the production of ethylene and ammonia may create harmful effects. Ammonia is toxic to earthworms in particular and this may result in impeded soil aeration and drainage. Ethylene is especially damaging to plant roots (Meyer, B.S., Anderson, D.B. Böhning, R.H. 1968), and an anerobic soil atmosphere is therefore undesirable.

In addition to liquid ponding of soil surfaces there is also a danger of colloidal organic material in slurries choking the infiltration of slurry into the soil and again restricting free gaseous exchange. Drenching of a soil with liquid allows lubrication between the crumbs and a mass settling effect occurs (Berryman, C. Newcastle Symposium 1970). The water sorting of fine particles may also lead to the formation of an impervious layer at or near the surface. This surface capping can destroy the crop.

During very dry conditions the application of slurries may lead to direct entry into aquifers through fissures.

During winter months when fields are at capacity and rainfall exceeds transpiration there is a danger of direct run-off from the land surface into watercourses.

During normal conditions there is a danger of inorganic and organic material being leached through freely-drained soils either into underground water supplies or into field drains and hence watercourses. The problems of leaching and run-off
will be dealt with more fully in subsequent chapters.

3.4.5 DISEASE RISKS

The survival of potentially pathogenic organisms in slurry storage and treatment systems is obviously an important factor to consider when spreading fields with manures. According to Evans (ARC Conference, Glasgow, 1972) Salmonella dublin may survive in pig slurries stored anaerobically for nearly a year. The first month accounts for a 90% reduction in viable cells probably due to the accumulation of toxic fatty acids and two months is required for a further 90% reduction probably due to the removal of these fatty acids by methane-producing bacteria using them as substrates.

Aerobic treatment destroys 90% S. dublin in about 2 days probably due to protozoal grazing of the free-swimming Salmonellae.

Salmonellae may be present in symptomless carriers or clinically affected carriers and outbreaks of Salmonellosis have been recorded where it is directly attributable to slurry spreading (Venn, Newcastle Symposium 1970), and Salmonellae can survive on pastures for at least three months.

S. typhimurium is pathogenic to man as well as to animals and has been found in both pigs and poultry. Jack and Hepper (1969) reported an outbreak of S. typhimurium attributable to the spreading of slurry and the organism has been shown to survive for 84 days on contaminated pasture (Jones, ARC Conference Glasgow, 1972).

The common Salmonella of pig is S. choleraesuis and of poultry are S. pullorum and S. gallinarum. Other serotypes from poultry, namely Meunchen and Virchow, have been reported as causing clinical disease in cattle grazing pastures spread
The presence of Johne's disease in slurries presents an important problem since the organism may survive for 249 days, under normal climatic conditions. However, normally young calves are most susceptible and these are not sent out to grass before a resistance has naturally developed with age. Older calves may become infected if subjected to continual exposure to the organism.

Bovine tuberculosis is now rare due to the eradication scheme, but if a carrier is excreting tubercle bacilli then slurry presents an easy method of dissemination with a survival time similar to Johne's disease bacteria.

Avian tuberculosis may be disseminated to cattle by spreading grazing land with manure containing the droppings from an affected bird. Again, its survival is similar to Mycobacterium tuberculosis and M. johnei.

The products of conception during abortion by an infected animal contain high levels of Brucella abortus (Venn, 1970) and these have been shown to survive in faeces for a year. Fortunately, exposure to sunlight destroys these bacteria.

Viral infections are relatively uncommon except for the foot-and-mouth pandemic virus. Use of organic irrigation by spray guns may present a serious risk of disseminating the disease to adjacent premises.

3.5 SUMMARY

The four methods of disposal of farm wastes outlined previously can now be seen in perspective.

Spreading on the land in order to use nutrient contents of slurries as fertilisers or in order to use the land as a
biological filter has limitations other than legal. The dangers of poaching and ponding, nutrient imbalance, disease transmission, run-off and leaching, odour production and toxic trace elements must be recognised. The soil type and the growing crop must be considered and the topography and weather conditions noted before any decision to spread manure is taken.

The use of manure as a feed or as a further by-product must also include a consideration of the composition of the product and health and social risks cannot be neglected.

However, before manure can be used or disposed of it must be collected and, if necessary, stored.
4.1 INTRODUCTION

Reference to Fig 3(2) will illustrate the properties of manures as related to their moisture content. The flow characteristics of manure are an important factor in the consideration of selection of a cleaning - handling - storage system. Grabs and buckets will handle manure plus bedding, and pumps and augers will handle much more liquid slurries. The choice of system will also depend upon the costs involved with manual systems requiring higher labour inputs - than automatic systems, and with liquid systems demanding a higher quantity of diluting water which must be paid for.

In order to produce a slurry suitable for vacuum tanker spreader an equal volume of water must be added to the neat manure, and in order for the slurry to be pumpable a further volume must be added. Figure 4.1 is abstracted from Riley (Muckmem 18 and Newcastle Symposium 1970) and illustrates that handling neat manure involves considerably less weight and volume than does handling slurries.

The relative cost considerations must be borne in mind in the appreciation of the systems.

Fig. 4.1

1,000 layers produce manure which can be handled as:

<table>
<thead>
<tr>
<th>Liquids:</th>
<th>70%</th>
<th>85%</th>
<th>92%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1540 lbs)</td>
<td>(3740 lbs)</td>
<td>(8140 lbs)</td>
<td></td>
</tr>
<tr>
<td>(700 kg)</td>
<td>(1700 kg)</td>
<td>(3700 kg)</td>
<td></td>
</tr>
<tr>
<td>Solids:</td>
<td>30%</td>
<td>15%</td>
<td>7.5%</td>
</tr>
<tr>
<td>(660 lbs)</td>
<td>(300 kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neat</td>
<td>Slurry</td>
<td>Liquid</td>
<td></td>
</tr>
<tr>
<td>1+ cu.yd.</td>
<td>2+ cu.yd.</td>
<td>3-4 cu.yd.</td>
<td></td>
</tr>
<tr>
<td>(0.76+ m³)</td>
<td>(1.53+ m³)</td>
<td>(2.3-30 m³)</td>
<td></td>
</tr>
</tbody>
</table>
4.2 HOUSING METHODS

Broadly speaking the methods of cleaning out animal houses are dictated by the type of housing. Existing housing can rarely be economically altered to accommodate a more efficient manure cleaning system, but new housing and expanding housing can be arranged around the cleaning method to be adopted. Building design is an important factor in cleaning operations but is outside the scope of this thesis. However, mention of the types of houses and their bedding or litter requirements is necessary.

Most pig herds are housed indoors throughout the year and Danish-type or Suffolk-type housing are the most common. Both provide for a littered bedded area and a non-littered dunging area. Fortunately pigs very rarely soil their bedding and all faeces and urine collect in the dunging area and can then be scraped to a collection or storage area. Slatted floors will be mentioned later.

Cows may be housed in a variety of ways being fully-covered, semi-covered, or non-covered. The latter two types are obviously subject to the collection of rainfall and hence added water into the manure systems. Fully bedded systems house the herd on a complete straw bed and faeces and urine are absorbed by the straw, this being constantly trampled underfoot. This system is generally mucked out once a year when the cows are turned out to grass.

Partially bedded yards give the cows a flat area of concrete, either covered or uncovered, and a strawed, covered bed area. The cows use the concrete as a collecting and exercise area and this can be scraped or hosed down to a manure collection and/or storage area. However, unlike pigs, cows do soil their beds and the straw bedding does have to be periodically removed. Full bedding requires
less frequent removal and partial bedding requires constant removal and replacement.

The present day trend is towards individual beds for cows by way of cubicles or kennels. Cubicles are partitioned areas of existing covered sheds and kennels are especially constructed covered beds in an uncovered yard. The concreted collecting and exercise areas again can be scraped or hosed and the bedding removed and renewed as necessary.

Full bedding requires about 21 cwts (1063 kg) straw/cow/winter if fully covered, 30 cwts (1515 kg) straw/cow/winter if semi-covered, and partial bedding about 10 cwts (505 kg) straw/cow/winter (MAFF, NAAS Milk Group Slurry Panel, 1962).

The main reason for the trend towards the use of less bedding is to reduce the costs, an important factor in areas where straw is not readily available. The maps in Chapter 1 show the areas that are predominantly dairy do not coincide with large straw producing regions.

Weller (Newcastle Symposium, 1970) has suggested that in-store costs for straw are between £6 and £8/tonne. However, bought-in straw can be as low as £4/tonne in some regions and can be as high as £15/tonne in a wet year. Sawdust is generally less than £4/tonne and can usually be obtained on a monthly contract.

Using straw bedding the costs per cow are about £0.32/week which includes the spreading. Shavings probably halve this cost. Lighter bedding in cubicles or kennels may reduce the costs to about £0.10/week/cow, and since sawdust is usually used in these systems as a liquid absorbant, the costs reduce even further to about £0.035/head/week (Weller, Newcastle Symposium, 1970). Bedding and little for pigs is about £0.050/head/week. Thus,
partial bedding systems are becoming more common.

In recent years a no-bedding regime has developed using perforated or slatted floors through which faeces and urine fall to a below-ground slurry sump. This system will be discussed more fully later.

The daily cleaning of concreted areas in cow yards cannot be avoided and the costs of covering such areas must be balanced against the costs for an absorbing type litter. Unless water is being used for cleaning it is desirable to cover concreted areas and the costs range from £1.62/sq.yd (no stanchions) to £2.25/sq.yd (one row stanchions) to £3.22/sq.yd (two rows stanchions) (MAFF, NAAS Milk Group Slurry Panel Report 1962). In areas of 10" winter rainfall an increase in slurry volume of 15% can be expected when yards are uncovered and the costs for covering must be less than the extra costs for cleaning and increased storage capacity before covers are considered.

Cowsheds must be kept as dry as possible to prevent cows from slipping and consequent injury. Where bedding is expensive or undesirable, due to a preference to handle as slurry rather than solid manure, then alternative means of absorbing the urine may be employed.

Sawdust may be used for this purpose and dry sawdust has good absorbent properties. It is easily brushed and spread on the land and does not stick to the cows' flanks.

Sand is available to farms near adequate supplies and fine calcareous sands are most suitable, gritty sands being unsuitable. Sand must be kept out of drainage systems.

Ground limestone may be used but is in danger of caking and becoming slippery.
Superphosphate may also be used and when mixed with manure produces calcium phosphate and ammonium phosphate, so conserving nitrogen (and reducing its loss) and reducing ammoniacal odours.

Calcereous sand and ground limestone qualify for lime subsidy when finally spread on the land (MAFF, NAAS Milk Group Slurry Panel Report 1962).

Poultry houses lend themselves to more mechanical or automated cleaning systems and will be discussed later.

4.3 CLEANING METHODS

Basically there are three types of cleaning methods available depending on the size of the enterprise, the constituency of the material (amount of bedding and any rainwater), and the design of the building: - manual, manual - mechanical, and automatic.

4.3.1 MANUAL CLEANING

Shovels, brushes, scrapers and squeegees are in common use where hand scraping of concreted areas is practised. The task is unpleasant and difficult, the build up of slurry in front of a broad-faced implement making forward pushing not feasible for more than about 20 feet. (MAFF, NAAS Milk Group Slurry Panel Report 1962). After scraping for 20 ft. it is necessary to lift the slurry into a wheelbarrow or trailer for removal from the yard.

A normal 11" shovel requires little effort and a broad faced 24" shovel about 15" deep can be handled efficiently. A larger shovel mounted between two wheels and pushed along is in use in the Netherlands (Rijkenbarg, 1965).

Scrapers are more effective on "stiff" slurries as otherwise the liquid flows round the edges onto the already cleaned lanes. Concave scrapers overcome this difficulty to a certain degree, and the fitting of a rubber base (squeegee) enables the cleaning of more liquid slurries.
A 15" yard brush is of little use for slurries as it will clog, and a larger brush will become too heavy to handle. However, brushes can be used effectively in cleaning pig dung channels as the faeces remain whole and do not form a slurry and also in clearing very wet slurries as the bristles prevent slurry escape by seepage round the ends.

Hoses may be used to wash down concreted areas and buckets of water can be used as sluices. Usually manual scraping is first carried out and washing down used in addition. Power hoses may do both jobs simultaneously. A clean concrete area is important for cows in order to maintain milking efficiency by keeping udders clean, and washing is normally performed once per day. During summer months considerably more water may have to be used to remove the caked manure, but it takes about 25% longer to wash down in the winter due to there being more slurry anyway.

Power hoses are the quickest means of washing down, buckets taking twice as long and mains hoses three times as long (MAFF, NAAS Milk Group Slurry Panel 1962).

Power hoses must be chosen carefully as too much pressure causes splashing and difficulty in handling the hose, while too little water is insufficient to float the slurry away. The NAAS Milk Group Slurry Panel recommend a length of hose not more than 36 ft. with a diameter of 1½" and nozzle of 1" delivering 3,600 gals/hour at 15 lbs/sq.in pressure as the most efficient power hose. Plasticised P.V.C. hoses are light and can withstand pressures of up to 50 lb/sq.in and are recommended in preference to rubber hoses.

Using water for cleaning down obviously increases the final volume of slurry to be stored and disposed and Table 4.1 illustrates the water usage and corresponding slurry volume increase: (MAFF, NAAS data)
TABLE 4.1

<table>
<thead>
<tr>
<th>Method</th>
<th>Gallons/100 sq.ft.</th>
<th>% Increase in amount of slurry*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket of water</td>
<td>4.5</td>
<td>21.5</td>
</tr>
<tr>
<td>Mains hose</td>
<td>2.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Power hose **</td>
<td>17.0</td>
<td>81.5</td>
</tr>
</tbody>
</table>

* 1 cu ft/cow/day, 1 cow/30 sq.ft concrete
** 60 gals/min

4.3.2 MANUAL/MECHANICAL CLEANING

Tractor mounted scrapers and blades are now in common use. The housing must have a concrete floor area without obstruction and sufficiently wide to allow a tractor to manoeuvre. Right-angled bends are difficult to negotiate. Scrapers may be front or rear-mounted and of a single or double action. Single action scrapers require the tractor to pull or push the slurry in one direction and be lifted to enable the tractor to reverse to the start position. Double bladed scrapers may be left on the floor to both push and pull the slurry depending on the direction of the tractor's motion. Some single bladed scrapers can be used in forward and reverse directions by lifting and rotating.

Table 4.2 gives the dimensions, costs, and descriptions of some tractor mounted scrapers. (Manufacturer's brochures, 1970-1971).

TABLE 4.2

<table>
<thead>
<tr>
<th>Manufacturer or Supplier</th>
<th>Model</th>
<th>Width</th>
<th>Depth</th>
<th>Weight</th>
<th>Features</th>
<th>Approx Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.C. Bamlett Ltd</td>
<td>Raker</td>
<td>6'0&quot;</td>
<td>1'2&quot;</td>
<td>2041b</td>
<td>Pulls or pushers</td>
<td>£55</td>
</tr>
<tr>
<td>Station Road, Thirsk, Yorks</td>
<td></td>
<td>7'0&quot;</td>
<td>1'2&quot;</td>
<td>230lb</td>
<td>Scraper flips over automatically</td>
<td>£60</td>
</tr>
<tr>
<td>Manufacturer or Supplier</td>
<td>Model</td>
<td>Width</td>
<td>Depth</td>
<td>Weight</td>
<td>Features</td>
<td>Price</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>---------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Bonnels of Audlem Ltd., Nr. Crewe, Cheshire</td>
<td>Swing over</td>
<td>6'6&quot;</td>
<td>-</td>
<td>-</td>
<td>Pulls or pushes, Wings must be manually turned</td>
<td>£35</td>
</tr>
<tr>
<td></td>
<td>Pull or Push</td>
<td>7'0&quot;</td>
<td>-</td>
<td>-</td>
<td>Pulls or pushes</td>
<td>£35</td>
</tr>
<tr>
<td>Eaton Berry Ltd</td>
<td>Scraper</td>
<td>7'4&quot;</td>
<td>-</td>
<td>253lb</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£35</td>
</tr>
<tr>
<td>Caversham</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W.G.Hart &amp; Sons</td>
<td>Heavy-Duty</td>
<td>6'2&quot;</td>
<td>1'1&quot;</td>
<td>280lb</td>
<td>Pulls or pushes, Wings must be manually turned</td>
<td>£45</td>
</tr>
<tr>
<td>Stourminster Newton, Dorset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hosier Equipt.</td>
<td>Slurry Hurry</td>
<td>7'0&quot;</td>
<td>1'6&quot;</td>
<td>196lb</td>
<td>Pulls or pushes, Front or rear mounted Wings manually turned,</td>
<td>£55</td>
</tr>
<tr>
<td>Marlborough, Wiltshire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Brian Langmead Ltd.</td>
<td>Push</td>
<td>6'3&quot;</td>
<td>1'2&quot;</td>
<td>365lb</td>
<td>Pushes only</td>
<td>£70</td>
</tr>
<tr>
<td>Selsey, Sussex</td>
<td></td>
<td>6'3&quot;</td>
<td>1'8&quot;</td>
<td>500lb</td>
<td>Pushes only</td>
<td>£95</td>
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<td></td>
<td>Pull</td>
<td>6'3&quot;</td>
<td>1'2&quot;</td>
<td>425lb</td>
<td>Pulls only</td>
<td>£70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6'3&quot;</td>
<td>1'8&quot;</td>
<td>550lb</td>
<td>Pulls only</td>
<td>£95</td>
</tr>
<tr>
<td></td>
<td>Pull and Push</td>
<td>6'3&quot;</td>
<td>1'2&quot;</td>
<td>570lb</td>
<td>Pulls and pushes, Main frame &quot;H&quot; shaped</td>
<td>£95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6'3&quot;</td>
<td>1'2&quot;</td>
<td>625lb</td>
<td>Pulls and pushes, Main frame &quot;H&quot; shaped</td>
<td>£110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6'3&quot;</td>
<td>1'8&quot;</td>
<td>840lb</td>
<td>Pulls and pushes, Main frame &quot;H&quot; shaped</td>
<td>£130</td>
</tr>
<tr>
<td>Lawrence Edwards &amp; Co. Ltd., Kidderminster, Worcestershire</td>
<td>Fixed Wing</td>
<td>6'0&quot;</td>
<td>1'6&quot;</td>
<td>-</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£35</td>
</tr>
<tr>
<td></td>
<td>Swing Wing</td>
<td>6'0&quot;-</td>
<td>7'0&quot;</td>
<td>1'6&quot;</td>
<td>Pulls or pushes, Wings manually turned, can be adjusted for width</td>
<td>£40</td>
</tr>
<tr>
<td>Manufacturer or Supplier</td>
<td>Model</td>
<td>Width</td>
<td>Depth</td>
<td>Weight</td>
<td>Features</td>
<td>Approx Price</td>
</tr>
<tr>
<td>--------------------------</td>
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<td>-------</td>
<td>-------</td>
<td>--------</td>
<td>---------------------------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>F.W. McConnel Ltd</td>
<td>Yard Scraper</td>
<td>6'4&quot;</td>
<td>1'2&quot;</td>
<td>280 lb</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£45</td>
</tr>
<tr>
<td>Mechanaid Marketing Ltd</td>
<td>Swing Wing</td>
<td>6'0&quot;-</td>
<td>1'3&quot;</td>
<td>224 lb</td>
<td>Pulls or pushes, Wings turned, can be adjusted for width</td>
<td>£45</td>
</tr>
<tr>
<td></td>
<td>Rigid Wing</td>
<td>5'11&quot;-</td>
<td>1'3&quot;</td>
<td>224 lb</td>
<td>Pulls or pushes. Main frame &quot;H&quot; shaped</td>
<td>£40</td>
</tr>
<tr>
<td>Salop Fencing Co.,</td>
<td>Standard</td>
<td>7'0&quot;</td>
<td>-</td>
<td>-</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£35</td>
</tr>
<tr>
<td>Dorrington, Shropshire</td>
<td>Contour</td>
<td>7'0&quot;</td>
<td>-</td>
<td>-</td>
<td>Pulls or pushes, Wings manually turned</td>
<td>£40</td>
</tr>
<tr>
<td>Sure Grip Broom Clamp Co.</td>
<td>Dub'l -Lif</td>
<td>6'3&quot;</td>
<td>-</td>
<td>-</td>
<td>Pulls or pushes, Wings manually turned</td>
<td>£35</td>
</tr>
<tr>
<td>Taunton</td>
<td>Standard</td>
<td>6'3&quot;</td>
<td>1'4&quot;</td>
<td>400 lb</td>
<td>Automatic tractor coupling</td>
<td>£60</td>
</tr>
<tr>
<td>J.H. Taylor Ltd.</td>
<td>Standard</td>
<td>6'3&quot;</td>
<td>1'10&quot;</td>
<td>-</td>
<td>Pulls or pushes, Wings manually turned</td>
<td>£55</td>
</tr>
<tr>
<td>Consett, Co. Durham</td>
<td>Scaper</td>
<td>6'2½&quot;</td>
<td>1'10&quot;</td>
<td>-</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£45</td>
</tr>
<tr>
<td>Twose Ltd. Tiverton</td>
<td>Heavy Duty</td>
<td>6'3&quot;</td>
<td>1'1&quot;</td>
<td>364 lb</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£60</td>
</tr>
<tr>
<td>Devon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. Wilder Ltd. Wallingford, Berks.</td>
<td>Standard</td>
<td>6'3&quot;</td>
<td>10&quot;</td>
<td>252 lb</td>
<td>Pulls or pushes</td>
<td>£45</td>
</tr>
<tr>
<td></td>
<td>Heavy Duty</td>
<td>6'3&quot;</td>
<td>1'1&quot;</td>
<td>364 lb</td>
<td>Pulls or pushes, Main frame &quot;H&quot; shaped</td>
<td>£60</td>
</tr>
</tbody>
</table>
The running costs of operating a scraper depend on its life and the cost of the tractor. A tractor plus a man is more expensive than a man alone and so sufficient area must be present to ensure that mechanical scraping is cheaper than manual. Tractor scrapers are in frequent use today and have replaced manual scraping on all but the smallest of farms, and the larger the concrete the less is the cost per unit area for mechanical scraping (MAFF, NAAS Milk Group Slurry Panel 1962).

4.3.3 AUTOMATIC CLEANING

These methods of cleaning either obviate the need for a daily or even weekly routine or else they function automatically in the daily cycle.

Examples of the former are slatted floors for cows, pigs, and poultry. The design of slats is different in each case, and poultry may be housed on a mesh rather than slatted floor. The droppings fall through the floor and collect in a sump or in channels leading to a sump in the case of pigs and cattle, and the slurry-type waste generally will flow by gravity into a sump or pit. The channels may need to be hosed down or a flume may be employed with automatic sluice gates controlling the flow of water from the flume.

In the case of poultry, three-tier cages are most common (MAAF A.L. 387) and droppings fall through either into trays or onto a belt. Trays are manually emptied once or twice a week and the endless belt method requires daily cleaning. Droppings are conveyed to one end of the poultry house by the belts into a collecting channel or directly into barrows or trailers. Conveyance from the collecting channels to either spreader or storage is not possible using gravity alone as poultry slurry is too stiff.
(75% moisture), and augers are in common use. Swift-type poultry augers can be supplied up to 100 ft long and are designed to empty directly into a pit or to feed a positive auger elevator to lift the manure into a spreader. (Ardleigh Swift Ltd., Martells Factory Ardleigh, Colchester, Essex). Alternatively, poultry manure can be stored in a liquifying tank where water is added and the contents agitated to enable it to be withdrawn by vacuum tanker or pumped to rain guns.

The storage pit for perforated floors requires periodic cleaning depending on its capacity and a tractor with fore-end loader or bucket, pumps and pipes, augers, or flushing may be used for emptying. Removal by vacuum tanker requires about 1 man hour/month/100 pigs, for example, whilst using tractor and bucket takes four times as long since the slats have to be removed. (Livingston, Roberts 1967). In some cases the latter difficulty can be overcome by using the slope of the land to construct the house on a terrace over a deep pit enabling a tractor to drive directly underneath the house for slurry removal. Californian-type layer cages use this principle in suspending batteries of cages over a deep pit requiring emptying once a year by tractor and grab.

Slatted floors provide a number of advantages over daily cleaning such as very much reduced labour requirements, elimination of a disagreeable and unpleasant daily task, a change in labour distribution enabling disposal to be carried out during slack periods of the year, and the ability of the already liquid system to cope with rainwater, washing water and other liquid wastes. (Casler, Cornell Conference, 1969). However, perforated floors have a high capital cost and slats together with pit would cost about £55/cow place and
£4/pig place (Weller, Newcastle Symposium 1970). The savings by not using bedding and by using less labour tend to offset the high installation costs, and perforated floor systems can be substantially cheaper than scraped passages in the long term (Weller, J.B. 1970). No actual costs have been quoted to support this view.

One of the dangers with deep pits is the production of gases, some of which are heavier than air and accumulate in the buildings sometimes lethally. Modern slatted buildings provide for high level air intake and below floor level extraction with at least 0.35 metres between the top of the slurry and the perforated floor. (Weller, Newcastle Symposium 1970).

Poultry may also be housed on deep litter when only one clean-out per year is necessary (MAAF A.L. 384). Concrete floors are preferred to earth floors since they can be easily washed and disinfected reducing the risks of infection at flock change-over, but this adds about 15% to the cost of the house. Wood shavings or shavings/straw mixture is recommended as the best litter, straw alone tending to matt together, particularly in winter months, and being less readily bio-degraded. A 4-6 inch litter is recommended gradually increasing to 9 inches during the production year.

Automatic scrapers and flood-flushing systems fall into the daily cleaning routine and are useful as labour saving methods. Slats and deep litter systems reduce cleaning out to a few times each year, while automatic scrapers and flood-flushing, although self operating, require daily inspection and attention.

In flood-flushing systems water from header tanks is periodically released into the dung channels sweeping the manure into a collecting channel or sump from which it is removed to a storage compound, or directed into the storage system.
Automatic scrapers are of several different designs such as winch operated, wire rope or chain and scraper, continuous chain and flight, or reciprocating rod and flight type scrapers. Winch operated scrapers consist of a circuit of chain up to 525 ft. (160 m) to which are attached two folding scrapers, on parallel arms of the circuit. The winch pulls the chain first one way and then the other, giving each scraper a work stroke and a return stroke. The delta scraper (Alfa Laval, Cwmbran, Mon.) has two arms hinged in the centre so that on each work stroke an open V scrapes slurry forward, and the blades close for the return. Cows step over the scraper without injury since the velocity is low, about 3 to 4 m per minute (Glerum, de Jong, Poelma, Newcastle Symposium, 1970). The centre of the scraper has a locating bar which slots into a central channel in the dung passage, and this also houses the chain out of the way of cows' feet. Delta scrapers for cows are adjustable from 5'4" - 10'8" (160-320 cm) in width and are 8" (20 cm) high, the pig scrapers being adjustable from 2'6" - 8'4" (80-250 cm) wide and 4" (10cm) high. The winch is ½ h.p. (0.56 kw) and can easily be automated by use of an electric timer. Costs are quoted as £6-£10 for installment per cow place (Payne, Newcastle Symposium 1970).

Continuous chain and flight scrapes are operated on a single channel. A chain pulls a plough-type scraper along a dung passage or under a slatted floor. At the end of the stroke the scraper is lifted and returned. MFE plough scrapers (Master Farm Equipment, Sudbury, Suffolk) are manufactured up to 5' wide and are 8" deep. MFE shuttle stroke manure conveyers are similar to the Delta scraper in that the blades are hinged and fold together on the return stroke, but rather than have one scraper on a winched chain, there are several smaller blades joined together by flat bars. These scrapers
can also lift manure up a chute for direct loading into a spreader. Installation costs are likely to be £5/cow place and the cost of equipment about £10/cow place. (Payne, Newcastle Symposium 1970).

Finally, the reciprocating rod and flight scraper which can be installed in up to 300 ft (91.44 m) lengths. These operate at 12 reciprocations per minute with a stroke of 5'6" (1.68 m). Steelfab Odin of Sweden claim that reciprocating scrapers mix liquids and solids together giving a slurry of even consistency. The cost of equipment is about £10 per cow place installed. (Payne, Newcastle Symposium, 1970).

4.4 HANDLING METHODS

Having discussed the cleaning methods available, the different handling techniques must now be considered. Once collected the manure, slurry, or liquid must be transferred to storage if not already in storage, or direct to spreader or treatment plant. Sometimes the liquids and solids are deliberately separated at this stage and the two fractions handled and treated separately. Various separators will be discussed in Chapter 6. However, most situations handle dung and urine together, along with any bedding material, and use a mixed storage method. Separation, if necessary usually occurs automatically on storage or a separator is used to treat the material from the store.

Some of the housing systems discussed automatically put the material into store; slats over a deep pit for example. However, where a temporary collection area is used by way of concrete apron or dung channel, then the material must be transferred to the store, spreader, or treatment plant. The handling equipment available treats materials of limited moisture content, and reference to Fig 3.2 (Weller, Newcastle Symposium 1970) demonstrates
methods will be discussed starting from dry handling and progressing to wet handling.

4.4.1 FORKS AND RAKES

For handling and lifting manure mixed with large amounts of bedding a fork or rake, either manually operated or attached to a tractor, is ideal. Fig. 4.2 illustrates a Farmhand F.11 30 cwt. fork (Farmhand U.K. Ltd., Suton, Wymondham, Norfolk) attached to the front of a tractor. This model costs £500 and is capable of lifting farmyard manure into a spreader.

Rear-mounted forks also act on a manure/straw mixture and Fig 4.3 illustrates a Knight-Kidd 30 cwt rear-mounted loader (£105) putting farmyard manure into a Fymax 3 ton spreader (£570) (Archie Kidd Ltd., Roundway, Devizes, Wilts).

4.4.2 GRABS

Free standing hydraulic grabs such as the Garnier Heywang, Fig. 4.4, can lift nearly a ton (1,000 kg) to 16'4" (5m) height and a radius of 19'4" (5.9m). The hydraulic pump is driven from the tractor power take off (p.t.o.) and the grab can be interchanged with a bucket.

Fig. 4.5 illustrates a Twose (Twose Ltd., Riverton, Devon) Grab loader costing £660, at 1970 prices.

4.4.3 BUCKETS

When less straw is present buckets can be used on the front or rear of tractors. Hosier's Slurry Grab is illustrated in Fig.4.6 (Hosier Ltd., Collingbourne Ducis, Wilts) and can empty pits up to 8 ft below the level of the tractor front wheels.

The Lister Slurry Put (£100) (R.A. Lister & Co. Ltd., Dursley, Glos) is a fixed bucket which is attached to the tractor fore-loader. It has 18 cu.ft (0.5 m³) capacity and a 25° tilt back ensures that it can handle near liquid slurries without excessive spillage.
Farmhand F11 30-cwt grab, £500.

Kidd rear loader, £105, Fymax 3-ton spreader, £570.
Garnier grab loader.

FIG. 4.(5)

Twose '190' grab, £660.
Hosier 'Miracle' grab.
Buckets are more versatile than grabs in that they can handle a wider range of material from slurries to farmyard manure with equal ease.

Normal tractor mounted scrapers can be used to push slurries or manures along flat areas to storage compounds or pits. However, to be able to lift slurries a bucket is required as scrapers are fixed.

4.4.4 BUCKET AND CHAIN ELEVATORS

Continuous chains fitted with buckets to elevate manure into a storage tank or spreader work at about 200 gal/min (0.91 m³/min) and can handle thick slurries or liquid slurries. The cost is about £300 and the power is by p.t.o. or separate motor (Payne, Newcastle Symposium, 1970).

Alternatively the chain may be fitted with flights scraping the manure up inside a box section for delivery into tank or spreader. MFE reciprocating shuttle scrapers can be extended so as to deliver slurry cleared from under slats or dung channels from the building onto a ramp and over the ramp to storage or spreader.

4.4.5 AUGER ELEVATORS

Augers for moving poultry manure from laying houses have been discussed, but more generally augers can be used for a variety of slurries ranging from about 30% dry matter to virtually nil. The usual augers are 6" to 9" (152-229 mm) and will elevate up to a total of about 20 ft.

The Howard Slurry Auger (Howard Rotavator Co. Ltd., West Horndon, Essex) may be mounted on the three-point tractor linkage and transported from one collection pit to another or may be fixed to operate at the one site. This auger weighs 504 lbs (229 kgs) and can empty pits up to 9' (270 cms) deep discharging up to 12' (360 cms) from its 5" (125 cms) diameter outlet. The model delivers 600 gal/min and costs £470.
An auger's capacity is dependent on its size, its speed, and the material being handled. For example, a 6" auger operating at 540 rev./min will deliver 178 gal/min (0.81 m³/min) of 12.3% dry matter manure and 150 gal/min (0.68 m³/min) of 27.7% dry matter manure (Payne, Newcastle Symposium, 1970).

Costs range from £200 for a 6" auger at 180 gal/min to £400 for a 9" auger at 500 gal/min. Again, augers can be used to transfer either into store or out from store.

4.4.6 FREE FLOW CHANNELS

For more liquid manures such as that produced under slats, free flow channels may be used to transport the material to store. Hosing or sluicing may help the material along and water requirements have been discussed previously. Usually water is only deliberately added where irrigation is used for disposal or high dilution is required for treatment.

4.4.7 PUMPS

Pumps are frequently used for transporting slurries either to or from storage and there are four basic types: diaphragm, centrifugal, scroll-and-stator, or piston type and the latter three are most common. (Payne, Newcastle Symposium 1970). The pumps may be electrically, diesel, or p.t.o. powered and can generally be used for agitation of storage contents as well as for slurry transfer. This is an important factor as crust formation can be prevented and anaerobiosis deterred thus halting the production of odours, and the contents are agitated to homogeneity enabling easy transfer and constant composition of the material to be handled.

1) Piston pumps are the most expensive in the range and their capacity varies with the type of pump and the number of cylinders. A two cylinder pump will deliver up to 150 gal/min (0.68 m³/min) consuming 25 h.p. (18.6 kw). Spate pumps
are the most common piston type pumps found on the farm. (W.R. Selwood Ltd., Eastleigh, Hants). A Molex 360 gal/min pump costs £1145 and a Gorman-Rupp 300/gal/min pump £525.

2) Scroll and stator pumps are in general cheaper than piston type models and will handle a thicker slurry. Farrow pumps (Farrow Irrigation Ltd., Spalding, Lincs) claim to be able to handle agricultural slurry, sewage effluents and sludges, high viscosity liquids, and liquids containing suspended solids, fibrous matter, and abrasive media. Their eccentric helical rotor pumps available in single, two, and four-stage versions cover a wide range of applications ranging from 1 gal/min (4.5 l/min) to 1,000 gal/min (4546.0 l/min) delivery.

Molex Langer eccentric worm pumps (W.E. Waite Ltd., Farnham, Surrey) operate on the same principle and handle liquids with up to 20% dry matter content. Again the capacity depends upon the speed at which the rotor is driven.

Mono pumps (Mono Pumps Ltd., Clerkenwell Green, London) also produce a variety of scroll-and-stator pumps suitable for agricultural slurries.

3) Centrifugal pumps are much cheaper and more commonly used in agriculture. Usually the impellor also acts as a macerator to chop any straw bedding and other litter that may enter the waste system. Different manufacturers use different impellor systems and pump designs. Alfa Laval Tivematic pumps, Garnier Slurry pumps, and Bamfords slurry-agitator pumps are usually tractor mounted and therefore easily transported. The impellors are p.t.o. driven and deliver 1100 gals/min, 600 gals/min, and 1500 gals/min respectively and all claim efficient
impellor, blade, rotor, and protecting vane design. The Alfa Laval pump costs £575 for a 12' shaft model, the Garnier pump £285 for a 11'6" shaft model, and the Bamfords slurry pump costs about £425. All three pumps may be permanently fixed if required and a tractor coupled as necessary.

Farrow's Gylle 500 pump, MFE's manure pump, and Nixon's Brougham pump are fixed models and are electrically or p.t.o. powered. 500 gals/min, 1,000 gals/min, and 2,000 gals/min are the respective capacities. Nixon's pumps are £600 for the electrically driven version (20 h.p. at 1500 r.p.m.) and £370 for the p.t.o. driven type. The Gylle 500 costs £360.

4.5 STORAGE METHODS

Most of the methods discussed for handling manure between collection and storage can also be used to handle manure after storage for disposal or treatment. The pumps also act as agitators. This section deals with methods of storing manure prior to disposal. Some storage methods inevitably act as pre-treatment plants as biological action naturally degrades the collected material. These aspects will be discussed under treatment system. In-situ storage under slats or on deep litter has been discussed in Section 4.2 and the other systems are now considered.

4.5.1 COMPOUNDS

Simple storage compounds can usually be made fairly cheaply on the farm by unskilled labour. Uncovered compounds can be simply cut into a sloping piece of land using the banked spoil as retaining walls. The front end of the compound is protected by railway sleepers slotted into rolled-steel joists. If the land is flat, all three containing walls may be constructed from
sleepers with or without a fill of earth. The base may be concreted if desired. Seepage of liquid between the sleepers is contained in blind ditches and this eventually percolates through the soil but care must be taken if the water table is high as there is a danger of polluting this ground water.

Compounds are best used for farmyard manure effluents where the bedding and litter absorb most of the moisture and urine. The compound may be lined with straw for this purpose, or alternative layers of manure and slurry used. More liquid manures may require poured concrete, concrete block, or brick walls to contain all of the slurry without seepage, and this is particularly important where straw or litter is unavailable.

Usually, storage compounds have sufficient capacity for a winter's production of manure and serve as holding tanks pending dryer weather when muck spreaders can get onto the land.

This type of storage compound is usually served by tractor and scraper except on smaller units using manual cleaning, and a concrete ramp or road is required as access to the compound. Table 4.3 estimates costs/cu.ft storage capacity for various constructions (ADAS, Interim Report MH2, 1971).

<table>
<thead>
<tr>
<th>Construction</th>
<th>Costs in pence/cu.ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth walls and base</td>
<td>0.02 - 0.5</td>
</tr>
<tr>
<td>Earth walls, concrete base</td>
<td>0.4 - 4.6</td>
</tr>
<tr>
<td>Sleeper walls, concrete base</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Concrete walls, concrete base</td>
<td>3 - 10</td>
</tr>
<tr>
<td>Steel walled compounds</td>
<td>5 - 16</td>
</tr>
</tbody>
</table>
Hathersham Farm, Horley, Surrey (Occupier: D.S. Knight) has such a compound for 200 cows. The farm has 440 acres situated on heavy Weald clay over a high water table and daily tractor scraping cleans 400 sq.yds. of cubicle passages and 1100 sq.yds. of other uncovered concrete areas. The compound is 70 yds x 40 yds and holds a full year's slurry with earth walls on three sides which are 6 ft high, 17 ft wide at base, and 5 ft wide at the top. The natural slope forms the fourth wall. A concrete ramp extends 30 ft. into the compound and has a 25 ft slatted steel extension. The tractor scrapes slurry up the ramp and the material falls between the steel slats into the compound and this flows to its own level. The compound is emptied and spread each July taking nine ten-hour days in all. Construction costs at 1970 prices were:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound Walls</td>
<td>£260</td>
</tr>
<tr>
<td>Concrete ramp</td>
<td>£216</td>
</tr>
<tr>
<td>Steel ramp extension</td>
<td>£113</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>£589</td>
</tr>
</tbody>
</table>

The compound holds 18,000 cu.ft. of material and the capital cost is therefore 2.64 pence/cu.ft. exclusive of the ramps. This is slightly high compared with ADAS costs in the previous table, but nevertheless represents a cheap form of storage.

### 4.5.2 PITS

Pits or sumps are usually used for slurry storage and may be part-sunk or completely sunk below ground level. Once excavated the pit may be lined with PVC or butyl rubber sheeting, brickwork, or concrete work, or a steel tank may be sunk into the hole. The sumps must be watertight to prevent seepage and pollution of water supplies and also to prevent influx of unwanted ground water. The sumps must also be able to resist the pressures to float when the water table rises during winter.
Excavation costs depend largely on the contractor or farm equipment available. Liner costs depend on their construction, and concrete or blockwork is generally cheaper using farm labour or contracted labour.

Costs for PVC and butyl rubber liners are given in Table 4.4 (Stephens (Plastics) Ltd., Corsham, Wilts): all at 1970 prices, ex-works.

**TABLE 4.4**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Sheet Size</th>
<th>Cost £ 0.014&quot;PVC</th>
<th>Cost £ 0.030&quot; Butyl</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000 gals</td>
<td>33' x 27'</td>
<td>29.70</td>
<td>82.00</td>
</tr>
<tr>
<td>10,000</td>
<td>42' x 29'</td>
<td>40.80</td>
<td>125.67</td>
</tr>
<tr>
<td>15,000</td>
<td>48' x 32'</td>
<td>51.30</td>
<td>143.64</td>
</tr>
<tr>
<td>25,000</td>
<td>54' x 37'</td>
<td>66.60</td>
<td>189.01</td>
</tr>
<tr>
<td>50,000</td>
<td>68' x 45'</td>
<td>102.00</td>
<td>305.98</td>
</tr>
<tr>
<td>100,000</td>
<td>88' x 57'</td>
<td>168.00</td>
<td>485.78</td>
</tr>
<tr>
<td>150,000</td>
<td>99' x 64'</td>
<td>211.20</td>
<td>581.35</td>
</tr>
<tr>
<td>200,000</td>
<td>110' x 70'</td>
<td>256.80</td>
<td>706.90</td>
</tr>
<tr>
<td>250,000</td>
<td>135' x 70'</td>
<td>315.00</td>
<td>884.57</td>
</tr>
<tr>
<td>500,000</td>
<td>160' x 90'</td>
<td>480.00</td>
<td>1320.07</td>
</tr>
</tbody>
</table>

Periodic aeration of contents is essential to prevent odour production and solids settling. Pits and sumps may be emptied by pumps, augers, or vacuum tankers.

**4.5.3 TANKS**

Above ground steel tanks can be purchased for slurry storage. The steel must be epoxy-coated, plastic-lined, or of vitreous enamelled construction to prevent corrosion. This obviously...
makes the costs of such tanks high and, depending on make, extent of foundation work and capacity some costs are given in TABLE 4.5
(Payne, Newcastle Symposium, 1970):

**TABLE 4.5**

Costs of Vitreous Enamelled Metal Tank, Foundations, and Erection at 1970 prices

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Height</th>
<th>Capacity</th>
<th>Cost</th>
<th>Cost/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 ft. (9.45 m)</td>
<td>13.5 ft (4.1 m)</td>
<td>10,100 cu.ft (286 m³)</td>
<td>£1280</td>
<td>13p/cu.ft. (£3.85/m³)</td>
</tr>
<tr>
<td>48 ft (14.63 m)</td>
<td>13.5 ft (4.1 m)</td>
<td>25,000 cu.ft (708 m³)</td>
<td>£1970</td>
<td>8p/cu.ft (£2.78/m³)</td>
</tr>
</tbody>
</table>

These costs fall within the estimates of ADAS for steel containers of 5-16p per cu.ft. (ADAS, Interim Report MH2, 1971).

As with pits and sumps agitation and aeration of the contents is necessary. Tanks may be emptied by auger or pump, or directly into a vacuum tanker or organic irrigation system.

Alfa Laval Slurry Tanks are available in 13 diameters and 4 heights ranging from 570 cu.ft (3,563 gal) to 29,538 cu.ft. (184,615 gal) capacity, and discharge is via a sluice gate into a collection chamber for agitation prior to distribution by tanker.

### 4.6 COMPARISON OF COLLECTION/STORAGE SYSTEMS

Caution is required when comparing two systems of cleaning and storage as no two situations are exactly similar. Furthermore, different authors have used several different methods of analysing costs and so cost comparisons are difficult. For this reason all analyses have been brought to the common base, as explained at the beginning of this thesis, in order to make direct comparisons possible.
Since cows produce by far the greatest volume of manure of any farm animal, and hence pose the biggest problems, it is not surprising that dairy systems have been most fully investigated. Pig and poultry enterprises have attracted comparatively few studies.

### 4.6.1 DAIRY ENTERPRISES

Boyer and Quick (1968) compared different cleaning regimes for cowsheds, semi-covered yards, and cubicles. Their results have been recalculated and are presented in TABLES 4.6, 4.7, and 4.8.

**TABLE 4.6 COWSHEDS**

<table>
<thead>
<tr>
<th>Removal Method</th>
<th>No. of Cows</th>
<th>Time Taken</th>
<th>Operating Cost/Month</th>
<th>Annual Fixed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Scraping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-litter daily</td>
<td>40</td>
<td>40 mins</td>
<td>£ 25.00</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand and tractor scraping.</td>
<td>40</td>
<td>28 mins</td>
<td>£ 25.00</td>
<td>£ 8.85</td>
</tr>
<tr>
<td>Re-litter daily</td>
<td>80</td>
<td>55 mins</td>
<td>£ 49.50</td>
<td>£ 8.85</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>1 hr. 23 mins</td>
<td>£ 74.50</td>
<td>£ 8.85</td>
</tr>
<tr>
<td>Hand scraping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Gutter cleaning</td>
<td>40</td>
<td>24 mins</td>
<td>£ 25.00</td>
<td>£ 92.00</td>
</tr>
<tr>
<td>Re-litter daily</td>
<td>80</td>
<td>48 mins</td>
<td>£ 49.50</td>
<td>£186.00</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>1 hr. 12 mins</td>
<td>£ 74.50</td>
<td>£275.00</td>
</tr>
<tr>
<td>Buckets of water</td>
<td>40</td>
<td>4 mins</td>
<td>£ 0.24</td>
<td>-</td>
</tr>
<tr>
<td>Mains hose washing</td>
<td>40</td>
<td>7 mins</td>
<td>£ 0.24</td>
<td>£ 0.59</td>
</tr>
<tr>
<td>80</td>
<td>14 mins</td>
<td>£ 0.47</td>
<td>£ 1.18</td>
<td></td>
</tr>
<tr>
<td>Power hose washing</td>
<td>80</td>
<td>4 mins</td>
<td>£ 2.60</td>
<td>£ 24.00</td>
</tr>
<tr>
<td>Power wash floors and channels, lift sluices to empty channels</td>
<td>120</td>
<td>11 mins</td>
<td>£ 3.90</td>
<td>£292.00</td>
</tr>
</tbody>
</table>
TABLE 4.7 SEMI-COVERED YARDS

<table>
<thead>
<tr>
<th>Removal Method</th>
<th>No. of Cows</th>
<th>Time Taken</th>
<th>Operating Cost/Month</th>
<th>Annual Fixed Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored in situ</td>
<td>40</td>
<td>15 mins</td>
<td>£35.40</td>
<td>-</td>
</tr>
<tr>
<td>Re-litter daily</td>
<td>80</td>
<td>30 mins</td>
<td>£70.90</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>45 mins</td>
<td>£106.00</td>
<td>-</td>
</tr>
<tr>
<td>Hand and tractor</td>
<td>40</td>
<td>10 mins</td>
<td>£6.21</td>
<td>£9.70</td>
</tr>
<tr>
<td>Scarping daily</td>
<td>80</td>
<td>20 mins</td>
<td>£12.40</td>
<td>£9.70</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>30 mins</td>
<td>£18.61</td>
<td>£9.70</td>
</tr>
<tr>
<td>Power hose daily</td>
<td>40</td>
<td>3 mins</td>
<td>£1.18</td>
<td>£24.20</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>6 mins</td>
<td>£2.60</td>
<td>£25.30</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>9 mins</td>
<td>£3.78</td>
<td>£26.60</td>
</tr>
</tbody>
</table>

TABLE 4.8 COVERED CUBICLES

<table>
<thead>
<tr>
<th>Removal Method</th>
<th>No. of Cows</th>
<th>Time Taken</th>
<th>Operating Cost/Month</th>
<th>Annual Fixed Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand and tractor</td>
<td>40</td>
<td>17 mins</td>
<td>£0.47</td>
<td>£9.70</td>
</tr>
<tr>
<td>Scarping. Re-litter</td>
<td>80</td>
<td>34 mins</td>
<td>£0.94</td>
<td>£9.70</td>
</tr>
<tr>
<td>daily</td>
<td>120</td>
<td>51 mins</td>
<td>£1.42</td>
<td>£9.70</td>
</tr>
</tbody>
</table>

This type of analysis, although accepted by the MAFF for cost comparisons, produces unexpected results as few economies of scale appear to be evident. It is suspected that each system has been investigated for a herd size of, say, 40 cows and the times and costs simply doubled for a herd size of 80 cows. One might expect some form of unit time saving and unit cost saving with increased herd size. The only apparent unit cost saving is in the annual fixed charges in such systems as tractor scraping where a scraper must be purchased irrespective of herd size.

Comparing the total annual costs for hand and tractor scraping for the three types of housing one arrives at £7.58 per cow for cowsheds, £2.10 per cow for semi-covered yards, and £0.71 per cow for covered cubicles. (Based on a 40 cow herd). Thus it is
possible to see that more modern housing (cubicles) using less litter and giving cows less space can be considerably cheaper to clean. The ease of operation and this cost saving probably are causes of the trend away from the more traditional cowsheds and yards.

No basis for the annual fixed charges or the derivation of operating costs was given in this analysis (Boyer and Quick, 1968), but it is interesting to note that by far the greatest contributor to cleaning costs is that of capital equipment. Table 4.6 illustrates that as a cleaning system becomes more automated and less labour intensive, then the fixed costs grow in proportion and labour costs decrease. This is to be expected. The total annual cost per cow is £7.50 for hand scraping taking 1 min/cow, £7.58 for hand and tractor scraping taking 0.70 min/cow, £9.80 for mechanical gutter cleaning taking 0.60 min/cow, £0.87 for mains hose taking 0.18 min/cow, and £0.69 for power hose taking 0.05 min/cow (Based on an 80-cow herd). The two types of hosing represent the cheapest, quickest method of cleaning, but the introduction of water into the waste disposal system may be very undesirable indeed in certain systems. Considering the manual, manual/mechanical, and mechanical scraping systems it is seen that the more automated the system, the greater the total cost/cow/year but the unit time taken is less. Thus a farmer using automatic scraping would be able to release his labour to other tasks sooner than a farmer using manual scraping, and the greater cost of manure cleaning would be offset against the use of the freed labour elsewhere.

More recent analysis (Quick, A.J., Newcastle Symposium 1970) has demonstrated that cleaning by power hose, although cheap, may not give great savings in a disposal system in toto. For example,
tractor scraping and above ground storage for spreaders costs £3.30/cow/year, whilst power hosing connected to irrigation may cost £2.80/cow/year (No details of derivation of costs). Thus, the cost saving during cleaning by power hose may not be great when considering the rest of the disposal system. However, the time saving may be significant.

An investigation of 26 farms in Northern Ireland (Robinson, 1966) included final disposal method as well as cleaning method for cost comparisons. In all, 20 separate systems were analysed and Robinson used a 10 year life for equipment and 10% interest rate on capital. In the light of modern experience a 5 year life on scrapers and buckets is probably more realistic. The results have been re-calculated at 1970 prices and condensed into the following summaries. Throughout the analysis a cow is assumed to require 10 cu.ft storage for one week's waste, a winter is assumed to be 180 days, storage tanks are for 90 days' product, and a herd size of 64 cows is the base.

**System 1.** Tractor scrape and store in a ground level midden.

**Initial capital outlay:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floors</td>
<td>£ 194</td>
</tr>
<tr>
<td>Slurry area</td>
<td>£1,100</td>
</tr>
<tr>
<td>Midden and cover</td>
<td>£ 508</td>
</tr>
<tr>
<td>Scraper and bucket</td>
<td>£ 178</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>£1,980</td>
</tr>
</tbody>
</table>

**Annual fixed costs = £307**

This system requires 51.1 hours of labour/year at £0.33/hour.

**Annual variable costs = £17.0**

**Total annual costs = £324/64 cows**

**= £5.05/cow/year**
System 2. Tractor scrape to below-ground sump. Initial capital outlay:

Floors £ 194  
Slurry area £ 855  
Sump and cover £ 508  
Scraper and bucket £ 178  
Total £1,735 per 64 cows

Annual fixed costs = £268

This system requires 46.5 hours of labour/year at £0.33/hour.

... Annual variable costs = £15.4

... Total annual costs = £283.4/64 cows  
= £4.42/cow/year

System 3. Tractor scrape and above ground storage. Initial capital outlay:

Floors £ 194  
Tank £1,123  
Cover £ 510  
Scraper £ 30  
Total £1,857 per 64 cows

Annual fixed costs = £287

This system requires 46.5 hours of labour/year at £0.33/hour.

... Annual variable costs = £15.4

... Total annual costs = £302.4/64 cows  
= £4.72/cow/year

System 4. Cows housed on slats with hand scraping of other concrete areas. Initial capital outlay:

Tank £1,122  
Slats £ 710  
Total £1,832 per 64 cows

Annual fixed costs = £284

This system requires 72.4 hours of labour/year at £0.33/hour.

... Annual variable costs = £23.6

... Total annual costs = £307.6/64 cows  
= £4.79/cow/year
System 5. Cows housed on slats with tractor scraping of other concrete areas. Initial capital outlay:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank</td>
<td>1,122</td>
</tr>
<tr>
<td>Slats</td>
<td>710</td>
</tr>
<tr>
<td>Scraper</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,862</strong></td>
</tr>
</tbody>
</table>

Annual fixed costs = £289

This system requires 30.7 hours of labour/year at £0.33/hour.

Annual variable costs = £10.18

**Total annual costs** = (£299.2/64 cows) = (£4.67/cow/year)

Robinson's analysis demonstrates that the labour saving in automatic systems may not be large in monetary terms as it is offset by higher capital costs. The analysis is in agreement with Boyer and Quick (1968) in that capital costs contribute by far the larger proportion to overall cleaning and storage costs.

The selection of above or below-ground storage appears to have little financial effect and is largely a matter of convenience to the farmer. Robinson further pointed out that collection and storage costs probably did not include economies of scale. Boyer and Quick implied no economies of scale in their analyses but this does appear surprising. However, Robinson did point out that large scale effects were present in the distribution of the manure, and land spreading may cost £10-£13 per cow for 20-cow herds and £5-£6 per cow for 100-cow herds. It thus appears that the greatest savings may be made in the disposal rather than the collection equipment. This is probably due to smaller herds operating at below the capacity of the disposal equipment.

4.6.2 POULTRY ENTERPRISES

The only authoritative survey of poultry enterprises was sponsored by MAFF (Muckmem 24) and included 175 units. Costs were
given for cleaning and disposal and these were probably measured costs as no bases or assumptions are given. The average actual costs arrived at were:

- **Removal to midden** - £20.37/1,000 birds/year
  55.31 hours/year labour
- **Direct to spreader** - £19.30/1,000 birds/year
  58.26 hours/year labour
- **Removal to slurry pit** - £15.07/1,000 birds/year
  46.27 hours/year labour.

The labour costs are included in the actual costs. It appears that reduction in labour does reduce the operating costs noticeably. This was not true for cattle where equipment costs were much greater than labour costs. This suggests that poultry house cleaning is more labour-intensive than cow house cleaning which is somewhat surprising since poultry houses more readily lend themselves to automation (Sections 4.2 and 4.3). It is suspected that the enterprises chosen for this survey were comparatively small and on a high degree of manual labour (Wheelbarrows, shovels) was employed.

4.6.3 PIGGERY ENTERPRISES

No reference to piggery cleaning could be found by the author or by Guildford MAFF, and a time-and-motion study was initiated by the author and Nielson, V.C. (MAFF) to establish some costs for piggery cleaning. Four surveys were undertaken and these now represent MAFF guidelines for further investigations. The surveys are included in the format in which they were presented to MAFF.
This study was led by V.C. Nielson (M.A.F.F. Guildford) who judged that the pigman was constant in his procedure and the piggery was of standard design. The layout is shown in plan below:

The dunging channels are 3'4" wide and 60' long representing an area of 400 square feet to be swept. They are swept twice a day - at 7.00 a.m. and at 4.00 p.m. - the contents being drained into a sump of cross-sectional area 20.5 square feet.
The routine consisted of fetching the brush, opening the door and feeding all the pigs with pre-weighed meal. This generally made sure that the pigs were in the feeding area leaving the dunging passages free for cleaning. This was achieved by opening all the doors along side one and sweeping about 1/3 - 1/2 of the top end of the passage into the top channel. When this was completed the doors were closed as the pigman walked back down the passage sweeping and closing the doors after him as he went.

Then side 2 passage was opened, the tap turned on to help the dung down the channels and all the doors opened. The pigman then swept the whole channel from the far end closing the doors as he went.

Finally the brush and boots were washed, the tap turned off, and the doors bolted.
### Analysis of Times

**9/12/70**  
**170 pigs**  

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.60</td>
<td>0.60</td>
<td>Collect brush from shed.</td>
</tr>
<tr>
<td>0.60</td>
<td>0.70</td>
<td>0.10</td>
<td>Brush left by door and door opened.</td>
</tr>
<tr>
<td>0.70</td>
<td>3.70</td>
<td>3.00</td>
<td>Pigs fed.</td>
</tr>
<tr>
<td>3.70</td>
<td>4.50</td>
<td>1.20</td>
<td>Pick up brush, open dung channel cover, open door 1.</td>
</tr>
<tr>
<td>4.50</td>
<td>5.60</td>
<td>1.10</td>
<td>Dung doors opened.</td>
</tr>
<tr>
<td>5.60</td>
<td>6.60</td>
<td>1.00</td>
<td>Dung in end 1/3 - 1/2 swept.</td>
</tr>
<tr>
<td>6.60</td>
<td>6.80</td>
<td>0.20</td>
<td>Close end 1/3 - 1/2 doors.</td>
</tr>
<tr>
<td>6.80</td>
<td>8.70</td>
<td>1.90</td>
<td>Rest of passage swept, doors closed behind operator.</td>
</tr>
<tr>
<td>8.70</td>
<td>9.22</td>
<td>0.52</td>
<td>Outer door closed, passage 2 opened.</td>
</tr>
<tr>
<td>9.22</td>
<td>9.24</td>
<td>0.02</td>
<td>Tap turned on.</td>
</tr>
<tr>
<td>9.24</td>
<td>10.30</td>
<td>1.06</td>
<td>Passage 2 dung doors opened.</td>
</tr>
<tr>
<td>10.30</td>
<td>13.60</td>
<td>3.30</td>
<td>Passage 2 swept, doors closed behind operator.</td>
</tr>
<tr>
<td>13.60</td>
<td>14.30</td>
<td>0.70</td>
<td>Boots and brush cleaned, tap turned off.</td>
</tr>
<tr>
<td>14.30</td>
<td>14.50</td>
<td>0.20</td>
<td>Door closed, brush left outside.</td>
</tr>
</tbody>
</table>

**Total 14.50**
<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.60</td>
<td>0.30</td>
<td>Collect brush.</td>
</tr>
<tr>
<td>0.60</td>
<td>3.90</td>
<td>3.30</td>
<td>Open door, feed all pigs.</td>
</tr>
<tr>
<td>3.90</td>
<td>5.10</td>
<td>1.20</td>
<td>Opens passage 1 door, goes along opening all doors.</td>
</tr>
<tr>
<td>5.10</td>
<td>6.00</td>
<td>0.90</td>
<td>Top section swept.</td>
</tr>
<tr>
<td>6.00</td>
<td>6.30</td>
<td>0.30</td>
<td>Close top section doors.</td>
</tr>
<tr>
<td>6.30</td>
<td>8.20</td>
<td>1.90</td>
<td>Rest of passage swept, doors closed.</td>
</tr>
<tr>
<td>8.20</td>
<td>8.30</td>
<td>0.10</td>
<td>Closes outer door.</td>
</tr>
<tr>
<td>8.30</td>
<td>8.55</td>
<td>0.25</td>
<td>Walks to side 2 and opens door, turns on tap.</td>
</tr>
<tr>
<td>8.55</td>
<td>9.75</td>
<td>1.25</td>
<td>Opens dunging doors.</td>
</tr>
<tr>
<td>9.75</td>
<td>13.40</td>
<td>3.65</td>
<td>Sweeps passage closing doors.</td>
</tr>
<tr>
<td>13.40</td>
<td>13.90</td>
<td>0.50</td>
<td>Washes brush and boots, tap turned off, door locked.</td>
</tr>
</tbody>
</table>

Total 13.90
<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.45</td>
<td>0.45</td>
<td>Brush collected.</td>
</tr>
<tr>
<td>0.45</td>
<td>2.40</td>
<td>1.95</td>
<td>Side 2 opened, dung doors opened.</td>
</tr>
<tr>
<td>2.40</td>
<td>3.60</td>
<td>1.20</td>
<td>Top section swept.</td>
</tr>
<tr>
<td>3.60</td>
<td>4.10</td>
<td>0.50</td>
<td>Closes top section doors.</td>
</tr>
<tr>
<td>4.10</td>
<td>5.50</td>
<td>1.40</td>
<td>Sweeps rest of passage, closing doors.</td>
</tr>
<tr>
<td>5.50</td>
<td>5.75</td>
<td>0.25</td>
<td>Closes outer door.</td>
</tr>
<tr>
<td>5.75</td>
<td>6.00</td>
<td>0.25</td>
<td>Opens side 2, tap on.</td>
</tr>
<tr>
<td>6.00</td>
<td>7.10</td>
<td>1.10</td>
<td>Doors opened.</td>
</tr>
<tr>
<td>7.10</td>
<td>10.70</td>
<td>3.60</td>
<td>Passage swept.</td>
</tr>
<tr>
<td>10.70</td>
<td>10.82</td>
<td>0.12</td>
<td>Brush and boots washed, tap off.</td>
</tr>
<tr>
<td>10.82</td>
<td>10.95</td>
<td>0.13</td>
<td>Brushes ramp, tap on.</td>
</tr>
<tr>
<td>10.95</td>
<td>11.30</td>
<td>0.35</td>
<td>Dung washed down channel, tap off.</td>
</tr>
<tr>
<td>11.30</td>
<td>11.60</td>
<td>0.30</td>
<td>Door locked.</td>
</tr>
</tbody>
</table>

**Total 11.60**
<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.80</td>
<td>0.80</td>
<td>Collects brush.</td>
</tr>
<tr>
<td>0.80</td>
<td>2.20</td>
<td>1.40</td>
<td>Opens side 1, opens doors.</td>
</tr>
<tr>
<td>2.20</td>
<td>3.10</td>
<td>0.90</td>
<td>Top section swept out.</td>
</tr>
<tr>
<td>3.10</td>
<td>3.40</td>
<td>0.30</td>
<td>Top section doors closed.</td>
</tr>
<tr>
<td>3.40</td>
<td>5.80</td>
<td>2.40</td>
<td>Rest of passage swept and doors closed.</td>
</tr>
<tr>
<td>5.80</td>
<td>6.20</td>
<td>0.40</td>
<td>Outer door closed, walk to Side 2.</td>
</tr>
<tr>
<td>6.20</td>
<td>6.40</td>
<td>0.20</td>
<td>Opens door, uncovers channel.</td>
</tr>
<tr>
<td>6.40</td>
<td>6.42</td>
<td>0.02</td>
<td>Tap turned on.</td>
</tr>
<tr>
<td>6.42</td>
<td>7.60</td>
<td>1.18</td>
<td>Opens all doors.</td>
</tr>
<tr>
<td>7.60</td>
<td>11.40</td>
<td>3.80</td>
<td>Sweeps passage.</td>
</tr>
<tr>
<td>11.40</td>
<td>11.60</td>
<td>0.20</td>
<td>Sweeps ramp, cleans boots and brush.</td>
</tr>
<tr>
<td>11.60</td>
<td>11.95</td>
<td>0.20</td>
<td>Tap off, door closed.</td>
</tr>
</tbody>
</table>

Total 11.95
On 9/12/70 - it took about 3.00 mins. to feed the pigs, 4.20 mins. to sweep the passages, and 5.20 mins. to open and close the doors.

The sump rose by 6½" representing an effluent volume of 11.05 cu.ft., about 66.5 galls. A 1.25 gall. bucket fills in 0.45 mins. from the tap, the tap was on for 5.06 mins., a volume of 14 galls. Therefore dung and urine volume = 52 galls.

On 16/12/70
3.30 mins. to feed pigs.
4.90 mins. for opening/closing doors.
4.30 mins. for sweeping
Sump increased by 19" - i.e. 32.5 cu.ft. i.e. 195 galls.
Tap water was 14.9 galls.
Input effluent from cows (1 inch every 3 mins.) = 1.7 cu.ft/3 mins. = 49 galls. for the 13.90 mins.
Therefore pig dung and urine = 130 galls

On 7/1/71
Pigs were already fed.
4.4 mins. for sweeping.
4.9 mins. for opening/closing doors.
No dung measured.

On 8/1/71
Pigs already fed.
4.8 mins. for sweeping.
5.2 mins. for opening/closing doors.
13" increase in sump - 115 galls. Tap water is 15 galls.
Therefore pig dung and urine = 100 galls.
Conclusions

Mornings -
Sweeping times - 4.8 mins and 4.4 mins.
Average - 4.6 mins
Doors operating - 5.2 mins and 4.9 mins.
Average - 5.05 mins.
Miscellaneous - 2.1 mins

Total - 11.80 mins.
Dung - ½ gall./pig/15 hours
i.e. 1 gall./pig/day

Afternoons
Sweeping times - 4.30 mins. and 4.20 mins.
Average - 4.25 mins.
Doors operating - 4.90 mins. and 5.20 mins.
Average - 5.05 mins
Miscellaneous - 5.0 mins. (including feeding)

Total - 14.30 mins.
Again, effluent/pig/day 1 gall.

The times for the operations were constant over the four readings showing the strict routine of the pigman. The tap water and influent from the dairy made it difficult to assess the amount of dung entering the sump attributable to the pigs.

S.L. Willetts (Report No. 1)
This study was led by V.C. Nielson (M.A.F.F., Guildford) as was the Danish Piggery Cleaning (See previous report).

The pigman cleaning the Solari Sow and Litter units was the same that cleaned the Danish piggery, and so his routine was judged to be constant. He was thus timed on two consecutive mornings to enable an average time/unit to be calculated.

The procedure started by collecting wood shavings for the bedding from covered bunkers adjacent to the Solari Unit.

Each unit was then opened, cleaned out, and re-bedded. The time for this operation was variable due to differing amounts of mess created by the occupants in each unit.

After cleaning all the units out with a squeegee, a tractor and scraper was employed to scrape the following area:
After scraping, the concrete area was washed down by two men using about 30 buckets - full of water, each of 2 gall. This took about five minutes.

The hand squeegee was a broom-like implement using a blade 24" by 4".

A full analysis of the times is shown in the following two tables:
<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.70</td>
<td>0.70</td>
<td>Collect squeegee and shavings outside sty 1.</td>
</tr>
<tr>
<td>0.70</td>
<td>1.20</td>
<td>0.50</td>
<td>Open door, clean sty 1.</td>
</tr>
<tr>
<td>1.20</td>
<td>1.60</td>
<td>0.40</td>
<td>Rebed and close sty 1.</td>
</tr>
<tr>
<td>1.60</td>
<td>2.40</td>
<td>1.20</td>
<td>Open door, clean sty 2, close door.</td>
</tr>
<tr>
<td>2.40</td>
<td>4.30</td>
<td>1.90</td>
<td>Open door, clean sty 3.</td>
</tr>
<tr>
<td>4.30</td>
<td>4.90</td>
<td>0.60</td>
<td>Rebed, and close sty 3.</td>
</tr>
<tr>
<td>4.90</td>
<td>5.80</td>
<td>0.90</td>
<td>Open door, clean sty 4, close door.</td>
</tr>
<tr>
<td>5.80</td>
<td>6.50</td>
<td>0.70</td>
<td>Open door, clean sty 5 - stop to attend to other business</td>
</tr>
<tr>
<td>0.00</td>
<td>0.90</td>
<td>0.90</td>
<td>Complete sty 5.</td>
</tr>
<tr>
<td>0.90</td>
<td>1.05</td>
<td>0.15</td>
<td>Collect more shavings.</td>
</tr>
<tr>
<td>1.05</td>
<td>1.60</td>
<td>0.55</td>
<td>Rebed, and close sty 5.</td>
</tr>
<tr>
<td>1.60</td>
<td>2.40</td>
<td>0.80</td>
<td>Open door, clean sty 6.</td>
</tr>
<tr>
<td>2.40</td>
<td>2.80</td>
<td>0.40</td>
<td>Collect more shavings.</td>
</tr>
<tr>
<td>2.80</td>
<td>3.10</td>
<td>0.30</td>
<td>Rebed, and close sty 6.</td>
</tr>
<tr>
<td>3.10</td>
<td>3.60</td>
<td>0.50</td>
<td>Clean and rebed sty 7.</td>
</tr>
<tr>
<td>3.60</td>
<td>5.90</td>
<td>2.30</td>
<td>Clean and rebed sty 8.</td>
</tr>
<tr>
<td>5.90</td>
<td>7.40</td>
<td>1.50</td>
<td>Soiled bedding scraped well into road.</td>
</tr>
<tr>
<td>7.40</td>
<td>7.50</td>
<td>0.10</td>
<td>Replace squeegee, finish.</td>
</tr>
</tbody>
</table>

**Total**  14.4
<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.70</td>
<td>0.70</td>
<td>Start tractor and bring into position.</td>
</tr>
<tr>
<td>0.70</td>
<td>7.10</td>
<td>6.40</td>
<td>Scrape concrete areas.</td>
</tr>
<tr>
<td>7.10</td>
<td>7.30</td>
<td>0.20</td>
<td>Replace tractor</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7.30</td>
<td></td>
</tr>
<tr>
<td>6.50</td>
<td>10.60</td>
<td>4.10</td>
<td>Wash and sweep concrete.</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4.10</td>
<td></td>
</tr>
<tr>
<td>Start</td>
<td>Finish</td>
<td>Time</td>
<td>Operation</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>0.00</td>
<td>0.90</td>
<td>0.90</td>
<td>Collects squeegee and shavings.</td>
</tr>
<tr>
<td>0.90</td>
<td>1.40</td>
<td>0.50</td>
<td>Opens door, cleans sty 1, no need to rebed.</td>
</tr>
<tr>
<td>1.40</td>
<td>2.20</td>
<td>0.80</td>
<td>Opens door, cleans sty 2, no need to rebed.</td>
</tr>
<tr>
<td>2.20</td>
<td>2.80</td>
<td>0.60</td>
<td>Opens door, cleans sty 3, no need to rebed.</td>
</tr>
<tr>
<td>2.80</td>
<td>3.40</td>
<td>0.60</td>
<td>Opens door, cleans sty 4.</td>
</tr>
<tr>
<td>3.40</td>
<td>3.95</td>
<td>0.55</td>
<td>Rebedded.</td>
</tr>
<tr>
<td>3.95</td>
<td>5.40</td>
<td>1.45</td>
<td>Opens door, cleans sty 5.</td>
</tr>
<tr>
<td>5.40</td>
<td>5.85</td>
<td>0.45</td>
<td>Rebedded, door closed.</td>
</tr>
<tr>
<td>5.85</td>
<td>7.60</td>
<td>1.75</td>
<td>Opens door, cleans sty 6.</td>
</tr>
<tr>
<td>7.60</td>
<td>8.00</td>
<td>0.40</td>
<td>Rebedded, door closed.</td>
</tr>
<tr>
<td>8.00</td>
<td>8.50</td>
<td>0.50</td>
<td>Opens door, cleans sty 7, not rebedded.</td>
</tr>
<tr>
<td>8.50</td>
<td>9.60</td>
<td>1.10</td>
<td>Opens door, cleans sty 8.</td>
</tr>
<tr>
<td>9.60</td>
<td>10.00</td>
<td>0.40</td>
<td>Rebedded, door closed.</td>
</tr>
<tr>
<td>10.00</td>
<td>10.60</td>
<td>0.60</td>
<td>Sweeps soiled bedding well on to concrete.</td>
</tr>
<tr>
<td>10.60</td>
<td>11.00</td>
<td>0.40</td>
<td>Replaces squeegee, finish.</td>
</tr>
</tbody>
</table>

Total 11.00

Tractor Scraping - 5.30 mins
Washing Concrete - 5.00 mins
Conclusions

The amount of mess required to be cleaned out was variable, and so the times for cleaning out cover the broad span of 0.5 to 1.9 mins, with an average time of about 1.0 min.

Rebedding took about 0.5 mins on average.

Tractor scraping of the concrete pathways took between 5.30 and 7.30 mins.

Washing the concrete down with 60 galls. water and sweeping it took two men about 5.00 mins.

The floor area of each Solari Unit was 16' x 5'3" - 84 sq. ft.

S.L. Willetts (Report No. 2)

Stephen L. Willetts
This is the third report in a series under the supervision of Mr. V.C. Nielson (M.A.F.F., Guildford).

The Dry Sow Yard at Merrist Wood consists of two separate halves and each half was studied independently. The system of gates separating the cubicles was difficult to observe and time adequately due to their opening and latching mechanisms being complicated.

Mr. Barnes, the head pigman, was the operator. His system consisted of cleaning a cubicle, shutting the sows into the cubicle, and scraping the manure into the centre of the passageway ready for scraping away by tractor. Until all the sows were shut into the cubicles both the end gates were closed as a safety measure. Only when the complete yard was cleared ready for scraping were the end gates finally fixed open.

The plan of the sow unit is shown below, and the time study follows:

---

**KEY**

- [1] = Cubicle No
- [2] = Gate No
- [3] = No of Sows
9/3/71  1:15 a.m.

Side 1

28 Sows.  5 cubicles

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.20</td>
<td>1.20</td>
<td>Collects shovel and squeegee from shed, walks to yard.</td>
</tr>
<tr>
<td>1.20</td>
<td>3.20</td>
<td>2.00</td>
<td>Opens outer gate, enters yard, closes outer gate, enters cubicle 1 and cleans out.</td>
</tr>
<tr>
<td>3.20</td>
<td>3.80</td>
<td>0.60</td>
<td>Shuts in sows, scrapes manure from edges of yard.</td>
</tr>
<tr>
<td>3.80</td>
<td>4.70</td>
<td>0.90</td>
<td>Opens inner gate 1, enters cubicle 2 cleans out, shuts in sows, scrapes yard edges.</td>
</tr>
<tr>
<td>4.70</td>
<td>5.50</td>
<td>0.80</td>
<td>Opens inner gate 2, cleans cubicle 3, shuts in sows.</td>
</tr>
<tr>
<td>5.50</td>
<td>6.40</td>
<td>0.90</td>
<td>Chains gates 1 and 2 open and secures to the wall.</td>
</tr>
<tr>
<td>6.40</td>
<td>7.70</td>
<td>1.30</td>
<td>Cleans gutter and edge of yard.</td>
</tr>
<tr>
<td>7.70</td>
<td>8.40</td>
<td>0.70</td>
<td>Opens gate 3, cleans cubicle 4, shuts in sows.</td>
</tr>
<tr>
<td>8.40</td>
<td>10.90</td>
<td>2.50</td>
<td>Opens gate 4, cleans cubicle 5, shuts in sows.</td>
</tr>
<tr>
<td>10.90</td>
<td>12.00</td>
<td>1.10</td>
<td>Chains gates 3 and 4 open and secures to wall.</td>
</tr>
<tr>
<td>12.00</td>
<td>12.60</td>
<td>0.60</td>
<td>Cleans gutter and edge of yard.</td>
</tr>
<tr>
<td>12.60</td>
<td>14.00</td>
<td>1.40</td>
<td>Opens two outer gates and chains to wall.</td>
</tr>
<tr>
<td>14.70</td>
<td>19.20</td>
<td>4.50</td>
<td>Mounts tractor, starts up, scrapes out yard, switches off, dismounts.</td>
</tr>
<tr>
<td>19.20</td>
<td>20.10</td>
<td>0.90</td>
<td>Closes two outer gates as safety measure.</td>
</tr>
<tr>
<td>20.10</td>
<td>23.20</td>
<td>3.10</td>
<td>Opens all cubicles and unchains inner gates.</td>
</tr>
</tbody>
</table>

Total Time  - 23.20 mins
25 sows.  7 cubicles

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.50</td>
<td>1.50</td>
<td>Enters yard, closes outer gate, cleans cubicle 6, shuts in sows.</td>
</tr>
<tr>
<td>1.50</td>
<td>2.40</td>
<td>0.90</td>
<td>Cleans gutter and yard edge.</td>
</tr>
<tr>
<td>2.40</td>
<td>3.20</td>
<td>0.80</td>
<td>Enters cubicle 7, cleans out, shuts sows in.</td>
</tr>
<tr>
<td>3.20</td>
<td>4.00</td>
<td>0.80</td>
<td>Cleans gutter and yard edge.</td>
</tr>
<tr>
<td>4.00</td>
<td>5.00</td>
<td>1.00</td>
<td>Enters cubicle 9 (no sows in 8) cleans out, shuts in sows.</td>
</tr>
<tr>
<td>5.00</td>
<td>5.50</td>
<td>0.50</td>
<td>Chains open two inner gates to the wall.</td>
</tr>
<tr>
<td>5.50</td>
<td>5.70</td>
<td>0.20</td>
<td>Scrapes gutter and yard edge.</td>
</tr>
<tr>
<td>5.70</td>
<td>6.70</td>
<td>1.00</td>
<td>Cleans cubicle 10, shuts in sows.</td>
</tr>
<tr>
<td>6.70</td>
<td>7.40</td>
<td>0.70</td>
<td>Scrapes gutter and yard edge.</td>
</tr>
<tr>
<td>7.40</td>
<td>7.60</td>
<td>0.20</td>
<td>Chains open two inner gates to the wall.</td>
</tr>
<tr>
<td>7.60</td>
<td>10.60</td>
<td>3.00</td>
<td>Scrapes cubicles 11 and 12 (manure from last week).</td>
</tr>
<tr>
<td>10.60</td>
<td>11.40</td>
<td>0.80</td>
<td>Walks to tractor cleaning out gutter at same time.</td>
</tr>
<tr>
<td>11.40</td>
<td>11.90</td>
<td>0.50</td>
<td>Opens outer gate and chains to wall.</td>
</tr>
<tr>
<td>11.90</td>
<td>17.50</td>
<td>5.60</td>
<td>Mounts tractor, starts up, scrapes yard, switches off, dismounts.</td>
</tr>
<tr>
<td>17.50</td>
<td>20.00</td>
<td>2.50</td>
<td>Opens sow cubicles, closes inner gates.</td>
</tr>
</tbody>
</table>

Finished.

Total Time  -  20.00 mins

Plus 1.10 mins to tidy up midden.
Cleaning out of this yard is undertaken once a week. It used to be undertaken more frequently but the sows suffered from damage through walking on hard concrete.

Normally the unit accommodates 80 sows and is considered a one-man unit.

The sows are usually re-bedded after cleaning out, but this was not considered as part of the mucking-out process.

S.L. Willetts (Report No. 3)

Stephen L. Willetts
Danish Piggery Cleaning

This is the fourth report in a series of surveys led by V.C. Nielson (M.A.F.F., Guildford).

The situation at Stanway Green consisted of two Danish-type pig houses, one with 40 units and one with 30 units. About 900 pigs were housed in the two units. Cleaning out of the houses was a two-stage process:

Stage 1 - tractor scraping of the dung passages.
Stage 2 - hand sweeping of the individual units and re-bedding with straw.

These two stages were carried out using the following timetable:

Monday - Tractor scraping of both houses
          Pens of house 2 swept.
Tuesday - Pens of house 1 swept.
Wednesday - Tractor scraping of both houses.
Thursday - Pens of house 2 swept.
Friday - Tractor scraping of both houses.
          Pens of house 1 swept.

House 1 was the 40 unit (pen) house
House 2 was the 30 unit (pen) house.

The study was from 8.00 a.m. on Friday, 14th May 1971 and the operator was Mr. David Crane, who assured us that a normal procedure was followed despite his being watched and timed.

A plan of the unit follows:
KEY 1 = ORDER OF RE-BEDDING
The time study revealed the following breakdown for analysis:

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>2.40</td>
<td>2.40</td>
<td>Opens 21 doors of house 1, side 1.</td>
</tr>
<tr>
<td>2.40</td>
<td>2.70</td>
<td>0.30</td>
<td>Walks to house 2, side 1.</td>
</tr>
<tr>
<td>2.70</td>
<td>5.00</td>
<td>2.30</td>
<td>Opens 16 doors of house 2, side 1.</td>
</tr>
<tr>
<td>5.00</td>
<td>5.20</td>
<td>0.20</td>
<td>Walks to house 1, side 2.</td>
</tr>
<tr>
<td>5.20</td>
<td>7.30</td>
<td>2.10</td>
<td>Opens 21 doors of house 1, side 2.</td>
</tr>
<tr>
<td>7.30</td>
<td>7.60</td>
<td>0.30</td>
<td>Walks to house 2, side 2.</td>
</tr>
<tr>
<td>7.60</td>
<td>10.50</td>
<td>2.90</td>
<td>Opens 16 doors of house 2, side 2.</td>
</tr>
<tr>
<td>10.50</td>
<td>12.30</td>
<td>1.80</td>
<td>Walks to get face-mask from shed (About 75 yds. away).</td>
</tr>
<tr>
<td>12.30</td>
<td>12.50</td>
<td>0.20</td>
<td>Mounts and starts tractor.</td>
</tr>
<tr>
<td>12.50</td>
<td>12.60</td>
<td>0.10</td>
<td>Drives 25 yds. to house 2, side 2.</td>
</tr>
<tr>
<td>12.60</td>
<td>12.80</td>
<td>0.20</td>
<td>Scrapes house 2, side 2.</td>
</tr>
<tr>
<td>12.80</td>
<td>13.20</td>
<td>0.40</td>
<td>Reverses.</td>
</tr>
<tr>
<td>13.20</td>
<td>13.50</td>
<td>0.30</td>
<td>Re-scrapes house 2, side 2.</td>
</tr>
<tr>
<td>13.50</td>
<td>13.90</td>
<td>0.40</td>
<td>Reverses.</td>
</tr>
<tr>
<td>13.90</td>
<td>14.25</td>
<td>0.35</td>
<td>Drives to house 2, side 1.</td>
</tr>
<tr>
<td>14.25</td>
<td>14.60</td>
<td>0.35</td>
<td>Scrapes house 2, side 1.</td>
</tr>
<tr>
<td>14.60</td>
<td>14.90</td>
<td>0.30</td>
<td>Reverses.</td>
</tr>
<tr>
<td>14.90</td>
<td>15.30</td>
<td>0.40</td>
<td>Rescrapes house 2, side 1.</td>
</tr>
<tr>
<td>15.30</td>
<td>15.50</td>
<td>0.20</td>
<td>Reverses.</td>
</tr>
<tr>
<td>15.50</td>
<td>15.80</td>
<td>0.30</td>
<td>Drives to house 1, side 2.</td>
</tr>
<tr>
<td>15.80</td>
<td>16.20</td>
<td>0.40</td>
<td>Scrapes house 1, side 2.</td>
</tr>
<tr>
<td>16.20</td>
<td>16.60</td>
<td>0.40</td>
<td>Reverses.</td>
</tr>
<tr>
<td>16.60</td>
<td>17.00</td>
<td>0.40</td>
<td>Rescrapes house 1, side 2.</td>
</tr>
<tr>
<td>17.00</td>
<td>17.40</td>
<td>0.40</td>
<td>Reverses.</td>
</tr>
<tr>
<td>17.40</td>
<td>17.60</td>
<td>0.20</td>
<td>Drives to house 1, side 1.</td>
</tr>
<tr>
<td>17.60</td>
<td>18.10</td>
<td>0.50</td>
<td>Scrapes house 1, side 1.</td>
</tr>
<tr>
<td>18.10</td>
<td>18.40</td>
<td>0.30</td>
<td>Reverses.</td>
</tr>
<tr>
<td>Start</td>
<td>Finish</td>
<td>Time</td>
<td>Operation</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>18.40</td>
<td>18.90</td>
<td>0.50</td>
<td>Rescrapes house 1, side 1.</td>
</tr>
<tr>
<td>18.90</td>
<td>19.50</td>
<td>0.60</td>
<td>Drives to side 2 of house 1 and parks tractor.</td>
</tr>
<tr>
<td>19.50</td>
<td>22.10</td>
<td>2.60</td>
<td>Closes 21 doors of house 1, side 1.</td>
</tr>
<tr>
<td>22.10</td>
<td>22.50</td>
<td>0.40</td>
<td>Walks to house 2, side 2.</td>
</tr>
<tr>
<td>22.50</td>
<td>24.50</td>
<td>2.00</td>
<td>Closes 16 doors of house 2, side 2.</td>
</tr>
<tr>
<td>24.50</td>
<td>25.30</td>
<td>0.80</td>
<td>Moves tractor away from doors of house 1, side 2.</td>
</tr>
<tr>
<td>25.30</td>
<td>28.20</td>
<td>2.90</td>
<td>Closes 21 doors of house 1, side 2.</td>
</tr>
<tr>
<td>28.20</td>
<td>28.30</td>
<td>0.10</td>
<td>Walks to house 2, side 2.</td>
</tr>
<tr>
<td>28.30</td>
<td>30.40</td>
<td>2.10</td>
<td>Closes 16 doors of house 2, side 1.</td>
</tr>
<tr>
<td>30.40</td>
<td>30.60</td>
<td>0.20</td>
<td>Walks to and mounts tractor.</td>
</tr>
<tr>
<td>30.60</td>
<td>39.00</td>
<td>8.40</td>
<td>Scrapes concrete yard, dung piled into heap.</td>
</tr>
<tr>
<td>39.00</td>
<td>40.00</td>
<td>1.00</td>
<td>Drives to diesel tank in front of house 2.</td>
</tr>
<tr>
<td>40.00</td>
<td>41.90</td>
<td>1.90</td>
<td>Fills tractor with diesel.</td>
</tr>
<tr>
<td>41.90</td>
<td>42.50</td>
<td>0.60</td>
<td>Parks tractor.</td>
</tr>
<tr>
<td>42.50</td>
<td>46.00</td>
<td>3.50</td>
<td>Walks to house 1 and collects brush and shovel.</td>
</tr>
<tr>
<td>46.00</td>
<td>55.40</td>
<td>9.40</td>
<td>Scrapes 6 pens of house 1, side 2 bedding into dunging passage.</td>
</tr>
<tr>
<td>55.40</td>
<td>63.30</td>
<td>7.90</td>
<td>Repeats house 1, side 1, 6 pens.</td>
</tr>
<tr>
<td>63.30</td>
<td>72.30</td>
<td>9.00</td>
<td>Repeats house 1, side 2, 8 pens.</td>
</tr>
<tr>
<td>72.30</td>
<td>81.40</td>
<td>9.10</td>
<td>Repeats house 1, side 2, 6 pens.</td>
</tr>
<tr>
<td>81.40</td>
<td>90.50</td>
<td>9.10</td>
<td>Repeats house 1, side 1, 6 pens.</td>
</tr>
<tr>
<td>90.50</td>
<td>101.80</td>
<td>11.30</td>
<td>Repeats house 1, side 1, 8 pens.</td>
</tr>
<tr>
<td>101.80</td>
<td>109.20</td>
<td>7.40</td>
<td>Sweeps between feeding mangers into central passageway.</td>
</tr>
<tr>
<td>109.20</td>
<td>112.80</td>
<td>3.60</td>
<td>Walks about 50 yds. to hay barn and fetches down 20 bales.</td>
</tr>
<tr>
<td>112.80</td>
<td>113.80</td>
<td>1.00</td>
<td>Loads 7 bales onto trolley.</td>
</tr>
<tr>
<td>Start</td>
<td>Finish</td>
<td>Time</td>
<td>Operation</td>
</tr>
<tr>
<td>-------</td>
<td>---------</td>
<td>-------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>113.80</td>
<td>116.40</td>
<td>2.60</td>
<td>Pushes Trolley into central passage of house 1, beds out at ½ bale per pen, the first 14 pens.</td>
</tr>
<tr>
<td>116.40</td>
<td>118.00</td>
<td>1.60</td>
<td>Takes trolley back and loads 7 bales.</td>
</tr>
<tr>
<td>118.00</td>
<td>120.20</td>
<td>4.20</td>
<td>Pushes trolley back, beds out next 14 pens.</td>
</tr>
<tr>
<td>120.20</td>
<td>122.00</td>
<td>1.80</td>
<td>Takes trolley back and loads 6 bales.</td>
</tr>
<tr>
<td>122.00</td>
<td>124.00</td>
<td>2.00</td>
<td>Pushes trolley back, beds last 12 pens.</td>
</tr>
<tr>
<td>124.00</td>
<td>129.40</td>
<td>5.40</td>
<td>Sweeps central passageway pushing trolley along in front. Rubbish (feed, straw) thrown bac into pens.</td>
</tr>
<tr>
<td>129.40</td>
<td>129.60</td>
<td>0.20</td>
<td>Parks trolley.</td>
</tr>
<tr>
<td>129.60</td>
<td>132.30</td>
<td>2.70</td>
<td>Closes two end doors of central passageway.</td>
</tr>
<tr>
<td>132.30</td>
<td>Finish</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Time = 2 hours 12.30 minutes.
The internal structure of the two houses (with dimensions) was as follows:

**HOUSE 1**

- 1'6½" MANGER
- 1'1" PASSAGE
- 1'6½" MANGER

- 4'2"

- 3'8" 15'4" 7'6"

- 50 ft.

**HOUSE 2**

- 1'7" MANGER
- 1'7" PASSAGE
- 1'7" MANAGER

- 4'9"

- 3'6" 16'4" 7'9"

- 124'10"

- 52 ft.
Analysis

It can be seen that about 4,200 sq. ft. was tractor scraped and this took about 3.05 minutes actual scraping with 3.25 minutes manoeuvring and 0.90 minutes driving to and from the houses.

About 4,680 sq. ft. of pens was hand scraped and this took about 55.80 minutes. This mainly involved pushing the soiled bedding into the dunging passage.

Sweeping 1,200 sq. ft. of central passageway and between feeding-manger areas took 12.80 minutes. This included throwing the rubbish into the pens as bedding.

Operation of the doors in house 1 took 4.50 minutes opening and 5.50 minutes closing. House 2 took 5.20 minutes opening and 4.10 closing. These doors were all single-bolt type fastenings.

Conclusions

A strict comparison with Merrist Wood Agricultural College is not valid due to both the type and size of houses being different, and consequently the cleaning routine. However, it is interesting to note that both Mr. Barnes (Merrist Wood) and Mr. Crane (Stanway Green) emphasised that their respective routines had been self-evolved and were considered the most efficient. Judging by their confidence in their methods they would seem to be correct.

The two different systems of cleaning can be compared in the following table:

<table>
<thead>
<tr>
<th>Item</th>
<th>Merrist Wood</th>
<th>Stanway Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweeping of dunging</td>
<td>0.55 mins/100 sq.ft.</td>
<td>0.15 mins/100 sq.ft.</td>
</tr>
<tr>
<td>passages by man and</td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td>tractor</td>
<td>0.275 mins/unit</td>
<td>0.09 mins/unit</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>2.25 mins/100 pig</td>
<td>0.70 mins/100 pig</td>
</tr>
<tr>
<td>places</td>
<td></td>
<td>places</td>
</tr>
</tbody>
</table>

This is as far as any comparison can be taken due to the difficulties outlined previously. However, costing a man at £0.50 per hour and a man and tractor at £1.00 per hour it can be seen that Merrist Wood pays about £1.50 per week for 20 units and Stanway Green about £6.33 per week for 70 units.

S.L. Willetts (Report No. 4)
4.7 SUMMARY

From the choice of systems available it seems to be a matter of personal preference or convenience as to which one is finally used. Dry systems requiring bedding and covers will require manual or manual/mechanical cleaning, while wet systems will require a decreased labour input and higher capital input. Economies of scale are a little uncertain but it is expected that economies will be present for capital equipment if not for labour.

For handling equipment there are also economies of scale. For example, Section 4.4 illustrates that augers of a 6" diameter cost about £1 for each gal/minute delivered while a 9" auger about £0.80 for each gal/min. However, it is extremely difficult to compare different manufacturer's equipment due to differing specifications. Scale effects are definitely present within one manufacturer's model range. Table 4.2 quotes the costs of scrapers, and Brian Langmead's 6'3" push scraper, for example, costs £5 per inch of depth on the smaller and £4.75 per inch of depth on the larger model. However, other 6'3" scrapers cannot be compared with Langmead's models due to differing constructions and specifications.

Finally, once a system is chosen, it is important that a constant and efficient routine be followed. The time and motion studies on piggery cleaning indicate that some 50-60% of manual cleaning is unproductive - fetching and carrying opening and closing doors, etc.
"For overlaboured with so long a course,
'Tis time to set at ease the smoking horse."

(The Georgics. John Curtis 1791-1862,
author of British Entymology and Farm Insects)
5.1 INTRODUCTION

The cultivation of crops, and, to a lesser extent, grass for grazing or cutting, requires a high degree of husbandry skill and the farmer today wishes to know exactly what is being given to his crops by way of nutrients. To achieve maximum yields fertilisers must be applied in appropriate quantities and at appropriate times of the year, and the quantities recommended by M.A.F.F. and fertiliser manufacturers are used as guidelines to enable the farmer to extract maximum yield. Reference to fig 1(17) illustrates the increases in yields per acre for wheat, barley, and oats since 1946 and these increases must be due, in part, to a changing fertiliser regime in that period. This fact is illustrated in Figs 5(1) and 5(2) where the increased use in fertilisers since 1954 (44%) is paralleled by the increased cereal harvest in the same period (60%). Increased yields must also be due to genetic selection of cereal strains by farmers. (Fertiliser statistics have only been available since 1954).

In contrast to the use of specific synthetic inorganic fertilisers there is the need to dispose of farm wastes onto the land and, as has been shown in Chapter 3, the manurial nutrients can be used as crop fertiliser. Firstly the use of inorganics is studied, and then the use of manures.

5.2 USE OF SYNTHETIC INORGANIC FERTILISERS

The nutrients under consideration are N, P, and K and Figs 5(3), 5(4), and 5(5) show the increased applications of these nutrients since 1954. The greatest increase is shown
FIG. 5.1

UK Consumption of all Fertilisers.
[1954/55-61/62; Years ended June]
[1962/63 onwards; Years ended May]

Source: Stats. 27, MAFF. [54/55, 55/56 for G.B.]
FIG. 5.2

Annual UK Harvest of:
- wheat, barley, oats, corn & rye;
- all crops.

Sources: Annual Abstract of Statistics, HMSO.
Stats. PF & POV, MAFF.
FIG. 5.(3)

UK Consumption of Nitrogen in Fertilisers.

Source: Stats, 27, MAFF.

[54/55, 55/56 for GB]

[1954/55-61/62; Years ended June]

[1962/63 onwards; Years ended May]
UK Consumption of $P_2O_5$ in Fertilisers:
[1954/55 - 61/62; Years ended June]
[1962/63 onwards; Years ended May]

Source: Stats. 27 MAFF.
[54/55, 55/56 for GB]
FIG. 5.5
UK Consumption of K₂O in fertilisers.
[1954/55-61/62; Years ended June]
[1962/63 onwards; Years ended May]

Source: Stats. 27, MAFF. [54/55, 55/56 for GB]
in the use of nitrogen (150%) with potassium next (73%) and finally phosphorus (37%). Figs 5(6) and 5(7) demonstrate the distribution in the application of total fertilisers and in the application of nitrogenous fertilisers. It can be seen that all fertilisers are generally evenly distributed but that nitrogenous fertiliser usage is biased to the cereal-growing counties in the East of England.

Tables 5(1) and 5(2) give M.A.A.F. and Fisons' advised fertiliser applications for winter and spring cereals. (M.A.A.F., NAAS Advisory Papers No. 4; Fisons Fertilisers 1971-72).

**TABLE 5(1)**
Winter Cereals - Top Dressing

<table>
<thead>
<tr>
<th>Previous Crop</th>
<th>NAAS(units/acre)</th>
<th>Fisons (units/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Grazed leys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*40-60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**40</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***40</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>Fallow or arable break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*60-90</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>Cereal crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*80-160</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**80</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***80</td>
<td>30-60</td>
<td>30</td>
</tr>
</tbody>
</table>

* - Wheat
** - Barley
*** - Oats and Rye

The ranges quoted by the Ministry are dependent on soil type and rainfall and NAAS give each soil type its own recommendation. These figures are grouped together in the tables. (1 unit is 1.12 lb weight).
FIG. 5.(6)
Total fertiliser applications,
1 dot = 1,000 tons.
[1970]
Fig. 5.7

Total nitrogen applications,
1 dot = 100 tons.
[1970]
<table>
<thead>
<tr>
<th>Previous Crop</th>
<th>NAAS (units/acre)</th>
<th>Fisons (units/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*40-60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**40-60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***0-30</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>Arable break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*70-80</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**60-90</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***50-60</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*90-100</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>**90-140</td>
<td>30-60</td>
<td>30</td>
</tr>
<tr>
<td>***70-80</td>
<td>30-60</td>
<td>30</td>
</tr>
</tbody>
</table>

* - Wheat
** - Barley
*** - Oats and Rye

The actual fertiliser applications can be computed from Figs 5(3), 5(4), and 5(5) giving 900,517 tons N, 496,539 tons P_{2}O_{5}, and 420,074 tons K applied in 1970/71 to 12,088,000 acres of cereals (2,495,000 acres wheat, 5,542,000 acres barley, 929,000 acres oats, 196,000 acres mixed corn, and 11,000 acres rye) and 17,917,000 acres of other crops and grass in the U.K. (MAFF Stats. 27 and Annual Abstract of Statistics). This represents general application rates of 71 units/acre N, 40 units/acre P, and 34 units/acre K. The actual fertiliser usage is therefore in the region of the recommended usage but there is definite scope for increased applications of synthetic fertilisers. Fig 5(1) demonstrates a rather uncertain trend in overall usage of fertilisers and has been oscillating since the 1960's. Figs 5(3), 5(4), and 5(5) demonstrate the factors contributing to this fluctuating but steadying trend and it is seen that K_{2}O application has levelled, P_{2}O_{5} application
has fluctuated from year to year and may be steadying, but nitrogen usage has shown a steady increase since 1954. Not only has N use increased but the use has become concentrated in the cereal counties (Fig 5(7)).

With light dressings of nitrogen, crop retention is of the order 0.005-0.05% (Walters, 1970) and heavy dressings increase this retention to 0.2 - 0.6% and the soil nitrate levels obviously increase. These high nitrate levels in crops and soil are becoming of concern (Garner, 1958). However, nitrogen use is increasing and is likely to increase since grasses exhibit a linear growth response up to about 300 - 400 units/acre of N (Hood, A.E.M. Jealott's Hill Research Station Personal communication 2/3/72). However, certain schools of thought are advocating the use of less nitrogen/acre taking into account the consequent high nitrate levels in crops and soil even with present day applications. Barry Commoner (Center for the Biology of Natural Systems, Missouri, Personal communication 5/9/72) advocates the use of a maximum of 90 units/acre and the seeding of soils with free-living nitrogen-fixing bacteria. Experiments are under trial at Washington University to test these ideas, but the present trends in Britain are towards increased synthetic fertiliser usage.

Fig. 5(8) shows the Price Index for fertilisers and its apparent non-influence on the input of fertilisers at constant (1954/55) prices, Fig 5(9). The fertiliser subsidy is shown in Fig 5(10) for information. The effect of reducing and eliminating this subsidy on fertiliser usage will be discussed in Chapter 10.
FIG. 5.8  UK Fertiliser Price Index

[Average 1954/55-56/57=100]

Source: Annual Abstract of Statistics, HMSO.
FIG. 5(9)

U.K. Fertiliser input at constant prices.

[Years ended May]

[Average 1954/55-1956/57 = 100]

Source: Annual Abstract of Statistics, HMSO.
FIG. 5(10) Exchequer Support to UK as Subsidy paid on Fertilisers. [o-as £, o-as %]

Sources: Stats. 21, MAFF & Cmnds. 2621, 4321, 4623, HMSO.
5.3 USE OF MANURE AS FERTILISER

In Chapter 3 it was shown that manures have a variable but low NPK content and are unlikely to act as suitable fertilisers in an intensive cropping regime. Added to this is the relatively high cost of actually distributing manure when used as a low-value (both in terms of NPK and £p) fertiliser. However, as a means of disposal, land spreading is relatively cheap and frequently used, and once spread it does release N, P and K into the soil in a form available to growing plants although probably in low and variable amounts. It is for this reason that most manure is spread onto grassland rather than intensive arable crops with specific requirements, coupled to the fact that, as demonstrated in Chapter 1, if land is available for spreading it is invariably the grassland used for grazing.

There are two arguments for the use of organic manure purely as fertiliser and not only as a disposal method. The first concerns trace elements. The trace elements excreted in manure and spread onto the land become available to the plants once again. On a farm relying intensively upon inorganic fertilisers there is a constant removal of essential trace elements from the soil at each harvest; land spreading of manure will help replace these.

The second argument revolves around the humus content of manures and the beneficial effects of humus on soil structure. The over-application of manure and consequent damaging effects have been discussed in Chapter 3, but moderate applications are said to be beneficial to soil and hence to the plants growing therein. (Personal communications and visits; Rothamstead Experimental Station, Harpenden, Herts; Levington Research
This stems basically from the ability of humus to promote a good crumb structure in the soil.

The Agricultural Advisory Council's inquiry into modern farming and the soil implicated the eastern counties of England, the Midlands around Warwickshire and Northamptonshire, Sussex, and Montgomeryshire as having soils incapable of forming and maintaining crumb or granular structures. This is apparently due to overcultivation, monoculture, the exclusive use of artificial fertilisers, and the lack of organic humus. In wet weather the heavy clay soils (e.g. Midlands) become waterlogged and become intractible and consolidated by machinery passing over them so making it difficult for plant roots to penetrate in order to obtain oxygen, moisture, and nutrients. During dry weather the clays shrink, set hard, and sometimes crack. In sandy soils (e.g. East Anglia) the lack of humus causes them to dry out excessively during periods of drought and the soil collapses to fine particles which may then be eroded by rain and wind.

The ability of humus to promote a granular structure in soils is therefore of benefit, and the formation of crumbs is dependent on a variety of factors. Firstly the chemical nature of the soil: Sands and silts are largely silica based and chemically inert, but other soils have varying amounts of iron, magnesium, aluminium, and calcium introducing valency forces between particles. Secondly, the physical nature of the soil: the ultimate particle size is of interest here with sands having larger particles than clays, and such forces as van der Wall's, frictional and electrostatic are dependent on these particles.
Humus acts as a binder in both chemical and physical terms and acts along with inorganic binding agents such as the hydrated oxides of iron and aluminium and organic binding agents such as fungal and bacterial mycelium, lignins, and polysaccharides to promote a good crumb structure. (Pilpel, N. 1970).

B.P. Chemicals (U.K.) Ltd., are currently examining the manufacture of a polyelectrolyte synthetic soil conditioner for sale in areas where soils have a "bad" crumb structure (Personal communications with project leader). The details and prices of the compounds under test are, as yet, confidential, but results seem to indicate that good crumbs can synthetically be produced. If a reliable soil conditioner can be manufactured this would obviate the need for fallow or break years in crop rotations. Commercial preparations of "Kdilium" (hydrolysed polymer of vinyl acetate and maleic anhydride, Monsanto), polyvinyl alcohol; and "Humofina" (hydrophobic and hydrophilic material residual in refineries, Petrofina (Belgium)) have seen limited field trials as soil conditioners. (Low, 1972).

However, animal wastes provide a ready supply of humus and the soil benefits by becoming freely aerated, freely drained, rich in nutrients, and is buffered against fluctuations in moisture, soil structure, and to some extent the effects of large applications of synthetic fertilisers. (Organic Fertilisers, Fertilisers Journal Ltd., Introductory Chapter).

It is thus apparent that in some circumstances manures may be spread to act as fertiliser and conditioner or may be spread simply as a disposal method. Synthetic fertilisers
are generally in a granular form and easy to handle and spread, usually during Spring at the beginning of the growing season. Organic wastes generally are bulky and unpleasant in nature and require heavy equipment for their spreading, usually onto wet land in the Autumn so that the manure can be ploughed in and partially "weathered" into the soil before crops are sown or before animals are turned out to graze.

5.4 SPREADING OF MANURE

The M.A.F.F. Experimental Husbandry Farms are currently investigating the effects of spreading manures in terms of crop or grass growth and in terms of soil structure effects. Different spreading rates are used and parameters such as herbage yield, botanical composition, chemical composition, and soil temperature are recorded. The analyses of these experiments is incomplete as yet but preliminary work at Trawscoed farm in Wales suggests that adverse effects are only seen with application rates equivalent to 100 pigs/acre or 5 cows/acre. (Personal communications with Farm manager).

Haughley Research Farms Ltd. (Stowmarket, Suffolk) have been comparing soil structures in three adjacent fields for 25 years' treatment with either synthetic, organic, or mixed fertiliser regimes. The results indicate that organically farmed soils are better able to form seed beds and allow free germination than are synthetically farmed soils. However, during the 25 year experiment no suitable controls were established and no soil samples taken at the start of the experiment so strict conclusions are difficult to formulate. (Personal communications and visit to Farm Director).
The actual techniques used for spreading fall into three categories using solid, semi-solid, or liquid manures.

5.4.1 SOLIDS SPREADERS

Manure spreaders are all operated via the tractor power take off (p.t.o.) and consist of trailers equipped with a moving floor and ejector mechanism. The moving floor usually consists of a series of slats on an endless chain which move the manure to the ejector mechanism at the rear. The ejectors may be rotary flails, chains, or fixed choppers. Fig 5(11) illustrates the rotary flail principle and Fig 5(12) the fixed chopper principle. Fig 5(11) is a Kemper Europa 3½ ton (7½ cu.yd.) model at £660 and Fig 5 (12) the Farmhand 450 model of 7 ton capacity at £1250. Fig 5(13) demonstrates the mode of action of a manure spreader and is the kidd Fymax 3 ton model at £570. This model has double rotary flail ejectors. All manufacturers advertise an even spread with their models with a width of 6.5 to 7.5 ft. (2 to 2.4 m) and a throw of up to 30 ft (9.8m). The market accommodates many makes of manure spreaders with varying capacities and actions some with vertical rotary spreaders and some with side ejector mechanisms.

5.4.2 SLURRY SPREADERS

The transition from solid manure to slurry is not definite and many manure spreaders can be converted to slurry spreaders by fitting leakproof doors at the rear. Fig 5 (14) illustrates the Howard Rotaspreader 250 with a capacity of 600 gals (7 cu.yd.) costing £750. This is the only model of its type and operates equally well with manure or slurry, a p.t.o. driven shaft centrally mounted along the horizontal axis and equipped with
Kemper Europa 3½-ton, £660.

Fymax 3-ton, £570.

Farmhand '450' 7-ton, £1,250.
Bamford’s ‘FY5’
750-gallon open tanker,
£480.

Bamford’s ‘FY6’
1,000-gallon vacuum tanker,
£990.
chains serving to flail out the material. The outlet quadrant can be sealed by the lid to prevent spillage during transport on the public roads.

More conventional slurry spreaders exist in two forms; open topped non-pressurised tankers with a p.t.o. driven pump discharge, or closed tankers using a variety of filling and emptying techniques. Open-topped tankers require a pump to fill them or direct scraping of slurry from animal houses into the tankers. Fig 5(15) illustrates the Bamfords FY5 model open-top tanker of 750 gal capacity at £480. Fig 5 (16) illustrates the closed tanker Bamfords FY6 with 1,000 gal capacity costing £990.

The closed tankers range from 450 gal to 1400 gal capacity, the larger ones having flotation tyres to prevent ground damage in wet weather.

Open-top tankers may be constructed from cheap fibre-glass or plastic as they are not pressurised during their operation and are consequently cheaper than closed tankers. Fig 5(17) illustrates the three forms of closed tanker operation, viz. vacuum fill/gravity discharge, vacuum fill/pressure discharge, and vacuum fill/pump discharge. (Reproduced with permission of the editor from December 1964 Farm Mechanisation). The price of a tanker varies with its capacity and its pumping mechanisms.

Spread widths of up to 40 ft and throws of up to 80 ft. can be achieved.

Some examples of prices and specifications are given in Table 5(3) the information being abstracted from manufacturers literature of 1970.

Most of these tankers can be adapted to spread via irrigation lines and rain guns onto land too wet to receive vehicles. However, most organic irrigation systems are separately run.
SLURRY TANKER ACTION

**FILLING**
- Float valve
- Control valve
- Vacuum pump

**B) AGITATION OF TANKER CONTENTS**
Air passed through

**C) AGITATION OF STORAGE TANK**
Exhaust air via pipe to tank

**D) DISCHARGE**
On to plate or driven spinner

1: Vacuum fill/gravity discharge
SLURRY TANKER ACTION

A) FILLING
1. Water trap
2. Control valve
3. Vacuum pump compressor

(B) AGITATION OF TANKER CONTENTS
NONE

(C) AGITATION OF STORAGE TANK
Air via filling pipe to tank

(D) DISCHARGE
To fan jet or pipeline;
filling pipe plugged

Fig. 2: Vacuum fill/pressure discharge
(B) AGITATION OF TANKER CONTENTS
Recirculation by irrigation pump

(D) DISCHARGE
To jet or pipeline

3: Vacuum fill/pump discharge

Vacuum  Air  Slurry
<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Capacity (gals)</th>
<th>Action</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfa Laval</td>
<td>S4</td>
<td>860</td>
<td>Not self-filling.</td>
<td>£580</td>
</tr>
<tr>
<td></td>
<td>S5</td>
<td>1,100</td>
<td>Discharge by centrifugal, pump, or drill</td>
<td>£635</td>
</tr>
<tr>
<td></td>
<td>S8</td>
<td>1,760</td>
<td></td>
<td>£1,160</td>
</tr>
<tr>
<td>Bamfords</td>
<td>FY5</td>
<td>750</td>
<td>Open-topped. P.t.o. driven, impeller discharge.</td>
<td>£480</td>
</tr>
<tr>
<td></td>
<td>FY6</td>
<td>450 - 1,250</td>
<td>Pressurised fine spray</td>
<td>£590</td>
</tr>
<tr>
<td></td>
<td>(5 sizes)</td>
<td></td>
<td></td>
<td>upwards</td>
</tr>
<tr>
<td>Bauer</td>
<td>VS range</td>
<td>485 - 660</td>
<td>Vacuum fill, pressure discharge</td>
<td>£700</td>
</tr>
<tr>
<td></td>
<td>VEV &amp; VSV</td>
<td>375 - 660</td>
<td>Vacuum fill, pressure discharge</td>
<td>£700 to</td>
</tr>
<tr>
<td></td>
<td>VG</td>
<td>660 - 1,320</td>
<td>Tandem axle, high capacity compressor</td>
<td>£1,390</td>
</tr>
<tr>
<td></td>
<td>MV &amp; MVB</td>
<td>370 - 990</td>
<td>Rota pump discharge up to 165 ft</td>
<td>To £1,890</td>
</tr>
<tr>
<td></td>
<td>B &amp; S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>450</td>
<td>Pressurised spreading to rear or side</td>
<td>£590</td>
</tr>
<tr>
<td></td>
<td>3500</td>
<td>700</td>
<td></td>
<td>£750</td>
</tr>
<tr>
<td></td>
<td>4500</td>
<td>1,000</td>
<td></td>
<td>£930</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>700</td>
<td>Rear mounted centrifugal pump discharge</td>
<td>£500</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>1,000</td>
<td></td>
<td>£590</td>
</tr>
<tr>
<td>Holz</td>
<td>BTS/Holz</td>
<td>620</td>
<td>Snake pump discharge up to 140 ft</td>
<td>£900</td>
</tr>
<tr>
<td>Howard</td>
<td>Slurry puncher</td>
<td>1,000</td>
<td>Open-topped. Rear spinner</td>
<td>£535</td>
</tr>
<tr>
<td>MFE</td>
<td>450</td>
<td>450</td>
<td>Vacuum fill. Chopper/shredder auger discharge</td>
<td>£540</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>700</td>
<td></td>
<td>£680</td>
</tr>
<tr>
<td>Molex</td>
<td>880 - 1,200</td>
<td></td>
<td>Pump filled, pump discharge</td>
<td>£960</td>
</tr>
<tr>
<td></td>
<td>Non-pressurised glass fibre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vicon</td>
<td>Hippo</td>
<td>450</td>
<td>Vacuum fill, pressure discharge</td>
<td>£890</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td></td>
<td></td>
<td>£630</td>
</tr>
<tr>
<td>right Rain</td>
<td>Multi-purpose</td>
<td>700</td>
<td>Vacuum fill, pressure discharge</td>
<td>£730</td>
</tr>
<tr>
<td></td>
<td>Gold Deal</td>
<td>700</td>
<td>Pressurised wide-angle rear discharge</td>
<td>£875</td>
</tr>
</tbody>
</table>
In October 1967 there were 422 holdings using liquid manure spreading by irrigation (MAAF, personal communication) and it is suspected that the high expense will keep installations around this level or even less. There are currently two British concerns and one Austrian competing for this market being Farrow, Wright Rain, and Bauer respectively.

The irrigation pumps used may be of the types discussed in Chapter 4 and Fig 5 (18) illustrates the Wright Rain, p.t.o.-driven farm-flow pump at £1100. Liquid manure is pumped into pipes such as those depicted in Fig 5 (19) which feed manure or rain guns jetting the liquid into the air, or sprinklers giving a 360° spread, or self-travelling sprinkler-booms for high volume irrigation.

The pipes are generally alloy in construction and must be frequently moved or switched from one fixed set to another to prevent waterlogging by continuous, static manure applications. Fig 5-(20) illustrates a Wright Rain Laureau Giant Sprinkler Boom which is periodically towed to a different site, and Fig 5(21) a self-travelling Farrow Rainamatic Sprinkler which covers 2 acres per day and costs £690.

The main disadvantage with organic irrigation is either a high capital cost for below-ground fixed systems with cross-over valves and frost protection, or a high labour requirement if movable pipes and guns are employed. The tasks involved in dismantling and moving guns is unpleasant and messy. These two factors probably explain the static, perhaps decreasing, numbers of organic irrigators.

5.5 COSTS OF SPREADING

No comprehensive Surveys have been conducted on the costs of spreading manures because of the large number of variable factors
Wright Rain 'farm-flow' system, from £1,100.

Prime's pipe transporter, £167.
Wright Rain 'laureau' sprinkler.

FIG. 5(21)

Farrow 'rainamatic' sprinkler, £690.
that can influence these costs - capacity of storage system, capacity of soil to absorb manure, capacity of crops and grass to make use of the manurial nutrients, the distance of fields from the storage base, whether public roads must be travelled, the proximity of human habitation and consequent complaints of nuisance, the proximity of ground or underground water, the nature of the terrain, local labour supply, local contractor charges, and the weather conditions. Consequently only a few investigations into the costs of spreading manure have been conducted, and these are generally related to dairy enterprises.

The Dairy Husbandry Panel (Tooby, 1968) costed three different systems for disposal - solid spreader (Howard Rotasreader), slurry tanker (700 gals, vacuum), and irrigation (Wright Rain Farm Flow). The costs have been adjusted to 1970 levels and the D.C.F. basis for repayments at 10% over 5 years assumed. The herd is 60 cows, each producing 1½ cu. ft. (10 gals) per day over a 200 day winter.

**Solids Spreader.** 300 gals (2 cu. yds.) requiring 300 loads/winter with 5 mins to load, 10 mins to travel, 5 mins to empty, giving 3 loads/hour. Total labour is 100 hours.

- Initial Capital Outlay = £565
- Annual fixed costs = £147
- Annual variable costs consist of 100 hrs using labour at 35p/hour and tractor at 35p/hour = £70
- Total Annual costs = £217 /60 cows
  = £3.62 /cow/year
**Slurry Spreader**

700 gal tanker requiring 1 to 1 dilution giving 345 loads/winter. 5 mins. to load, 10 mins. to travel, 5 mins. to empty gives 115 hours/winter.

Initial Capital Outlay = £790

Annual fixed costs = £205

Annual variable costs consist of 115 hours using labour at 35p/hour and tractor at 35p/hour = £81

Total Annual costs = £286/60 cows = £4.77 /cow/year

**Irrigation**

2 to 1 dilution required giving a total of 360,000 gals/winter. S.T.L. 67 (MAFF) recommends 16,000 gals/acre/winter with 3 applications/winter. Thus requirements are 25 acres with a daily application of 100 gals/min. for 20 mins over ¼ - 1/3 acre.

Initial Capital Outlay = £1,125

Annual fixed costs = £ 292

Annual variable costs consist of 60 hours using labour at 35p/hour and 60 hours using tractor for the pump at 35p/hour =£42

Total Annual costs = £334 /60 cows = £5.57 /cow/year

Thus it can be seen that liquid disposal systems require a higher capital outlay and, despite the labour saving, are more expensive over all. However, the above analyses only hold true where a tanker or spreader has free access to the land and this may well not be the case requiring a higher expenditure on storage and/or some form of pre-treatment prior to Spring spreading rather than continuous Winter spreading.
Reference to Fig 3(2) illustrates the types of manure that can be handled by the spreading equipment outlined.

5.6 SUMMARY

From the previous discussion it is clear that manure may be spread onto the land for two purposes. The first is purely as a means of disposal and any beneficial effects on the soil structure or fertilising of the grass is incidental. The second is to use manure as a soil conditioner and/or fertiliser whilst secondarily providing a means of disposal. The equipment that is marketed for land disposal is comprehensive.

As with cleaning and handling equipment economies of scale are difficult to detect owing to manufacturers' differing specifications. However, as with other equipment economies do exist within a manufacturer's model range. For example, in Table 5(3), B and S market 3 models of tanker and these cost £132, £107, and £93 per 100 gals for the smallest, medium, and largest sizes respectively.

Solids spreaders do not appear to exhibit marked economies of scale and this may be due to differing specifications. The Kidd-Fymax 3 ton model costs £190/ton, the Kemper Europa 3½ ton model £188/ton, and the Farmhand 7 ton model £180/ton capacity.

However, with this sort of disposal equipment it is likely that larger models are more ruggedly built and will perhaps have a longer life by a year or two. Thus, even if scale effects are small in purchase price, the running costs for larger capacity equipment may well be cheaper per unit of capacity than smaller models.
6.1 INTRODUCTION

This chapter is divided into four sections, the first dealing with methods of separating solids and liquids, the second with roughing plant, the third with polishing plant, and the fourth with complete treatment systems. The sequence is a logical one since it may be desirable to separate liquids for treatment or discharge while using the solids as fertiliser; the roughing plant will degrade coarse material sufficiently to be used for a number of purposes such as washing down or irrigation; the polishing plant may be applied after rough treatment to attain Royal Commission Standards (Chapter 2) enabling complete discharge; and the complete treatment systems are designed to allow safe use or total discharge of the material.

Strictly speaking the drying of manure should be included in the last section of this chapter but its special applications merit a chapter of its own - Chapter 7.

6.2 SEPARATION OF LIQUIDS AND SOLIDS

6.2.1 SCREENS

6.2.1 (a) BAR SCREENS These consist of vertically or horizontally arranged bars situated in the flow of the waste; the spaces between the bars determine the size of material which passes through. The debris removed from the waste is mechanically raked from the screen periodically. This type of screen has been tried and tested in the sewage treatment industry for blocking out macro matter such as papers and rags, but its main use in farming is to prevent stones, plastic bags, and wood from entering
into any pumps and subsequent treatment system.

6.2.1 (b) BAND SCREENS These consist of perforated mesh panels on an endless belt principle and can be used to screen out coarse fibres, leaves and weeds from waste material in cases where the water is to be passed on for purification. Coarse material is screened from the effluent and is slowly passed to the top of the band as it slowly rotates and is then washed off by a powerful jet of water. This water must then be passed back into the effluent system.

6.2.1 (c) ROTARY SCREENS Rotating perforated discs may be set in the waste flow and a small mesh will remove fibrous matter such as straw and hairs. As the screens rotate and each section is lifted out of the effluent the sections are blasted clean by water passing from the reverse side. This type of fine screening is only necessary if the waste water is to enter a sophisticated treatment plant, a case not common in farming practice but under experimental study at the moment.

6.2.1 (d) PARKWOOD SCREENS These self-cleaning mesh drum screens have found a use in farming practice as reliable means of removing fibres from wastes. The semi-circular drum screen is mounted horizontally or vertically in the waste flow and four nylon brushes sweep grass fibres from the screen and deposit them into a collection area or manure spreader. Fig 6(1) shows the Parkwood Screen at the Grassland Research Institute (Hurley, Maidenhead, Berkshire). The central pipe injects dairy waste onto the screen, solids are raked out over the plate, as shown, and the liquids falling through the screen pass over into an oxidation ditch for treatment. Fig. 6(2) illustrates the process in sectional view. (From Parkwood's Literature).
Parkwood screen separator.

FIG. 6(3)

Gascoine, Gush & Dent separator (on gantry).
Flocor tower (rear centre).
Extended aeration tank (centre right).
6.2.2 PRESSES

Conventional sewage filtration presses such as Boulton models have been applied to farm wastes but with little success (Session 4, A.R.C. Conference, Glasgow, 1972). This is due to both a high cost and the nature of the equipment which requires skilled and trained operators. The advantages of pressing farm wastes are not obvious, and the opinion of workers (Glasgow, 1972) in the field is that filter presses have no future.

A combination of screen and press has been recently developed by Gascoine, Gush and Dent. Original trials with a perforated nylon belt passing through a domestic Acme clothes wringer proved the process viable and led to the development of a separator consisting of two horizontal cylindrical screens 280 mm in diameter rotated between pairs of spring-loaded and rubber-faced rollers 50 mm in diameter. Raw waste is fed onto the outside of the first screen and the retained, pressed solids passing under the roller are scraped off and fed onto the second belt and roller. The resultant liquid is suitable for small-bore pumping and irrigation.

Fig 6(3) shows in the foreground such a separator erected onto a gantry with solids falling into a conventional spreader. The liquid is passed into the extended aeration tank just on the left or onto the floccor tower in the background. This equipment is installed at the National Institute of Agricultural Engineering (Silsoe, Bedfordshire) and will be discussed later in this chapter.

6.2.3 CENTRIFUGES

There are two types of centrifuges in present use for farm wastes.
The bowl-type centrifuge is in use by G.A. Wright (Forest Lodge Farm, Winkfield Row, Windsor, Berkshire) and is a reconditioned Sharples model purchased for £2,500. The 15 h.p. motor operates the rubber-mounted centrifuge at 3,250 r.p.m. on the outer cone and 3,200 r.p.m. on the inner cone costing £2.00/week to run. With depreciation and maintenance costs Mr. Wright estimates (personal visit, Nov. 1970) a total of £10.00/week running costs. The complete system of treatment is discussed fully in section 6.5.5 (f).

The decanter-type centrifuge has been under test at NIAE, Silsoe and the operation is depicted in Fig. 6(4) taken from Alfa-Laval's literature. The decanter consists of a cylindric-conical rotor inside of which is a screw conveyor. Both rotate in the same direction but the outer cone at 4,750 r.p.m. and the inner screw at 4,780 r.p.m. Effluent is fed into the centre of the screw and immediately is rotated to the outside and the heavier solids form a layer on the sides of the barrel. The screw augers these solids through the barrel to the narrow end of the cone where they are discharged whilst the clarified water overcomes the auger and flows out through the wide end of the barrel. N.I.A.E. claimed that the machine is expensive and requires skilled supervision (ARC Conference, Glasgow, 1972).

Master Farm Equipment (Sudbury, Suffolk) have marketed a manure screwpress centrifuge specifically for handling pig manure reducing moisture content from over 90% down to 60%. Two models exist, one accommodating the waste from 500 pigs in a six hour day and the other accommodating 1,000 pigs. Although the makers claim economical and odour-free operation with automatic controls and minimum upkeep, the author has not found one in use in Britain. The viability cannot therefore be discussed.
FIG. 6.(4)

Decanter Centrifuge
A type of centrifuge, namely the hydrocyclone, has been under investigation at the North of Scotland College of Agriculture (Craibstone, Bucksburn, Aberdeen). This consists of a vertically mounted cone rotating at high speed; the effluent is fed tangentially in at the top, spirals down the cone, and the solids separate onto the wall and are discharged through the outlet nozzle's outer hole, while the liquids are drawn up the inner hole and ascending vortex to discharge. The outlet nozzle diameter affects the moisture content of the dewatered sludge produced.

6.2.4 COAGULATION

Chemical co-agulation or flocculation of suspended particles is a well-proven technique in the sewage treatment industry. Inorganic flocculants such as aluminium chlorohydrate and alumino-ferric salts have previously been used but the sludges produced are sloppy, bulky, and difficult to dry or dispose of. Sludges cannot be spread on the land, as can those from screens, presses, and centrifuges, due to their high concentrations of aluminium and/or ferric salts. Costs of co-agulants are at least £3.00/cow/year (Hepherd, ARC Glasgow 1972)

However, the use of polyelectrolytes has recently attracted much attention in sewage treatment. (Water and Waste Treatment, August 1972 pp 9-16). Applications to farming would be restricted to the process waters from vegetable or fruit preparation and not to manurial wastes as the process is more suitable for co-agulation of fine suspended solids and not gross fibrous matter.

6.2.5 FLOTATION

Sludge removal by flotation on air bubbles has been developed in two applications in the agricultural industry. N.I.A.E. at Silsoe have investigated the general principals and the Halmarl
system (discussed fully in section 6.5.5 (e) has applied the principals to a complete treatment system.

The underlying principal is to produce fine air bubbles at the base of a tank containing the effluent, and as these rise they take fine suspended solids to the surface where they float. The air bubbles may be produced, as in the Halmarl system, by electrolysis of the effluent to give bubbles of hydrogen and oxygen, or by atomising an air stream.

This latter system has been developed by Voith of St. Pölten, Austria in their Fiscalin aeration system. This was originally used for the recovery of fibres from effluent from paper manufacture and produces air bubbles between 10 and 40 μm. A mixture of air and effluent is injected into the reaction chamber which promotes spiral flow-paths. Heavy shearing forces occur on the boundary layers and atomize the air bubbles. On settlement in a tank the bubbles float the fine solids to the surface.

6.2.6 BALES

N.I.A.E. at Silsoe have tested a cylindrical straw bale arrangement into which pig slurry is tipped. Water seeps through the straw bales in one to four weeks; solids are filtered out and remain in the bales. The bales can then be used as fertiliser or burnt. The experiments have shown the system to be very slow in operation and probably not viable on a farm scale (Personal visit).

6.3 ROUGHING TREATMENT

This section deals primarily with two types of degradation, anaerobic and aerobic, both being naturally occurring biological degradative processes. The usefulness of degrading wastes was discussed earlier and it was pointed out that a reduction in the
BOD of a waste in many cases enabled it to be discharged onto limited land where raw wastes would be unacceptable.

6.3.1 ANAEROBIC DIGESTION

6.3.1 (a) PRINCIPLES

Anaerobic fermentation of organic matter occurs widely in natural conditions in marshes and swamps, and, if conditions are suitable, in muds containing organic matter on river and estuary beds. The conditions required, as the name implies, are the complete absence of oxygen or oxidising agents along with the presence of water. The microorganisms responsible for the fermentation degrade organic carbon to methane and carbon dioxide and nitrogen to ammonia. If sulphur is present this is released as the malodourous hydrogen sulphide. If only partial digestion occurs then other intermediate metabolites are formed many of which also have very unpleasant odours.

The microorganisms have been isolated and documented (Society for Applied Bacteriology Symposium June 1971, Liverpool University, "The Microbial Aspects of Pollution") but these are difficult to culture in laboratory conditions due to their reliance on an oxygen-free atmosphere. The biochemical reactions occurring during fermentation of complex organic wastes is, then, not fully understood (Pettet et al, 1959, Baines, Newcastle Symposium 1970). The complete digestion is a two-stage process. The first brings about the degradation of organic macromolecules to simpler intermediates such as alcohols and volatile fatty acids, and is carried out by a large range of microorganisms. The second stage, involving a much smaller group of organisms, is the conversion of these simpler molecules to methane.
Anaerobic digestion was first applied to waste treatment in order to stabilise sewage sludges. It was found that digested sludges are granular in character, readily dewatered, are not malodourous, do not attract flies, and are easy to remove from drying beds, whilst undigested sludge is very glutinous, objectionable, and difficult to handle.

The digestion is usually carried out in circular enclosed tanks with provision for gas collection and de-sludging. Retention time is normally 30 days and the digester is maintained at 35°C by electric heaters or hot water immersion coils. Some plants are able to collect and use the methane to generate electricity sufficient for heating purposes and any surplus is sold to the National Grid (Old Woking Sewage Works, Surrey, Personal Visit November, 1970).

Some digesters may be mixed by impellor or gas re-circulation systems to ensure maximum contact between micro organisms and substrate. This promotes highest efficiency in terms of digestion but a separate chamber must then be used to allow solids to settle out for collection. Static tanks allow settling of solids but their action is less efficient.

This type of digestion requires a very substantial capital outlay and must be operated by trained engineers. Methane is explosive when mixed with air, combustible, and asphyxiating so skill in operation is essential. However, the principles of this type of digestion have been successfully applied to degrading farm wastes. The resultant liquor is rarely suitable for direct discharge into watercourses and is generally recirculated; the sludge must also be disposed of.

Fortunately anaerobic digesters are well tried and documented
and certain essential factors may be listed. Dilution of the waste is necessary because an overload of organic matter gives rise to the production of excess fatty acids in the first stage, depressing the pH and inhibiting the gas-forming microorganisms of the second stage. The optimum pH is between 6.0 and 6.5 (McKinney, 1962). The total solids content of the digester and the BOD leading are also important factors (Baines, Newcastle Conference 1970).

Digestion of farm wastes at the West of Scotland Agricultural College (Auchincruive, Ayr) and at the Rowett Research Institute (Bucksburn, Aberdeen) has been studied using poultry, pig, and cattle wastes. The results are well documented (ARC Conference, Glasgow, 1972) and demonstrate a dependence on loading rate, temperature, dilution, and pH. The anaerobes responsible have been extensively surveyed at the Rowett Institute (SAB Symposium, Microbial Aspects of Pollution, see Hobson and Shaw).

6.3.1 (b) LAGOONS

The provision of digestion equipment and heaters is not practicable for farmers. Moreover, the resultant sludges and liquors are still not easy to dispose of. However, even under temporary storage farm wastes may soon establish anaerobic conditions and the provision of a lagoon promotes anaerobiosis. In many instances a crust of floating solids and undigested hay forms along with any bedding and litter, and this effectively seals out oxygen from the lagoon. A lagoon is simply an excavated area and can be dug into any suitable ground, with or without lining as discussed in Chapter 4. Fig 6 (5) shows a simple earth excavated lagoon with the concrete apron and ramp over which cow slurry is scraped. The author was present during the construction of this lagoon and the relevant cost data was:
Simple earth-banked lagoon.
Excavation of lagoon area - £ 787.22
Concrete - labour and materials - £ 300.00
Fencing - labour - £ 70.00
posts - £ 72.00
wire - £ 297.00
Total £1,526.22

The lagoon is 4 ft deep, 450 ft long, and with an average width of 150 ft. The working capacity was estimated as 270,000 cu.ft. and took 1 month to excavate. At 6 working days/week for four weeks the 192 excavating hours costed £4.00/hour approximately, slightly higher than Nix's figures of £3.25/hour for hire of excavator plus driver (Nix, Farm Management Pocketbook).

This particular lagoon is primarily designed for winter storage for a herd of 162 Freisians but the depth of 4 ft ensures anaerobic activity. Problems of odour have been noticed. (Photograph and figures courtesy Sir Charles Forté, Jury Farm, Ryde Farm Estate, Ripley, Surrey.)

6.3.1 (c) ON-FARM DIGESTERS

Apart from the simultaneous anaerobic activity of lagoons some farmers have designed and built digesters for animal wastes, either to degrade the wastes in some way or to make use of the methane given off as a by-product.

Lord Iveagh, for instance, operated a number of methane plants the last one being built on his estate at Pyrford, Surrey in 1929, and incorporating the advantageous design features of the earlier models. The digester consisted of a steel cylinder 28 ft. high, 16 ft. in diameter and with a conical base under which a fire was lit if necessary. Ports and vents allowed the withdrawal of spent sludge, the exhaustion of gases, and the
feeding of fresh manure. 165 cart-loads of manure together with 3,000 gals of water primed the digester and 30 cart-loads throughout the year was sufficient to keep it topped up. The gas produced was used in the kitchens of the Mansion and to heat the Head Gardener's house with a total continuous supply of 450 cu.ft./day. Once electricity was installed the digester fell into disuse. (Personal visit, Pyrford Estate, Near Send, Surrey).

The students at Camarthen Technical and Agricultural College have designed and operated a digester fed with pig slurry. The 250 gal digester is electrically heated to 35°c and the pH is periodically adjusted. The retention time is 21 days and a new cycle is then operated this being a batch and not a continuous process. Eventually the total effluent from the cow-yard is hoped to be treated by this method. (Personal visit, Camarthen Tech. and Agric. College).

Harold Bate of Totnes, Devon operates his small digester using poultry manure; again the primary object is for gas collection rather than waste disposal but the anaerobic process does stabilise the sludge produced. The importance of this will be fully discussed later. The gas collected here is passed into a storage bottle for use to power Mr. Bate's saloon and two Land Rovers, petrol not having been bought for 15 years. The methane is claimed to be more efficient than petrol in combustion, non-carbon depositing as it is completely burned, and does not dilute lubricating oil as does petrol. (Personal visit, Totnes 14/10/71).

Although the above cases in experimental digestion may seem trivial they do make use of the production of methane for a gain
and the waste is suitable for other treatment or land spreading. Wright Rain Ltd. introduced their effluent disposal plant at the 1963 Royal Show and advocated the use of the methane in the kitchen, central heating, and converted diesel and petrol engines. This commercial plant was never a success due to the fact that it involved a high capital cost for low returns. Although methane was produced and could be used the actual waste consumption was low and carting onto the land still had to be performed.

Thus anaerobic digestion as a treatment process has not become popular in farming, although isolated cases have provided valuable information.

6.3.1 (d) SURREY UNIVERSITY PROJECT

The author was involved in a project of the Department of Biological Sciences (Bell, C. and Prof Smith, J.E.) in 1972 which set out to confirm some of the principles of anaerobic digestion discussed earlier and to make use of these principles in a complete treatment system. After consultation with the Principal at Merrist Wood Agricultural College, Worplesdon, Guildford and Messrs. Vokes Ltd., Normandy, Guildford the author and C. Bell commissioned plans for a small-scale digester.

Laboratory studies confirmed that anaerobic digestion produced an easily dewatered sludge but actually increased the COD of the material. This is due to the breakdown of complex organic matter to simpler alcohols and acids which are more prone to permanganate oxidation and so exert a higher COD. It was hoped to use the effluent from the digester to feed the second stage of the treatment, an aerobic system with primary settlement.
The stabilised sludge from the digester would dewater readily in the settlement tank and so rapidly sink. The effluent from the digester, although having a high COD value, would readily be consumed by aerobic bacteria due to its simple organic nature and the exposure to atmosphere. Figs 6(6) and 6(7) illustrate an artist's impression of the external view of the system and the internal view of the digestion vessel.

The working capacity was 200 litres and was fed with a cow slurry diluted 1:7 at a rate of 60 litres/week giving a retention time of about 3 weeks.

During five months of operation, gas chromatographic analysis indicated 70% methane in the exhaust gases, and dewaterability of the sludge improved 80 fold. The Pitts P.V. measurements (Willetts and Bell, Effluent and Water Treatment Journal, July, 1972) fell from 1880 ppm in the fresh slurry to 1350 in the digester and 1140 in the primary oxidation tank. (C. Bell, Ph.D thesis, "The Anaerobic Digestion of Bovine Faecal Effluent" 1972, Surrey University).

The project confirmed the principal that anaerobic followed by aerobic treatment was a valuable sequence and a workable system. Section 6.5 will illustrate how the pilot-scale digester above was converted into an on-farm system, handling the effluent from 80 cows, by the author and C. Bell. However, the principles and uses of the aerobic stage must first be studied.

6.3.2 AEROBIC TREATMENT

6.3.2 (a) PRINCIPLES

As with anaerobic digestion it is found that the principles of aerobic digestion applied to farm wastes have stemmed from the sewage engineering field and the organisms responsible and
The Bell & Willetts' anaerobic/aerobic system.

**FIG. 6.(7)** Exploded view of anaerobic vessel.

Basically the process requires the presence of aerobic microorganisms and a plentiful supply of oxygen. Broadly speaking there is a correlation between the amount of oxygen absorbed by the system and its reduction in BOD content. As will be seen from the ensuing discussion the primary aim is to introduce as much oxygen into the system as possible.

6.3.2 (b) LAGOONS

As with anaerobic storage and pre-treatment, the lagoon affords the simplest and cheapest method of construction for aerobic storage. With a working depth of up to 3 ft. the lagoon is equipped with an aerating device, mainly electricity driven aerators. The aerators may be floating or submerged.

The Satec mechanical aerator consists of paddle wheels which churn the lagoon surface transferring atmospheric oxygen into the liquids to satisfy the biological oxygen demand. Power requirements range from 1 to 25 h.p. and the aerator operates from a bridge, submerged structure, or floating pontoon. (Satec sales literature). Simon Hartley manufacture a similar range of impellor aerators under the name of Simcar.

Compressed air may also be used in a number of designs to promote intimate contact between air and liquid. The most common is simply a submerged array of perforated plastic pipes on the lagoon floor through which air is bubbled. More sophisticated aeration devices from sewage engineering have
recently been adapted to lagoon aeration. The aeromix system, for example, draws the liquid waste into a submerged pipe and injects air into the stream recirculating the aerated liquid from the surface to the bottom of the lagoon. (Mass Transfer Ltd., sales literature). The Ïhelixor system consists of an array of vertical polythene columns on the base of the lagoon the interiors of which have a monolithic Ïelix component. Air and liquid are injected together at the base and are forced upwards through the spiral path causing high turbulence and aeration at the surface (Polcon Corporation sales literature).

Most commercial aerators have well documented transfer characteristics and can be adapted to suit the BOD of farm wastes.

Where insufficient land is available to construct a lagoon a tank may be built and an extended aeration system established. This again has been adapted from the contact stabilisation and activated sludge methods of sewage treatment. Fig 6(8) illustrates such a tank at N.I.A.E., Silsoe, undergoing trials using dairy waste. One of the obvious problems of aerating wastes is evident, that of foaming, and this can be seen in the tank. Steam is also visible, being produced by the intense biological activity of the aerobic bacteria promoted by these conditions. (This tank can be seen as part of the N.I.A.E. project on Fig. 6(3).

6.3.2. (c) OXIDATION DITCHES

Fig. 6(9) shows the essentials of the oxidation ditch installed at the National Grassland Institute, Hurley. The toothed rotor can be seen driving the waste around the racetrack ditch. The foam trap can also be seen, but no foam is apparent in this photograph due to diesel oil having been poured onto
Extended aeration tank.

**FIG. 6. (9)**

Oxidation ditch.

**FIG. 6. (11)**

Barri ered ditch.

*Stephen L. Willetts*
the surface in order to try to control foaming. This does eliminate the foam but upsets the bacteria and the efficiency of the ditch for BOD removal falls off. This particular ditch takes pre-screened waste from the Parkwood solids separator in Fig 6 (1). The design of the ditch is one adapted from Pasveer's ditch for human sewage treatment in Holland. Scheltinga first experimented with farm wastes in such a ditch and has led research in Holland on this subject. (Sunningdale Conference (1968), Walter Frank Freeborn Memorial Paper (Water Pollution Control, 1969), Newcastle Symposium 1970, Poelma, Farm Buildings, No. 16, 1967, and Pig Farming, April, 1968.)

British experience with oxidation ditches has met with little success when applied to farm wastes. This is due to the inability of aerobic organisms to use large organic macro molecules as substrates, and the oxidation ditch's primary use is as a secondary treatment process, perhaps following an anaerobic primary process for maximum BOD removal. The oxidation ditch is then capable of removing up to 99% of the remaining BOD load (Scheltinga and Poelma, Newcastle Symposium, 1970).

The actual construction of the ditch determines its characteristics and costs. Simple earth excavation with plastic or butyl sheet lining is the simplest construction and concrete ditches are obviously more expensive. Since there are so few ditches in Britain and the ones in operation are home-built it is difficult to quote any figures as to cost. The costs of excavation equipment, butyl liners, and concrete work have been discussed in Chapter 4 (Cleaning and Storage). No data can be found relating to the best size of oxidation ditch or loading rates and so costs cannot be computed for certain herd or flock
sizes. This again is due to the lack of success and hence lack of widespread application of the ditch.

However, the rotors providing the circulatory and aeration actions are well documented and this is entirely due to the sewage engineering profession taken an interest in oxidation ditches for secondary aerobic treatment of human sewage. Whitehead and Poole, Manchester, for example, market oxidation ditches for sewage treatment from 100 to 6,000 persons giving recommended rotor constructions, rotor lengths, rotor horse power, and the ditch dimensions for each system. Cheltenham, Droitwich, Great Bromley, Tamworth, and Aughton Rural District Councils have installed such ditches and the performance and results are available from Whitehead and Poole.

The design of the rotor has also been extensively investigated in Holland and Britain, the aim being to design a rotor using little power but having good oxygen transfer characteristics. Simple brush rotors, toothed cages, barrel cages, spiral teeth, and simple paddle beater rotors have been tested. One of the drawbacks with research into oxidation ditches and the inconsistency of designs and results is the lack of experienced research workers and little progress has been made or is foreseen (Personal communications; Hurley oxidation ditch, V.C. Nielson, M.A.F.F. Guildford, C.T. Riley, M.A.F.F. Guildford, K.B.C. Jones, Institute of Water Pollution Control).

Fig 6(10) illustrates the four basic designs of Whitehead and Poole's ditches. For continuous feed systems the ditch must have provisions for a certain amount of the contents to overflow into a settlement tank where the effluent liquid is
THE OXIDATION DITCH

1. Intermittent System
   - Sewage inlet
   - Surplus sludge trap
   - Final effluent

2. Continuous System
   - Sewage inlet
   - Surplus sludge
   - Return sludge
   - Clarifier
   - Final effluent

3. Split Channel System
   - Sewage inlet
   - Surplus sludge trap
   - Alternate flow and settlement channels
   - Outfall control
   - Channel control gates (alternative operation)
   - Final effluent

4. Side Channel System
   - Sewage inlet
   - Final effluent
drawn off and the sludge re-circulated into the ditch. The sludge contains bacteria and thus it is desirable to return them to the ditch contents.

Experiments at Hurley in which the ditch water is washed through the cow houses and back into the ditch have failed due to the inability of the ditch to cope with such high BOD wastes as dairy effluent and pig effluent (Personal visit, Hurley).

The operation of the ditch is best discussed in Scheltinga's work as referenced.

6.3.2 (d) BARRIER DITCHES

The first experiments with barrier ditches were about five years ago and performed by J. Egdell of A.D.A.S. Bristol. No two barrier ditches are the same, their design depending upon their situation, the slope of the land, the type of soil, the input volume of effluent, the height of the water table, and the proximity of rivers or watercourses.

Fig. 6(11) illustrates some sections of a barrier ditch. The purpose is to achieve maximum sedimentation of solids while allowing biological breakdown of the waste and this is carried out by creating a series of "mini-lagoons" each overflowing into the next with final discharge to watercourse. The system does not lend itself to all farms as a natural slope of land from animal house to watercourse is necessary and this must be at least 350 yards if the effluent is to be led into the watercourse. It is recommended that the barrier ditch accepts as much clean rainwater or low BOD wash water as possible since the dilution afforded by such waters obviously reduces the BOD of the ditch contents and renders them more amenable to treatment. (Egdell, personal visit 19/10/71).
The construction of the ditch depends on the situation but certain guidelines have been drawn by Egdell - sufficient capacity for 60 days retention, working depth of 5-6 ft. at least 4 barriered sections of 15-30 yds., and a free-flowing stretch at least 250 yds. long to the watercourse. Problems in construction have been met of which the most serious is to make the barriers water-tight. Concrete barriers are preferred to the original sleeper barriers as sleepers are becoming more expensive and difficult to make water-tight. The ditch itself is not normally lined but very porous soils or an abundance of rabbit warrens, for example alongside a hedgerow, can lead to the disappearance of all ditch contents. At first sight this may seem desirable, but the presence of underground aquifers could lead to serious pollution problems.

Another problem that occurred with the first ditches was the periodic flushing of total contents into the watercourse following a heavy storm and this has been solved by fitting a "Throat slot" into the barrier which limits the flow of liquid from one section to another, or the adaption of a "constant head" device serving the same purpose.

The maintenance of the ditch involves annual de-sludging of the first section and the removal of vegetation from the banks as any debris in the ditch may cause blockage of the throat or constant head. Fencing is also required where animals or humans are in the vicinity.

The first ditches installed have regularly been monitored and are accepted, in principle, by the Gloucestershire and Wiltshire water boards. Table 6(1) shows some typical values.
(24 sample mean, sampled over 15 months) for the ditch performance:

<table>
<thead>
<tr>
<th></th>
<th>BOD ppm</th>
<th>SS ppm</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outfall to ditch</td>
<td>700</td>
<td>573</td>
<td>7.2</td>
</tr>
<tr>
<td>Passing over dam 2</td>
<td>374</td>
<td>232</td>
<td>7.4</td>
</tr>
<tr>
<td>Passing over dam 3</td>
<td>288</td>
<td>108</td>
<td>7.5</td>
</tr>
<tr>
<td>Passing over dam 4</td>
<td>163</td>
<td>95</td>
<td>7.7</td>
</tr>
<tr>
<td>Discharge to Watercourse</td>
<td>21</td>
<td>34</td>
<td>7.7</td>
</tr>
</tbody>
</table>

It can be seen that the above figures indicate a good performance of the barrier ditch system, but the design and operation of these ditches is, as yet, still in its infancy. So much of its action depends upon the length of the ditch and the nature of the input, and much more research is being undertaken by Bristol A.D.A.S. and Derby A.D.A.S. (Harrison, J., A.R.C. Glasgow Conference, September, 1972).

6.4 POLISHING TREATMENT

6.4.1 FILTRATION

The most widely used polishing treatment for domestic sewage, industrial effluents, and farm wastes is that of biological filtration. With reference to farm wastes, once spread onto the land the soil acts as a physical filter holding back particulate matter, and the microorganisms act as a biological filter withdrawing both organic and inorganic nutrients from the liquid as it percolates through the soil. However, this process is very slow and, as pointed out previously, the land is only capable of absorbing a certain amount of material before its soil spaces become filled and run-off problems occur. The use of high-rate biological filters is designed to overcome these problems but
retain biological filtration as a purification or polishing medium; the high rate filter simulates the soil conditions but has intersitial spaces so large that they do not block.

Again, the idea originated in sewage treatment where settled liquor is fed over trickling filters consisting of a bank of clinker ash, granite chips, or, more recently, random plastic modules. The material must contain a large proportion of voids and the minimum block size is about 1½ in. packed to give a filter about 6 ft deep (Notes on Water Pollution No. 5, June 1959 W.P.R.L.).

The filter eventually builds up a biomass of micro organisms such as bacteria, algae, and protozoa. The carbon:nitrogen ratio must be capable of supporting such biological growth, and faecal matter is generally suitable whereas some industrial effluents may need adjustment (Notes on Water Pollution No. 5, June, 1959).

The liquid trickles over and through the filter where the biomass extracts nutrients; this is essentially an aerobic process as atmosphere easily permeates the voids. There is some danger of "ponding" or blocking of the voids with biomass but any heavy growth is usually washed through except in the winter months when chlorine or bleach is used to clean the filter. W.P.R.L. recommend a loading of 80 gals of effluent of 200-250 ppm BOD per cu. yd. of filter and the resultant liquor should be of the order of 20 ppm.

Where a filter has a high loading there may be an increased danger of ponding and alternating double filtration may be used.
Here two filter beds are used alternately, usually on a weekly cycle, and about twice the volume of liquid can be treated. Where the input BOD exceeds 300 ppm the W.P.R.L. recommend re-circulation of the filtered liquor.

Much work has been instigated by W.P.R.L. and the large sewage engineering concerns. The biomass present on the filters have been extensively investigated and well documented (W.P.R.L. reports, particularly No. 43. December, 1968 and No. 57 December, 1969).

The development of random plastic modules for the filter beds led to the construction of filter towers for use in the farm waste field. Mass Transfer Ltd. (Newcastle, Staffs) market Filterpack, plastic cylinders about 2" diameter, 2" long, and with plastic cross-members for packing towers. I.C.I. Ltd. market Flocor, a modular form of corrugated PVC sheeting easily stacked into a tower. Fig (6(12) illustrates such a module and the flocor tower at Silsoe is depicted in Fig. 6(3). Surfpac standard and Surfpac crinkle-close resemble flocor but have a smaller void volume and larger surface area. Cloisonyle consists of a close-packed assembly of 8 cm diameter plastics tubes each divided into fourteen longitudinal compartments of 2 cm diameter.

Table 6 (2) (from Notes on Water Pollution No. 40, March, 1968) compares the characteristics of the types of media discussed.
A Flocor module.
The low bulk-densities of plastics media enable them to be packed into towers requiring little land area (Fig 6(3)) and the high proportion of voids virtually eliminates ponding. W.P.R.L. have experimented with plastic filter towers (Jackson, W.P.R.L. Report No. 583). However, W.P.R.L's concern is basically with industrial and domestic effluents which have lower BOD's than farm wastes and hence are easier to treat. The use of flocor medium in agricultural waste treatment has been investigated at Silsoe, at Lane End Poultry Farm, (University of Reading) and at Merrist Wood Agricultural College (Worpleston, Surrey).

In the Silsoe experiment (Hepherd, ARC Conference, Glasgow, September, 1972) cow waste is periodically fed to tipping trays at 500 gals/hour at the top of the tower. This effluent contains 0% oxygen and emerges from the tower at 60-70% saturation, 80-90% of BOD having been removed. However, the input has undergone primary sedimentation, anaerobic digestion, and fibre separation before being fed into the tower. The production of a sludge at 3-5% dry matter constitutes a handling and storage problem.
The Lane End Poultry Farm tower is under the auspices of M.A.F.F. (Riley, ARC Conference, Glasgow, September, 1972). The results are not encouraging and the tower, using poultry wastes, although extremely reliable in operation does not remove a great deal of the BOD. Raw poultry waste is used and continuously re-circulated but a high BOD effluent still remains, and sometimes an increased S.S. count occurs due to the formation of biomass and consequent death and accumulation of cell debris. Full results of the trials at Lane End are not, as yet, for publication, but it is evident that filtration is not viable as a primary treatment process. (Personal visit, November, 1970)

The Merrist Wood flocor module tower is used solely for polishing purposes and takes mixed cow and pig liquor from an anaerobic followed by an aerobic lagoon. As a polisher it works extremely well, removing 90% of the BOD. (Personal visits 1971, 1972, 1973).

Flocor towers are currently used to treat total poultry wastes at J.P. Wood & Sons (Poultry) Ltd. a subsidiary of Unilever Ltd., and known for "Chukie" chickens and at Bernard Matthews Ltd., of Norfolk, known for "Norfolk Manor" turkeys. Ross Poultry Ltd., the largest poultry enterprise in the world, have also installed flocor treatment.

Bernard Matthews Ltd., use existing screening and sedimentation facilities to provide a waste amenable to aerobic filtration and the system handles 120,000 gal/day successfully. (Water & Waste Treatment October, 1972, p. 19).

A development by Mann of W.P.R.L. (ARC Conference, Glasgow, September, 1972) is the brushwood filter. Most farmers are obliged to trim their hedgerows bordering public roads and
Mann suggests piling these clipings into a "birds nest" arrangement for use as a filter. With a specific surface of $35 \text{ m}^2/\text{m}^3$, void percentage of 91.5, and density of 64 kg/m$^3$, brushwood compares favourably with other media except for its low area. (Table 6(2)). However, when baled under pressure the area becomes comparable with plastics media. One of the obvious advantages of brushwood is its low cost, one of the less obvious is that brushwood tends to hold back particulate matter on the filter and, when dried, can readily be burnt to destruction with removed solids.

It is evident from the above discussion that filtration affords a useful polishing tool.

6.4.2 BIO-DISCS

Bio-disc filters consist of circular discs concentrically mounted onto a rotating shaft. The discs are 2-3 m in diameter and moulded from expanded polysterene ensuring a low power consumption. The discs are 40%-50% immersed in a basin of effluent and rotate in the direction of effluent flow at 2-10 r.p.m. During rotation the discs become exposed to the atmosphere enabling oxygen absorption and promotion of aerobic activity. C.J.B. Developments Ltd. have reported the successful installation and operation of bio-discs treating the waste from 50 to 100,000 persons. The use of a sufficient number of batteries of rotating discs can ensure a Royal Commission Standard effluent. Performance is enhanced when preceded by standard activated sludge treatment (Hartman, 1965).

The Polystyrene discs allow shaft lengths of up to 6 m without intermediate bearings and there are normally 30 discs per metre. The polystyrene itself is completely inert to biological attack. Power consumption is said to be 20 watts/head/day whereas conventional extended aeration plant uses 56-166 watts/head/day.
The use of metal discs has been reported, but plastic media of 1/30th the density of metal is favoured due to its lower power requirement (Water and Waste Treatment, October, 1972 p.13).

Unpublished experiments with rotating discs at M.A.F.F. (Guildford) have proved unsuccessful in the treatment of high BOD, high SS farm wastes. Again, the main use envisaged is a polishing tool.

6.4.3 ADSORPTION

The Electricity Council have experimented with adsorption by activated charcoal (Barret, Newcastle Symposium, 1970). The unit consists of perspex tubes fitted with stainless steel mesh plates to hold the carbon. Vegetable process waters and sewage that has undergone tertiary treatment have been used in the investigations. Organic matter is adsorbed, the amount depending on the contact time of the water passing through the columns.

Experimental work has shown that reduction of a 25 ppm COD effluent to 6 ppm COD costs about 6p/1,000 gals at 1970 prices and if the charcoal is thermally regenerated the cost reduces to 4p/1,000 gals. This is expensive in the context of cows producing effluent at the rate of 10 gals/day/cow.

6.4.4 REVERSE OSMOSIS, ELECTRO DIALYSIS, ION EXCHANGE

These methods are only suitable for removing inorganic impurities from a relatively pure effluent as difficulties due to membrane poisoning by organic materials promoting algal growth arise using contaminated effluents.

Reverse osmosis equipment operates by producing a hydraulic pressure on the dilute side of the membrane higher than the normal osmotic pressure. Normal osmotic flow of solvent from dilute to
concentrated solutions is therefore reversed and an already dilute solution can be further purified. Barret (Newcastle Symposium, 1970) reported that such pure waters are obtained from reverse osmosis equipment as to make it uneconomic simply to re-use the high purity water for vegetable washing when a lower purity will suffice. The applications to farm wastes are, therefore, necessarily limited, perhaps non-existent, but the theory may be applied later.

Similarly electro-dialysis and ion exchange have limited applications in farm waste disposal.

6.5 COMPLETE TREATMENT

This section deals with those treatment processes that render the waste innocuous or convert it into a usable by-product, and those processes that operate by total disposal with no re-use.

6.5.1 COMPOSTING

Composting is probably the oldest form of manure storage and stabilisation. When bedding or litter is collected with manure, or deliberately added after collection, the moisture is absorbed by the litter and a fibrous, solid heap is formed. Many farmers use this muck heap purely as a temporary store and without regard to the processes of deliberately holding and composting the waste.

The heterogenous organic matter of farm wastes will have an associated indigenous mixed population of micro organisms derived from the air, soil, or water. At 50-60% moisture and when freely aerated microbial action increases and heat is generated. Sugars, starches, proteins and fats are first degraded, then hemicelluloses, the resistant cellulose material of plant cell walls, and finally the very resistant lignin. The decomposition of these materials follows a definite pattern during composting.

Firstly, mesophilic micro organisms use the readily degradable
carbohydrates and proteins. Since the compost is heaped the heap is to some degree insulated and a noticeable rise in temperature occurs. The actual time taken and the temperature reached depends upon the composition of the waste, the availability of nutrients, the moisture content, the size of the heap, the particle size, and the degree of aeration or agitation. Simple organic acids are also produced by mesophiles and the pH drops. (Gray, et al, 1971).

With the increase in temperature mesophilic activity is depressed and thermophilic organisms take over liberating ammonia and increasing the pH in the process. Above 60°C the thermophilic bacteria are destroyed but spore-forming bacteria and actinomycetes remain active. Waxes, proteins, and hemicelluloses are then attacked and with the loss of readily decomposable material bacterial activity declines, heat loss occurs, and the heap cools down. During the cooling process the thermophilic fungi can again attack the heap (60°C - 40°C) and start to degrade the celluloses. Where wheat straw is used as litter there is an abundance of cellulose and temperature rises again at this point (Gray, et al, 1971). Eventually the heap cools to ambient temperature with residual mesophilic activity either from spores or from re-invasion. Although acids are again produced the heap normally remains slightly alkaline. Fig. 6(13) demonstrates this composting cycle:
The first three stages generally take days, perhaps a few weeks, while maturing requires months. This is a major disadvantage of composting as a disposal method, but an advantage as a storage method in that, being aerobic, no odouriferous products are formed, and the long times involved eventually produce stable humus and humic acids (Gray, et al, 1971).

The deliberate use of composting as a stabilisation process for sewage sludges and vegetable and fruit refuse is fairly common, though on-farm waste composting is rare except incidentally during storage. Both fruit and vegetable wastes and sewage sludges alone are unsuitable for composting as they are too moist, but municipal refuse is widely used to adjust the moisture into
the optimum range of 50-60%. The National Canners Association of America are studying vegetable and fruit waste composting extensively with particular reference to maintaining an optimum C:N ratio for maximum decomposition. The aim, is therefore, disposal and not simply storage. (Rose, et al, 1965). Much work has been done on the organisms responsible for composting and the consequent attempts to establish ideal conditions for decomposition (Shelesky and Maniotis, 1969).

In Britain the composting of sewage with municipal refuse has been attempted. The Worthing Hygiene Unit, for example, uses this process for stabilisation prior to land-tipping. Settled solids from the sewage are passed into anaerobic digesters maintained at 85°F. using the methane produced (this also generates sufficient power to operate the whole sewage plant, the adjacent refuse handling plant, underfloor heating of the transport pool, the sludge dewatering and compost plants). The sludge is then removed from the digesters and stored prior to dewatering. The Refuse Handling Plant is on an adjacent site and after collection the refuse is mechanically and manually sorted so that 1/3 is re-sold as salvage. The refuse is passed through rotary screens removing dust and ash and then under an electro-magnet removing tins and ferrous metals for re-sale. Carpets, rags, bones, felt, paper, etc. are hand picked as the refuse passes along a conveyor belt. The balance is fed to the compost drum. Dewatered sewage sludge and the refuse "tailings" are fed into the compost drum.

The drum is 90 ft long and 12 ft diameter revolving at 0.6 r.p.m. for 11 hours each day and at 0.1 r.p.m. for the remaining 13 hours, at weekends, and Bank Holidays. Air and
water are continually fed into the tumbling mass to promote aerobic composting. The product is passed over vibrating screens and about $\frac{1}{2}$ is rejected and tipped while $\frac{1}{2}$ is sold as compost. Worthing has a ready market in the market garden industry for compost, but objections to the use of human sewage have necessitated the composting of domestic refuse only.

Therefore, with the process and the market proven the composting of farm wastes may prove a valuable, perhaps lucrative, disposal method. The mushroom industry in particular is a user of compost and this has been increasing at the rate of 25% per annum (Ganney, Agriculture, November, 1971). Between 1946 and 1965 the Agricultural use of horses fell from 519,000 to 21,000 in Great Britain (M.A.F.F., A Century of Agricultural Statistics), and this is the major supply of compost to the mushroom industry (Ganney, 1971). This falling supply and rising demand may indicate that animal manures other than horse will be used by the mushroom industry, and there is now a demand for deep litter chicken manure (Ganney, 1971).

The investigations into the use of animal manures for composting are centred at Birmingham University (Gray, op. cit and Glasgow ARC Conference September, 1972). Compost cubicles were constructed and pig slurry and straw layered into these on a grid. Air is forced upwards through the grid and into the compost and the following criteria were achieved (Gray, Glasgow, September, 1972):

1) Virtually all slurry solids filtered onto the straw bed, the liquid draining away for treatment.

2) The straw formed an open matrix holding the solids free for aeration.
3) Temperatures of 60°C held for several days killing pathogens and weak seeds.

4) Oxygen demand of the aerobes satisfied.

5) Cheap, simple, reliable construction.

During the discussion at Glasgow reference was made to the fungal spores responsible for the disease of "farmer's lung" and Gray admitted that in the moist, warm conditions this disease risk could be considerable but so far not encountered.

6.5.2 INCINERATION

There are basically two types of incinerators in use for sewage sludge destruction and hence suitable for farm waste applications.

Firstly there is the multiple hearth furnace conceived by Herreshoff in 1889 for roasting pyrites during sulphuric acid manufacture. The furnace is a cylindrical refractory-lined shell containing a series of self-supporting horizontal refractory hearths. The hearths have drop holes at the centre and at the periphery. A vertical rotating shaft extends through the furnace and carries "rabble" arms at each hearth level and these sweep the material from each hearth through the drop holes onto the next lower hearth.

There are three operating zones, the upper hearths constituting the drying zone where most of the moisture is evaporated. The combustion zone is then encountered at 1450-1600°F and finally the cooling zone at the base of the furnace.

Exhaust gases are wet-scrubbed before discharge to the atmosphere by cyclonic, water impringement, or venturi type scrubbers. The ash residue contains less than 1% combustible material and can be transported mechanically, hydraulically, or
The expansion of this method of sludge disposal is evident from U.S. data where the first furnace was commissioned in 1934 and 165 have been built since then. (McAteer, 1968). The obvious high capital and maintenance costs of such equipment seem to limit their use in farm waste disposal, though collection points feeding a central furnace could be operated.

The second type of sludge incinerator is the cyclone furnace. This consists of a vertical refractory cylinder with a solid hearth at the base. Air is blasted in through inclined tangential high-velocity nozzles which ensures a cyclonic path of the gases leading to a central vortex at 800°C. A rotating scraper slowly pushes the combusted products through a central exit and the speed of this arm can be varied depending upon the length of time required for complete combustion of the material.

The costs, as with multiple hearth furnaces, are very high. A suitable furnace for farm wastes would be in the region of upwards of £40,000 (Stirling, J.B. personal communication and visit to Lucas Furnace Developments Ltd., Wednesbury, Staffs). Again, economical operation can only be envisaged using an incinerator common to several farm premises.

6.5.3 ZIMPRO

This is a process of wet air oxidation using air at elevated pressures and liquid water at up to 700°F. The first plant was constructed in Chicago in the 1960's serving 2.5 million persons (Zimpro Division, Sterling Drug Inc., New York).

Zimpro oxidation treats sludges of up to 99% water whereas incineration requires much drier sludges of about 75% moisture. Hence subsidiary de-watering apparatus is unnecessary using Zimpro. Oxidation of the material is flameless and the low temperatures
involved (300-400°F working) do not produce fly-ash, dust, sulphur
dioxide or nitrogen oxides. Exhaust gases are wet-scrubbed or
passed through an afterburner before discharge to the atmosphere.

The products of the reactor are settled, filtered, co-agulated
or centrifuged to produce a sterile solids portion for disposal
and a sterile liquid portion for further bio-treatment if necessary.
Organic matter reduction is of the order of 93% and the BOD of
the effluent liquid is about 8,000 p.p.m. using sewage sludge.
(Harding and Griffin, 1965).

Satec Ltd., the U.K. Licensees for Zimpro, commissioned the
first British plant at Guildford on 9th October, 1972 at the
Hockford works. For a population of 30,000 the contract was
valued at over £130,000. Reference to Chapter 3 shows that
considering the volumes and difficulties of treatment of animal
wastes the Zimpro process is probably prohibitively
expensive for farm wastes. (Personal communications, Hockford
works).

6.5.4 BOREHOLES

One of the questionnaires detailed in Chapter 8 revealed
an uncommon method of manure disposal and the farm location is
kept confidential.

1,000 pigs are swill-fed by pipeline and waste is channeled
into four settlement pits below ground. Solids either settle
or float in the first pit, and liquids overflow into the second
allowing further separation, and so into the third and fourth
pits. The liquids then enter the borehole. This is an 18-inch
diameter steel shaft sunk 50 ft. into the ground and the lower,
25ft is slotted. Liquids collect in the shaft and seep through
the slots into the surrounding soil. The farm is 500 ft above sea level with a water table at 250 ft, and the land overlays chalk.

The Thames Conservancy have agreed to the discharge of 1,000 gals/day and the borehole is capable of taking this discharge. Some difficulties were noticed with the fats from waste swill blocking the soil pores and the consequent filling of the shaft with no out-seepage. This is remedied by pumping hot water under pressure into the shaft.

The only running costs, apart from routine checking and maintenance, are £60 p.a. for removal of sludge and crusts from the four settlement tanks.

Neither the NFU nor the Thames Conservancy are happy about future prospects of this system (Personal visit, 20th July, 1972).

6.5.5. STAGED PARTIAL TREATMENT

This section deals with a few examples of the use of a combination of some of the above processes for the effective disposal or safe re-use of farm wastes.

6.5.5 (a) MERRIST WOOD SYSTEM

Merrist Wood Agricultural College (Worplesdon, Guildford) uses a lagoon and flocor treatment system. Mixed dairy and piggery wastes are periodically (twice a week) pumped into a 5 ft. deep lagoon which has formed a floating crust and is therefore considered anaerobic. Liquids drain over into a 2 ft. deep lagoon with a prolific algal covering indicating aerobic treatment. The aerobic treatment is continued by trickling the outfall over four 1 m cube flocor modules (See Fig 6(12) and script) and thence along a 200 yard culvert before discharge into the River Wey. The BOD and SS are less than the River at the discharge point.

6.5.5 (b) LYMINGTON SYSTEM

The Surrey University project outlined in Section 6.3.1 (d)
led to the installation of a two-lagoon system at Vicars Hill Farm, Lymington (Manager, D. Pitt-Pitts). The principle of anaerobic breakdown of macro-organic matter followed by aeration to stimulate breakdown of simpler organic material was applied to the existing pit system of the farm. The lagoons and aeration channel are described in Appendix 2 and reference to section 3.3.5 and Appendix 1 illustrate the methods used to monitor oxygen demand.

6.5.5. (c) HURLEY SYSTEM

The oxidation ditch at Hurley uses a Parkwood screen (Fig. 6(1)) to remove fibrous matter before entering the ditch (Fig. 6(9)). Outflow from the ditch is held in pyramid-based clarifiers before re-use for washing down the cow-house.

6.5.5. (d) SILSOE SYSTEMS

The waste disposal complex at Silsoe investigates numerous combinations. The primary intake tank is agitated and the contents augered into a Gascoine, Gush, and Dent Separator (Fig. 6(3)) and the solids carted onto the land. The liquid fraction is alternately fed into the extended aeration tank (fig. 6(8)) or the flocor tower (Figs. 6(3) and 6(12)) for aerobic digestion. Effluent liquors are passed into a bale filter (See section 6.2.6), through pyramid-based clarifiers and to final discharge.

6.5.5. (e) HALMARL SYSTEM

The Halmarl system of waste purification is depicted in Fig. 6(14) (adapted from sales literature and personal visit 2/12/71) and uses a considerable array of bio-treatments, basically aerobic (Water and Waste Treatment October, 1971, Top Livestock Farming, December, 1971)
Halmarl System.
The effluent from 50 veal calves is channeled into the intake tank and is macerated, agitated, and aerated by an archimedean screw (½ H.P.) in continuous operation. Slurry is delivered (½ H.P. pump) onto a continuous nylon mesh belt through which liquids fall into a 2'6" wide 2'6" deep moat around the circumference of the building, and from which hair and solids are brushed into a collection chamber for disposal. The liquid is circulated round the moat (½ H.P. motor) and aerated by a perforated disc rotor.

Liquid is drawn off from the moat (½ H.P. pump) up into the central distribution tank fitted with six 2" bore outlet pipes channelling the liquid onto six hanging filters. These are fed by tipping trays which empty every 7 minutes as the weight of liquid builds up; the filters are corrugated plastic sheets. The effluent trickling from the filters falls back into the moat. At two-hour intervals a time-switch diverts liquid from the distribution tank into the electrolytic flotation tank equipped with two plate grid electrodes (formerly stainless steel, now lead dioxide coated titanium). A potential difference applied to these electrodes forms hydrogen and oxygen bubbles which float suspended solids to the surface (See Section 6.2.5 (Separation: Flotation). Dead solids (bacterial cells, etc.) sink to the bottom and are periodically returned into the day intake tank. The time switch then operates a pump (½ H.P.) removing the liquid between the settled solids and floating scum to the base of a sand filter. During this emptying procedure the scum level reaches a probe just above this outlet pipe to the sand filter and this diverts the tank contents back into the day intake tank. Thus only clear liquid is fed into the sand filter.
The first sand filter is filled with pea-beach gravel and acts as a self-cleaning upward-flow clarifier. The outflow is taken to the base of a similar filter filled with a finer sand and the discharge is then suitable for sterilisation (ozone, U.V. chlorine), for re-use or for discharge into river.

The effluent has a BOD of less than 7 ppm from an influent of 11,100 ppm. The prototype cost in the region of £4,000 with glass lining as an anti-corrosion measure and has a power consumption of 1½ kW hr.

Since the prototype by Halmarl Co. Ltd. (c/o Merrieweathers Farm, Mayfield, Sussex) the system has been offered for sale to the Agricultural community by Pollution Technical Services Ltd. (Abingdon, Berks) treating from 50 cows (125 calves, 250 pigs) to 300 cows (750 calves, 1500 pigs) to within Royal Commission Standards.

6.5.5. (f) WRIGHT SYSTEM

The Wright system of centrifugation has been discussed in Section 6.2.3 Separation: Centrifuges, and the complete process is depicted in Fig. 6(15) (adapted from Power Farming April, 1972 and Personal visit November, 1970).

Slurry from 1,000 pigs is collected in a concrete sump 54' long and 5'6" wide with a sloping floor from 3' - 4' deep. The slurry is pumped from the deep end via an overhead pipe (2 H.P. motor) to the shallow end and this acts as agitator and aerator. The same motor feeds the centrifuge (Section 6.2.3) and solids are augered out into a covered heap while the liquids fall into an aeration tank.

The aeration tank is segmented and turbulence is achieved by a propellor (from one of Wrights boats). This acts as an
oxidation ditch and the discharge is somewhere in the region of 4 - 5,000 ppm BOD. The liquid is pumped onto a sacrificial 11-acre grass field rented solely for liquids disposal.

The collected solids are allowed to stand in a heap and compost up to 140°F, which Wright considers sufficient to sterilise the product, and are then sold into an unstable market of local rose-growers and amateur gardeners.

6.6 COSTS OF TREATMENT

A cost comparison of the treatment systems outlined in this chapter is necessary, even though artificial. Most of the systems are situated at experimental premises interested in design and treatment parameters with little regard to a cost analysis, and many are simply one-off products unlikely to be marketed. It has been estimated (Jones, Newcastle Symposium 1970) that fewer than 10% of British farms have recourse to any form of treatment. The remaining 90% employ traditional handling and land disposal methods outlined in Chapters 4 and 5.

However, simple land disposal may not be possible if trends towards intensification (Chapter 1) continue. The technology for waste treatment is available and the costs must become important considerations in future planning. Some estimates of the costs of treatment systems are essential, therefore, as guidelines.

6.6.1 SEPARATORS

It is important to realise that separators offer an initial pre-treatment facility and the costs of solids/liquids separation must be added to any costs for subsequent treatment.

6.6.1 (a) SCREENS

As yet screens are not in widespread use for farm waste treatment. A simple bar screen in a shallow channel would cost
about £2,000 installed and the smallest ones manufactured would accommodate the waste flow from any present agricultural enterprise. This type of screen is the cheapest and rotary screens from £3,000, band screens from £5,000, and Parkwood screens from £5,000 are more sophisticated and more expensive. The life of such screens is calculated as well over 20 years and installations in Sewage Works confirms this. (Figures courtesy Vokes Ltd.)

6.6.1 (b) PRESSES

As with screens the smallest press would be capable of handling manure from the largest enterprises at present. The cost would be upwards of £15,000 installed and skilled supervision is required. It is considered unlikely that presses will be used on farms in the immediate future. (Boulton Presses Ltd.)

6.6.1 (c) CENTRIFUGES

A centrifuge handling 1,000 pigs or 100 cattle would cost about £7,000 new and would cost about £2.00 per week to run. Maintenance and supervision increase costs to around £10.00 per week (Section 6.2.3). The useful life of a centrifuge would depend upon the standard of maintenance but could be around 10 years (Sharples Centrifuges Ltd.)

6.6.1 (d) COAGULANTS

Co-agulants are not in widespread use for farm waste treatment and it is difficult to arrive at realistic costs. A typical flocculant would be used at the rate of 1 ml of 0.05% solution per 500 ml of slurry (1 ppm) and would cost around £1/1 kg. (Allied Coloids Ltd.) For 100 cows or 1,000 pigs this would represent around 750 gallons p.a. of 0.05% solution costing around £1 per year. This is a very cheap form of solids/liquids
separation but of limited use except for final rather than initial slurry treatment. Straw and other gross solids would not be removed by this method, but suspended solids could be clarified.

6.6.1 (e) FLOTATION

The Electrolytic flotation principle has been used as a part of a treatment system but not as a separate unit and its cost is therefore difficult to assess. A suitable chamber and electrodes for 50 cows would cost around £200 but the running costs, life, and efficiency cannot be estimated as yet (Halmarl Ltd). As with flotation, this type of solids/liquids separation could only be effectively used on slurries that had already been somewhat clarified.

6.6.1. (f) BALES

Straw bales would costs around £3.50 - £5.00/ton depending on the area and the season (Fulbrook et al 1973) and about 1-1½ tons of straw bales would make a tank sufficient to hold the waste from 50 pigs or 5 cows (N.I.A.E. Silsoe). However, difficulty in the blocking of the bales with solids may preclude this as a system for solids/liquids separation.

6.6.2 ROUGHING TREATMENT

6.6.2. (a) ANAEROBIC LAGOONS AND

6.6.2. (b) AEROBIC LAGOONS

Table 4.3 estimates the costs of construction of a simple earth lagoon as around 0.5 pence/cu.ft. With fencing and ramps the total cost for a typical lagoon may be around £1,500 for 180 cows (270,000 cu.ft.) (Section 4.5 details lining costs and aerators may cost between £100 and £1,000 (Section 4.4.7 details costs of pumps which may be used as aerators).
6.6.2 (c) ANAEROBIC DIGESTERS

The Bell and Willetts digester (6.3.1 (d)) cost £500 and would handle the waste from 1/10 cow or 1 pig. Assuming economies of scale obey the 2/3 power (cost proportional to surface area of vessel, not cubic capacity) then 100 cow or 1,000 pig digester would cost around £3,350,000. However, as a one-off prototype the original digester obviously is expensive and it is expected that the cost of a chamber suitable for anaerobic digestion of the waste from 100 cows would cost tens of thousands and not hundreds of thousands of pounds (Vokes Ltd.)

6.6.2 (d) OXIDATION DITCH

Cost estimates for the oxidation ditch are mainly of Dutch origin (Scheltinga, Sunningdale Conference 1968, Scheltinga and Poelma, Newcastle Symposium 1970) and: a concrete-lined ditch of 10,000 gallons capacity and would cost around £500 to construct. The aerator brush would be upwards of £300 and the total cost for a ditch with collection, settlement, and discharge facilities for 100 cows would be around £1,000. Running costs of £1.00/year are claimed in Holland (Scheltinga, Newcastle Symposium 1970) but little success has been achieved in this country. (6.3.2 (c)).

6.6.2 (e) BARRIER DITCHES

The construction costs of a barrier ditch depend on the natural resources of the land into which it is built. Costs of between £200 and £1,000 have been experienced in Wiltshire for 100 cows (Egdell, ADAS, Bristol). Naturally sloping land impervious to water affords easy construction whereas lining or building up of banks increases the costs. The running costs amount to a few tens of pounds each year for periodic de-sludging and small repair work. No mechanical or electrical equipment is employed and this system may well provide a useful settlement
and partial treatment system.

6.6.3 POLISHING TREATMENT

6.6.3 (a) PLASTIC MODULES

Section 6.4.1 quotes WPRL recommendations of 1 cu metre plastic module for each 80 gals of 250 ppm BOD effluent. Therefore 100 cows producing 365,000 gals of pretreated effluent each year would require a minimum of 4,500 modules if the input was around 200 - 250 ppm. Each module costs around £20 (I.C.I.) and with associated tower work, pumps, collection pits and ancillary work the cost is more like £50 per module. This high cost therefore precludes plastic towers from large-scale applications to farm wastes but work at Reading (Nielson, V.C., A.D.A.S.) is intended to exploit this method more fully for polishing effluents.

6.6.3. (b) BIO-DISCS

The cost of plant installation for bio-discs is likely to be of the order of tens of thousands of pounds when foundations, concrete-work, and buildings are taken into consideration. Unfortunately, C.J.B. developments declined to comment on actual costs and would not indicate running costs for their rotating discs. The refusal to estimate costs was based upon the fact that the treatment is a polishing system and has not, as yet, seen use in an agricultural programme. The effectiveness of the discs could not therefore be ascertained.

However, it was stated that running costs would be low as the minimal amount of power is necessary to turn the polystyrene discs.

6.6.3 (c) CHARCOAL

Charcoal adsorption is viable only for already extensively treated effluents and an improvement from 25 ppm COD to 5 ppm COD
costs in the region of 5 pence/1,000 gallons (Barret, Newcastle Symposium, 1970). Thus, an extra cost of around £20 per year for 100 cows or 1,000 pigs would cover this type of polishing to better than Royal Commission standards.

However, skilled operation and supervision is necessary for this type of plant.

6.6.4 COMPLETE TREATMENT

6.6.4. (a) COMPOSTING

Straw will absorb about 1½ times its own weight of slurry (Nielson, V.C. Personal communication 3/5/73) and at around £5.00/ton (Section 6.6.1.(f), inclusive of any earth works for holding the compost and any labour for turning the heap, it would cost around £13 per day to absorb the total effluent from 100 cows or 1,000 pigs. If the cows are out during the summer then a 180-day winter would put the cost of straw and labour at around £2,300 per year per 100 cows. For in-bought straw this method is therefore unlikely, but home-grown straw may be considerably cheaper.

As a means of storage, the compost heap is therefore comparable to the cost of a lagoon and the costs of ultimately spreading either the compost or slurry are about the same for a given volume. However, the compost heap will be less in volume than the contents of a lagoon and composting may indicate that a solid system is cheaper to operate than a slurry system.

6.6.4 (b) INCINERATION

A Lucas-type cyclone incinerator would cost £40,000 (Section 6.5.2) and this would be capable of operating on the largest of present enterprises. A group operation of a furnace on a continuous basis could incinerate the waste from 420 cows, 4,200 pigs, or 84,000 hens.
Running costs are not, as yet, available but are expected to be "competitive" (Lucas Furnace Developments Ltd., personal communications 1972). Skilled operation and supervision would be required for such an incinerator.

6.6.4 (c) ZIMPRO

The smallest practicable Zimpro unit costs around £130,000 and the one operational at Guildford handles domestic waste from 30,000 people. At 30 gallons per day (Jeger, 1970) this plant could handle the effluent from 1 million pigs or 100,000 cows. Thus a group operation would be necessary and the cost would then be about £130 capital for each unit of 100 cows or 1,000 pigs. However, at a density of 200 cows and 200 pigs per 1,000 acres (Section 1.3.2) in an average agricultural area, each Zimpro plant could treat the total effluent from 500,000 acres. Not every unit in this area would subscribe to such a scheme and the area covered may actually be greater. The transportation costs of the slurries to the Zimpro unit may therefore make such a project unworkable.

6.6.4 (d) BOREHOLES

The borehole described in Section 6.5.4 was constructed for £250 and treats the effluent from 500 pigs and, on a volume basis, could therefore handle 60 cows. At an annual cost of £60 p.a. for sludge removal this system is probably the cheapest in operation. However, the locations in which such a system could legally be operated would be few due to the possibilities of contamination of aquifers.

6.6.4 (e) HALMARL

The Halmarl "package deal" offers complete treatment of the effluent from 50 cows or 250 pigs for £4,000 capital. Since this is based on a prototype no estimates of any economies of
scale are possible. Indeed, larger units may be impracticable on technical as well as economic grounds.

Where treatment to Royal Commission Standards is required this system offers the cheapest method except for contracted removal of waste from the farm premises. Even as the cheapest method, the Halmarl system has attracted few if any customers presumably due to the high capital outlay for an, as yet, unproved system.

6.7 SUMMARY

It is clear from this Chapter that technology exists for the treatment and disposal of farm wastes, but any form of treatment is expensive when the earning power of the animals concerned is considered. It will be shown later (Chapter 8) that the vast majority of farmers still employ land disposal, possibly with some form of storage. However, the detailed accounts of the available treatment methods in this chapter serve as guidelines for future developments of intensive animal husbandry or future legislation becoming more strict. Systems for disposal are available, but none are as cheap as simple land disposal.
7.1. INTRODUCTION

It is clear that poultry manure is the only one with an initial moisture content low enough to render it suitable (economically) for drying. It is also suitable from the point of view of a useful end product as poultry manure is one of the richest in plant nutrients (Chapter 3). During storage there is a risk of nutrient loss in drainage water and volatilisation (notably of ammonia) due to anaerobic fermentation.

However, there has been a great reluctance of farmers to use neat poultry manure as a fertiliser (Fertiliser Journal Ltd., 1954) due to "scorching". Poultry waste is excreted as a faecal and urinary mixture, the urine containing a high proportion of urea which is rapidly converted to ammonium carbonate in the soil. This compound is one of the most readily available ammonium salts and is responsible for the "scorching" effect of young plant and seedling roots.

Therefore, there has been an interest in the drying of poultry manure which may overcome scorching effects. The interest is now new and the first kiln dryers, using a coke furnace and a system of flues, were operational as long ago as 1932 (Journal of the Ministry of Agriculture, No.39, p.656). More recently a number of dryers have appeared on the market specifically for poultry manure, and all but one use heat as the drying source.
Certain criteria must be met if these driers are to produce a suitable end product. Too little heat results in large particles still moist inside, too fierce a heat produces charred particles unevenly dried. Four criteria for efficient operation were established at the Sunningdale Conference (Ryder, c).

1) The manure should expose the maximum surface area to promote even drying
2) The temperature should not be excessive so as to cause scorching
3) The input material should already be as dry as possible
4) Moist vapours should be rapidly removed.

Criterion 3) could be met using air drying during storage, perhaps with forced ventilation to speed the process.

Certain types of industrial dryers can be considered and their suitability for use with poultry manure investigated.

1) Continuous sheet or band dryers
2) Mixed dryers
3) Drum dryers
4) Vertical cylinder dryers
5) Tunnel dryers
6) Vacuum dryers
7) Pneumatic lift dryers
8) Spray dryers

Some of these can be immediately dismissed as unsuitable; continuous sheet dryers require a thin material (e.g. paper), vertical cylinder dryers are expensive and usually operate on
abrasive solids, tunnel dryers are very expensive, and spray driers generally require an input material in the form of an emulsion. Manure dryers have, therefore, been based on two types of machine - rotary drum and flash dryers. Several such machines are commercially available and are discussed in section 7.3.

7.2. ODOUR PROBLEMS

Early poultry manure dryers met with a severe odour problem as drying tended to intensify the already pungent aromatic odour of neat manure. Later developments have tried to either contain or remove the odour, or not produce odour at all. Microwave dryers are an example of the latter, but most machines use heat and odour production is inevitable. Devices for odour removal can be incorporated into or added onto heat dryers.

7.2.1. RECIRCULATION

Recirculation of exhaust gases into the incoming air stream, as in the Douglas Rownson drier, can reduce odours. However, the capital cost is increased due to the provision of pumps and flues, but fuel consumption is reduced as the exhaust gases pre-warm the incoming air.

7.2.2. SCRUBBING

Scrubbing with water will only remove soluble gases, but most of the sulphur containing products of heat degradation of proteins are soluble and these are certainly pungent odour producers. Wet scrubbers involve greatly increased cost and further create a waste water disposal problem.
7.2.3. AFTER - BURNERS

Since dryers operate efficiently at relatively cool temperatures it is feasible to employ a high temperature after-burner to destroy odouriferous material by oxidation. The extra fuel required increases running costs and in some cases the after-burner may be more expensive to operate than the dryer itself. Such difficulties have already led to the withdrawal of at least one dryer from the market (Haro Manure Dryer).

7.2.4. OZONISATION

Ozone may be employed to oxidise the offending gases but its production is probably too costly.

7.2.5. ULTRA VIOLET IRRADIATION

The chemical structure of the exhaust gases may be altered by ultra-violet treatment. However, as with ozonisation, the process is relatively sophisticated and expensive.

7.3. THE DRYERS

Each dryer has an optimum capacity at which the unit costs are minimum, but a full description and analysis of each dryer is excessively space-consuming. Some of the more successful and popular dryers are examined in detail and others are briefly described and compared.

7.3.1. FLASH DRYERS

7.3.1.(a) RAYMOND FLASH

International Combustion Ltd., the makers of this dryer have been manufacturing industrial dryers for some time and claim, therefore, that this model is virtually trouble-free.
The input manure is mixed with a little of the final dried product and then broken into small particles in order to expose the maximum surface areas to hot air at 550-650°C at a flow rate of 80 ft./sec. The solids enter the hot gas stream where heat is lost due to evaporation of water until the gas has cooled to 100-150°C. The cooled gas carries the particles away from the hot zone into a cyclone collector.

The burner uses heavy fuel oil giving low running costs which more than offset the high capital cost. Automation of the burner is claimed to keep it operating at maximum efficiency given a certain %age moisture content for the dried product (Nominally 10-15%).

The operating temperature within the particles is said not to exceed 55°C which is sufficient to pasteurise the manure and dry it to a fine flowing material with minimum loss of volatile nitrogen. The end product is 10-mesh size with a bulk density of about 30 lbs/cu.ft. Feathers pass through the burner unscathed and with very little heat degradation producing a product with the average composition:

- Moisture: 10-12%
- Nitrogen: 4-8%
- Phosphorus: 4%
- Potassium: 2.8%

The running costs depend on the moisture content of the input manure. Clearly, the more water there is present, the more has to be removed, and so more fuel is required.

Table 7(1) illustrates this point:
### TABLE 7(1)

<table>
<thead>
<tr>
<th>Wet Manure/1,000 birds/week</th>
<th>Fuel Oil for 12% product</th>
<th>Power for 12% product</th>
<th>Moisture to be evaporated to 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Water</td>
<td>lbs weight</td>
<td>gals/ton</td>
<td>Kw Hrs/ton</td>
</tr>
<tr>
<td>80</td>
<td>3300</td>
<td>79.7</td>
<td>159</td>
</tr>
<tr>
<td>79</td>
<td>3145</td>
<td>75.2</td>
<td>150</td>
</tr>
<tr>
<td>78</td>
<td>3000</td>
<td>70.2</td>
<td>140</td>
</tr>
<tr>
<td>77</td>
<td>2875</td>
<td>66.3</td>
<td>133</td>
</tr>
<tr>
<td>76</td>
<td>2750</td>
<td>62.6</td>
<td>125</td>
</tr>
<tr>
<td>75</td>
<td>2640</td>
<td>59.1</td>
<td>118</td>
</tr>
<tr>
<td>74</td>
<td>2540</td>
<td>56.0</td>
<td>112</td>
</tr>
<tr>
<td>73</td>
<td>2445</td>
<td>53.1</td>
<td>106</td>
</tr>
<tr>
<td>72</td>
<td>2360</td>
<td>50.3</td>
<td>105</td>
</tr>
<tr>
<td>71</td>
<td>2280</td>
<td>47.7</td>
<td>95</td>
</tr>
<tr>
<td>70</td>
<td>2200</td>
<td>45.3</td>
<td>91</td>
</tr>
</tbody>
</table>

### COSTS

A Raymond dryer with a 4ft. cyclone (the smallest made, the largest being 18ft.,) has an evaporative capacity of 860 lbs. water/hour at a fuel consumption of 9 gals/hour and power consumption of 18 kw Hrs. The capital cost of the 4ft. dryer is £12,000, and assuming a 10 year life with repayment of capital at 10% interest and maintenance at 2½% of capital (manufacturers recommendations) then the annual fixed costs are £2,186.

For a 40,000 bird unit producing 685 tons dried manure per year this represents fixed costs of £3.18 per ton of dried product.

At 75% moisture using 59.1 gals of fuel oil at £0.04/gal and 18 kw Hrs. at £0.01/unit the running costs are £2.95/dried ton.

Total cost per dried ton is, therefore, £6.13.
Using this method of calculation the total costs per dried ton for various flock sizes are presented in table 7(2).

**TABLE 7(2)**

<table>
<thead>
<tr>
<th>Flock Size</th>
<th>Capital cost per dried ton</th>
<th>Running cost per dried ton</th>
<th>Total cost per dried ton</th>
<th>Operating hours/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>£12.68</td>
<td>£2.95</td>
<td>£15.63</td>
<td>22</td>
</tr>
<tr>
<td>20,000</td>
<td>£6.39</td>
<td>£2.95</td>
<td>£9.34</td>
<td>44</td>
</tr>
<tr>
<td>30,000</td>
<td>£4.25</td>
<td>£2.95</td>
<td>£7.20</td>
<td>66</td>
</tr>
<tr>
<td>40,000</td>
<td>£3.18</td>
<td>£2.95</td>
<td>£6.13</td>
<td>88</td>
</tr>
<tr>
<td>50,000</td>
<td>£2.55</td>
<td>£2.95</td>
<td>£5.50</td>
<td>110</td>
</tr>
<tr>
<td>60,000</td>
<td>£2.12</td>
<td>£2.95</td>
<td>£5.07</td>
<td>132</td>
</tr>
</tbody>
</table>

With a market price of £10/dried ton the Raymond seems viable for 15,000 bird units and larger. The upper limit is determined by the cost of labour for supervisory work and 100 hours is considered the maximum (MAFF, personal communications). Thus the Raymond is suitable for 15,000 – 45,000 bird enterprises.

7.3.1.(b) SCOLARI

These flash dryers are of Italian design and a continuous or intermittent feed is employed depending on the type of model. The continuous feed models require constant surveillance, whereas the intermittent models can be loaded, started, and left unattended. There are 10 models in all each with about the same running costs per dried ton of product.

The quoted analyses are:

- Moisture - 12%
- Nitrogen - 5.5 - 7%
- Phosphorus - 2.6%
- Potassium - 2.0%
These values are a little lower than those from the Raymond drier, probably due to the operating temperature being high at 115°c.

The capital costs are:

**Continuous**
- A 13 k - £4,100
- A 20 k - £4,700
- A 28 k - £5,200
- A 40 k - £6,450
- A 64 k - £8,500

**Intermittent**
- A 13 p - £3,060
- A 20 p - £3,445
- A 28 p - £4,050
- A 40 p - £5,025

Operational data is presented in table 7(3).

**TABLE 7(3)**

<table>
<thead>
<tr>
<th>Model</th>
<th>A 13</th>
<th>A 20</th>
<th>A 28</th>
<th>A 40</th>
<th>A 64</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hourly evaporation:</strong> (lbs/hour)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>396</td>
<td>562</td>
<td>990</td>
<td>1,320</td>
<td>2,640</td>
</tr>
<tr>
<td><strong>Wet input @ 75% moisture (lbs/hour):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>553</td>
<td>794</td>
<td>1,383</td>
<td>1,848</td>
<td>3,700</td>
</tr>
<tr>
<td><strong>Dry output @ 12% moisture (lbs/hour):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>157</td>
<td>232</td>
<td>393</td>
<td>528</td>
<td>1,060</td>
</tr>
<tr>
<td><strong>Fuel requirements (lbs/hour):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>15.4</td>
<td>26.2</td>
<td>35.3</td>
<td>70.8</td>
</tr>
<tr>
<td><strong>Power requirements (Kw Hs):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.58</td>
<td>5.37</td>
<td>9.42</td>
<td>12.70</td>
<td>21.20</td>
</tr>
</tbody>
</table>
Scolari claim that at £0.05/gal for fuel and £0.01/Kw Hr the following running costs/ton dried product are realised:

<table>
<thead>
<tr>
<th>A</th>
<th>13 k</th>
<th>A 20 k</th>
<th>A 28 k</th>
<th>A 40 k</th>
<th>A 64 k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>£4.50</td>
<td>£4.65</td>
<td>£4.65</td>
<td>£4.70</td>
<td>£4.60</td>
</tr>
</tbody>
</table>

The Italian makers do not state whether these costs include depreciation and maintenance, but it is suspected that they do not. Insufficient data was available from the manufacturers to include a cost analysis similar to that of the Raymond to deduce optimum flock sizes, and the estimates below are the author's:

<table>
<thead>
<tr>
<th>A</th>
<th>13 k</th>
<th>A 20 k</th>
<th>A 28 k</th>
<th>A 40 k</th>
<th>A 64 k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum flock:</td>
<td>20,000</td>
<td>30,000</td>
<td>50,000</td>
<td>70,000</td>
<td>140,000</td>
</tr>
</tbody>
</table>

Total running costs are more likely to be in the range of £5-8 per dried ton and the manufacturer's estimates are considered low.

7.3.1.(c) DOUGLAS ROWNSON

This dryer operates as a flash-drying drum with a cyclone separator, and part of the dried product is admixed with the input manure. Centrifugal fans remove exhaust gases to an after-burner at 650°C and thence to a heat exchanger where they warm the incoming air.

The capital cost of the drier is £9,000 and can operate on a throughput of 500 kgs/hour of 75% moisture content manure. This produces 135 kgs/hour of product at 10% moisture. An operation of 50 hours per week developing 351 dried tons per year is recommended and this can, therefore, treat the waste from up to 25,000 birds.

Annual fixed costs, plus 2½% maintenance – £1,625 p.a.
This represents £4.65/dried ton.
The prototype uses 12 gals/hour gas oil and 24 Kw Hrs electricity and the manufacturers claim running costs of £9.00/dried ton.

Total cost is therefore £13.65/dried ton which is above the market price of £10/dried ton for the product. The oil consumption of this dryer is extraordinarily high, presumably due to the after-burner (Section 7.2.3).

7.3.2. DRUM DRYERS

7.3.2. (a) COLMAN

This is a drum dryer of mild steel construction fed by twin feed augers from the input hopper which may be in any position from vertical to horizontal. The drum is rotated by a 5 h.p. 3-phase motor at 380/440 volts through two "V" belts and a pulley drive. Internal augers provide an even flow of slurry through the primary pass of the rotating chamber and break the manure into small particles. A reverse pass completes the drying and discharge is into a collecting pit.

The oil-fired burner can evaporate 90 gals water/hour, using 6 gals of 35 second oil, and produces 380 lbs per hour of friable dried manure. With 1,000 birds producing approximately 1 ton of wet manure per week at 75% moisture, the Colman drier is most suitable for 20,000 - 40,000 bird enterprises.

Exhaust gases are passed through a dust collector box, a fine dust cyclone arrestor, and an exhaust gas suppressor burner. The gas suppressor uses a fully automatic pressure-jet burner firing into a refractory-lined, turbo-flow after-
burner chamber. The gases are finally vented to the atmosphere via a 36 ft. tall chimney.

No capital cost could be ascertained but running costs are around £3.00/dry ton according to the manufacturer. With capital costs, maintenance and labour the total costs may approach £8.00/dry ton.

7.3.2. (b) HARO

This is a stainless-steel lined drum dryer operating at 210-240°C. A low fuel consumption of 3½ gals/hour is claimed.

Manure is propelled through the oven by a spiral agitator (3 h.p.) and dried manure is extracted by a 4 h.p. centrifugal blower into a cyclone separator. Steam and exhaust are vented to the atmosphere via a tall chimney optionally equipped with an "Alamask" odour control device (May and Baker Ltd.).

The dryer is batch fed, each cycle taking 1½ - 1¾ hours, depending on the moisture content, and a 9 hour day can accommodate between 15,000 - 25,000 birds.

The capital cost is £2,750 for a manual model requiring 2½ hours supervision per day and £3,250 for a fully automated model requiring only 30 mins. per day supervision.

Drying costs are said to be £3 - £4 per dry ton including capital repayment, maintenance, fuel, and labour. This is probably very optimistic and this dryer has met with severe odour problems (Section 7.2.3) requiring a high capital outlay for the solution.
7.3.2. (c) JONES

The manager of Recycled Feeds Co. (Sevenoaks, Kent) designed the Jones dryer to incorporate the advantages of dryers already on the market.

Manure is augered from the input hopper into the drum and the auger shaft has a reverse screw for the latter half. Thus the manure passing through the oven needs to overcome the effect of this auger pushing it back into the chamber. The retention time is thus increased.

Using 35 second oil the output is 250 lbs dried manure per hour dependent on the initial moisture content. Exhaust is purged by an impingement unit and diluted with fresh air before venting to the atmosphere through a boundary-layer type chimney head.

Under commercial use for 18 months at a 10,000 bird unit Jones claims costs of:

- Depreciation - £2.40
- Diesel Oil - £0.90
- Electricity - £0.30
- Overheads - £0.40
- Labour - £1.00

TOTAL - £5.00 / dried ton

With an estimated capital cost of £3.700 - £4.000 (based on the prototype) this dryer may be viable for the smaller poultry producers.
7.3.2. (d) M.F.E.

Master Farm Equipment market three models capable of drying the output from 4,000 - 20,000 birds. Exhaust gases are drawn into a cyclone separator and the dust-free air is then drawn through a duct system within an after-burner at 900°c. Table 7(4) shows the data for the three models.

TABLE 7(4)

<table>
<thead>
<tr>
<th>Model</th>
<th>No.8</th>
<th>No.12</th>
<th>No.22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flock Size</td>
<td>4,000 - 8,000</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Input (75% water)</td>
<td>100-130 kg/hr</td>
<td>150-200 kg/hr</td>
<td>300-400 kg/hr</td>
</tr>
<tr>
<td>Output (12% water)</td>
<td>30-60 kg/hr</td>
<td>45-90 kg/hr</td>
<td>90-180 kg/hr</td>
</tr>
<tr>
<td>Oil Consumption</td>
<td>7-11 litres/hr</td>
<td>11-18 litres/hr</td>
<td>20-35 litres/hr</td>
</tr>
<tr>
<td>Power Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drum Drive</td>
<td>(0.5 h.p.) 0.4 kw</td>
<td>(1.0 h.p.) 0.75 kw</td>
<td>(1.3 h.p.) 1.0 kw</td>
</tr>
<tr>
<td>Fan Motor</td>
<td>(0.25 h.p.) 0.2 kw</td>
<td>(0.5 h.p.) 0.4 kw</td>
<td>(3.0 h.p.) 2.2 kw</td>
</tr>
<tr>
<td>Price</td>
<td>£2,500</td>
<td>£3,350</td>
<td>£4,700</td>
</tr>
</tbody>
</table>

Running costs are said to be £8.00 for 10,000 birds on a 40 hour week. This is £1.75 - £2.00 per dried ton and must be considered as very optimistic indeed.

7.3.2. (e) ORM

This drum dryer is encased in glass fibre to improve heat efficiency. Input is 720 lbs/hour at 79% moisture giving an output of 174 lbs/hour at 12% moisture and uses 5½ - 6 gals of oil per hour with 3 Kw Hr.

Capital cost is £4,750 and at 2½% maintenance the annual fixed costs are £855 p.a.
Running costs at £0.04/gal for oil and £0.01/Kw Hr electricity are £3.20/dried ton.

Fixed costs for a 12,000 bird unit on a 46 hour week are £855/156 dry tons which is £5.50/dry ton giving total costs of £8.70 per dried ton.

Fixed costs for a 20,000 bird unit operating a 76 hour week are £855/260 dry tons which is £3.30/dry ton giving total costs of £6.50 per dried ton.

This machine therefore may well be viable.

7.3.2. (f) STURTEVANT

This drum dryer accepts 900-1,000 lbs wet manure per hour at 75-82% moisture and produces 190-200 lbs/hour dried product at 12-18% moisture. The plant operates an 8 hour day and can therefore accommodate 25,000 birds. No odour control is included.

Capital cost is £6,500 and at 2½% maintenance the fixed costs are therefore £1,164. This is £3.50 per dried ton.

Fuel is used at 7½ gals/hour and electricity at 3.75 Kw Hrs giving running costs of £4.73/dry ton.

Thus total costs are £8.23/dried ton.

7.3.3. ATRITOR DRYERS

The Herbert Atritor-Dryer-Pulverisor is the only one of its type offered for use with poultry manure. The input is fed into a hopper from which it descends onto a horizontal rotating disc. A knife scrapes material from this disc into a chute. It then passes into the swing hammer zone where hard particles are shattered and into the pulverising zone which uses rotating fixed hammer segments.
Hot air carries the much reduced particles into the atritor which consists of a rotor equipped with pegs. The manure particles are repeatedly thrown out to the periphery of the chamber by the complex turbulence and vortices produced by the pegs. Abrasive action of the manure over the pegs further breaks down the particle size.

Particles pass to the "eye" end of the atritor in the air stream and rotating spoons fling back larger particles. Fine particles pass between the spoons into a collection cyclone.

The hot air feed for the atritor is produced in an oil-, gas-, or coke-fired burner.

Industrial applications of this type of dryer have been successful and drying costs in the region of £2.52 - £2.97 per dried ton are claimed. There are seven models to accommodate 10,000 - 300,000 birds and the capital cost of a 50,000 bird dryer would be £14,400. Thus, the Herbert dryer would be one of the most expensive manure dryers available, but may be attractive for extremely large enterprises.

7.3.4. RING DRYERS

The Pennwalt Ring Dryer has only one fan, which reduces maintenance costs, and this produces a vigorous circular flow with continuous material renewal in a circular duct.

Wet manure is cascaded into the ring duct by a feeder and is carried in floating contact with a hot air stream. The manifold fan forces particulate matter to the outer edges of the ducting and is aided by injector air streams. The
lightest and dryest fractions overcome the centrifugal forces and are withdrawn from the inside of the ducting via a central outlet.

This type of dryer can use hot air, inert gases, or exhaust gases as the carrier stream and can be fired by steam, electricity, gas, oil, coke, or waste hot gases via a heat exchanger. Capital costs are extremely expensive at £29,000 and an oil burner would consume in the region of 31 gals/hour.

Total running costs of the prototype are £19.40 per dried ton (depending on the input) and this type of dryer therefore has a limited future even for very large enterprises.

7.3.5. FLUIDISED BED DRYERS

Such dryers as the Stokes and Sharples fluid bed models are in common industrial use. A mesh base acts as an initial support and distribution place within the dryer and hot air is forced through the material causing it to float and boil, the turbulence being controllable from a slow simmer to a vigorous bubble. Heat transfer from the air to the solids is extremely rapid and the air temperature soon falls preventing any over-heating. A cyclone separator recovers the dried product.

7.3.6. MICROWAVE DRYERS

Lucas Furnace Developments (Section 6.5.2) claim production of 1-2 ton/hour of dry poultry manure at a cost of £1/dried ton from their microwave dryer.

The first process, surprisingly, is to wet the manure which is then double sieved to remove feathers, cigarette packets, etc., before being pressed down to 50-60% moisture
for feeding into the dryer. A belt moving at 200 ft/hour transfers the material through a zone treated by microwaves which is programmed to deliver a product of anywhere between 0 and 50% moisture. The manure emerges as a long strip of "Weetabix"-like material and the microwaves ensure a sterile product.

Electricity consumption is rated at 35 pence per dried ton. With a capital cost of £25,000 over 10 years the fixed costs are also quoted as 35 pence per dried ton. Total costs including supervisory labour and maintenance are, therefore, about £1/dried ton. However, this assumes continuous operation and would then accommodate 400,000 birds. Even a 150,000 bird unit operating at only 40 hours per week could return operating costs of £2/dried ton.

This type of drier may be attractive to very large enterprises or integrated producer groups.

7.3.7 COMPARISONS

It is clear from the preceding sections that the manufacturers of dryers have little idea of the total running costs or the capacities of their products. This may stem from the fact that, as yet, poultry manure drying is relatively uncommon, though certainly not new. Also many of the dryers are marketed from the results of one prototype and subsequent models rarely receive the same supervision, and maintenance costs appear to be high.

Table 7(5) indicates the range of costs per dried ton claimed by the manufacturers or estimated from manufacturer's specifications. It will be noticed that the author's estimates are generally higher than the manufacturer's and an average cost of about £8-10 per dried ton for conventional and tried...
models is reasonable, inclusive of all labour, fuel, depre­
ciation, and maintenance.

### TABLE 7 (5)

<table>
<thead>
<tr>
<th>Model</th>
<th>Flock Size</th>
<th>Capital Cost</th>
<th>Fixed Costs /dry ton</th>
<th>Running Costs /dry ton</th>
<th>Total Costs /dry ton</th>
<th>Manufacturers Estimate /dry ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raymond</td>
<td>40,000</td>
<td>£12,000</td>
<td>£3.18</td>
<td>£2.95</td>
<td>£6.13</td>
<td>N.A.</td>
</tr>
<tr>
<td>Scolari</td>
<td>50,000</td>
<td>£5,200</td>
<td>£1.10</td>
<td>£2.50</td>
<td>£3.60</td>
<td>£4.65</td>
</tr>
<tr>
<td>Douglas</td>
<td>25,000</td>
<td>£9,000</td>
<td>£4.65</td>
<td>£9.00</td>
<td>£13.65</td>
<td>£13.65</td>
</tr>
<tr>
<td>Rownson</td>
<td>20,000</td>
<td>N.A.</td>
<td>N.A.</td>
<td>£3.00</td>
<td>£8.00</td>
<td>£4.00</td>
</tr>
<tr>
<td>Colman</td>
<td>20,000</td>
<td>N.A.</td>
<td>N.A.</td>
<td>£3.50</td>
<td>£3.50</td>
<td>£3.50</td>
</tr>
<tr>
<td>Haro</td>
<td>20,000</td>
<td>£3,250</td>
<td>£1.70</td>
<td>£2.00</td>
<td>£3.50</td>
<td>£3.50</td>
</tr>
<tr>
<td>Jones</td>
<td>10,000</td>
<td>£4,000</td>
<td>£4.15</td>
<td>£2.60</td>
<td>£6.75</td>
<td>£5.00</td>
</tr>
<tr>
<td>M.F.E.</td>
<td>10,000</td>
<td>£3,350</td>
<td>£3.55</td>
<td>£3.57</td>
<td>£7.12</td>
<td>£2.00</td>
</tr>
<tr>
<td>Omn</td>
<td>12,000</td>
<td>£4,750</td>
<td>£5.50</td>
<td>£3.20</td>
<td>£8.70</td>
<td>N.A.</td>
</tr>
<tr>
<td>Sturtevant</td>
<td>25,000</td>
<td>£6,500</td>
<td>£3.50</td>
<td>£4.73</td>
<td>£8.23</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

N.A. - Not available.

* These are based on a 10 year life at 10% interest with 2 ½% p.a. for maintenance and the cost of oil and electricity of manufacturer's specifications. None include labour costs and the lower cost machines (Scolari, Haro) operate with almost continuous supervision.

### 7.4. DRIED POULTRY MANURE AS A FERTILISER

Reduction of water content from 75-80% to the 10-15% of the dried product decreases the weight to about ¼ of the original and concentrates the plant nutrients (subject to some loss by volatalisation) by about 4 or 5 times.
Typical analyses produced by the Jones dryer (personal visit and communications 9/11/71) are:

- Nitrogen - 6.0%
- Phosphate - 3.5%
- Potash - 1.6%

This concentration of the nutrients effectively increases the market value of dried poultry manure over that for fresh poultry manure and, using the analysis of Chapter 3, this puts the 1970 market price at about £8.00 - £10.00/ton. As has been shown (this Chapter) drying costs may well be around £10.00/dried ton, sometimes lower, and so sale as a fertiliser could provide a free or even profitable means of manure disposal.

An organised market is essential to prevent the need for large storage sheds and an alternative means of disposal. This is by no means easy for people concerned with poultry farming and not marketing strategy, and a restricted market has caused a number of dryers to revert to more traditional disposal methods. (Personal visits and communications). However, a successful market outlet could provide a more lucrative industry than the original production of eggs or table birds, and in some cases this has been demonstrated. (Poultry Farmer, September 27th 1967. Poultry World, April 1968 No.4).

Manufacturers of dryers continually maintain that dried poultry manure does not "scorch" as do fresh dropings, but it is suspected that the traditional fear of scorching may have led to the difficulties met by some enterprises practising drying.
7.5. DRIED POULTRY MANURE AS A FEED

Ruminant feeds are traditionally composed of grass or cereals supplemented with oilseed cakes or meals. The ability of ruminants to use non-protein nitrogen was known as far back as 1842 but the recycling of poultry manure as a uric acid source is comparatively recent. The ruminant digestive system produces urea during protein degradation and the gut micro-fauna metabolise this urea to re-synthesise protein. The microorganisms eventually die within the ruminant's gut and provide a ready and immediate protein source. The feeding of straight urea has been investigated at I.C.I.'s Jealott's Hill and has proved to be very satisfactory in maintaining a constant 'uric environment' for the gut bacteria which produces a constant host-animal performance, whereas standard feed changes from grass to silage often change gut conditions, destroy the gut organisms and reflect in the detriment to the host's performance. (Top Livestock Farming, August 1972 pp 4-5).

Since dried poultry manure contains significant levels of nitrogen as uric acid (Evans et al, Bangor University) it may prove to be a useful feed supplement. The Nitrogen is distributed as shown in Table 7(B).

<table>
<thead>
<tr>
<th>Sample</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N</td>
<td>7.94</td>
<td>4.54</td>
<td>4.90</td>
<td>4.11±0.20</td>
</tr>
<tr>
<td>Protein N</td>
<td>3.92</td>
<td>1.47</td>
<td>2.17</td>
<td>1.24±0.08</td>
</tr>
<tr>
<td>Uric acid N</td>
<td>2.94</td>
<td>0.96</td>
<td>1.41</td>
<td>-</td>
</tr>
<tr>
<td>Ammonia N</td>
<td>1.23</td>
<td>0.43</td>
<td>0.75</td>
<td>0.36±0.02</td>
</tr>
</tbody>
</table>

Sample 4 - means and standard deviations of 20 samples from the same source).
The variation in the samples is evident, and the same work by Evans quotes some foreign sources producing even higher variations.

Jones (Sevenoaks, Kent) has an extensive re-cycling campaign and consequently has detailed analyses performed on his dried poultry manure. Typical analyses are in tables 7(7) to 7(9)

**TABLE 7(7)**

**Crude Analysis**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (N x 6.25)</td>
<td>25.5%</td>
</tr>
<tr>
<td>Fibre</td>
<td>8.3%</td>
</tr>
<tr>
<td>Oil</td>
<td>2.1%</td>
</tr>
<tr>
<td>Ash</td>
<td>22.20%</td>
</tr>
</tbody>
</table>

**TABLE 7(8)**

**Mineral Analysis**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>5.85%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>2.67%</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>1.20%</td>
</tr>
<tr>
<td>Silica</td>
<td>1.4%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.46%</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.1%</td>
</tr>
<tr>
<td>Copper</td>
<td>60 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>439 ppm</td>
</tr>
<tr>
<td>Zinc</td>
<td>560 ppm</td>
</tr>
<tr>
<td>Arsenic</td>
<td>65 ppm</td>
</tr>
<tr>
<td>* Cobalt</td>
<td>0.7 ppm</td>
</tr>
<tr>
<td>* Molybdenum</td>
<td>3.4 ppm</td>
</tr>
</tbody>
</table>

(* - Evans et al, Bangor)
### Amino Acid Analysis (g/100 gm crude protein)

<table>
<thead>
<tr>
<th></th>
<th>Jones' Manure</th>
<th>Barley Meal**</th>
<th>Fish Meal**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartic Acid</td>
<td>0.78</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Serine</td>
<td>0.37</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.47</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Valine</td>
<td>1.55</td>
<td>0.64</td>
<td>3.14</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>1.19</td>
<td>0.63</td>
<td>2.70</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.90</td>
<td>0.46</td>
<td>2.12</td>
</tr>
<tr>
<td>Lysine</td>
<td>1.35</td>
<td>0.46</td>
<td>5.03</td>
</tr>
<tr>
<td>Arginine</td>
<td>1.25</td>
<td>0.71</td>
<td>4.67</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.66</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Glutamic Acid</td>
<td>1.35</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cystine</td>
<td>7.05</td>
<td>0.64</td>
<td>7.01</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.40</td>
<td>0.34</td>
<td>0.66</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.79</td>
<td>0.23</td>
<td>2.04</td>
</tr>
<tr>
<td>Leucine</td>
<td>1.80</td>
<td>0.98</td>
<td>4.74</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>1.33</td>
<td>0.75</td>
<td>2.63</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.62</td>
<td>0.27</td>
<td>1.39</td>
</tr>
</tbody>
</table>

(** - Fairbairn, C.B. NAAS Cambridge. Personal Communications)

The comparative metabolisable energies are shown in table 7(10) (Fairbairn, personal communication).

### Table 7(10)

<table>
<thead>
<tr>
<th></th>
<th>Energy k Cal/lb dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried Poultry Manure</td>
<td>500</td>
</tr>
<tr>
<td>Maize</td>
<td>1780</td>
</tr>
<tr>
<td>Barley</td>
<td>1450</td>
</tr>
<tr>
<td>Oats</td>
<td>1270</td>
</tr>
<tr>
<td>Fish Meal</td>
<td>1430</td>
</tr>
</tbody>
</table>
Table 7(11) adapted from R. Newbold's final year project (1970, Surrey University, Chemistry) and compares protein content (N x 6.25) and costs for some common feedstuffs:

**TABLE 7(11)**

<table>
<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>Protein</th>
<th>Price/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>1.52</td>
<td>9.5</td>
<td>£21.50</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.76</td>
<td>11.0</td>
<td>£23.50</td>
</tr>
<tr>
<td>Maize</td>
<td>1.44</td>
<td>9.0</td>
<td>£26.50</td>
</tr>
<tr>
<td>Oats</td>
<td>1.68</td>
<td>10.5</td>
<td>£20.00</td>
</tr>
<tr>
<td>Beans</td>
<td>4.48</td>
<td>28.0</td>
<td>£29.00</td>
</tr>
<tr>
<td>Linseed</td>
<td>5.12</td>
<td>32.0</td>
<td>£49.00</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>5.76 - 6.4</td>
<td>36.0 - 40.0</td>
<td>£35.00</td>
</tr>
<tr>
<td>Soyabeanes</td>
<td>7.2</td>
<td>45.0</td>
<td>£50.00</td>
</tr>
<tr>
<td>Urea</td>
<td>46.4</td>
<td>290</td>
<td>£37.00</td>
</tr>
</tbody>
</table>

Thus poultry manure can be seen to have a protein value about the same as, and metabolizable energy about 1/3, that of cereals. The price, however, is about 1/3 - 1/2 that of cereals.

**7.5.1. ARSENIC**

Some concern has been expressed over the use of arsenic as a poultry additive and the possible effects of using such affected manure as fertiliser or feed. Medication at 100 ppm arsenic will produce droppings which contain, when dried, 270 ppm arsenic (Marriot, J.V.R. personal communication). Part of this faecal arsenic is organically bound and unavailable to livestock ingesting it.

It has been shown (Frost, 1953, 1965) that arsenic is an essential trace element and exists in detectable amounts in soil, air and water. No adverse effects are predicted from using arsenical poultry manure.
7.5.2. PATHOGENS

With the drying of manure one would expect significant reductions in bacterial populations and with a re-feeding programme it is essential that a sterile product is used. Jones (Sevenoaks, Kent) produces a manure with the average analysis as in Table 7(12).

TABLE 7(12)  

<table>
<thead>
<tr>
<th>No. of organisms per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total bacteria at 37°C</td>
</tr>
<tr>
<td>Coli-aerogenes</td>
</tr>
<tr>
<td>Bacillus cereus</td>
</tr>
<tr>
<td>Bacterial spores</td>
</tr>
<tr>
<td>Moulds at 40°C</td>
</tr>
<tr>
<td>Salmonellae</td>
</tr>
</tbody>
</table>

With no salmonellae surviving the risk of infection due to re-feeding is virtually zero.

7.5.3. OTHER CHEMICALS

Apart from the arsenic problem, certain other chemicals excreted in poultry manure may be fed and accumulate in livestock producing toxicity problems. Such trace elements as copper and molybdemum may have effects, though these have not been encountered as yet.

In Jones' dried manure BHC (benzene hexa-chloride) was detected at 2.3 ppm, but no other chlorinated insecticides. The persistence of such compounds must be viewed cautiously.

7.5.4. FEEDING TRIALS

Having established that poultry manure may serve as a relatively cheap feedstuff with no obvious dangers or disadvantages, it is pertinent to comment on feeding trials.
The dried product has been used effectively in feeding sheep, beef cattle, and back to poultry themselves.

Trials at Bangor University have been performed feeding dried poultry manure as a part diet to sheep (Evans et al, Sunningdale Conference 1968, Linda Hudson's Honours Agriculture thesis, Dr. Chamberlain's research notes). The findings are of interest and are briefly summarised.

Sixty sheep were allocated 3 diets from self-feed hoppers for 4 months as in Table 7(13).

**TABLE 7(13)**

<table>
<thead>
<tr>
<th></th>
<th>Diet A</th>
<th>Diet B</th>
<th>Diet C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>83%</td>
<td>72%</td>
<td>60%</td>
</tr>
<tr>
<td>Soyabean Meal</td>
<td>17%</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Chicken Manure</td>
<td>0%</td>
<td>17%</td>
<td>35%</td>
</tr>
</tbody>
</table>

The trials allowed for 1½ lbs. of concentrates/day and ½ lb. hay/day.

The 1970 costs using manure at £10.00 per ton, Soyabean meal at £50.00/ton and Barley at £21.50/ton (previous tables) have been used by the author to provide the diet costs of Table 7(14).

<table>
<thead>
<tr>
<th></th>
<th>Diet A</th>
<th>Diet B</th>
<th>Diet C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of diet and hay for experimental period.</td>
<td>£1.70</td>
<td>£1.40</td>
<td>£1.30</td>
</tr>
<tr>
<td>Total feeding and Inwintering costs/head (including £0.20/head building depreciation)</td>
<td>£1.90</td>
<td>£1.60</td>
<td>£1.50</td>
</tr>
</tbody>
</table>

Diet C with the highest proportion of chicken manure offers financial advantage and even at £20.00/ton the diet is estimated at £1.70 total cost.
Apart from cost advantages the sheep on diet C showed improved live-weight gains. Bangor's work on cattle showed a slight depression of live-weight gain. This is probably due to the lower energy value of poultry manure compared to cereals, or too high levels of calcium depressing growth rate.

The interrelations of energy and minerals are well documented (Feed Service (Livestock) Ltd. "The Role of Minerals in Ruminant Nutrition").

Experiments in America using isocalorific (916 K cal of productive energy) and isonitrogenous (16.0% protein) diets of up to 20% dried poultry manure show a favourable comparison with the control or basal diets (Quisenberry and Bradley, 1969). Again, dried poultry manure diets were cheaper and remained cheaper when the Texas A and M University College Station installed their own drier.

Jones (Sevenoaks, Kent) has been operating a diet of 10% manure back to his 20,000 birds and 30% to beef cattle. Satisfactory results are claimed though he estimates that 85 week feeding may build up a toxic level of trace elements in the birds' livers producing fatalities. Jones therefore operates feeding in a 60 week lay commencing from 20 weeks of age. Excess manure is sold to a fertiliser and feed compounder at £17-20 per ton.

7.6 OTHER DISPOSAL METHODS

This brief section on alternative methods of disposal may, at first glance, seem trivial in content, but the methods have been seriously discussed at Conferences and Symposia and may well prove valuable outlets for animal manures.
Edwin Danks & Co. (Oldbury) Ltd. (Babcock & Wilcox Ltd.
Group) have carried out preliminary trials in the use of dried
poultry manure as a fuel to provide heat. The following
discussion is based on a personal communication (Seaman, P.T.
22/12/70).

Originally the dryer was to be an Oldbury Chain Grate
Stoker mounted underneath a rotary kiln. The dried manure
would then be fed into the stoker as a fuel, there being a
base fire of coal to ensure total destruction of the manure.
The prototype was designed at a 10 ton/day input and would
therefore accommodate a unit of 100,000 birds.

In principal the prototype worked well producing dried
manure fuel at 6,500 B.T.U's per lb. (Coal 12,000 B.T.U's/lb;
Oil 18,500 B.T.U's/lb) and the furnace was to have been sold
at around £7,000 which, for a 100,000 bird unit, would have
proved attractive as a total disposal system.

Attempts to link the stoker to a boiler for steam generation
were abandoned due to technical reasons. The whole project
was eventually abandoned due to economic difficulties and the
ever-present problems of odour.

The U.S. Bureau of Mines (Bruceton, Pa.) have been
investigating two processes for the production of fuel from cow
manure. The first is pyrolysis, a process of heating for six
hours at 900°C in an air-free environment at atmospheric pressure.
At this temperature the manure is converted to gas, oil, and
solids having calorific values of 500 B.T.U's/cu.ft, 15,000
B.T.U's/lb and 5,000-13,000 B.T.U's/lb respectively.
The second process is that of heating under pressure in the presence of carbon monoxide, steam, and a catalyst. The process is basically hydrogenation since the manure is subjected to hydrogen produced by the shift reaction between carbon monoxide and steam. A 20 minute contact time at 380°C and between 2,000-5,000 p.s.i. pressure produces a virtually sulphur-free heavy paraffinic of 14,000-16,000 B.T.U's/lb.

The latter process is of greater commercial promise since a single product is formed, obviously simpler to store and market than the three pyrolysis products.


7.6.2 PROTEIN EXTRACTION

Poultry manure is suitable for protein precipitation by the Alwatech process (Summers, 1972). This process involves the addition of fully sulphonated sodium lignosulphate to manure of pH 3.4 (established by sulphuric acid addition) and air flotation is employed to recover a protein and grease concentrate. This method is limited by the high costs of the chemicals involved.

7.6.3 PROTEIN CONVERSION

Prof. D. Bellamy (Cardiff University) recently outlined three methods of using manure to fatten other organisms for collection and use as animal or human feed (New Scientist, 23rd November, 1972 p.456).

The first is to push the farm effluent into a pond in order to produce plankton for the feeding of coarse fish such as carp or mullet. Apparently this is well-tried in China where duck-houses may be established over waterways.

The second method is that of using bivalve molluscs whose anatomy and physiology are designed to filter out nutritious
particles. The nutritive value of such fresh water molluscs (probably as animal food) would be complemented by their possible value as water purifiers (Technology Review 16th November, 1972 p. 392).

The third possibility is the growth of algae for harvesting and for oxygenation of waters. Light supply would be the limiting factor here.

Work by McGill and Swinburne (Glasgow ARC Conference Sept. 1972) has led to the growth of sewage fungi on pig slurry and recovery of the fungi's 35-37% crude protein. Mucor racemosus proved the best fungus as this would grow in abundance on a 50% diluted slurry. Leptomitus lacteus appeared intolerant to the phosphorus levels in pig slurry and dilution to 1-2% was necessary, but this led to dilution of other nutrients and halted growth.

This work has led to experiments in the production of dried mycelial protein as a feedstuff.

Recently Australia released four species of dung beetles in order to clear their stockland of persistent cow pats which would otherwise remain for years in the dry climate. Some success has been reported as the beetles use dung as a food for themselves and their offspring. This may have possibilities in warm climates for manure disposal, and perhaps harvesting of the beetles (Laboratory News, Nos. 31 13/6/72 pp 12-13).

7.6.4 OTHERS

Discussion at the Glasgow Conference included: 1) the use of powdered dried chicken manure in cosmetic face powders. The material is suitable because it does not absorb atmospheric
moisture.

2) the use of manures in aggregates for building purposes. Work in America using ground glass and manure was noted.

3) the use of manure as a substrate for fermentation processes and the subsequent recovery of chemicals (namely alcohols) on a large scale. This method was considered particularly attractive due to the recent alarm at the disappearance of crude oil supplies.

4) also with reference to oil supplies, it was suggested (seriously) that manure should be pumped into wells now devoid of oil and allowed to undergo natural pyrolysis and hydrogenation beneath the earth's crust to form a new supply of oil. This was thought, perhaps, to be a lengthy process.

5) Sweden claimed to have a market for treated chicken manure as a cure to premature baldness in men, but this was thought to be a somewhat limited outlet.

7.7 SUMMARY

The drying of poultry manure appears to be an unstable industry at present with few exceptions (Poultry Farmer, 1967, Poultry World 1968). This is mainly due to the costs of drying being about the same as the market price of the product's constituents. There is also a very real reluctance by farmers to use dried poultry manure as fertiliser or to feed poultry with their own manure. This is demonstrated by the fact that most successful drying enterprises rely on farm-gate sales or on the relatively uncertain markets offered by rose-growers and amateur gardeners. Success in re-feeding is possible (Jones, Sevenoaks) but not common.

However, with constant development of drying technology,
increased prices of fertilisers with the abolition of the subsidy payments, and a stimulated interest in re-cycling methods the drying of poultry manure may well become attractive.

Other uses of manures or by-products seem limited at present and the use as fertiliser or feed are the major outlets.
CHAPTER 8

FREQUENCY OF METHODS

8.1 INTRODUCTION

Having discussed in some detail the problems associated with farm waste disposal, the solutions available and the costs of these solutions, this chapter attempts to define the most popular methods of disposal. Little published work is available on the frequency of each of the methods in use and MAAF estimated that 80% of farms still used traditional land spreading (Riley, Jones, Nielsen, personal communications). However, in so far as stocking densities of more than one cow equivalent per acre are used, it was thought possible that some form of treatment would be used.

Discussion with R.E. Eden (Dept. of Civil Engineering, Southampton University) established the idea of a questionnaire to determine how many farms were forced to use some form of on-farm treatment. A preliminary survey within MAAF promised substantial Ministry backing and a National survey was at first envisaged. A suitable questionnaire design was thought to be that of the algorithmic or flow-type style and the pilot questionnaire was prepared (Appendix 3).

8.2 PILOT STUDY

The twelve Ministry Experimental Husbandry Farms in England and Wales, and the three Scottish Agricultural Colleges were contacted by telephone and all agreed to participate in the pilot survey. A covering letter, questionnaire and stamped return envelope were sent to each of the participants in April, 1971. This pilot survey furnished 11 completed questionnaires and comments about experimental design, ease of operation, usefulness of questions and inherent ambiguities were recorded. The pilot
survey served the purpose of a trial to enable the formulation of the final questionnaire.

At this stage the promised support from MAAF was withdrawn owing to the re-organisation of the National Agricultural Advisory Service (NAAS) into the new Agricultural Development and Advisory Service (ADAS) with a consequent reduction in available money and time.

8.3 SAMPLE SELECTION

The National survey at first envisaged had to be abandoned since MAAF would no longer be of assistance, and the Eastern Agricultural Region (Berkshire, Buckingshamshire, S.E. Greater London, Hampshire, Isle of Wight, Kent, Oxford, Surrey, East Sussex, and West Sussex) was chosen as a suitable region for a reduced questionnaire survey. This region offered a number of advantages – a cross-section of farming types, soil types and weather conditions, and proximity to the Guildford base should any visits be necessary.

350 questionnaires were planned in accordance with the available University budget and the reluctance of MAAF to furnish any names and addressed at all.

The Agricultural Research Council was then asked for financial help by R.E. Eden who explained the merits of the project. However, help was not offered for the project.

A maximum of 350 questionnaires could therefore be operated. This presented a problem in sample selection since the Eastern Region contained well over 20,000 agricultural holdings. Two criteria were used to determine the sample:

1) Cut-off point. It was decided that only farms having more than 39 cattle, 99 pigs, or 999 poultry would be considered. These cut-off limits represent about the smallest commercially competitive units and include more than 80% of the holdings anyway.
2) Disproportionate random stratified sampling. With such a small sample it was possible to miss some of the minority groups such as those rearing cattle, pigs, and poultry together. Therefore a proportion of these minority groups were deliberately picked into the random sample.

Using the June 1970 Agricultural Census in Coded Data form, the 24,970 holdings in the Eastern Region were studied. Each holding qualifying in more than the cut-off limits for livestock was noted and its Registration Number filed under cattle (C), pigs (P), poultry (F), cattle and pigs (C + P), cattle and poultry (C + F), pigs and poultry (P + F), or all three (C+P+F). This hand picking drew 9,271 holdings and the data is represented in Table 8.1.

350 questionnaires would then be distributed amongst the categories in a disproportionate sample. This was to ensure the inclusion of minority groups, and the numbers chosen were as follows:

**TABLE 8.1**

Numbers of holdings in each category

<table>
<thead>
<tr>
<th>County</th>
<th>C</th>
<th>P'</th>
<th>F</th>
<th>C&amp;P</th>
<th>C&amp;F</th>
<th>P&amp;F</th>
<th>C, P, F</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>BERKSHIRE</td>
<td>522</td>
<td>82</td>
<td>62</td>
<td>67</td>
<td>25</td>
<td>7</td>
<td>11</td>
<td>776</td>
</tr>
<tr>
<td>BUCKINGHAM</td>
<td>837</td>
<td>119</td>
<td>89</td>
<td>76</td>
<td>29</td>
<td>20</td>
<td>10</td>
<td>1,180</td>
</tr>
<tr>
<td>GREATER LONDON: S.E.</td>
<td>49</td>
<td>61</td>
<td>20</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>145</td>
</tr>
<tr>
<td>HAMPSHIRE</td>
<td>980</td>
<td>212</td>
<td>191</td>
<td>114</td>
<td>57</td>
<td>23</td>
<td>10</td>
<td>1,587</td>
</tr>
<tr>
<td>ISLE OF WIGHT</td>
<td>224</td>
<td>19</td>
<td>7</td>
<td>28</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>282</td>
</tr>
<tr>
<td>KENT</td>
<td>845</td>
<td>259</td>
<td>209</td>
<td>70</td>
<td>39</td>
<td>29</td>
<td>7</td>
<td>1,458</td>
</tr>
<tr>
<td>OXFORD</td>
<td>745</td>
<td>117</td>
<td>48</td>
<td>63</td>
<td>28</td>
<td>15</td>
<td>11</td>
<td>1,027</td>
</tr>
</tbody>
</table>
TABLE 8.1 (cont'd)

<table>
<thead>
<tr>
<th>County</th>
<th>Category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C.</td>
<td>P.</td>
</tr>
<tr>
<td>SURREY</td>
<td>420</td>
<td>150</td>
</tr>
<tr>
<td>SUSSEX, EAST</td>
<td>948</td>
<td>120</td>
</tr>
<tr>
<td>SUSSEX, WEST</td>
<td>568</td>
<td>80</td>
</tr>
<tr>
<td>TOTALS</td>
<td>6,138</td>
<td>1219</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Actual Nos. of Holdings</th>
<th>Questionnaires to be sent out</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>6,138</td>
<td>200</td>
</tr>
<tr>
<td>P</td>
<td>1,219</td>
<td>40</td>
</tr>
<tr>
<td>F</td>
<td>901</td>
<td>40</td>
</tr>
<tr>
<td>C &amp; P</td>
<td>561</td>
<td>25</td>
</tr>
<tr>
<td>C &amp; F</td>
<td>266</td>
<td>20</td>
</tr>
<tr>
<td>P &amp; F</td>
<td>121</td>
<td>10</td>
</tr>
<tr>
<td>C.P.F.</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>TOTALS</td>
<td>9,271</td>
<td>350</td>
</tr>
</tbody>
</table>

Each holding was then numberd and a series of numbers drawn from a list of random digits in order to draw out the first 200 C's, 40 P's, etc. until 350 Agricultural Holding Numbers with the required disproportionate distribution were chosen. These numbers were forwarded to MAFF who supplied the names and addresses of the occupiers of the holdings.

18 persons had either retired, gone bankrupt, or were no longer farming for a variety of reasons, leaving 332 names and addresses distributed as follows:
A letter to introduce the questionnaire was posted to each address in late November 1971 and the questionnaire, with reply paid envelope, was posted a month later. This time of year was chosen as being relatively slack for the farmer, free from census forms and other agricultural returns, and during a festive period. Dividends were paid in that an excellent response rate was achieved.

In mid-February 1972 a reminder letter, second questionnaire, and reply paid envelope were sent to those address from which no reply had been received.

A final post-card reminder was posted in March and the Survey terminated on March 31st 1972. This operation is detailed in Appendix 4.

Six questionnaires were returned by the Post Office as "address unknown" or "gone away" reducing the survey to 326 participants. 203 questionnaires were returned, a 62% response rate. The Sociology Department at Surrey and MAFF were impressed with such a high response rate as the average for questionnaires is reckoned to be below 30%. However, of the 203 returns only 185 were useable and some of these were incomplete so that analyses do not always tally to 185.
Crude numerate analysis gave the returns as in Table 8.2.

Statistical Package for the Social Sciences (Nie, Bent, Hull, - MacGraw Hill 07-046530-4) was chosen as a computer package suitable for adaptation to analyse the questionnaire. The questionnaire was coded for punching as shown in Appendix 5 and each reply punched and recorded. Thus each reply was characterised by a numerate printout describing the total farm system, and correlations between any part of the system could be investigated by inspecting the relevant columns. The data is shown in Tables 8.3.

COSTS

One of the major aspects of the questionnaire was the provision for estimates of cost and only 42 respondents attempted to indicate costs. Most of these were incomplete and unusable. Pig and poultry enterprises seemed best able to provide cost data.

Estimates per cow per year varied from 50 pence to £10, per pig per week from 50 pence to £4, and per 1,000 poultry per week from 50 pence to £1.50.

The cost data provided was, on the whole unsatisfactory.

VOLUMES

The estimates of volumes of wastes also proved unsatisfactory as cows produced between 1 gallon and 150 gallons per day.

Again, pig and poultry enterprises seemed best able to produce figures bearing relationship to those of the MAFF and other workers (see Chapter 3).

It was therefore decided to ignore cost and volume data of the questionnaires and to use published figures for the analyses in Chapter 10.

8.5 ANALYSIS OF REPLIES

8.5.1 CONTINUOUS DATA

The continuous data obtained from the questionnaires, that is,
### Questionnaire analysis

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number Concerned Per 185</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collection</strong></td>
<td></td>
</tr>
<tr>
<td>Housing on slats</td>
<td>7</td>
</tr>
<tr>
<td>Scraping manure</td>
<td>105</td>
</tr>
<tr>
<td>Flushing</td>
<td>13</td>
</tr>
<tr>
<td>Continuous belt</td>
<td>5</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td>12</td>
</tr>
<tr>
<td>Manual</td>
<td>139</td>
</tr>
<tr>
<td>Gravity pipe</td>
<td>9</td>
</tr>
<tr>
<td>None</td>
<td>17</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td></td>
</tr>
<tr>
<td>Sump</td>
<td>22</td>
</tr>
<tr>
<td>Tank</td>
<td>3</td>
</tr>
<tr>
<td>Heap (free-standing)</td>
<td>77</td>
</tr>
<tr>
<td>Midden (confined)</td>
<td>28</td>
</tr>
<tr>
<td>None</td>
<td>47</td>
</tr>
<tr>
<td><strong>On farm processing</strong></td>
<td></td>
</tr>
<tr>
<td>Drying</td>
<td>0</td>
</tr>
<tr>
<td>Composting</td>
<td>16</td>
</tr>
<tr>
<td>Digestion tanks</td>
<td>2</td>
</tr>
<tr>
<td>Lagoon</td>
<td>6</td>
</tr>
<tr>
<td>Oxidation ditch</td>
<td>2</td>
</tr>
<tr>
<td><strong>No processing</strong></td>
<td>159</td>
</tr>
<tr>
<td>Spread on own land</td>
<td>151</td>
</tr>
<tr>
<td>Spreader</td>
<td>123</td>
</tr>
<tr>
<td>Tanker</td>
<td>13</td>
</tr>
<tr>
<td>Irrigation</td>
<td>11</td>
</tr>
<tr>
<td><strong>Contractor removal</strong></td>
<td>18</td>
</tr>
<tr>
<td>Pay</td>
<td>4</td>
</tr>
<tr>
<td>Paid</td>
<td>2</td>
</tr>
<tr>
<td>Free</td>
<td>6</td>
</tr>
<tr>
<td>Disposal to sewer or watercourse</td>
<td>7</td>
</tr>
</tbody>
</table>

---

*Signature: Stephen L. Willets*
TABLES 8.3 - Questionnaire Analysis
|   1   |   2   |   3   |   4   |   5   |   6   |   7   |   8   |   9   |  10  |  11  |  12  |  13  |  14  |  15  |  16  |  17  |  18  |  19  |  20  |  21  |  22  |  23  |  24  |  25  |  26  |  27  |  28  |  29  |  30  |  31  |  32  |  33  |  34  |  35  |  36  |  37  |  38  |  39  |  40  |  41  |  42  |  43  |  44  |  45  |  46  |  47  |  48  |  49  |  50  |  51  |  52  |  53  |  54  |  55  |  56  |  57  |  58  |  59  |  60  |  61  |  62  |  63  |  64  |  65  |  66  |  67  |  68  |  69  |  70  |  71  |  72  |  73  |  74  |  75  |  76  |  77  |  78  |  79  |  80  |  81  |  82  |  83  |  84  |  85  |  86  |  87  |  88  |  89  |  90  |
acres of crops or numbers of livestock, provides an indication
of the distribution of the types of farms and the "average" farm.
Tables 8.4 represent the descriptive data of the respondents in
tabular form.

The "average" farm had 146 acres of grass ranging between
a minimum of 2 acres and a maximum of 1,000 acres. The values
of kurtosis and skew indicate the distribution of the grassland
amongst the respondents. A positive kurtosis indicates the
position and width of the mean peak, and the skewness represents
the degree of slope.

The following diagrams clarify this point:

Thus, Tables 8.4 illustrate the distribution of the respondents
by woodland, cattle number etc.,

8.5.1a LAND TYPES

The distribution of woodland shows both positive kurtosis and
skew with the mean at 30 acres. Thus the majority of the 76 farms
TABLES 8.4 - Continuous Data
# Farm Waste Treatment Data

**File: Farm** (Creation Date = 21/02/73) Waste

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data Description</th>
<th>Mean</th>
<th>Std Error</th>
<th>Std Dev</th>
<th>Kurtosis</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAR2</td>
<td>Grassland</td>
<td>145.840</td>
<td>10.596</td>
<td>137.746</td>
<td>8.698</td>
<td>2.333</td>
</tr>
<tr>
<td>VAR3</td>
<td>Woodland</td>
<td>31.461</td>
<td>8.207</td>
<td>71.549</td>
<td>25.088</td>
<td>4.719</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Valid Observations</th>
<th>Missing Observations</th>
</tr>
</thead>
<tbody>
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<td>16</td>
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<tr>
<td>VAR3</td>
<td>76</td>
<td>109</td>
</tr>
<tr>
<td>VAR4</td>
<td>49</td>
<td>136</td>
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</tbody>
</table>
### VARIABLE vars ARABLE LAND

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>264.347</td>
</tr>
<tr>
<td>Std Error</td>
<td>34.098</td>
</tr>
<tr>
<td>Std Dev</td>
<td>370.404</td>
</tr>
<tr>
<td>Variance</td>
<td>137198.793</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>9.240</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.908</td>
</tr>
<tr>
<td>Range</td>
<td>1997.000</td>
</tr>
<tr>
<td>Minimum</td>
<td>3.000</td>
</tr>
<tr>
<td>Maximum</td>
<td>2000.000</td>
</tr>
<tr>
<td>Valid Observations</td>
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<tr>
<td>Missing Observations</td>
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</table>

### VARIABLE vars HEAD OF CATTLE

<table>
<thead>
<tr>
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<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
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<tr>
<td>Std Error</td>
<td>11.513</td>
</tr>
<tr>
<td>Std Dev</td>
<td>138.159</td>
</tr>
<tr>
<td>Variance</td>
<td>19088.028</td>
</tr>
<tr>
<td>Kurtosis</td>
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</tr>
<tr>
<td>Skewness</td>
<td>2.040</td>
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<tr>
<td>Range</td>
<td>691.000</td>
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<tr>
<td>Minimum</td>
<td>9.000</td>
</tr>
<tr>
<td>Maximum</td>
<td>700.000</td>
</tr>
<tr>
<td>Valid Observations</td>
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</tr>
<tr>
<td>Missing Observations</td>
<td>41</td>
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### VARIABLE vars HEAD OF PIGS

<table>
<thead>
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</thead>
<tbody>
<tr>
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<tr>
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<tr>
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<td>Kurtosis</td>
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<td>Skewness</td>
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</tr>
<tr>
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<td>3990.000</td>
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<tr>
<td>Minimum</td>
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</tr>
<tr>
<td>Maximum</td>
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</table>
## VARIABLE VAR8 - HUNDREDS OF POULTRY

<table>
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<tr>
<th>Statistic</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>132.229</td>
</tr>
<tr>
<td>Std Error</td>
<td>62.685</td>
</tr>
<tr>
<td>Std Dev</td>
<td>434.298</td>
</tr>
<tr>
<td>Variance</td>
<td>188614.351</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>23.698</td>
</tr>
<tr>
<td>Skewness</td>
<td>4.858</td>
</tr>
<tr>
<td>Range</td>
<td>2649.000</td>
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<tr>
<td>Minimum</td>
<td>1.000</td>
</tr>
<tr>
<td>Maximum</td>
<td>2650.000</td>
</tr>
<tr>
<td>Valid Observations</td>
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<tr>
<td>Missing Observations</td>
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</table>

## VARIABLE VAR12 - THOUSANDS OF GALS PER WEEK

<table>
<thead>
<tr>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
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<tr>
<td>Std Error</td>
<td>71.953</td>
</tr>
<tr>
<td>Std Dev</td>
<td>557.342</td>
</tr>
<tr>
<td>Variance</td>
<td>310630.129</td>
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<tr>
<td>Kurtosis</td>
<td>50.908</td>
</tr>
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<td>Skewness</td>
<td>7.151</td>
</tr>
<tr>
<td>Range</td>
<td>4299.000</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.000</td>
</tr>
<tr>
<td>Maximum</td>
<td>4300.000</td>
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<tr>
<td>Valid Observations</td>
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<td>Missing Observations</td>
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</tbody>
</table>

## VARIABLE VAR22 - DISCHARGE ONTO ROOT CROPS

<table>
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<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>26.826</td>
</tr>
<tr>
<td>Std Error</td>
<td>8.946</td>
</tr>
<tr>
<td>Std Dev</td>
<td>42.901</td>
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<tr>
<td>Variance</td>
<td>1840.514</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>10.051</td>
</tr>
<tr>
<td>Skewness</td>
<td>3.225</td>
</tr>
<tr>
<td>Range</td>
<td>199.000</td>
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<tr>
<td>Minimum</td>
<td>1.000</td>
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<tr>
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</tr>
<tr>
<td>Missing Observations</td>
<td>162</td>
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</table>
### VARIABLE VAR23  DISCHARGE ONTO GRASS

<table>
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<tr>
<th>MEAN</th>
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<th>14.573</th>
<th>STD DEV</th>
<th>151.444</th>
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<td>KURTOSIS</td>
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<td>SKEWNESS</td>
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<td>MINIMUM</td>
<td>5.000</td>
<td>MAXIMUM</td>
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</tbody>
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**VALID OBSERVATIONS** - 108  
**MISSING OBSERVATIONS** - 77

### VARIABLE VAR24  DISCHARGE ONTO CEREALS

<table>
<thead>
<tr>
<th>MEAN</th>
<th>186.459</th>
<th>STD ERROR</th>
<th>33.654</th>
<th>STD DEV</th>
<th>262.843</th>
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</thead>
<tbody>
<tr>
<td>VARIANCE</td>
<td>69086.319</td>
<td>KURTOSIS</td>
<td>3.766</td>
<td>SKEWNESS</td>
<td>2.141</td>
</tr>
<tr>
<td>RANGE</td>
<td>994.000</td>
<td>MINIMUM</td>
<td>5.000</td>
<td>MAXIMUM</td>
<td>999.000</td>
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</tbody>
</table>

**VALID OBSERVATIONS** - 61  
**MISSING OBSERVATIONS** - 124

### VARIABLE VAR25  DISCHARGE ONTO OTHERS

<table>
<thead>
<tr>
<th>MEAN</th>
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<th>STD ERROR</th>
<th>41.633</th>
<th>STD DEV</th>
<th>144.220</th>
</tr>
</thead>
<tbody>
<tr>
<td>VARIANCE</td>
<td>20799.356</td>
<td>KURTOSIS</td>
<td>4.424</td>
<td>SKEWNESS</td>
<td>2.351</td>
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<td>RANGE</td>
<td>500.000</td>
<td>MINIMUM</td>
<td>5.000</td>
<td>MAXIMUM</td>
<td>505.000</td>
</tr>
</tbody>
</table>

**VALID OBSERVATIONS** - 12  
**MISSING OBSERVATIONS** - 173
farms having woodland all have around 30 acres (kurtosis) with some having more but very few having less (skew).

The arable average of the respondents indicates that a number of the 118 farms have less than the average 264 acres and this is to be expected. A lot of the farms will have small arable acreages for produce for local consumption.

It appears that 49 farms have wasteland, and most of these around 28 acres.

8.5.1b LIVESTOCK NUMBERS
The farms are nearly normally distributed with regard to cattle numbers. The pig farms have a mean herd size of 500 with a number of smaller producers, and the poultry flock averages 13,000 with some larger producers.

8.5.1c WASTE DISCHARGE TO LAND
It is interesting to note that of those who spread waste onto grassland, the distribution of the acreage used is similar to the distribution of grass available to the farm. This indicates that spreading is carried out onto the total available acreage and few, if any use sacrificial land purely for waste disposal.

8.5.2 DISCONTINUOUS DATA
Tables 8.5 provide some useful observations, the variables attracting the most in number being statistically more useful. These histograms serve to describe the farms' systems for waste disposal.

8.5.2a WASTE REMOVAL
The average farm cleans up the manure once every 1 to 7 days (67.6%), if not, then probably only every month or so (21.1%). This reflects the different methods of cleaning as most of the farms (56.8%) use scraping which needs to be done each day, and
TABLES 8.5 - Discontinuous Data
<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>** (17) 9.2 PCT</td>
<td>CATTLE</td>
</tr>
<tr>
<td>2.00</td>
<td>** (12) 6.5 PCT</td>
<td>PIGS</td>
</tr>
<tr>
<td>3.00</td>
<td>** (2) 1.1 PCT</td>
<td>POULTRY</td>
</tr>
<tr>
<td>9.00</td>
<td>** (1) 0.5 PCT</td>
<td>ALL</td>
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</tbody>
</table>

Valid Observations: 184
Missing Observations: 1
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<thead>
<tr>
<th>CODE</th>
<th>VARIABLE</th>
<th>COMMENTS</th>
</tr>
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<tr>
<td>1.00</td>
<td>ADDITIONAL WATER ADDED</td>
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</tr>
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<td>2.00</td>
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</tr>
<tr>
<td>0.00</td>
<td>(MISSING)</td>
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</table>

<table>
<thead>
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<th>FREQUENCY</th>
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<td>70</td>
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</tr>
<tr>
<td>90</td>
<td>100</td>
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</table>

21/02/73 PAGE 11
### VARIABLE: VAR11 - MILKING AND DOMESTIC ADDED

<table>
<thead>
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<th>CODE</th>
<th>Descriptio</th>
<th>Valid Observations</th>
<th>Missing Observations</th>
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</thead>
<tbody>
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<td>3.00</td>
<td>********************************** ( 62) 33.5 PCT</td>
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<tr>
<td>4.00</td>
<td>********************************** ( 107) 57.8 PCT</td>
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**FREQUENCY**

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</tbody>
</table>
FARM WASTE TREATMENT DATA

FILE FARM (CREATION DATE = 21/02/73) WASTE

VARIABLE VAR13 HOW OFTEN WASTE REMOVED

CODE

1.00 *********************************************** ( 125) 67.6 PCT
   1-7 DAYS

2.00 ******** ( 14) 7.6 PCT
   8-28 DAYS

3.00 ****************** ( 39) 21.1 PCT
   OVER 28 DAYS

0.00 ***** ( 7) 3.8 PCT
(MISSING)

FREQUENCY

VALID OBSERVATIONS = 178
MISSING OBSERVATIONS = 7
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<th>METHOD OF REMOVAL</th>
<th>FREQUENCY</th>
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<tr>
<td>5.00</td>
<td>SLATS</td>
<td>3.8 PCT</td>
</tr>
<tr>
<td>6.00</td>
<td>SCRAPING</td>
<td>56.8 PCT</td>
</tr>
<tr>
<td>7.00</td>
<td>FLUSHING</td>
<td>7.0 PCT</td>
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<td>8.00</td>
<td>CONTINUOUS BELT</td>
<td>2.7 PCT</td>
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<tr>
<td>9.00</td>
<td>OTHER</td>
<td>21.1 PCT</td>
</tr>
<tr>
<td>0.00</td>
<td>(MISSING)</td>
<td>8.6 PCT</td>
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**Valid Observations:** 169  
**Missing Observations:** 16
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<th>MISS</th>
<th>TOTAL</th>
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</thead>
<tbody>
<tr>
<td>1.00</td>
<td>MANUAL OR MECHANICAL</td>
<td>139</td>
<td></td>
<td>75.1%</td>
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<td>2.00</td>
<td>GRAVITY PIPE</td>
<td>9</td>
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<td>3.00</td>
<td>NONE USED</td>
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<td>10.8%</td>
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Valid Observations: 165
Missing Observations: 20
FARM WASTE TREATMENT DATA

FILE FARM (CREATION DATE = 21/02/73) WASTE

VARIABLE VAR16 STORAGE

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<td>5.00</td>
<td>TANK</td>
<td>1.6 PCT</td>
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<td>6.00</td>
<td>HEAP</td>
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<td>7.00</td>
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<td>15.1 PCT</td>
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<td>25.4 PCT</td>
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<tr>
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FREQUENCY

VALID OBSERVATIONS = 180
MISSING OBSERVATIONS = 5
### Farm Waste Treatment Data

**File:** Farm  
**(Creation Date = 21/02/73)** Waste

**Variable:** VAR17  
**On Farm Treatment**

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<tr>
<td>9.00</td>
<td><strong>NO</strong></td>
<td>(159)</td>
<td>85.9 PCT</td>
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**Valid Observations:** 159  
**Missing Observations:** 26
## Farm Waste Treatment Data

**File Name**: Farm (Creation Date = 21/02/73) Waste

**Variable**: Var19 Discharge To

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<td>1.00</td>
<td>Own Land</td>
<td>152 (82.2%)</td>
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<td>Watercourse</td>
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<tr>
<td>3.00</td>
<td>Public Sewer</td>
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<td>4.00</td>
<td>Contractor</td>
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(Missing) 9 (4.9%)

<table>
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</thead>
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**Valid Observations**: 176

**Missing Observations**: 9
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<td>125</td>
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<td>2.00</td>
<td>MOBILE TANKER</td>
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<td>7.6 PCT</td>
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<td>3.00</td>
<td>PIPES</td>
<td>11</td>
<td>5.9 PCT</td>
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<td>GRAVITY PIPE</td>
<td>4</td>
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<td>PIPE AND PUMP</td>
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<td>0.5 PCT</td>
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<td>6.00</td>
<td>DITCH</td>
<td>2</td>
<td>1.1 PCT</td>
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<td>7.00</td>
<td>PAY CONTRACTOR</td>
<td>4</td>
<td>2.2 PCT</td>
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<td>8.00</td>
<td>PAID BY CONTRACTOR</td>
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<td>1.1 PCT</td>
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<td>9.00</td>
<td>FREE DISPOSAL</td>
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<td>16</td>
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## VARIABLE: VAR21 - CONSENT CONDITIONS

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<td>20 40 60 80 100 120 140 160 180 200</td>
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<tr>
<td>2.00</td>
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<tr>
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</table>

**Valid Observations:** 5  
**Missing Observations:** 180
24.9% use slats or other (deep litter) methods requiring less frequent waste removal.

Manual or mechanical handling is the most frequent means of dealing with the waste (75.1%) with a few farms using pumps (10.8%) or gravity flow (4.9%). This is consistent with the most popular removal method being scraping, and the farms using flushing (7.0%) or slats (3.8%) with no litter will be handling the waste with pumps or gravity flow.

8.5.2. b. STORAGE METHODS

As one would expect with manual or mechanical scraping and handling of the waste, the most favoured storage method is the free-standing heap (41.6%) or temporary storage in a spreader immediately prior to land disposal (25.4% no storage). The liquid-type storage in sump or tank (13.5%) will be employed by the enterprises using flushing or slats for waste collection and pumps or gravity flow for transport. The sump is favoured probably because it is cheaper to construct than an above-ground tank, and can be filled using gravity rather than pumps.

8.5.2. c. DISCHARGE METHODS

The main discharge facility was the farm's own land and this is confirmed by reference to section 8.5.1. c. Contractor spreading accounted for 9.7% of the respondents but no further information could be gained from them. These are smaller operators and presumably cannot afford the capital to buy their own spreading equipment. 67.6% use their own muck spreaders for disposal and this follows from the popularity of manual/mechanical means of collection and handling. 16.2% use liquid disposal systems and these will be the ones using flushing or slats and pumps or gravity flow for waste handling.
Some of the farms employing liquid disposal systems use methods of discharge other than their own land. 5 farms used a sewer or watercourse for disposal and 2 of these used ditch arrangements prior to discharge into watercourse. Only one of these respondents had to conform to Royal Commission Standards and one had to reach 164 BOD and 44 SS. The farmer discharging into the sewer confirmed that it was only dairy washings and some yard water that was disposed of this way, and he was charged by the Local Authority at the G.L.C. Mogden rate (a charge based on volume BOD, and treatability). One of the farms claimed to have been discharging into the watercourse since 1930 without revision of standards, and the final respondent had no idea what BOD or SS meant but claimed that his discharge apparently satisfied the Hampshire River Board.

8.5.2. d TREATMENT ON FARM

14.1% of farms claimed some form of waste treatment. These comprised of 8.6% composting, 1.1% digesting, 3.2% lagooning, and 1.1% oxidation. The majority of the composting respondents were suspected of considering their storage heaps as compost treatment. These, and the others claiming treatment, were all contacted by letter. (Section 8.6).

8.5.3 CROSSTABULATIONS

The straight frequency analyses of Sections 8.5.1 and 8.5.2 are simple to operate and interpret but the crosstabulations produce some confusing results. Correlation co-efficients were obtained for all crosstabulations but some are meaningless as there cannot be any connection between mutually exclusive systems such as scraping and slats. The correlation co-efficients
greater than 0.6 are treated qualitatively as "good".

The first analysis proved useless as the continuous variables were treated individually. Thus each cow, pig, acres of grass, etc. was a separate case. Grouping of the data was used to overcome this problem and reference to 8.5.1 will show that semi-logarithmic grouping is the most useful as all the categories show some degree of positive kurtosis and skew. Table 8.(6) shows the groupings used.

Table 8 (6)

<table>
<thead>
<tr>
<th>Category</th>
<th>Group 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>Grassland</td>
<td>0-50</td>
<td>51-100</td>
<td>101-200</td>
<td>401-400</td>
<td>401-800</td>
<td>801-1600</td>
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<td>21-50</td>
<td>51-100</td>
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<td>51-100</td>
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<td>51-100</td>
<td>101-200</td>
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<td>801-200</td>
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<td>101-200</td>
<td>201-400</td>
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<td>201-400</td>
<td>401-800</td>
<td>801-1600</td>
<td>1601-4000</td>
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<td>51-200</td>
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</table>

8.5.3 (a) MOST POPULAR SYSTEMS

Table 8(7) represents a semi-pictoria method of presenting the flow of waste from collection to treatment. The numbers on the diagonal represent the percent of the total number of farms operating as per row or column heading. For example 62.1%
<p>| TABLE 3 (7) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| <strong>REMOVAL FREQUENCY</strong> | <strong>REMOVAL METHOD</strong> | <strong>HANDLING METHOD</strong> | <strong>STORAGE METHOD</strong> | <strong>WASTE TREATED</strong> |</p>
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<th>1-7 DAYS</th>
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<th>SLATS</th>
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<th>FLUSHING</th>
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<th>HANDLING/MECHANICAL</th>
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<td>NONE</td>
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<td><strong>WASTE TREATED</strong></td>
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<td>YES</td>
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</table>

**Waste Treated (percentage)**: The table presents the percentage distribution of waste treated based on removal, handling, and storage methods. Each row represents a different waste management practice, with columns indicating the percentage of waste treated under each condition.
of all farms use scraping as the method of waste collection.

The elements in each row of each box sum to the diagonal percentage. Thus, the 62.1% of farms using scraping for waste collection comprises of 49.7% using manual or mechanical handling, 2.4% gravity pipe, 4.1% pump and pipes, and 5.9% no handling. The same 62.1% comprises of 7.1% storing in a sump, 1.8% in a tank...and so on. Similarly, each column of each box sums to the diagonal. The sum of all the elements in one box is 100%.

By inspection of Table 8(7), then, it is possible to quickly appreciate the most popular systems of waste disposal. The "average" farm cleans out the waste once every 1 to 7 days by scraping and uses manual or mechanical methods of handling. Storage is in a heap and no form of treatment is operated.

The second popular system is that for wet handling and the farms using flushing for waste collection frequently use a pipe network for transferring the waste to a sump for storage.

These systems are expected, one dry and one wet, both traditional systems.

It is interesting to note that of the 42.7% of farms using a heap for storage a considerable number did not specify the method of collection. Inspection of the questionnaires revealed that this popular method of waste collection was a hand shovel and wheelbarrow.

8.5.3. b EFFECTS OF HERD SIZE

The computer package chosen enabled a crosstabulation between herd or flock size and the waste disposal systems.
For cattle it seems that larger herds (201-400) may be cleaned out less frequently than the smaller herds and this is usually by flushing for storage in a sump. The larger the herd, the more tendency to lagoon the waste and this is no doubt connected to the flushing systems of waste collection. Smaller herds use contractors more frequently than the larger ones presumably because they cannot afford the capital cost of spreading equipment or do not produce sufficient waste to justify ownership of such equipment.

For pigs the picture is similar. The larger the herd, the less frequent is the cleaning out process, again due to automation by way of slats or flushing producing a slurry waste handled by pipes and stored in a sump. Lagooning is popular with the larger herds and spreading is by tanker for these wet systems and by solid spreader for the drier smaller units.

For poultry the effect of flock size is more noticeable as all the respondents with more than 15,000 birds used automated belts or pit systems and final removal by contractor. The smaller flocks employed traditional land spreading using their own equipment.

8.5.3. c. LAND DISPOSAL

87% of the farms discharged onto their own land, 84% of these using spreaders, 8.8% tankers, and 7.4% pipes and guns. 3 farms discharged to watercourse and 3 to sewer.

There was no correlation between disposal method and type of land indicating that, say, irrigation of root crops was no more or less popular than irrigation of arable land.

It was found that 21 cattle, 8 pig, and 7 poultry enterprises used root crops for disposal of manure and about 80% of these
used small (1-25) acreages. This may confirm that root crops are recognised as being able to absorb large dressings of manure.

There was a good correlation between size of cow herd and the area of grassland used for waste disposal. This is not surprising as larger herds need bigger pastures for grazing as well as manure disposal.

There was a good negative correlation between the size of pig and poultry units and the land available. This confirms that these animals are easily confined onto small areas.

21% of cattle farms had more than 1 cow/acre, 17% of pig farms had more than 4 pigs/acre, and 12% of poultry enterprises had more than 20 birds/acre. These farms would be expected to experience difficulty in manure disposal due to the intensive use of the land, but none was found.

Indeed, only 6% of these intensive units claimed to treat their wastes whereas 14.1% of the total number of respondents found treatment necessary. This suggests that farms most likely to have disposal problems are least likely to try and solve the problems.

Of the farms discharging onto cereal crops there was a good correlation between herd size and acres used for cows and pigs but poultry enterprises all used very large areas of cereals for manure disposal. This may be linked to the belief that poultry manure may "scorch" crops.

3 poultry and 1 pig farm used other land for disposal and these may be using land for storage or sacrifice as in the Wright system (6.5.5.f).

8.5.3.d. ADDITIONAL WATER

About half the farms involved allowed rainwater and roof and yard run-off to enter the waste systems. Additional rainwater
will aid in liquid disposal by tanker or lagooning and serve as dilution for those discharging into watercourse or sewer.

37% claimed to run in the liquid washings from milking parlours and/or domestic wastes. This may be disadvantageous to farms wishing to treat the waste as the BOD may increase due to the entry of suspended milk solids, and any disinfectants used in the washing down will be detrimental to any form of biological treatment in a lagoon or ditch system.

8.6 FURTHER INVESTIGATIONS

Inspection of the questionnaires produced 159 (85%) respondents using traditional land spreading for waste disposal. The 23 claiming some form of treatment system were all contacted by letter in June 1972 to ascertain the exact details of their systems (16 composting, 2 digestion tanks, 6 lagoons, 2 oxidation ditches, 1 other).

4 composters replied and it was found that these considered a free-standing heap as a deliberate treatment process. This appeared as one of the ambiguities of the questionnaire and these farms were re-coded for the analysis as employing no treatment.

None of the other respondents replied to the letter, except the farm having marked the "other methods" for treatment. On telephoning these enterprises it was decided to abandon further investigations into on-farm treatment as replies were becoming abusive. The one helpful farm employed a borehole and this is fully discussed in Section 6.5.4.

8.6.1 LARGE POULTRY ENTERPRISES

Due to the small sample used for the questionnaire it was decided to contact some large poultry enterprises separately to gain information on how very intensive poultry units tackled
Dear Sir,

Farm Waste Disposal Questionnaire 1972

Many thanks for completing the questionnaire I distributed earlier this year. On looking through the results, I noted that you are one of the enterprises using a composting/digestion tank/lagoon/oxidation ditch/contractor/sewer method of disposal.

If I could trouble you further I would like to ask if you could kindly supply details of the costs involved in this method of disposal. I am interested in the expenditure on capital equipment and any running costs incurred.

My analysis will, I hope, provide me with a realistic comparison in terms of costs and efficiencies of the various methods of disposal available to the farmer. I am, therefore, relying on first hand estimates of the costs involved in your particular system.

May I thank you now for any help you can kindly give me by way of a description of your system and the approximate expenditure involved.

Yours faithfully,

Stephen L. Willetts
waste disposal.

Ten such producers were contacted by letter in June 1972 and this furnished six replies. Two would not divulge details of manure disposal to outsiders owing to Company policy, three provided general details but would not be more specific, and one invited the author to inspect the system. These latter four cases were as follows:

**Case 1.** A broiler concern producing 50 tons of litter per day which it found impossible to sell because of the large quantities. Some is collected by neighbouring farms free of charge, but most is loaded onto their own trailers or lorries by tractor and loader or elevator. This is then delivered to local farms on a rota basis, spread on the farmer's land and the farmer undertakes to harrow the litter into the soil. The cost of carting and spreading is written off as a necessary loss and was estimated at £1.50/1,000 birds per year inclusive of labour, fuel, and all administrative and depreciation costs.

Experiments with dryers produced a saleable product but the rate of work of the machines in relation to the amount of waste handled led to the operations being discontinued.

**Case 2.** 120,000 layers were accommodated in deep-pit houses cleaned out once every six or eight weeks. The houses were deliberately sited in rural areas to minimise the cost of transporting and field spreading onto neighbour's land.

With the removal of the fertiliser subsidies this particular enterprise is showing interest in dryers in order to sell the produce thus making a return from it rather than giving it away at a cost to the enterprise.
Dear

I am carrying out research into farm waste disposal and have recently completed a survey of farms in South East England. However, the "average" farm only tends to have "average" problems when it comes to waste disposal.

Since you are one of the biggest and most efficient poultry enterprises in this country, I would like to ask you how you overcome your waste-disposal problems. In particular I am interested in the COSTS and METHODS of disposal of poultry manure. I feel sure that as an efficient producer in a competitive field you will be able to contribute greatly to solving some of the problems for the "average", but none-the-less important, producers.

May I, therefore, ask you to send me details of your disposal methods. My research is independent of any other organisation and your information will be kept strictly confidential.

Thanking you for any help you can kindly offer,

Yours sincerely,

Stephen L. Willetts

June 1972

Stephen L. Willetts, B.Sc.
either weekly, monthly, or annually. The Company operates 5 rota-spreaders and 3½ tractors (initial cost £10,500) and spreads the manure on neighbouring land.

Case 4. Several units are owned each having different waste disposal methods. Some have experimental dryers, but most operate the common system of free spreading onto neighbouring land.

8.7 SUMMARY

The questionnaire survey was important in establishing that this type of operation could be used to gain a good deal of information at a low cost. There has since been an interest in adapting the questionnaire format to a National, perhaps European, survey.

However, the small sample size led to some difficulty in interpreting the results. The analysis merely confirmed MAFF opinion that the majority of farms (80-85%) still operate traditional disposal systems. Farmers seem to have little idea about running costs of waste disposal, presumably because the operation is not costed as a separate item in the farm's accounts. Farmers also seem to have little idea about the amounts of waste they have to handle.

Since most farms use land spreading for disposal it can be assumed that the fertiliser value of manure is being realised and this benefit will offset the costs of spreading as the fertiliser bill will be reduced. This may be an important factor with the removal of the fertiliser subsidy and the growing concern about soil fertility from an organic content (Chapter 5).

The crosstabulations of results produced some useful data in that it was found that the larger enterprises tended to be more capital intensive than the smaller units. Liquid systems
or automated cleaning methods require a high capital outlay and little labour is needed for their operation. The smaller enterprises cannot, presumably, justify the expenditure on such systems and rely upon labour intensive manure or semi-mechanical systems. Again, the questionnaire merely confirmed a suspicion.

It was felt that such a small sample could not be "grossed up" to establish a National picture, but nevertheless could be used as an indicator of the present situation.
9.1 INTRODUCTION

The previous chapters have looked at the problems of disposal of animal wastes and this is by far the largest problem for the farmer in terms of waste management. However, if deposited onto the land many serious problems may arise, not directly concerning the farmer but attributable to his practices nevertheless. The most serious of these problems is that of run-off and leaching of plant nutrients (N.P.K.) into watercourses.

This chapter will also discuss other wastes arising from agricultural practices; this discussion is brief as the wastes involved have not, as yet, created the same extent of problems.

9.2 RUN-OFF AND LEACHING

When manure is spread onto a field it is normally expected to act as a fertiliser for the grass or crops and to provide long-term stability to the soil by way of its humus and organic content. However, the manure itself or, more frequently, its soluble constituents may be washed over the surface of the land or washed through the land into watercourses. Here the plant nutrients may stimulate the growth of aquatic plants - notably algae - which may lead to algal blooms in stagnant or slow-running waters. Algal blooms are capable of shielding out the light from the water and their respiratory oxygen demand may deplete available oxygen levels in the water. The combined effects may promote the death of fish and other aquatic life.

This process is termed eutrophication. Eutrophication is necessary for normal aquatic life, it is the means of conveyance
of nutrients into water. However, acceleration in the conveyance of these nutrients - a hypertrophication - can lead to an imbalance in an aquatic environment. Even if the algal blooms die, the cell bodies falling to the bottom exert an oxygen demand in their breakdown.

9.2.1 DUTCH OPINION

There is very little known about the circumstances leading to a state of eutrophication and there are differences of opinion about which nutrient usually sets a limit to algal growth. (Stikstof, 1972). Many believe that nitrates/phosphates may set the limit and that agricultural fertilisers practice may therefore enhance the prospects of eutrophication. According to Dr. Beek (Unilever) "The contribution of detergents to overall phosphate pollution may be put at 15-20%; about two thirds is accounted for by agriculture" (Elseviers Techno, 1971)

The Dutch are sceptical that agriculture contributes to eutrophication. In Stikstof's Review, Henkens demonstrates that the inflow/outflow balance for phosphate in two-crop rotation systems on sandy soil and clay soil of divergent fertility status shows an overall removal of phosphate by the crops at all but the lowest fertility. Henkens also demonstrates that for grassland farming, using manure as fertiliser, the phosphate balance again shows a net removal over the input. He concludes that the extra demand is satisfied from phosphate release of the soil skeletal material and that Dutch fertiliser regimes are barely adequate to maintain soil phosphate fertility.

De Jong (Stikstof, 1972) supports this view and the vertical displacement of phosphate by leaching was found to be confined to the top 50 cm. of soil, and leaching into drainage water of no significance. Soils susceptible to phosphate leaching
were found to be newly-cut peats and most soils rapidly and considerably immobilised phosphate.

Nitrates are discussed by Alberda, Huntjens, and Kolenbrander and the conclusion was that the amount of nitrogen needing to be supplied to achieve optimum growth - an amount far from that being used in practice - is about the same as the amount removed in the harvested crop. Leaching of nitrogen can consequently only take place if more nitrogen is released by the soil than is withdrawn by denitrification and by fixation. The eutrophication is dependent on soil characteristics and not fertiliser regime.

The whole of the Stikstof Review implies that agricultural run-off and leaching of phosphates and nitrates is much less than 5% of that applied as fertiliser or manure.

9.2.2 AMERICAN OPINION

The Americans are less conservative in their estimates of agricultural run-off and its effects. This is, in part, due to the abundance of inland lakes in the American Continent and the large watersheds which empty into them. Nitrogen appears to cause most concern and a comparison of the possible routes of transport of nitrates and phosphates serves to indicate why.

Most of the nitrogen in soils (about 95%) is organic and 50% of this is in the amino form (Armstrong & Rohlich, Agricultural Practices and Water Quality, Eds Willrich & Smith). The main inorganic forms are nitrate and ammonium, both readily available to plants, and a small quantity of nitrite. The actual amounts of nitrate and ammonium nitrogen present depend on the processes of organic nitrogen mineralisation and inorganic nitrogen
immobilisation, and soil organic matter generally provides an indicator of the nitrogen status of a soil.

Phosphorus exists as between 25% and 97% inorganic and the remainder organic. However, the inorganic phosphorus actually in solution and available to plants is extremely low due to adsorption of phosphate by the iron, aluminium, and calcium components of the soil.

The amounts of nitrate and phosphate transported to watercourses depends on the chemical processes of retention by the soil. Ammonium and nitrate nitrogen are readily soluble and are susceptible to rapid leaching, the amounts leached are therefore directly related to the drainage properties of the soil. Phosphates, on the other hand, are strongly retained in soils and run-off rather than leaching is the primary transport mechanism into watercourses.

Organic nitrogen and phosphorus are of low mobility in soils and the main danger is from washing out of particulate matter from the soil surface. Since the amount of organic nitrogen is high this may lead to extensive run-off problems, but the effects of organic nitrogen on the receiving waters are less than the effects of ammonium or nitrate nitrogen due to their none-availability to plants and hence algae. Armstrong and Rohlich indicate that the theoretical assumptions above hold true in practice, and several quantitative experiments are referred to. Nitrogen loss through leaching appeared significantly in all experiments, and phosphorus generally did not appear.

Lake Mendota in Wisconsin has provided the source for intensive investigation to evaluate the contribution of agricultural
land to the nutrient budget of a watershed. The Lake is 9,730 acres in area serving a watershed of 142,000 acres as in Table 9(1):

**TABLE 9 (1)**

<table>
<thead>
<tr>
<th>Acres</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>103,500</td>
</tr>
<tr>
<td>Corn</td>
<td>(51,000)</td>
</tr>
<tr>
<td>Oats</td>
<td>(18,500)</td>
</tr>
<tr>
<td>Pasture</td>
<td>(34,000)</td>
</tr>
<tr>
<td>Woodland</td>
<td>10,000</td>
</tr>
<tr>
<td>Pasture and other</td>
<td>11,400</td>
</tr>
<tr>
<td>Major Wetland</td>
<td>7,100</td>
</tr>
<tr>
<td>Urban</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>142,000</strong></td>
</tr>
</tbody>
</table>

The watershed consists of permeable, calcareous, loamy glacial deposits with a significant loess covering. Most soils were developed under prairie vegetation and are characterised by an A horizon 8 to 16 inches deep and relatively high in organic content. The estimated cow population is 100 cows/square mile.

The Lake Mendota Water Sub-committee estimated the nitrogen and phosphorus budget for the lake as in Table 9(2):

**TABLE 9 (2)**

<table>
<thead>
<tr>
<th>Nutrient Source</th>
<th>Lbs/Year</th>
<th>% of Total</th>
<th>Lbs/Year</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Nitrogen</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>Municipal &amp; industrial waste water:</td>
<td>47,000</td>
<td>17,000</td>
<td>10</td>
<td>36</td>
</tr>
<tr>
<td>Urban run-off:</td>
<td>30,300</td>
<td>8,100</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Rural run-off:</td>
<td>7,000</td>
<td>5,000</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Cropland</td>
<td>45,000</td>
<td>15,000</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>Manured Land</td>
<td>97,000</td>
<td>1,300</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Precipitation on lake surface:</td>
<td>2,000</td>
<td>600</td>
<td>52</td>
<td>2</td>
</tr>
<tr>
<td>Nitrogen fixation:</td>
<td>2,000</td>
<td>-</td>
<td>&lt;1</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>428,300</td>
<td>47,000</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
It appears, therefore, that rural run-off is the largest contributor of phosphorus (42%) and groundwater the largest contributor of nitrogen (52%). However, the quantity of nitrogen in rural run-off (52,000 lb/year) was larger than the corresponding quantity of phosphorus (20,000 lb/year). The large contribution of nitrogen by groundwater is the effect of nitrogen leaching through soils.

Direct measurements of nitrogen and phosphorus entry into the lake via its tributaries confirmed the estimates and indicated that they may even be a little low (Armstrong and Rohlich).

This Mendota project is in direct disagreement with the Dutch observations recorded at the beginning of this Chapter. Other American work tends to suggest that the Mendota project was not peculiar in its results and does in fact reflect the general state. In 1967 a Task Group of the American Water Works Association prepared a report on sources of nitrogen and phosphorus in U.S. water supplies. (McCarty, et al 1967). Their estimates included the summary as table 9 (3):

<table>
<thead>
<tr>
<th>Nutrient Source</th>
<th>% of Total Nitrogen</th>
<th>% of Total Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Waste</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Rural run-off:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural land</td>
<td>60</td>
<td>42</td>
</tr>
<tr>
<td>Non-Agricultural land</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Farm animal waste</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Urban run-off</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Rainfall</td>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The values suggest that agricultural land is an important contributor of both nitrogen and phosphorus. Again, this is in direct disagreement with Dutch observations.
However, most of the American estimates rely on several assumptions which may or may not be realistic. There is always danger in grossing-up experimental data. However, a more concrete experimental approach was recently employed for Lake Decatur in Illinois (Kohl, Shearer, Commoner, 1971). Measurements by the Illinois State Water Survey showed an increase in nitrate levels roughly paralleling increased fertiliser usage. The median nitrate nitrogen for 1956-1961 was 2.0 p.p.m. and for 1966-1969 was 7.4 p.p.m. - approaching the American Public Health Service's standard of 10 p.p.m. for drinking water.

The Decatur watershed is intensively cropped with alternate years of corn and soybeans with no discharge by industry or domestic sewage. An experiment was devised to calculate the amount of nitrate contributed by fertilisers in run-off and drainage waters. Studies were instigated into the relative amounts of \( ^{15}\text{N} \) and \( ^{14}\text{N} \) isotopes. Soil becomes enriched in \( ^{15}\text{N} \) as natural biochemical processes (denitrification, nitrification) and physical processes (evaporation) fractionate the isotopes and \( ^{14}\text{N} \) is favoured. Fertiliser nitrogen, on the other hand, has the normal \( ^{15}\text{N} / ^{14}\text{N} \) ratio.

Measurements using mass spectrometry of the water entering Lake Decatur indicated that 55% of the nitrogen was derived from fertiliser applications. Such mass spectroscopic measurements which are grossed-up to cover the whole Decatur watershed must presumably be liable to significant errors as the techniques involved rely upon minute samples. 200 gram soil
samples were taken for measurements and no indication is given as to how many samples were taken or from where they were taken.

These practical measurements on isotope ratios agree with the Task Force's (1967) estimates of nitrate contribution from agricultural land. However, the fertiliser regime employed at Decatur, a very heavily cropped area, was not specified and may well have been very high. It was also noted that the Decatur basin was previously badly drained and an abundance of sub-surface tile drains now rapidly took away any water straight into the Lake. The measured 55% contribution by fertiliser nitrogen may not therefore be surprising and in no way reflects upon an average soil.

A more rational and wider review of American experimental work was presented at a joint seminar between the University of Missouri-Columbia, College of Agriculture and the Missouri Water Pollution Board on April 9th, 1968 (Smith, World Agricultural Economics and Rural Sociology Abstracts). The conclusions reached in Missouri State were that, despite liberal fertiliser usage, crops are removing more nitrogen and minerals than are being added as chemical amendments. Many shallow wells were said to contain sufficient nitrate to affect the efficiency of livestock production, and this was due to direct leaching of nitrates from feedlots. However, only very few isolated cases provided an association between nitrates in surface or groundwaters with losses from fertilised farm fields. It was concluded that the vast bulk of nitrate in ground water appeared by natural soil erosion. Phosphate was invariably held in soil and abstracted by the crops.
Smith also pointed out that some of the nutrients applied as fertiliser invariably found their way into surface and groundwater but the percentage was relatively small. It was also pointed out that one of the best means of purifying water was to percolate it through soil (Kardos, L.T. 1967) – a living filter.

Thus the Americans have two Schools of thought on whether Agriculture contributes significantly to problems of eutrophication. Extreme pessimism estimates that about 60% of fertiliser nutrients find their way into watercourses and extreme optimism estimates that insignificant amounts do and that most nutrients arise from natural decay of soils. However, both agree that a great deal depends on local conditions.

Some practices whereby nutrient losses could be minimised have been suggested and tried experimentally (Frink, C.R.1969) (Commoner, Personal Communication Sept. 5th 1972). Frink suggests that corn hybrids should be selected which have increased efficiencies to scavenge nitrate from soil, genetic selection of dairy cows most efficient at converting nitrogen in their feed into protein, application of nutrients in small amounts, but frequently, and during the growing season. This latter suggestion necessarily implies improved, and perhaps costly, systems of storage and handling. Commoner suggests seeding the soil with free-living nitrogen-fixing bacteria and experiments conducted at the Center for the Biology of Natural Systems (Washington University, St. Louis, Missouri) have shown some progress at establishing nitrogen-fixing bacteria with non-leguminous crops.

9.2.3 CANADIAN OPINION

The Canadian viewpoint on eutrophication was summarised
at the Cornell University Conference on Animal Waste Management in 1969 (Webber and Lane), Guelph University has been looking at ways of land spreading manure as a method of disposal and an essential part of the research has been nitrate leaching and its effects. It was found that soils with a high organic carbon content released significantly less nitrogen than soils devoid of carbon. This was assumed to be due to bacterial denitrification by facultative anaerobes using nitrate as an oxygen donor. Experiments are in progress to determine the use of soil as a denitrifying agent in the disposal of liquid manure and season, soil-type, and crop cover are being investigated. The ploughing-in of carbonaceous matter after harvest is also being examined as this practice may stimulate denitrification in addition to its traditional role of improving soil tilth.

9.2.4 BRITISH OPINION

British concern about eutrophication problems stems from the limited amounts of potable water supplies and their possible contaminations. The major problem is that algal blooms sometimes slow down the filters in reservoirs, and the Metropolitan Water Board has been contending with this situation for 30 or 40 years. This is apparently the only problem and is not serious (Owens, M. and Garland, J., W.P.R.L. Personal visit 1972). However, the American situation causes concern for a different reason in that the U.S.A. has a large number of inland lakes which are used for recreation. Algal blooms can develop and accumulate on the leeward shores forming an objectionable putrescible mass. Stratification of large bodies of water also occurs and nitrate increase stimulates activity in the depths releasing pockets of noxious gas.

Eutrophication in the U.S.A. therefore constitutes a
problem due to people being offended at the sight and smell of algal masses. However, in Britain the same algal bloom present on a relatively unused recreationally, and shallow reservoir merely calls for a close watch on filter performance. The same water may be fit to drink but not fit to play on.

The health hazard of water containing more than 10 ppm Nitrate nitrogen is only apparent in infants younger than 6 months, or in ruminant animals. Nitrates in themselves present little problem and are normally rapidly excreted in the urine. In any case, a healthy adult normally consumes much more nitrate by way of solid food than by way of water (Wolff & Wasserman, 1972). The danger occurs when nitrates are reduced to the nitrite form - a heavy blood poison. (Koepf, 1969). The proved toxicity of nitrites is due primarily to their interaction with blood pigment to produce methemoglobinemia. The reactions are reversible until 70% of the haemoglobin in blood is combined with nitrite and then asphyxia occurs. (Wolff & Wasserman 1972).

The conditions under which nitrates are reduced to nitrites causing health problems are documented as:

1) The microbial environment in the rumen of cattle.
2) Infants up to 6 months do not have a full secretory function for stomach hydrochloric acid and the low acidity may permit growth of micro-organisms that can reduce nitrate to nitrite. Numerous deaths have been attributable to this (Wolff & Wasserman 1972).

3) Spinach naturally has a high nitrate content and spinach left at room temperature after cooking may develop micro-organism growth producing nitrites. Deaths have been reported.

4) Damp forage materials or ensided forages may become rich in nitrites and cause death of cattle (Wolff & Wasserman 1972).
However, as far as the human population is concerned deaths in adults are rare. Nitrite addition to cured fish and meats probably accounts for most nitrite consumption by man, and medicinal nitrites (Antidote to cyanide) have been administered at doses much higher than health recommendations without ill effect (Wolff & Wasserman 1972).

Health standards are generally 20 ppm nitrate in Europe and 10 ppm nitrate in the States (Owens, personal communication, Koepf 1969). In Britain the lowest concentration causing fatality was in Norfolk where water abstracted from a well contained 78 ppm nitrate. Several Norfolk wells and streams have nitrate concentrations in excess of 20 ppm and in India several streams used for multiple purposes have in excess of 400 ppm (Garland, personal communication). The nitrate level in streams appears to be independent of fertiliser usage (Owens & Garland, WPRL, personal visit).

The lower limit of nitrate for eutrophication is cited at 1/3 ppm (Webber & Lane, 1969). Water derived from limestone beds contains an average background concentration of 2 ppm and rainfall a further 1-2 ppm (Owens & Garland WPRL).

It therefore appears that nitrate levels naturally present in all bodies of water are sufficient to sustain algal growth. The appearance of nitrate levels sufficient to cause a health hazard seems rare in Britain, though bottled water is provided to infants in some areas of Norfolk.

Agricultural practices undoubtedly contribute to the nitrate content of waters though any correlation to fertiliser regime is difficult. The Dutch claim not more than 5% leaching, the Americans claim frequently more than 40%. A study of some 20 English rivers from 1957 to 1967 by WPRL demonstrated that in
14 of them nitrate levels remained the same and increased in the other six. No correlation to the doubling in fertiliser application was found and most probably, the six rivers experiencing nitrate enrichment did so because of sewage outlets of an increasing population (Owens & Garland). The river Soar in Leicestershire does demonstrate that land use nevertheless has an effect: water draining a heavily cropped soil has twice the nitrate content of neighbouring waters draining non-agricultural land.

British attempts at estimating nitrate contributions by agricultural land and the effects of eutrophication were presented at a Symposium on Eutrophication held in conjunction with the Annual General Meeting of the Society for Water Treatment and Examination in March 1970 (Water Treatment and Examination Vol 19 Parts 3 and 4 1970).

Cooke and Williams (Eutrophication Symposium) examined losses of nitrogen and phosphorus specifically from agricultural land. Two types of land were identified - heavy soils overlying impervious strata and requiring underdrainage (e.g. Boulder, London, Gault, Jurassic, Triassic, and Carboniferous clays), and soils with freer drainage (e.g. Clay-with-Flints, Chalk, Greensand, Jurassic limestones, and Triassic sandstones). The former class lose nitrogen directly into the field drains, and hence surface waters, and phosphorus by erosion, while the latter show slow leaching of nutrients, the leach-water traversing long distances before reaching underground aquifers.

Lysimeter studies at Rothamsted Experimental Station (undisturbed soil blocks) were established in 1870 and the drainage water monitored. The lysimeters have not been cropped
or fertilised but have been kept weed-free. From 1878-1905 the average nitrate content of drainage water was 9.8 ppm, ranging from 7.9 ppm in February to 12 ppm in September. Between 12-14% of nitrate lost was contributed in rainfall, and the remainder by mineralisation and fixation. In 1969 the average drainage nitrate content was 5 ppm, ranging from 3.5 ppm in April to 18 ppm in November (following two exceptionally dry and warm months).

Lysimeters established at Craibstone, Aberdeen in 1914 were cropped and fertilised. It was shown that grasses held most of the nitrogen applied, and that root crops and cereals held little.

Large scale field-drainage experiments were established at Rothamsted between 1843 and 1849, consisting of 17 parallel strips of land equal in area and each tile-drained in the centre. Different fertiliser regimes were used on the plots.

The plot receiving farmyard manure lost a considerable amount of its nitrate (12 ppm in drainage) while unfertilised plots average 4-5 ppm nitrate. Fertilised plots showed two peaks in nitrate leaching - one in the Spring and one in Autumn with nitrate fertilisers applied in Spring losing 12 ppm and ammonium fertilisers applied in Spring losing 7 ppm.

At Crawley Mill Farm, Woburn, field drainage experiments produce the same general conclusions. Intensively farmed arable land produces drainage waters rich in nitrate (22.5 ppm average) while grassland remains relatively low (8.0 ppm average) A nearby spring (formerly used as drinking water) contained 11.0 ppm nitrate and a lake 1.9 ppm nitrate. The lake supports
trout and no algal blooms have been reported. A point of interest arose owing to the constancy of nitrate in the drainage and the absence of Spring and Autumn peaks.

Losses of phosphorus and ammonium nitrogen in these lysimeter and field drainage studies were all below 1 ppm.

Tomlinson (Eutrophication Symposium) reported on the general trends in nitrate concentrations in English rivers in relation to fertiliser usage. Eighteen rivers were studies over the period 1953 to 1967 and, as was reported earlier (Owens and Garland, personal visit) in this section, only six showed a positive increase in nitrate concentration with time. The time distribution of river nitrate suggests that a great deal originates from land drainage and concentration is greatest in the Winter months, a period when flow is also greatest. Point sources, such as sewage outfalls, would lead to a decreased nitrate content with increased flow. The nitrate "flushing" of the Winter months corresponds to the lysimeter and field experiments mentioned in this Chapter. English soils do not drain during Summer months, usually, as the soils are not at field capacity. Autumn rain soon brings them to capacity and Winter rain is then free to drain and leach out nitrate.

Comparison of total nitrate carried in the Essex River Stour (rather than nitrate concentration) paralleled fertiliser usage. On average, for the twelve year period, the total nitrate carried was about 17% of that applied as fertiliser. The actual leaching of fertiliser nitrate is thus considerably less than 17% as other nitrate sources were ignored. This is certainly less than the American figures (50%) and more than the Dutch figures (5%) reported at the beginning of this Chapter.
The figures reported by Tomlinson may be compared with those of Owens (Eutrophication Symposium, personal visits). A study of the Great Ouse from its headwaters to Tempsford indicated that sewage out-falls accounted for approximately 95% of the total phosphorus and about 30% of the total nitrogen present in the water. Land drainage is thus an important contributor of nitrogen. Once again it was established that more nitrogen was likely to run off arable land than grassland.

**Great Ouse Analysis**

A more detailed analysis was carried out by the Great Ouse Associated Committee in their report on the expected nitrate levels of the Great Ouse. Five sampling points along the Great Ouse were selected and the total oxidised nitrogen concentration measured. The seasonal variation in total oxidised nitrogen was very apparent and the probability of 3 ppm being equalled or exceeded at Clapham at any one time was:

| % Probability |  
|----------------|---|
| During the year | 16 |
| From December - February | 33 |
| From March - May | 16 |
| From June - August | 2 |
| From September - November | 22 |

The mass of total oxidised nitrogen carried in the riverwater also showed the characteristic seasonal variation with most in January and least in August/September. The Committee's predictions to 1981 (Time-series analysis) indicate that the Great Ouse may exceed 10 ppm for four or five months during the year. (WHO recommendation max. 11.3 ppm)

The nitrogen budget for the Great Ouse was estimated using measured or assumed contributions from sewage outfalls, animal excreta, fertilisers, rainfall, crop residues and nitrogen
fixation, industrial sources, spring and well water, urban drainage and other impervious areas, aquatic plants and algae, and denitrification. Most of the assumptions were those adopted at the Newcastle Symposium on Farm Wastes and the Symposium on Eutrophication (both in 1970). The predictions were of increased nitrates, particularly from fertilised agricultural land, leading to concentrations exceeding WHO recommendations.

9.3 SOIL CHARACTERISTICS

It is evident from the preceding discussion that there are a variety of opinions on the contribution of agricultural land to nitrates in surface waters, especially land treated with synthetic or organic fertilisers. Much of the discrepancies in the measurements from worker to worker and from Country to Country could possibly be explained by the differing local conditions under consideration. Soil type and its drainage properties are obviously key factors, and crop cover and rainfall will also determine what leaches through, when it does so, and to what extent.

Some general comments on the effects of drainage patterns on leaching mechanisms can be gained (Parr 1969, Willrich and Smith Ch. 22), but little work appears to have been published linking the extents of drainage and run-off to specific soil types. However, some examples of soil types found in Britain will serve to illustrate that the soil structure must exert important contributory factors to the amounts and types of run-off and leaching.

A common method of representing a soil is by its profile,
the uppermost elluvial horizons being the A and E, the sub-surface illuvial horizon the B, and the parent material the C. The actual compositions of the soil types are represented in fig 9 (1) with descriptions of:

**Sand**  Soil consisting mostly of coarse and fine sand, and containing so little clay that it is loose when dry and not sticky when wet. It leaves no trace on the fingers.

**Loamy sand**  Mostly sand, but with sufficient clay to give slight plasticity and cohesion when wet. Leaves a slight film on the fingers.

**Sandy loam**  The sand fraction is still quite obvious; moulds when moist, but does not stick to the fingers.

**Loam**  A blended soil which moulds readily and sticks to the fingers to some extent.

**Silt loam**  Moderately plastic but not sticky and with a smooth, soapy feel of silt.

**Sandy clay loam**  Containing sufficient clay to be distinctly sticky when moist, but the sand fraction is still obvious.

**Clay loam**  Distinctly sticky when moist and the sand fraction is almost unnoticeable.

**Silty clay loam**  Unnoticeable amounts of sand. Sufficient loam to confer a soapy feel and not as sticky as silty clay or clay loam.

**Silt**  Smooth and soapy feel.

**Sandy clay**  Plastic and sticky when moist but with an obvious sand content.

**Clay**  Plastic and sticky when moist giving a polished surface on rubbing.

**Silty clay**  Very fine particles with the soapy silt modifying the action of the sticky clay.
FIG. 9.(I) SOIL TEXTURE.

The different soil textures confer different properties. Coarse-textured sandy soils are usually freely drained and may suffer drought in summer. Cultivation is relatively easy. Clay soils are poorly drained and cultivation difficult. Silty soils become very cloddy and the surface is easily sealed by rainfall, which may cause sheet erosion. From these drainage patterns it can be inferred that sandy soils may allow free percolation of nitrates but little surface run-off of phosphates and nitrates. The converse would be true with clay and silts where run-off would be greater, the silts possibly losing phosphates by erosion.

The degree of leaching in the history of the soil leads to classification by horizons. Podzolization, forming podzols, produces a leached soil of distinct horizons and usually occurs under arable land. The eluvial horizons are light in colour as the minerals are washed through. These minerals are deposited in the illuvial horizon. The brown earths have indistinct or no horizons as leaching is very great and re-deposition does not occur. These are usually loose-textured. Gleyed soils, on the other hand, are usually over impervious strata and the lower horizons become saturated with either downward moving surface water or upward moving ground water. Saturation produces anaerobic conditions and decay of organic matter may be very slow leading to peat formation - acid peats of the moors or alkaline peats of the fens. (Moor conditions and high rainfall leach out all bases leaving an acid peat, fen peats are usually supplied with liberal bases in the ground water).

Examples of these types of soils are seen in Figs 9 (2) - 9 (10). (These are taken from Bridges' World Soils with the permission of E.M. Bridges, Geography Dept. University College
of Swansea, and the publishers, Cambridge University Press).

Fig 9(2) shows a humus-iron podzol found in acid, freely drained sands and gravels. Elluvial and illuvial horizons can be seen.

Fig 9(3) is a gley podsol. Poor drainage causes the mottled appearance with areas of weakly cemented orange-brown sand. The surface soil is rich in organic matter and the profile has developed in blown sand.

Fig 9(4) illustrates a peaty gleyed podsol. High rainfall and peaty tendency cause poor drainage in the surface horizons. A thin iron pan can be seen beneath the peaty horizon and the soil beneath is freely drained.

Fig 9(5) depicts a brown podsol enriched with humus in the surface horizon. No elluvial E horizon is present.

Fig 9(6) pictures an acid brown soil with characteristic lack of definition of the horizons showing no evidence of accumulation of clay, iron, or humus.

Fig 9(7) is an example of a leached brown soil developed from fine-grained calcareous material. This soil is first leached and then clay begins to wash through into the B horizon.

Fig 9(8) typifies a brown earth with gleying where the pale colours indicative of slow drainage are superimposed on the brown soil.

Fig 9(9) demonstrates a gley soil showing saturation of the lower horizon. Poorly drained conditions cause chemical reduction of iron compounds, and mottled grey and orange colours are typical.

Fig 9(10) combines a gleyed subsoil with a peaty overlay and shows a blanket bog, acidic in nature.
**FIG. 9.(2)**

Humus-iron podsol,
Norfolk.

**FIG. 9.(3)**

Gley podsol,
Lincolnshire.

**FIG. 9.(4)**

Peaty gleyed podsol,
Breconshire.
Brown podsolic soil,
Glamorganshire.

Fig. 9.(6)
Acid brown soil,
Derbyshire.

Fig. 9.(7)
Leached brown soil,
Derbyshire.
FIG. 9. (9)

Gley soil,
Derbyshire.

FIG. 9. (10)

Brown earth with gleying,
Nottinghamshire.

FIG. 9. (10)

Peat, Breconshire.
It is somewhat surprising that with a wide range of soil types under cultivation in Britain no particular study of their drainage properties related to agriculture has been undertaken. From the figures of soil horizons it is evident that certain soils will rapidly show a loss of nitrate in leaching water whilst others are virtually impervious for long periods of the year. Some comment on the pollution potential of soil types is therefore warranted, but none can be given.

9.4 SILAGE LIQUOR

Silage liquor is the most highly polluting farm waste with a BOD varying between 12,500 - 66,400 ppm depending on the conditions of its formation. (Notes on Water Pollution No. 17). It is produced at late summer and is difficult to store due to growths of fungi (Moore et al, 1961) and separate treatment for discharge to watercourse is impracticable. Several farms are allowed to bleed silage liquor slowly into the sewage system provided there is sufficient capacity, but shock loadings are capable of disrupting the sewage works. (Notes on Water Pollution, No. 17).

The Sussex River Authority recently broadcast a message to livestock farmers warning that most pollution of rivers and streams in Sussex is caused by silage liquor. (Livestock Farming, July 1972 p. 7). It stated that "the pollution load of an average sized silage clamp is equivalent to that of the sewage discharged in a whole week by a town the size of Brighton. The BOD of silage liquor is such that when discharged into a stream it is liable to extract all the oxygen from the water, killing off fish and animal life".

The amount of silage effluent produced is closely related to the moisture content at the time of ensiling as shown in
table 9(4):

<table>
<thead>
<tr>
<th>%age dry matter of material at ensiling</th>
<th>Amount of effluent per ton of silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 15</td>
<td>80 - 100 gals</td>
</tr>
<tr>
<td>16 - 20</td>
<td>20 - 50 &quot;</td>
</tr>
<tr>
<td>25 and over</td>
<td>virtually nil</td>
</tr>
</tbody>
</table>

(MAFF, Short Term Leaflet No. 87)

Thus, a reduction in the volume of silage liquor can be achieved by wilting the grass in the field prior to carting away and clamping. In good weather four or five hours' wilting is sufficient to bring a silage-stage crop to 26% dry matter, but generally 24 hours must be allowed (MAFF, S.T.L. 87). The feeding value of grass silage increases with dry matter content and 25% dry matter is recommended (MAFF, Advisory Leaflet No. 494).

However, even when fully wilted it is inevitable that the fermentation processes and the weight of silage in a clamp or bunker will "squeeze" out some liquor. This must be treated in some way and both MAFF and WPRL recommend the use of soakaways or field spreading (S.T.L. 87, Notes on Water Pollution No. 17). Both authorities caution the former method as it may lead to contamination of below-ground water. Care in construction must be taken to ensure that the bottom of the soakaway is above the water table, and the land is such that the effluent will not run straight into an existing field drainage system.

Land spreading is the best recommended disposal method, with dilution to prevent scorching. The cost of construction of a soakaway pit is virtually nil whilst the cost of land spreading
may be significant, especially if no land-spreaders are used for the other farm wastes. In general silage liquor must be kept out of muck disposal systems as it is prone to attack concrete work due to its acid content, and likely to promote troublesome fungus growths in pipes or tanks. Thus the economics of silage liquor disposal point to simple soakaways with their attendant dangers, even though the recommended system is a spreading onto the land using a run separate from other muck and a washing of equipment afterwards.

9.5 FRUIT AND VEGETABLE WASHINGS

It is becoming evident that the fruit and vegetable packer or processor is asking the farmer to carry out some preliminary washing and/or scraping and/or peeling of his product. (Jones, Newcastle Symposium 1970). The effluent waters produced are extremely difficult to treat biologically because the carbon to nitrogen ratio is unbalanced for normal bio-digestion due to the presence of large quantities of starch. The pH of fruit peelings may also present problems for biological treatment owing to the presence of citric acid. Specific biocides persistent on leaves and fruit will also render wash waters less amenable to bio-treatment.

Table 9 (5) shows NAAS estimates for the acres of land in England and Wales under different crops (Jones, Newcastle Symposium 1970):
<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beet, washing</td>
<td>1,800</td>
</tr>
<tr>
<td>Beet, washing and peeling</td>
<td>10</td>
</tr>
<tr>
<td>Beet, cooling</td>
<td>10</td>
</tr>
<tr>
<td>Carrots, washing</td>
<td>26,600</td>
</tr>
<tr>
<td>Celery, washing</td>
<td>1,600</td>
</tr>
<tr>
<td>Leeks, washing</td>
<td>300</td>
</tr>
<tr>
<td>Lettuce, washing</td>
<td>150</td>
</tr>
<tr>
<td>Onions, salad, washing</td>
<td>600</td>
</tr>
<tr>
<td>Parsnips, washing</td>
<td>3,960</td>
</tr>
<tr>
<td>Peas, all processed</td>
<td>3,900</td>
</tr>
<tr>
<td>Potatoes, washing</td>
<td>1,070</td>
</tr>
<tr>
<td>Potatoes, washing and peeling</td>
<td>6,000</td>
</tr>
<tr>
<td>Radish, washing</td>
<td>155</td>
</tr>
<tr>
<td>Turnips, washing</td>
<td>380</td>
</tr>
<tr>
<td>Watercress, washing</td>
<td>30</td>
</tr>
</tbody>
</table>

With washing requiring between 10,000 - 12,000 gals/acre the water requirement by pre-processors may be put at 100 million gals per year (Jones, Newcastle Symposium, 1970).

Unless extensive re-cycling is in operation then this implies that 100 million gals/year of effluent waters are produced. Since the washing is seasonal one can expect that expensive plant will not be invested in, as it will necessarily lie idle for the greater part of the year. It is suspected that most enterprises employ some simple form of sedimentation to remove soil and peeling's and re-use the water or discharge to sewer.

Based on BOD and SS measurements, the costs imposed by sewage treatment authorities for such wash waters are indicated in table 9 (6): (Barret, Newcastle Symposium 1970)
TABLE 9 (6)

<table>
<thead>
<tr>
<th>Product wash water</th>
<th>BOD ppm</th>
<th>SS ppm</th>
<th>Cost of disposal per 1,000 gals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td>2,800</td>
<td>600</td>
<td>10.8 pence</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,100</td>
<td>2,200</td>
<td>9.6 pence</td>
</tr>
<tr>
<td>Beetroot</td>
<td>1,600</td>
<td>400</td>
<td>7.5 pence</td>
</tr>
<tr>
<td>Spinach</td>
<td>1,200</td>
<td>800</td>
<td>7.3 pence</td>
</tr>
<tr>
<td>Celery</td>
<td>700</td>
<td>600</td>
<td>5.6 pence</td>
</tr>
</tbody>
</table>

Thus, at 10 pence per 1,000 gals and using 100 million gals/year vegetable processors may be paying up to £10,000 per year for effluent treatment. This is probably a cheaper method of disposal than the alternative solids/liquid separation with subsequent treatment and disposal. For example, co-agulation of potato processing liquor with ferrous sulphate and flocculation at pH 8.5 - 10 (adjusted with sodium hydroxide) may cost 23.4 pence/1,000 gals and produce a sludge requiring disposal at 8.2 pence/1,000 gals.

However, the processed water from a separator may be re-used for washing at a saving of 10-15 pence/1,000 gals, the price usually paid for water from Water Boards (Barret, Newcastle Symposium 1970).

Since water is likely to become more expensive rather than cheaper, development of tilted-plate separators, co-agulation plant, adsorption columns, reverse-osmosis, dialysis, and electrolytic flotation methods for water recovery may produce attractive, and perhaps economical, treatment methods.

9.6 ARABLE PRODUCE WASTE

Most arable by-products are re-cycled and a use is found for practically everything. Cereal straw is either used as bedding or is burnt. The burning process removes some of the
organic content from the soil and may adversely affect soil structure. However, the soot, or carbon, produced may increase the C/N ratio in the soil and bring a heavily fertilised soil into line with the conditions suitable for vigorous bacterial growth. Conversion of nitrates in the soil into protein would then reduce leaching problems and so the burning of corn stalks may, on the one hand, detrimentally affect soil structure, whilst at the same time reducing fertiliser nitrate run-off.

For root crops, any leaves are generally fed to stock or ploughed back into the soil - a form of "green manuring".

In general, then, the arable enterprise produces little waste (Nelson, Merrist Wood Agricultural College, personal communication, February 1972).

9.7 AGROCIDES

It is not proposed to discuss the disposal problems relating to contaminated herbage or to discuss the effects of persistent insecticides on the biosphere. Such effects are well documented (Croll, 1969; Lowden, et al, 1969; Graham-Bryce and Briggs, 1970) and the economic needs to use such agroicides are also well established (Strickland 1965, 1967). Suffice it to say that agroicides are used in crop production and their residues must be considered as a farm waste. MAFF undertake to advise on the use of Agricultural Chemicals in their Approval Scheme and "Approved Products for Farmers and Growers, 1971" indicates the uses of various chemicals. It also points out the hazards.

Table 9.(7) indicates some of the common agroicides and possible harmful effects:
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Associated Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Herbicides</strong></td>
<td></td>
</tr>
<tr>
<td>Ametryne</td>
<td>Harmful to fish</td>
</tr>
<tr>
<td>Aminotriazole</td>
<td>Risk to other plant life</td>
</tr>
<tr>
<td>Propham</td>
<td>Harmful to fish</td>
</tr>
<tr>
<td>2.3.6 - TBA</td>
<td>Harmful to fish</td>
</tr>
<tr>
<td>Mecaprop</td>
<td>Harmful to other plant life</td>
</tr>
<tr>
<td><strong>Insecticides</strong></td>
<td></td>
</tr>
<tr>
<td>Aldrin</td>
<td>Harmful to fish and a risk to wild life</td>
</tr>
<tr>
<td>Azinphos-Methyl</td>
<td>Dangerous to bees and harmful to fish and livestock</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Dangerous to bees and fish</td>
</tr>
<tr>
<td>Lead arsenate</td>
<td>Harmful to fish, bees, and livestock</td>
</tr>
<tr>
<td>Mevinphos</td>
<td>Dangerous to bees, fish, livestock, game, wild birds and animals.</td>
</tr>
<tr>
<td><strong>Fungicides</strong></td>
<td></td>
</tr>
<tr>
<td>Binapacryl</td>
<td>Harmful to fish and livestock</td>
</tr>
<tr>
<td>Calomel</td>
<td>Harmful to fish</td>
</tr>
<tr>
<td>Copper</td>
<td>Harmful to fish and livestock</td>
</tr>
<tr>
<td>Fentin Hydroxide</td>
<td>Harmful to fish and livestock</td>
</tr>
<tr>
<td>Tridemorph</td>
<td>Harmful to fish</td>
</tr>
</tbody>
</table>

Fish, therefore, appear to be the most prone to harmful effects and agroicides may enter rivers directly through rain, aerial sprays, direct addition for the control of sub-merged aquatic weeds, surface run-off, and from leaching. Surveys made in the U.K. in 1965-66 (Croll, Lowden, op cit) indicated the average concentration of organo-chlorine pesticides was about 2 parts per 10,000 million.

A survey of six agricultural river systems in the South East showed that organo-chlorine pesticides, \( \gamma \)-BHC, dieldrin and DDT and its derivatives occurred in all the rivers but at
low levels (less than 60 ng/l). High peaks were recorded but did not correlate with any particular usage pattern. (Owens, personal communication, 1972). The lethal doses to trout of D.D.T., dieldrin, and \( \gamma \)-BHC are somewhere around 1,000 - 10,000 ng/l and only if persistent for three months (Salmon and Freshwater Fisheries Laboratory, M.A.F.F., personal communication, 1972).

The problems associated with contamination of waters by agroicides are more likely to occur from accidental spillage or careless dumping rather than from run-off, leaching, or spray-drift. The two surveys reported above indicate that the present levels are low and massive fish kills only expected if an accident occurs.

It is possibly more of a problem to dispose of the plastic container than to use the agroicide contents. This is dealt with in the next section.

9.8 FARM LITTER

It is evident that some farm premises are not as tidy as one might desire. Discarded plastic fertiliser bags, polythene buckets agroicide containers, trailers, and old machinery must inevitably be classed as a waste produce from a farming enterprise. It can be appreciated that many rural areas are not visited by Local Authority collectors and so such wastes must be disposed of by the farmer himself.

The burning of rubbish heaps is common, and the selling of machinery for scrap or its breakage for spare parts offers a disposal outlet. It is not proposed to dwell on these litter problems as it becomes a matter of taste whether or not a piece
of waste land on a farm may be used as a dumping ground, possibly causing an eyesore and a danger to livestock, wild animals, and children. Presumably a farmer owning a plot of land may use it as a dump if he so wishes, and considerable pressure by neighbours or Local Authority may be necessary to persuade him otherwise — perhaps even forcing free collection by the Authority if it receives sufficient complaints.

9.9 SUMMARY

In Section 9.2 it was apparent that opinions on the contribution of farm wastes and fertilisers to the nitrate and phosphate levels of watercourses are in dispute. The reports cited offer divergent, and in some instances contradictory, evidence. However, one point of importance is brought out in Section 9.3; that of the soil under consideration. The soil type must surely influence the leaching and run-off of nitrates and phosphates, although to what extent it is not certain. The investigations into nutrient losses from soils fail to define the soil characteristics, the fertiliser (organic or inorganic) application rates, the rainfall, and the crop cover and so their results must be a matter of conjecture.

Other wastes of the farming enterprise do not attract such widespread investigations either due to the seasonal nature of the waste or due to the, as yet, non-impact of their effects. These wastes may give rise to more concern in the future, but at present animal wastes attract most interest because of their volumes, their regularity of formation, and their seeming detriment to the environment if not disposed of safely.
For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?"

(Luke 14.28)
10.1 INTRODUCTION

Having examined the economic and technical aspects of farm waste disposal it is important to establish what role the subject plays in the Agricultural Economy. The costs for disposal of farm wastes have been outlined, and the possible benefits derived from land spreading of the wastes have been noted. The two must now be interrelated to ascertain what the farmer is paying and what he is getting.

10.2 ECONOMICS OF DISPOSAL

The most popular system of waste disposal is simple collection by scraping, storage in a compound, and use of a muck spreader (owned or contracted) to distribute the manure onto the available land (usually grassland). This can conveniently be termed "traditional" or "solid" disposal and accounts for around 75-85% of farmers. (Chapter 8).

The second popular system is the "slurry" system based on liquid collection and storage and disposal by tanker (majority) or pipelines (minority). This accounts for 10-15% of farmers. (Chapter 8).

Together these systems account for the great bulk of farmers and only a minority are operating any form of deliberate treatment or other disposal methods. The two systems are considered in detail and then in the context of the National picture.

10.2.1 SOLID DISPOSAL

Broadly speaking this disposal method can be said to be relatively labour intensive. Capital equipment is minimal and
cheap. Assuming a tractor is available, as it is on most farms, then additional equipment amounts to a scraper and spreader. The scraper can be conveniently made by farm labour or bought at around £50 (Chapter 4). A 5 year life can be expected. A spreader would cost around £500 (Chapter 5) for 500 gal capacity. A simple compound for storage of manure from 100 cows, 1,000 pigs or 10,000 poultry would not cost more than £200 (Chapter 4). The total capital outlay would therefore be hundreds of pounds (£750–£1,000) and not thousands. For a ten year life of spreader and compound and using two scrapers during this time the annual capital costs would therefore be about £130–£160.

The cheapness in terms of capital cost may well explain the popularity of traditional solid disposal methods.

Averaged over the year one man and a tractor could collect into storage daily and spread from storage each month using no more than about 1 hour per day per 100 cows, 1,000 pigs, or 10,000 poultry. At £1/hour for man and tractor the annual variable costs are therefore £350–£400 p.a. These variable costs obviously depend upon the housing systems, the skill of the operator, the size of the farm, the type of land, etc. However, they do serve as a general guide.

The total costs would therefore be around £500–£600 p.a. for 100 cows, 1,000 pigs, or 10,000 poultry. The assumptions above are obviously for a well-run farm giving an average of around £5 per cow per year, 50 pence per pig per year and 5 pence per bird per year. These figures are certainly of the right order, perhaps being a little low for pigs.
Economies of scale in the capital equipment are present in this system in that the smallest purchase can operate for 100 cows whereas the average herd is only about 30 cows. The annual fixed costs per cow therefore decrease as herd size increases up to about 100 cows. This is for one-man management. One spreader may well be able to cope with a greater volume of waste providing that it is used more frequently and/or for longer periods.

Fig 10.1 plots this data as a cost curve. The data assumes a ten year life of equipment and one scraper can handle up to 50 cows, 500 pigs or 5,000 poultry, one spreader up to 100 cows, 1,000 pigs, or 10,000 poultry. Labour costs are linearly dependent upon herd size requiring 1 hour/day for 100 cows, 1,000 pigs, or 10,000 poultry. Economies of scale are assumed for the storage compound and for each trebling in capacity there is a doubling in cost. The data plotted are derived thus, using 1 cow equivalent to 10 pigs or 100 poultry:

<table>
<thead>
<tr>
<th>Herd size (cow equivs)</th>
<th>Scraper Costs</th>
<th>Spreader Costs</th>
<th>Storage Costs</th>
<th>Annual Fixed Costs</th>
<th>Annual Labour Costs</th>
<th>Total Annual Unit Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>£50</td>
<td>£500</td>
<td>£75</td>
<td>£102</td>
<td>£73</td>
<td>£8.75</td>
</tr>
<tr>
<td>40</td>
<td>£50</td>
<td>£500</td>
<td>£115</td>
<td>£110</td>
<td>£146</td>
<td>£6.40</td>
</tr>
<tr>
<td>60</td>
<td>£100</td>
<td>£500</td>
<td>£145</td>
<td>£124</td>
<td>£219</td>
<td>£5.71</td>
</tr>
<tr>
<td>80</td>
<td>£100</td>
<td>£500</td>
<td>£175</td>
<td>£129</td>
<td>£292</td>
<td>£5.28</td>
</tr>
<tr>
<td>100</td>
<td>£100</td>
<td>£500</td>
<td>£200</td>
<td>£132</td>
<td>£365</td>
<td>£4.97</td>
</tr>
<tr>
<td>120</td>
<td>£150</td>
<td>£1,000</td>
<td>£230</td>
<td>£226</td>
<td>£438</td>
<td>£5.53</td>
</tr>
<tr>
<td>140</td>
<td>£150</td>
<td>£1,000</td>
<td>£255</td>
<td>£234</td>
<td>£511</td>
<td>£5.32</td>
</tr>
<tr>
<td>160</td>
<td>£200</td>
<td>£1,000</td>
<td>£275</td>
<td>£242</td>
<td>£584</td>
<td>£5.15</td>
</tr>
<tr>
<td>180</td>
<td>£200</td>
<td>£1,000</td>
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<td>£657</td>
<td>£5.01</td>
</tr>
<tr>
<td>200</td>
<td>£200</td>
<td>£1,000</td>
<td>£315</td>
<td>£251</td>
<td>£730</td>
<td>£4.90</td>
</tr>
</tbody>
</table>
Figure 10(1). Solid systems.
The economies of scale are evident and the costs for the average herd of 30 cows, 300 pigs, or 3,000 poultry is of the order of £8/cow, £0.80/pig, and 8 pence/bird per year. These figures correlate well with MAFF and other estimates (Chapters 4, 5 and 6).

10.2.2 LIQUID DISPOSAL

From the above estimates it is clear that the MAFF guidelines for £7–10 per cow per year, £3–5 per pig per year, and 5–10 pence per bird per year hold good except for the pigs. This is probably due to pig housing being very adaptable for expensive liquid collection systems such as slats or flushing and storage in sumps or tanks. The capital outlay for the installation of liquid systems is considerably more than with solid systems and so liquid systems are relatively capital intensive.

For the well-run 100 cow or 1,000 pig unit installation of slats and sump would cost around £50 per cow place and £5 per pig place (Weller, J.B. Newcastle Symposium, 1970). For a 10 year life this is therefore £8.10 per cow per year and £0.81 per pig per year. However, labour costs for cleaning are virtually zero in this system. Spreading costs would involve £500 outlay on a tanker (£80 per year over 10 years) using about 40 mins per day of labour and tractor giving an annual variable cost of £240.

The total disposal costs would therefore be higher than the solid system at around £11.50 per cow per year and £1.15 per pig per year.

The land spreading still requires a high degree of labour offsetting the saving in the collection of the waste. This is due to the slurry system requiring a 1:1 or 2:1 dilution with water, thus doubling or trebling the volume of waste to be disposed of.
Fig 10.2 plots data for liquid disposal using similar assumptions as for Fig 10.1. The installation of slats is assumed to follow a 2/3 power law - for a trebling in capacity there is a doubling in cost. A £500 tanker is assumed to be able to operate on herds of up to 100 cow equivalents (i.e. 1,000 pigs or 10,000 poultry).

<table>
<thead>
<tr>
<th>Herd size (cow equivs)</th>
<th>Cost of slats &amp; sump</th>
<th>Cost of tanker</th>
<th>Annual Fixed Costs</th>
<th>Annual Labour Costs</th>
<th>Total Annual Unit Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>£1,900</td>
<td>£500</td>
<td>£397</td>
<td>£48</td>
<td>£17.25</td>
</tr>
<tr>
<td>40</td>
<td>£2,900</td>
<td>£500</td>
<td>£564</td>
<td>£96</td>
<td>£16.50</td>
</tr>
<tr>
<td>60</td>
<td>£3,600</td>
<td>£500</td>
<td>£700</td>
<td>£144</td>
<td>£13.73</td>
</tr>
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<td>£500</td>
<td>£805</td>
<td>£192</td>
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<tr>
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<td>£5,000</td>
<td>£500</td>
<td>£912</td>
<td>£240</td>
<td>£11.32</td>
</tr>
<tr>
<td>120</td>
<td>£5,750</td>
<td>£1,000</td>
<td>£1120</td>
<td>£288</td>
<td>£11.73</td>
</tr>
<tr>
<td>140</td>
<td>£6,400</td>
<td>£1,000</td>
<td>£1240</td>
<td>£336</td>
<td>£11.22</td>
</tr>
<tr>
<td>160</td>
<td>£6,900</td>
<td>£1,000</td>
<td>£1310</td>
<td>£384</td>
<td>£10.68</td>
</tr>
<tr>
<td>180</td>
<td>£7,400</td>
<td>£1,000</td>
<td>£1390</td>
<td>£432</td>
<td>£10.10</td>
</tr>
<tr>
<td>200</td>
<td>£7,900</td>
<td>£1,000</td>
<td>£1480</td>
<td>£480</td>
<td>£ 9.80</td>
</tr>
</tbody>
</table>

Again, economies of scale are evident due to the unit costs of the slats and sump decreasing with herd size. Slats and a liquid disposal system are seen to be uneconomic for all but the larger herds (more than 100 cows) and this is found in practice. The traditional solid spreading techniques are the most popular for the average herds and this is easy to see on the cost basis.

The figures may be somewhat distorted for pigs and poultry, perhaps being a little on the high side. This is because the assumptions take no account of these animals being easy to confine into permanent buildings, without large adjacent areas for exercise.
Fig. 10.1 Liquid systems.
and extra cleaning. The costs are realistic for cows.

10.2.3 NATIONAL DISPOSAL

Assuming the above calculations hold good for most farming enterprises and we take total disposal costs of £10 per cow per year, £1 per pig per year and 5 pence per bird per year for the fully grown animals, then the animal population of Great Britain requires around £80-100 million per year for waste disposal (6 m adult cattle 6 m calves 6 m pigs, 120 m poultry). A good proportion of this (30% for solid and 80% for liquid systems) is capital costs and the remainder is about half for labour and half for machinery and maintenance.

The provision of capital must, then, play an important role in the choice of waste disposal systems. This is based on the fact that 80% of farms are using the traditional solid spreading technique with little capital outlay. However, with increasing herd sizes the economies of scale operating in the provision of fixed capital equipment may reduce unit costs considerably. Slats are generally considered uneconomic for all but the larger units of 100 cows or 1,000 pigs as the unit costs would otherwise be prohibitive.

Generally there is little evidence of economies of scale where labour is involved. It takes twice as long to collect or spread the waste from two cows as it does from one. The set operations for spreading may produce "steps" in the unit cost curve if, for instance, a spreader has to return for another journey because of the addition of a few numbers of livestock. The economics of such operations are poorly documented the only studies being that of Hunter at Reading University, 1969.

Any form of treatment is likely to be expensive (Chapter 6) and, generally, farms with more than 1 cow, 4 pigs, or 100 poultry per acre choose to transport their wastes to neighbouring
premises capable of absorbing the manure (Chapter 8).

It seems therefore that the consideration of the provision of capital is the prime factor in manure disposal systems. The labour intensive systems are chosen at present except on the largest of enterprises where unit capital costs may be considerably reduced. The cost of labour is rising, though agricultural workers wages are lower than those of other manual workers (Chapter 1). Should the cost of labour ever exceed the cost of capital then it is conceivable that more automated systems of collection and disposal may appear. However, this seems unlikely in the near future as present enterprises increasing their stock numbers, and new enterprises, are still planning waste disposal on traditional lines.

Pig and poultry enterprises are likely to be the first to completely abandon traditional disposal methods. This is because these animals are easy to confine and do not require grass for food; confinement of large numbers of animals on small land areas is common. These units may also experience the added difficulty of poor availability of neighbours' land in some areas. In the cereal areas in particular, it may be that the land is only accessible to manure spreaders for three or four weeks during the year. Any rainfall in this period will make the cereal grower unlikely to accept heavy machinery onto his land. Pig and poultry enterprises in this situation must, therefore, provide sufficient storage, sufficient treatment, or be willing to transport over larger distances, presumably by road, with their associated difficulties.

It is unlikely that cattle enterprises will move away from the grassland that is all-important for provision of food and manure disposal. Early zero-grazing units have been forced to
close down because of the difficulties encountered in manure
disposal (Cooper, M.M., Newcastle Symposium, 1970).

The actual circumstances where forms of treatment may prove
necessary are of interest here. It is conceivable that a farm
may be threatened with closure unless it stops spreading agricul-
tural waste onto the land due to the proximity of ground water,
surface water, or a complaining population. It is then likely
that a contractor will be consulted about removal of the wastes
from the premises as this is normally the next cheapest method.

Biological treatment is usually only recommended to reduce
BOD and odours for land spreading, and this may be possible in
some situations. In rare circumstances sacrificial land may be
rented to absorb the wastes, for example the Wright System
(Chapter 6). Normally land is not considered as an additional
cost in the overall spreading of manures. This is because the
land is always there and is necessary for the provision of grass.
The spreading of manure is of direct benefit to the soil and to
the crop cover, and, generally, the spreading is carried out
during the Autumn when the cows are brought in from the fields.
The land is therefore vacant and in a state able to receive manure.
There are no disease or palatability risks as the cows are no
longer grazing.

In paddock systems the manure is spread onto that paddock
that has just been grazed. A four-week rest period to overcome
palatability rejection is not a problem since the grass needs more
than four weeks to re-grow sufficient length for cattle grazing.
Cows pluck the grass with their tongues and require a long sward
for grazing. Sheep use their teeth to crop the grass and spread-
ing of manure cannot be practised where sheep follow cattle.
However, the cost of any sacrificial land must be included in disposal costs as this land would otherwise not be used and is therefore incurred as a necessary extra.

Zero-grazing units do not include a land cost as their land used for grass mowing is available throughout the year for manure spreading and the fertiliser value is of obvious benefit.

It is inconceivable, except for Government-run and subsidised local centres, that incineration or drying of cattle or pig wastes will be practiced in the near future. The costs associated have been outlined in Chapter 6.

10.3 FERTILISER VALUE

With the assumptions outlined in Chapter 3 it is seen that the equivalent value of the N, P and K in manure in England and Wales is about £65 million. It was pointed out that the manures contained certain amounts of N, P and K (Tables 3(3) and 3(4) which would cost a certain sum (Table 3(5)) if they were to be replaced by synthetic fertilisers. The net saving on the fertiliser bill by the land spreading of manure is, therefore, £65 million. This assumes that the manure is beneficially spread as a fertiliser and not solely as a method of "getting rid" of it, and that all manure produced is spread onto the land. Both these assumptions are reasonable.

The average application rate if the manure was to be spread evenly over the available crops and grass acreage would be about 3.7-4.0 tons/acre providing about 40+ units/acre nitrogen, 24 units/acre phosphorus, and 40 units/acre potassium (Chapter 3). The general synthetic fertiliser application rate in this Country is around 70 units/acre N, 40 units/acre P, and 35 units/acre K (Section 5.2). However, the synthetic fertiliser applications
are generally very biased to the eastern cereal-growing counties (Figs 5(6) and 5(7)) and the manure to the western counties (Fig 1(5)).

It has been pointed out briefly (Chapter 5) that the response curve to nitrogen is of this form:

![Graph showing yield and nitrogen application]

Point A represents the present rate of nitrogen consumption and point B the physiological maximum yield from the crop in question. Application rates above B cause a depression in yield.

Somewhere between A and B is the physiological optimum nitrogen application rate; unless of course A is already above this optimum, but this is unlikely, and this is point 0. Application rates above 0 produce diminishing returns in that correspondingly more fertiliser or nitrogen must be applied to achieve a unit increase in yield.

It is therefore important to ascertain where the points, A, 0 and B lie for grasses and cereals. Knowledge of these points - the present application rate, optimum application rate, and maximum application rate - can enable one to forecast the maximum additional fertiliser demand and one can establish the role that manures may play in any future fertiliser programme.
10.3.1 FERTILISER RESPONSE

It is not suggested that each farmer conducts field experiments to determine the optimum nitrogen application level. However, a knowledge of the nitrogen response curve is assumed and the levels of nitrogen applied must be decided taking into consideration the expected increase in production from each increment in nitrogen added, the cost per unit of nitrogen and application costs, the price per unit of produce, and the additional costs, if any, in harvesting and marketing. The consideration of these factors is probably intuitive to the farmers, and not requiring specific mathematical predictions.

Generally the accepted response to fertilisers is of a quadratic nature:

\[ y = a + bx + cx^2 \]

where \( y \) = expected yield and \( x \) = level of nutrient with \( a, b, \) and \( c \) constants (United Nations Industrial Development Organisation, 1965). This curve admits a decline in yield with heavy fertiliser dressings. However, some conditions cause modified responses and there are three other models:

1) Square-root function; \( y = a + b\sqrt{x} + cx \)

2) Misterlich function; \( y = y_0 + d(1 - 10^{-kx}) \)

(\( y_0 \) = yield of unfertilised land, \( d \) = limiting response, \( k \) = curvature of response curve)

3) Cobb-Douglas function; \( y = ax^b \)

These three alternative models can be used for different crops offering different responses. The response by crops is complicated to explain satisfactorily and much empirical work is being undertaken at present (Cleaver 1971, Cleaver et al 1971, Greenwood et al 1971). It is reasonable to assume that farmers
rely on manufacturers' and MAFF recommendations for nutrient applications and are not too concerned with the actual explanatory mathematical models.

It is suspected from the increasing use of fertilisers (Chapter 5) that farmers are operating below the physiological optimum rate. However, they may be operating at the economic optimum in which case fertiliser demand is unlikely to increase at its present rate. The actual response curves for the crops are of value here and Figs 10.3 and 10.4 plot approximate curves for cereal and grass based on I.C.I. data (Jeallot's Hill, personal communication). Depressed yields occur at 125 units N/acre for cereals and 300-400 units N/acre for grass.

Superimposed on Figs 10.3 and 10.4 are the fertiliser cost curve and the difference between the two is plotted as net returns (this is yield times a constant (price) minus the cost of fertiliser) and the economic optimum is clearly visible. Fertiliser costs start at 26 units N/acre for cereals and 68 units N/acre for grass as these are the base levels for manure already applied (See 10.42).

For cereals, the economic optimum can be established at around 110-115 units N/acre. This is the average application rate for cereal Counties (10.42) and so the Eastern Regions of England are, at present, economically optimally fertilised, and the use of synthetic nitrogen is then about 82-90 units/acre. The remainder is supplied by manure.

For grasses for response curve is of a different nature and the upper limit is likely to be governed by the light intensity and by the fact that the leaf area index is not always at optimum level (Jeallot's Hill, personal communication). The near-linear
Fig. 10.3 Cereal data.
Fig. 10.4 Grassland data.

Arbitrary units

Response curve
Cost curve
Net returns

Units N/acre
response to about 300 units per acre affords an economic optimum plateau rather than a definite point. This extends from 140-250 units per acre and most grass farms operate at the lower end of this plateau (10.42). Some farms do operate at the higher end and this is probably due to high stocking densities and the land is therefore required to produce more grass for animal consumption. Since net returns are still high, the intensive unit can afford to apply more fertiliser for proportional increases in grass yield. Less intensive units do not require the additional grass.

10.3.2 FUTURE DEMAND

Since cereals are receiving near their economic optimum fertiliser dressings it seems that grassland will afford the major potential for increased fertiliser usage. There appears scope for increased fertiliser use on grassland with increased stocking densities as unit costs for increased grass remain stable up to around 250 units N/acre. This area for growth has been recognised by fertiliser manufacturers and this is evident from the withdrawal of advertisements for normal arable fertilisers and the introduction of new, specially formulated, grassland fertilisers such as Fison's Extra Grass and After Cut.

The uncertain rises in fertiliser consumption outlined in Chapter 5 may reflect these conditions. Fertiliser consumption in terms of tons remained relatively stable in the mid and late sixties (Fig 5.1) with a sharp increase in the early seventies. This recent increase is primarily in nitrogen consumption (Fig.5(3)). The increases may also be due to two factors difficult to assess. The first may be successful advertising to promote the use of fertilisers in the relatively unexploited grassland market, and the second may simply be a "stocking up"
of cheap fertiliser prior to the removal of the 30% subsidy from
the Exchequer (Fig. 5(10)).

The interrelationships of these factors make the prediction
of future fertiliser demands difficult. A satisfactory model
is hard to formulate due to so many subjective decisions by the
farmers. An actual decrease in fertiliser demand with subsidy
abolition has been predicted by some (Chemistry and Industry,

Simple regression models to explain the fertiliser market
have failed. Regression of \( y = f(x) \) where \( y \) is the net expendi­
ture on fertilisers in the U.K. and \( x \) is the price index produces
\( y = 5.81 + 5.86(x) \) with standard errors of the co-efficients
being 6.70 and 7.05 respectively. The co-efficients are
significant at the 40% and 40% levels, and this is virtually
useless as a model.

When the fertiliser subsidy is introduced into the model
then
\[ y = -8.40 + 1.16(x_1) + 3.27(x_2) \]
where \( x_1 \) is the price index and \( x_2 \) the subsidy. Co-efficient
errors are now 2.27, 2.10, and 2.73 respectively being significant
and the 1%, 60%, and 30% levels. Again the model is not
satisfactory.

If a simple "manure index" is constructed where 1 cow = 10
pigs = 100 poultry then \( y = -1.92 + 9.11(x_1) + 1.86(x_2) + 1.26
(x_3) \) where \( x_1 \) is the price index, \( x_2 \) is the subsidy, and \( x_3 \) the
manure index. Co-efficient errors are now 2.17, 1.15, 2.75, and
2.14 being significant at 1%, all levels, 50% and 65% respectively.

These regressions use data from 1955-1971. It would be
wrong to say that fertiliser consumption is not dependent upon its price, but the relationship is not simple.

Future demands cannot therefore be predicted by simple models owing to the influence of factors that cannot readily be quantified. Other workers have attempted to explain fertiliser consumptions in terms of regression models but these too are not completely satisfactory (Cowling et al 1970). The recent years of turbulence generally explain the downfall of most models.

It seems likely that an increased awareness of grassland response to fertiliser dressings may increase the awareness of the nutrient content of manures and the better management of this product. Increases in prices of synthetic fertilisers will also cause a stimulation in the interest in the nutrient content of manures. ADAS has an active programme to make farmers aware of the fertiliser value and hence monetary value of their waste products. Use rather than disposal is being encouraged.

10.3.3 HUMUS VALUE

Mention of the humus value of manures must be made if their use as a fertiliser is envisaged. The practical aspects of the effects of humus on soil structure have been discussed elsewhere (Section 5.3) and organic matter, such as is found in manure, confers a high stability of soil aggregates improving structural stability, porosity, water infiltration, consistency, and workability. That such improvements are necessary in certain arable intensively cultivated regions is beyond dispute (A.A.C. Modern Farming and the Soil, 1970).

The Eastern Region is said to require bulky soil conditioners due to the reduction in organic content of intensively farmed soils. The West Midland Region must also have regard to soil
conditions but for a different reason – the heavy clays in this area are difficult to drain and bulky organics may well help here.

It is difficult to evaluate the effects of humus on soils, but the introduction of synthetic soil conditioners (Section 5.3) may serve as a guideline.

If peat is used to replace organic matter in a soil, the costs become prohibitive. Farmers do not use peat, probably for this reason, but horticulturalists wishing to improve a soil use about 20 tons/acre in the first year and then 1 ton/acre in successive years. At £17–£18 per ton delivered, but not spread, this may be more than the land is worth.

Waste sugar-beet sludge has been used as a soil conditioner in East Anglia and this material is free of cost. The usual rate of application is 50 tons/acre and the basic constituent is calcium carbonate (50%), the remainder being bulk. This is used as a soil binder.

Gypsum at £4–£5/ton applied at 30 tons/acre may also be used as a soil amendment.

The final alternative is a 3 year ley which is then ploughed in – a green manure. This results in complete loss of revenue for three years.

Manure as a soil amendment may well prove to be the cheapest solution, its unpleasant nature being the biggest disadvantage at present, plus, of course, the cost of transport and spreading.

Despite the Agricultural Land Survey's recommendations that some Counties need soil amendments, little is being done at present. The deterioration of the soil by monocultures is not of significant economic impact at present as synthetic fertilisers are able to sustain a high yield. However, soil binders must certainly play a large part in the soil management of these Counties in the future.
Manures possibly have a bright future as suppliers of organic matter and disposal costs would be reduced by the return to soil fertility.

(Based on discussions with and information from Richardson, S., Soil Science Dept., MAFF, Reading).

10.4 TRANSPORTATION MODEL

It is clear from the above discussion and the contents of other chapters in this thesis that there is a definite East-West split in Britain. The East uses fertilisers to the full but is short of organic conditions. The West appears to be capable of absorbing a lot more fertilisers but has an excess of manures. Increased spreading of manures in the West would satisfy some of the fertiliser demand but would lead, and has led, to problems concerning run-off, leaching, poaching, nutrient imbalance, palatability, disease risks, etc. These factors have been discussed elsewhere (Chapters, 3, 5 and 9).

It is therefore proposed to examine the feasibility of a transport network in Britain. This would move manure from the regions of production to the regions of potential consumption to have a two-fold benefit. The first would be the nutrient content of the manures and the second the humus value. This would alleviate problems of lack of humus in the East and excess of manure in the West. It would reduce fertiliser costs in the East and necessitate an increase in the use of synthetics in the West to replace the nutrients transported out in the manure.

The minimum cost for this operation is calculated, and the benefits examined. The transportation model has received some thought by MAFF but no feasibility study has yet been reported.
The system is based upon the apparent success of the Dutch "Manure Bank" system, and this system is first examined to provide a basis for the transportation model.

10.4.1. DUTCH MANURE BANK

This discussion is based upon information made available to the author by the Ministerie Van Landbouw en Visserij, Rijks Agrarische Afvalwaterdienst, Arnhem (Ir. J.H. Voorburg) and the Stichting Brabantse Mestbank, Tilburg, (J.L. v. Kreij).

The Manure Bank was established in 1970 and about 1,000 tonnes of manure was transported and applied to demonstration fields in the arable areas. This was carried out by the Dutch equivalent of A.D.A.S. The stimulated interest led to the sale of 2,500 tonnes of manure (80% broiler wastes) during 1971.

No charge was made for loading the manure from about 20 suppliers and the 30 arable buyers paid around £10-£15 per tonne depending on the distance it had been carted. This was an ad hoc arrangement whereby a buyer phoned the Bank, the Bank phoned a supplier and the ADAS completed the task. The Bank had a contract with a transport firm charging £10-£12 per tonne depending on the distance and so no, or very little, profit was made. However, the Bank did establish an interest and has rationalised its operation now.

Firstly, each supplier is paired to a buyer. A loading charge is now levied on the supplier of £1 - £1.50 per tonne. Secondly, the rationalisation of transport has reduced these costs to £9.50-£12 and the manure is sold at £11 - £16.50.

During May-August there is little demand for organic manures and the low price of £10 is still charged, the higher scale being
operational during the winter months when demand is greatest. This partly pays for any storage facilities necessary at the supplier's premises.

For pig manure buyers will only pay around £5 per tonne owing to its lower fertiliser value and the Government is willing, temporarily to pay a subsidy of £5 per tonne to make up the differential between transport costs and selling price.

Fig.10(5) illustrates the distances and areas covered by the Manure Bank.

10.4.2 ENGLISH COUNTY MODEL

The Dutch Manure Bank owes its success to the fact that manure is produced in quantity in some areas and not at all in others. The East-West differential in Britain has been made very clear throughout this thesis.

Figs 1(5), 1(7), and 1(8) should be reviewed. The latest maps show the greatest cattle concentrations in the western regions. Cattle produce very large volumes of relatively low nutrient wastes (Chapter 3). Pigs and poultry have localised concentrations, the bulk being in the east. These animals produce considerably less waste than do cattle.

Figs 10(6) and 10(7) illustrate the production of wheat and barley respectively. Both crops are concentrated in the areas away from the cattle centres. As was explained in Chapter 1, cattle need grassland for grazing and so this split is inevitable.

However, comparison of the maps does bear a similarity to the Dutch situation - producers and potential consumers of waste. Hence the potential for an English Manure Bank with a west-east movement of manure.

The basis for the Transportation Model is set out in Table 10.1. From the June 1972 Census the cattle, pig, and poultry
1970/71 production of wheat,
1 dot = 1,000 tons.
1970/71 production of barley,
1 dot = 1,000 tons.
TABLE 10.1
populations were listed for each English region. Lincoln was taken to include Holland, Kesteven, and Lindsey, Sussex was taken to include both East and West Sussex, Ely was grouped with Cambridgeshire, and the Soke of Peterborough grouped with Huntingdonshire.

The assumptions upon which the table is based are found in Chapter 3. An adult cow is taken as producing 9 gals effluent per day and each 1,000 gals contains 50 units available Nitrogen. Thus, in one year, a cow produces around 3,250 gals effluent containing 160 units N. The average cattle will produce slightly less - around 6 gals/day or 100 units N/year.

The pig produces 1 gal/day effluent containing 25 available units N/1,000 gals. Thus, in one year, each pig produces around 350 gals containing 9 units N.

1,000 poultry produces 1 ton manure per week, which is 2,240 lbs/week. Assuming 10 lbs is equivalent to 1 gal then 1,000 poultry produce 224 gals/week. 1,000 gals contains around 125 units available N and so 100 poultry produce about 125 units N/year.

(See Sections 3.2 and 3.3.11 for full discussion of derivation of these assumptions).

Thus the total amount of N produced by the animal population of each County in one year can be estimated. The consumption of synthetic N is available from Stats 27 (MAFF) as tons bought during the fertiliser year June 1971 - May 1972. 1 unit is defined as 1·12 lbs weight and so the units of N consumed can be derived from Stats 27.

The area under crops and grass at the June 1972 census was
derive the application rates of manurial N, synthetic N, and total N per acre of crops and grass. This, of course, assumes that all manure produced is applied to the land and all synthetics bought are actually used. From preliminary chapters, especially Chapter 8, it is reasonable to assume that all manure is put back to the land.

Each County was then defined as arable, mixed, or grass. Using A Century of Agricultural Statistics (MAFF, HMSO) those Counties having more than 50 acres of tillage per 100 acres of crops and grass were designated as arable. Those Counties having more than 25 acres grass for mowing per 100 acres of crops and grass were designated as grassland farms. These two categories are virtually mutually exclusive, only two Counties (Hampshire and Nottinghamshire) being classified both as arable and as grassland. These two Counties do not appear in the further analysis and so this factor was ignored. The other Counties were designated as mixed.

There were then 10 arable Counties, 12 grass, 16 mixed, and 2 arable with grass. These latter two were re-classed as mixed.

Grassland Counties were then defined as being well able to accept between 50 and 60 units manurial N/acre. Over 60 units/acre would lead to problems of ponding, the sealing of air spaces in the soil, disease risks, etc. This is covered in Chapter 3.

Arable Counties were assumed to be capable of absorbing up to 40 units manurial N/acre without danger to crops or soil. Mixed Counties were then assumed to be well able to absorb between 40 and 50 units manurial N/acre.

15 Counties were then found to be producing more than their "comfortable" quota of manurial nitrogen and 13 Counties found to be capable of absorbing more manurial nitrogen in safety. The
excess or deficit in units/acre was therefore multiplied by the area of the County's crops and grass to arrive at an estimate of the amount, in units, of manurial nitrogen that is over-produced or that could be safely absorbed.

The net excess for the 15 producing Counties amounted to some 62.49 million units and the 13 potential consuming counties were found to be capable of absorbing at least 91.66 million units.

Table 10.2 was then constructed as the Transport matrix giving mileages between convenient centroids for each of the consuming or producing Counties. The Automobile Association Member's Handbook was used to calculate centroids and mileages. This will be discussed subsequently.

It is interesting to note that the average units total N/acre for arable Counties was 116, for mixed Counties 136, and for grassland 140. Assuming that the potential deficit of manurial N in the arable Counties is fully satisfied then an increased level of N/acre occurs. However, at around 125 units/acre diminishing returns set in (10.3.1.). Therefore, if a County previously fertilised below 125 units/acre is now brought up to a maximum fertiliser regime with manurial N, then any N in excess of 125 units/acre can be saved in reduced synthetic purchases. This total saving amounts to some 46.29 million units of N.

Norfolk and Berkshire are peculiar in that, as arable Counties they consume more than the optimum 125 units/acre. It is suggested that Norfolk may be over-fertilised at present or, at any rate, very near the physiological maximum. (Norfolk is
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kept at 142 units/acre when calculating the synthetic fertiliser saving). Berkshire probably accounts for its 137 units/acre on a considerable area of grassland although primarily an arable County. (This is kept at 137 units/acre when calculating the savings).

It can be seen that the arable regions are almost optimally fertilised. The grassland regions, however, can absorb a great deal more N. This probably explains the advertisements in Farming Journals for fertilisers being prominent for grassland and definitely reduced for cereal crops. (10.3.2).

The previous definitions into arable, mixed, or grass based on the crop cover correspond well to the different fertiliser regimes in that arable areas consume least nitrogen, grassland the most. This is to be expected and lends support to the assumptions adopted.

The net saving of 46.29 million units N from the arable Counties must be balanced against the fact that the grassland areas must be increasingly fertilised since some of their N is transported out. The grass regions can comfortably absorb vastly more N than they do at present (up to 400 units/acre, section 10.3.1). However, on our assumptions, this cannot be supplied by more manure. The drying of manure would alleviate the problems associated with run-off, ponding, soil sealing, etc. that led to the selection of a maximum of 60 units/acre.

The total potential consumption exceeds the total over-production by 29.17 million units and so, even after the proposed re-distribution, the model allows for an increase of 291,000 cattle or 3,241,000 pigs, or 23.4 million poultry in England. The present numerical ratio of these animals is 6.81%: 5.56%: 87.63% and so the model allows for an increase of 19,800 cattle plus
180,000 pigs plus 20.4 million poultry. At the present growth rates (Chapter 1) the model for re-distribution of manurial nitrogen following the previous assumptions holds good for only a very few years. The increases in pigs and cattle would overtake the above estimates in one year, but poultry may take up to 10 years to increase the flocks by 20.4 million. Thus, cattle and pigs give rise to most concern. This is to be expected as the model's assumptions were based upon the adverse effects of liquid manures, and not so much upon the actual nitrogenous content.

The model predicts, therefore, that even with the most favourable re-distribution of manure, the wetter regions of England are already producing amounts of manure that are potentially undesirable or, at least, difficult to handle safely. The model is, however, based upon primitive assumptions and generalisations. Nevertheless, the results are valuable.

Results

The data from Table 10.2 was used in conjunction with Time Sharing Ltd's "Telroute" Transportation Problem package. The minimum distribution possible involved 8,351.20 million unit miles per year, where 1 unit mile represents one unit of N transported for 1 mile. The satisfied matrix is presented as Table 10.3 giving million units shipped from each supply to each demand. It can be noted that, as demand exceeds supply, four Counties still have a potential for consuming more manurial nitrogen. Cambridge could absorb a further
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9.26 million units/year, Essex 9.75 million units/year, Norfolk 9.37 million units/year, and Kent 0.79 million units/year. This indicates that it may be profitable to expand the pig and poultry industry further in these areas in preference to others where manurial consumption is already high.

The 8,351.20 million unit miles covered in order to re-distribute manurial nitrogen according to this model will have a cost. Reference to Table 10.1 shows that for each County a certain animal population produces a set amount of nitrogen, and the animal population will produce a set volume of manure. The cow populations swamp in volume the pig and poultry and the average production of manure contains 1 unit of nitrogen in 21 gallons. There is a variation of 1 unit/19 gallons in Counties with a high poultry population to 1 unit/23 gallons in Counties with a high cattle population.

With an average tanker size of 2,000 gallons, then, this model requires 87.7 million tanker miles per year as a minimum for re-distribution of manure.

Consultation with large tanker operators suggests economies of scale for transporting slurries depending on the distance. Redland Purle and P.D. Beatwaste have estimated costs for a 2,000 gallon as £20 for a 40 mile journey, £45/100 miles, and £75/200 miles. These are round journeys (e.g. 20 miles there 20 miles back) and the tanker costs are necessarily high owing to return of empty tankers. 200 miles would be the maximum allowed for any one tanker owing to driving regulations of the Ministry of Transport.
With an equal distribution of these short, medium, and long journeys the total re-distribution programme could be expected to cost around 44 pence per tanker mile resulting in £38.59 million per annum.

On a fertiliser saving basis, the 46.29 million units of synthetic N saved by this model would result in £1.85 million p.a. (4 pence/unit of N, Ch. 3) of cash not being spent. This is considerably lower than the £38.59 million p.a. required to distribute the manure. However, it would be a real saving resulting in a net cost for excess manure disposal of £36.74 million p.a. This may indeed be an attractive disposal method; at least the fertiliser benefit is retained.

To dry the manure before transport would be attractive inasmuch as reducing transport costs, but the drying of a mainly cow-manure slurry would cost more (Ch. 6) than the amount saved in reduced transport costs.

10.5 SUMMARY

This Chapter has attempted to put waste disposal into perspective within the Agricultural or the farm economy. It is evident that traditional methods of disposals are favoured on an economic basis. The hidden benefits of using the fertiliser value and organic content of manure also points to the continued preference for traditional systems. Some return is gained by the way of soil and crop benefit when land spreading is used as the disposal method. However, only
the fertiliser benefit is quantifiable and the soil benefit is still a matter for conjecture. The fertiliser content of the manures is low, but the organic soil conditioner may be of great benefit in some regions. The last section shows the minimum transport costs needed to use this as a soil conditioner.
11.1 INTRODUCTION

This Chapter attempts to put the processes of farm waste disposal and their effects into perspective within the National framework. The discussion is based firstly on a comparison with human waste disposal and then the effects on rivers is discussed.

11.2 SEWAGE DISPOSAL

In the year 1968-69 some £98 million was spent on sewage treatment (70% capital equipment, 30% running costs) representing about 0.5% of Britain's Gross National Product (Appendix 2, Jeger Report 1970). The amount spent per head on sewage disposal varies from Borough to Borough but is around £20 per head. At a per capita disposal income of about £600 (Annual Abstract of Statistics) this represents about 0.3% of an individual's earning power.

A cow may produce £88 p.a. for milk or £40 p.a. for beef, fattening pigs about £3.00 each, rearing pullets about 30 pence per bird, table poultry about 4 pence per bird, and turkeys about 50 pence per bird (Nix, 1969) in terms of earnings.

At 0.3% of earning power the equivalent expenditure to come into line with that for human waste disposal does not create a large sum of money for the farmer. When one considers the high BOD and SS of farm wastes it becomes clear that a farmer must be prepared to spend proportionately more on his animal waste disposal than the Nation does on human sewerage systems. A minimum cost for new sewage works is around £20 for a P.E. of 1 (Jeger, 1970) each each cow would therefore require £200, each pig £50 and each 100 lb poultry £52 for complete biological treatment. Clearly
biological treatment of all farm wastes is not economically viable considering the animals' earning powers, nor is it necessary. The above are minimum costs.

However, the above discussion does point out the high costs of waste treatment and the relatively small amount of money available for such treatment. Thus the "average" farm simply spreads manure onto the land to avoid costly treatment. Alternatively, costly plant is avoided by "home-built" treatments such as barrier ditches and lagoons which, although possibly not providing complete treatment, at least offer a cheap storage facility and partial treatment.

With harsher legislation concerning pollution of watercourses, disposal to land may become prohibited above certain stocking densities or in certain areas close to rivers or on certain types of soils. In this instance some form of biological treatment must be considered and it is unlikely that this will cost as little as human sewerage systems.

As an interesting comparison it was decided to try and estimate how much British zoos were spending on animal waste disposal. Although the disposal methods and the wastes involved are different from those of agriculture, similar problems are encountered. Six zoos were contacted but only two made any comment and Regent's Park Zoo was the only one able to estimate costs. Animal waste from these premises is collected twice a week by contractor (5 ton loads) at a cost of £480 per year. The ultimate fate was not known, and the proportion of the animals' earning power spent on waste disposal could not be estimated. However, it was pointed out that liquid wastes were discharged to the public sewer at no cost and so the £480 only represented partial waste removal. Whipsnade Zoo has been
forced to install its own sewage treatment plant as no local sewer will accept their wastes, and the estimate is for tens of thousands of pounds.

11.3 WATER POLLUTION

11.3.1 BACKGROUND

Common opinion relating to Agricultural pollution centers around the safe disposal of pesticide residues and the like, and fertiliser run-off. Very little is known or said about the effects of organic wastes upon reaching watercourses. This type of pollution appears low in the Governmental priorities (Royal Commission on Environmental Pollution 1971), and this may well be due to the insistence upon secrecy or confidentiality over the natures and quantities of wastes released into rivers (Royal Commission on Environmental Pollution 1972).

The apparent lack of knowledge concerning Agricultural pollution of watercourses will undoubtedly change as legislation becomes more stringent. Future plans for Canada, U.S.A., European mainland countries, and Japan are to improve river quality (Department of Trade and Industry, 1972) especially bearing in mind increased demands for potable water.

Industries other than Agriculture are currently spending some 10% of the cost of any new plant on pollution abatement according to the C.B.I. (Financial Times Survey, Environmental Control, 1972). No such estimates are available for the Agricultural industry.

However, it is certain that rivers in Britain are to be made cleaner and kept cleaner and this will affect farm waste disposal. This view is in keeping with world trends towards environmental protection (Chemical and Engineering News Sept. 20, 1971; Feb 21, 1972; June 19, 1972), and most British Industries are aware of
the consequences and are planning pollution control equipment to meet the more stringent standards (International Conference on Total Environmental Protection, 1972). The effects on Agriculture are not documented.

11.3.2. RIVERS SURVEY

An overall picture can be obtained from the Department of the Environment's River Pollution Survey (1970). This Survey set out to establish the exact chemical nature of all rivers in Britain with a flow of more than 1 million gallons per day (A two feet wide stream, 2 inches deep, flowing at 4 miles per hour would be about 1 mgd) and to compare the state of the rivers with that of the unofficial and unpublished survey of engineers and chemists of the former Ministry of Housing and Local Government and pollution officers of the then river boards in 1958.

Six questionnaires were used to ascertain the river classification (quality), discharges of sewage effluent, unsatisfactory storm overflows, trade effluent discharges, river upgrading and discharges of crude sewage. No special provision for farm wastes was included, presumably because such wastes would be considered under trade effluent discharges. However, the Confederation of British Industry (CBI) conducted a separate but parallel enquiry into the nature of industrial discharges and the expenditure by industry in respect of these discharges.

The rivers were classified into 4 groups defined thus:

Class 1  Rivers unpolluted and recovered from pollution.
(a) All lengths of rivers whatever their composition, which are known to have received no significant polluting discharges.
(b) All rivers which, though receiving some pollution, have a BOD of less than 3 ppm, are well oxygenated and are known to
have received no significant discharges of toxic materials or of suspended matter which affect the condition of the river bed.

(c) All rivers which are generally indistinguishable biologically from those in the area known to be quite unpolluted, even though the BOD may be somewhat greater than 3 ppm.

**Class 2** Rivers of doubtful quality and needing improvement.

(a) Rivers not in Class 1 on BOD grounds and which have a substantially reduced oxygen content at normal dry summer flows or at any other regular times.

(b) Rivers, irrespective of BOD, which are known to have received significant toxic discharges which cannot be proved either to affect fish or to have been removed by natural processes.

(c) Rivers which have received turbid discharges which have had an appreciable effect on the composition of the water or character of the bed but have had no great effect on the biology of the water.

(d) Rivers which have been subject of complaints which are not regarded as frivolous but which have not been substantiated.

**Class 3** Rivers of poor quality requiring improvement as a matter of some urgency.

(a) Rivers not in Class 4 on BOD grounds and which have a dissolved oxygen saturation, for considerable periods, below 50%

(b) Rivers containing substances which are suspected of being actively toxic at times.

(c) Rivers which have been changed in character by discharge of solids in suspension but which do not justify being placed in Class 4.
(d) Rivers which have been the subject of serious complaint accepted as well-founded.

**Class 4** Grossly polluted rivers.

(a) All rivers having a BOD of 12 ppm or more under average conditions.

(b) All rivers known to be incapable of supporting fish life.

(c) All rivers which are completely deoxygenated at any time, apart from times of exceptional drought.

(d) All rivers which are the source of offensive smells.

(e) All rivers which have an offensive appearance, neglecting for these purposes any rivers which would be included in this class solely because of the presence of detergent foam.

These classes are somewhat subjective in nature and no clear definition in terms of chemical or biological criteria is apparent. Chemical classification such as that used in Belgium (2.5.1.) or biological classification as used in Denmark (2.5.2) appear comprehensive and objective, but the Survey chose to adopt the four classes outlined above as these were originally used in the 1958 survey. Some river authorities did, in fact, complain about the classification of river quality (Survey, Volume 1, Section 3, paragraphs 6-8).

The general result of the Survey and the comparison with the state in 1958 can be summarised as in Table 11 (1):
It can be seen that non-tidal rivers are showing a definite improvement in quality whilst tidal rivers and canals are somewhat doubtful. Since the upper reaches of rivers provide a third of potable water supply this improvement is of great direct benefit but the state of tidal rivers and the lower reaches of non-tidal rivers are of concern.

Table 11.(1) giving river length by chemical class is based upon data giving equal weight to small upstream stretches as to estuaries. It often happens that the wider, lower reaches of rivers are more polluted and so the actual significance of this pollution may be greater than the arithmetical percentage may suggest.

The whole Survey is best appreciated by studying the maps
in Appendix 6 which clearly show river quality in the four Classes. (Reproduced with permission of H.M. Controller of H.M.S.O.)

As one would expect the majority of polluted rivers occur in and around the industrialised areas of England and Wales and the big cities. This is expected due to the classification of the rivers. However, as pointed out in Chapter 9, farming practices have an effect on the state of rivers especially where run-off occurs. The classification adopted by the Survey makes no provision for this and so rivers flowing through predominantly agricultural regions are Class 1 or 2.

Since the key factor in agricultural run-off is nitrate then the Survey's classification will not detect this. Nitrate is fully oxidised and so exerts no BOD, and eutrophication due to nitrate and phosphate will not be evident except in some slow-flowing or still waters. The deterioration in canal quality may, in part, be due to agricultural practices in the vicinity of the canal. However, this is unlikely because canals served as a means of industrial transport between conurbations and it is suspected that the stretches within cities are polluted but not from agricultural sources. Natural lakes and reservoirs may be more prone to the effects of farm waste run-off but these will rarely be included in the Survey as they will have a flow less than 1 mgd.

Some attempt at a biological classification for the rivers was part of the Survey but this was not the main purpose (Volume 1, Section 4). If this type of biological classification is adopted in the future, then farm wastes may be recognised as heavily polluting in some cases.
Information about future water supplies from the rivers brought out an interesting feature. Some Class 1 and Class 2 stretches of non-tidal rivers were considered to be unfit for potable supplies in the future owing to the presence of ammonia, greatly affecting Class 2 rivers in particular. The river authorities reporting excess ammonia were the East Suffolk and Norfolk, Sussex, Severn, Glamorgan, Mersey and Weaver, Lancashire, and Thames, Conservancy. Some of this ammonia is undoubtedly of industrial origin but some must surely be agricultural (Suffolk, Norfolk, Severn, Sussex). The possible source of this ammonia could well be farm waste or fertiliser application to land. Dissolution and percolation of nitrate into drainage through an anaerobic soil would result in conversion to ammonia and this would exert a considerable BOD in its reconversion to nitrate.

Manure disposal to land, may, therefore, be detected within the present Survey classification in some instances, but will escape detection in most.

11.3.3 C.B.I. SURVEY

This Survey, as one would expect, dealt mainly with discharge from manufacturing industries, and, although general farming was included, the data on farm wastes seems incomplete. The Survey concludes (Volume 2, Table 81) that general farming produces no significant effluent and no expenditure is allowed for existing or future treatment plant. The only contributor appeared to be 12,000 gallons per day of process water into a tidal stretch and the operating costs for 1968 were £9,000. No returns were tabled for farm waste discharges to sewers, for removal by contractor, incineration, or most importantly, from any diffuse discharges.
The forecasts for remedial expenditure to 1980 produced six river authorities recognising farming as a waste producer in need of improvement. The Somerset river authority plans to spend £3,610,000 by 1980, mainly on farm wastes and textile effluents. Sussex plans for £26,000 and the Isle of Wight for £5,000 mainly on farming. The Bristol Avon, South West Wales, and Dee and Clwyd river authorities plan for very small and unspecified expenditures on farming. None of the other 24 authorities allow for expenditure on farm wastes to 1980.

The more detailed analyses (Volume 2, Tables 188-217) provide some information on the discharges of farm wastes. It can be seen that the authorities planning expenditure in this direction do have unsatisfactory discharges, but the Mersey and Weaver's improvement campaign is overshadowed by more serious pollution from the chemical and petroleum refining industries. The Survey findings are condensed in Table 11.(2):

TABLE 11.(2)

<table>
<thead>
<tr>
<th>Authority</th>
<th>No. of discharges</th>
<th>Volume of discharges (gals)</th>
<th>% Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yorkshire</td>
<td>1</td>
<td>30,000</td>
<td>100%</td>
</tr>
<tr>
<td>Gt. Ouse</td>
<td>1</td>
<td>70,000</td>
<td>100%</td>
</tr>
<tr>
<td>Sussex</td>
<td>4</td>
<td>10,000</td>
<td>0%</td>
</tr>
<tr>
<td>Hampshire</td>
<td>1</td>
<td>1,000</td>
<td>0%</td>
</tr>
<tr>
<td>Isle of Wight</td>
<td>2</td>
<td>5,000</td>
<td>0%</td>
</tr>
<tr>
<td>Devon</td>
<td>1</td>
<td>1,000</td>
<td>0%</td>
</tr>
<tr>
<td>Somerset</td>
<td>119</td>
<td>1,236,000</td>
<td>0%</td>
</tr>
<tr>
<td>Bristol Avon</td>
<td>2</td>
<td>2,008,000</td>
<td>50%</td>
</tr>
<tr>
<td>Severn</td>
<td>1</td>
<td>10,000</td>
<td>0%</td>
</tr>
<tr>
<td>Wye</td>
<td>1</td>
<td>5,000</td>
<td>0%</td>
</tr>
</tbody>
</table>
### 11.4. EFFECTS OF POLLUTION

The main effect of agricultural run-off is the possibility of eutrophication and this is unlikely except in slow-running or stationary waters. Eutrophication is expressed as algal growth and/or weed growths. A number of enterprises may be affected by such effects:

- (a) Fishing
- (b) Boating
- (c) Swimming
- (d) Drinking water supply

#### 11.4.1 FISHING

Nutrient addition to oligotrophic stretches of water may stimulate the production of algae, the primary elements of a food chain, which may support the fish population. However, hyper-trophication may result in the disappearance of fish owing to oxygen depletion (Sec. 9.2) by excessive algal growth and consequent bacterial degradation of the debris. From the Rivers Survey it is apparent that Class 1 rivers are increasing in mileage and so waters capable of supporting fish are becoming more abundant. Angling clubs throughout Britain are often the first to report on suspected pollution of rivers containing fish and are generally

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**TABLE II(2) contd.**

<table>
<thead>
<tr>
<th>Authority</th>
<th>No. of discharges</th>
<th>Volume of discharges (gals)</th>
<th>% Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.W. Wales</td>
<td>1</td>
<td>1,000</td>
<td>0%</td>
</tr>
<tr>
<td>Dee &amp; Clwyd</td>
<td>11</td>
<td>67,000</td>
<td>0%</td>
</tr>
<tr>
<td>Mersey &amp; Weaver</td>
<td>17</td>
<td>74,000</td>
<td>0%</td>
</tr>
<tr>
<td>Thames Conservancy</td>
<td>1</td>
<td>10,000</td>
<td>100%</td>
</tr>
</tbody>
</table>

Anglers' complaints or reports of pollution generally concern "accidental" fish kills such as those resulting from tanker discharges, and visible forms such as petrol or oil. The only agricultural discharges likely to present any such visible effects are those of silage liquors and the Thames Conservancy has dealt with two in the past three years (Wheeler, personal communication)

11.4.2 BOATING

The boating community may also be expected to be affected by the arrival of farm wastes into a river. However, unless excessive weed growths or obnoxious smells are present, complaint is unlikely. Again, this community is more likely to occupy Class 1 and 2 rivers and some canals. It is arguable that complaint is not frequent because they add to river pollution themselves by discharge of oil, petrol, cooling water, and other effluents. Motor-powered boats are also often responsible for bringing mud from the bed to the surface resulting in the release of the gaseous products of anaerobiosis and obnoxious smells.

However, yachts may be affected by, and more likely to complain about, farm wastes appearing rivers. As yet the Royal Yachting Association has received no such complaint. This is probably due to such craft using expanses of water such as lakes and reservoirs rather than rivers. Room for tacking and a clear passage for the wind are the important criteria for yachtsmen. Where rivers are wide enough it is felt that other industrial pollution would certainly mask any effects of agricultural pollution since such rivers are likely to be commercial waterways anyway
The British Waterworks Association, the body controlling reservoirs, feels that yachting itself may produce pollution of a greater concern than agricultural run-off, and many water undertakings now insist that boats using their reservoirs must first be decontaminated. (Personal communication, B.W.A. 1972).

11.4.3 SWIMMING

The bathing in rivers and lakes by youngsters is probably very infrequent nowadays owing to active discouragement by parents and teachers and the availability of public swimming baths offering chlorinated water virtually free from disease risks. Bodies of water used for potable supplies are not bathed in and the pastime is probably rare.

Pollution of waters by agriculture would not, therefore, attract complaints from bathers.

11.4.4 DRINKING WATER SUPPLY

It has been estimated (Downing, A.L. Water Treatment and Examination 1970) that no more than a third of Britain's potable water is likely to be affected by polluting activities. One third originates in upland oligotrophic waters, and one third underground. The one third that is liable to show effects of pollution poses little difficulty.

Algal problems are generally dealt with by the addition of copper salts to suppress eutrophic blooms. However, this may be prejudicial to the maintenance of fisheries.

Pumping regimes to continually circulate the water and prevent stratification are cheap and effective methods of algal control.
Microstraining by way of chemical co-agulation and/or sand filters is also an effective control, but can prove costly as algae can block filters.

The toxicity of nitrates or nitrites in drinking water to babies is a non-problem in the U.K. (Downing, A.L. op cit). Only a few minor underground water sources exceed the WHO limit of 10 ppm (as N) and the situation is not expected to alter significantly during this century. European medical opinion is now asserting that levels twice the WHO standard could be well tolerated in such temperate climates as prevail in the U.K.

The need to bottle feed babies with drinking water therefore seems remote except in certain areas of Norfolk dependent upon contaminated well water (see Chapter 9). The Great Ouse Survey is of interest here in that nitrate levels in this river may exceed WHO standards twice a year (Sec. 9.2.4).

11.5 METHODS AND COSTS OF N & P REMOVAL

Certain regions in Western Europe and U.S.A. have experienced acute eutrophication problems and methods for nitrogen and phosphorus removal are well tried in these regions. Should it be necessary to suppress eutrophication in this Country then the benefit of foreign experience can be put to good use and the most efficient methods identified.

The methods discussed in this section are those likely to be adopted in the U.K. if any such measures do become desirable (Bayley, R.W. Water Treatment and Examination 1970).

It is unlikely that any serious consideration will be given to denitrify any diffuse agricultural waters in this Country, although the U.S.A. is proposing to denitrify 580 m.g.d. of agricultural drainage liquor (Bayley, R.W. op cit).
11.5.1 PHOSPHORUS

Any phosphorus spread onto the land by way of manure or fertiliser will not leach into water supplies and will only run-off the most hard-baked clays into watercourses (See Chapter 9). The main supplies of river-borne phosphorus are human faecal residues and synthetic detergents (Jeger Report, 1970; Albright & Wilson, 1972; Hudson, 1973). Phosphorus concentration in rural drainage is minimal and in rural run-off very low.

Phosphorus removal in waste water treatment plant is independent of calcium and magnesium concentration (hardness of the water). "Luxury uptake" seems to occur in activated sludge plants receiving a low-BOD waste provided there is an oxygen level of above 1.5 p.p.m. A biological process may be responsible for this uptake, or, alternatively, a physico-chemical relationship between the solubility of phosphorus and the rate of aeration may be the explanation.

Washing of the liquors from an activated sludge plant in an acid wash releases the phosphate adsorbed during "luxury uptake". Alkali neutralisation of the released waste is then necessary and cost of additional plant and chemicals would be around 2 pence per 1,000 gals for a plant treating 8 m.g.d. (Bayley, R.W. op cit).

Precipitation of insoluble phosphates by chemical co-agulants is limited by cost to lime and some aluminium and ferric salts. The amount of chemical co-agulant used is invariably more than the stoichiometric quantities and is usually determined by trial and error (Bayley, R.W. op cit). The main disadvantage of co-agulation of phosphates is the settling out of enormous quantities of other sludges providing a sludge disposal problem. The straight costs of co-agulants are around 2–2½ pence/1,000 gals for lime, 3–4 pence
1,000 gals for chlorinated copperas, and 4-5 pence/1,000 gals for alum. (Bayley, R.W. op cit).

11.5.2 NITROGEN

In normal biological treatment systems the inflow of nitrate in the sewage or farm waste is in excess of the needs of the bio-mass, and less than half the total nitrogen is normally removed by conventional processes. Polishing treatments for effluents, although capable of removing high percentages of SS and BOD, have little effect on the total concentration of nitrogen, and nitrate content may actually increase due to nitrogen oxidation during normal biological metabolism.

Evidence exists of nitrification of ammonia and nitrite to nitrate and subsequent denitrification to gaseous nitrogen in bio-processes. (Bayley R.W. op cit). The nitrification is caused by autotrophic bacteria such as Nitrosomonas and Nitrobacter, and these have doubling times somewhat longer than other bacteria and may easily be washed out of a biological treatment system. It requires careful control of oxygen levels and temperature to achieve high levels of nitrification. Subsequent denitrification under anaerobic conditions requires careful temperature control.

For agricultural run-off a carbon source for oxidation may be necessary to promote denitrification. Tests with a variety of organic compounds have shown that methyl alcohol (methanol) is suitably efficient and relatively cheap (McCarthy, P., Beck, L., Amant, P. St, 1969). The cost of methanol delivered in bulk in the U.K. is about £33/tonne and the amount required to stimulate denitrification of effluents is dependent upon the concentrations of nitrate, nitrite, and dissolved oxygen. For agricultural run-off at about 15 ppm nitrate and 5 ppm dissolved oxygen, the cost
of methanol treatment would be about ½ - 1 penny/1,000 gals 
(Bayley, R.W. op cit).

The presence of ammonia in agricultural drainage has been 
mentioned (11.3.2) and removal by air stripping is the most common 
method as yet. Since ammonia is dissociated in even slightly 
alkaline solutions it is necessary to add lime (400 ppm) to raise 
the pH of any agricultural liquor to be treated to 11.5. The 
addition of this amount of lime would also precipitate about 95% 
of the phosphorus present. Such ammonia desorption towers are 
in use and the total costs, including lime, are around 2½-3p/1,000 
gals treated (Bayley, R.W. op cit).

A natural zeolite, clinoptilolite, preferentially removes 
ammonia ions in the presence of sodium, magnesium, and calcium, 
and can be economically regenerated with a lime slurry containing 
calcium and sodium chlorides. (Pacific Northwest Laboratories, 
Batelle Memorial Institute, 1969). Laboratory studies in U.S.A. 
indicate that 99% removal of ammonia is possible given the right 
conditions. No full scale plants employing this system have been 
reported and so cost data is unavailable. It is understood that 
ion exchange removal of ammonia would be more expensive than 
air-stripping except in very cold climates where a desorption 
tower would need heating to prevent ice formation (Bayley, R.W. 
op cit).

11.6 SUMMARY

It is apparent from the early parts of this section that little 
money is available for the treatment of farm wastes when compared 
with the amount available for the treatment of human wastes. This 
may be surprising as the animal population produces wastes equivalent to twice the human population of the U.K. (Section 3.3.11) and
the waste is more difficult to treat. However, there is no great problem here in that most of the waste is either used or disposed of on the land (Chapter 8).

Secondary effluents that may reach watercourses could be of more concern Nationally. Leaching and run-off waters may find their way into public water supplies. The upstream third of rivers could be affected in this way (11.4.3) but seem not to be. Underground supplies would be affected by agricultural leachates and pretreatment to remove phosphorus and nitrogen could conceivably be necessary prior to storage in reservoirs.

Eutrophication of reservoirs does seem to be of no concern at present as water is usually microstraining anyway. The costs to the nation of microstraining and coppering raw water supplies is less than £1 million p.a. (Downing, A.L. op cit), this figure serving as an order of magnitude and not an exact value. Intensivisation of agricultural practices may lead to greater amounts of nitrogen and phosphorus reaching water reservoirs, but any farm wastes likely to upset the trophic balance of a reservoir would be kept out at the farmer's expense and not be treated at the public's expense (Wheeler, Thames Conservancy, personal communication).

The clearing of weeds from rivers is of some concern. Cladophora is an alga but has a frond-like habit of growth which could cause annoyance to fishing and boating activities. The River Authorities spend around £2.5 million p.a. on weed removal and this figure is increasing. However, weed growth does not seem to parallel the increase in nutrient content of the rivers (Downing, A.L. op cit).

If agricultural run-off was responsible for all the weed growth in the rivers then there would be a financial liability of the order of £2.5 million. It is doubtful whether the nutrients
from agricultural run-off could be removed for less than many times this figure.

The total banning of fertiliser use in Britain to curtail nitrogen and phosphorus levels would result in about an extra £200 million debt on the National balance of payments owing to the need to import more food (Downing, A.L. op cit). However, this would not preclude the nitrogen and phosphorus from animal wastes spread onto the land and the levels of nitrogen in rainfall after a storm are high enough to sustain algal growth anyway. (Chapter 9).

The total removal of nitrogen and phosphorus from agricultural waters would therefore be costly (directly and indirectly) and probably unnecessary as background levels are sufficient to support algae. Research into the practices of drainage and waste disposal to the land could prove a cheap and effective way of reducing the nitrogen and phosphorus of agricultural origin in watercourses. Reduction of nitrate levels in this way may be of value in the eastern regions of England, where natural nitrate levels are high, for drinking water supplies but eutrophication and weed growth would probably remain unaffected.
"In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oölitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upward of one million three hundred miles long; and stuck out over the Gulf of Mexico like a fishing-rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three-quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of 'fact.'

(Life on the Mississippi, Mark Twain)
CHAPTER 12

THE FUTURE

12.1 INTRODUCTION

The largest single factor to influence the pattern of British farming in the future is undoubtedly the entry into the European Economic Community (E.E.C.). The influences of the E.E.C's Common Agricultural Policy (CAP) can be classed as external factors.

British Parliamentary opinion on subsidies, farming strategy and on legislation for pollution can be classed as internal factors. The availability of land, labour, and capital are important here.

The internal and external factors affecting British farming will be present as short-term or long-term effects. There is obviously an overlap here.

These will be discussed in turn.

12.2 EXTERNAL FACTORS

The CAP applicable to the Common Market Countries will have far-reaching effects on British agriculture. British farming practice is recognised as being far in advance of the other members of this Community. A few facts illustrate this point (ADAS, Surrey University Conference, Dec. 1971). There are 4.2 million full-time holdings in the EEC with a distribution of the following:

<table>
<thead>
<tr>
<th>Acres</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 - 12.5</td>
<td>1.67 million</td>
</tr>
<tr>
<td>12.5 - 25</td>
<td>883,000</td>
</tr>
<tr>
<td>25 - 50</td>
<td>904,000</td>
</tr>
<tr>
<td>Over 50</td>
<td>750,000</td>
</tr>
</tbody>
</table>
The smaller, subsistence level farms predominate. The average British farm (50 acres) is twice as large and more than twice as productive.

In 1958 there were 17\(\frac{1}{2}\) million Community farmers and in 1970 there were 10 million. In 1970, 1 in 9 French farmers committed suicide. In Belgium 1/4 of the farmers on less than 25 acres are unmarried and have no successors. About half the Community's farms have dairy cows and 80% of these are in herds of less than 10. The average British herd is around 30. (Fig. 1(9)).

The scale of operation in the Community is thus too small. Many of the small farms would be run by \(\frac{3}{4}\) of a labour unit if in Britain. The inefficiency of the Community's small farms is combatted by the Farm fund aimed at improving land and consolidating farms (FEOGA). This puts pressures on the British Economy in three ways:

1) Effects on Balance of Payments. The Community's farming resources originate from proceeds of Customs duties - a 1% VAT and import levies. Britain is one of the largest food importers and so makes a substantial contribution to these funds. The resources are not re-allocated in proportion to donation and Britain loses here.

2) Effect on Prices.

Inflation in Britain has been higher than in the Community, and reduction in subsidy payments tend to increase food prices.

3) Effect on Trade

Cheaper Commonwealth sources are now reduced as an almost absolute preference is given to Community suppliers. The Third
World has no effective market in Europe and U.S.A. retaliation may hit Anglo-American trade.

These pressures produce three necessary reactions in Britain:

1) Agricultural output must increase to reduce imports.
2) Other aspects of the economy must be considered in relation to inflation. The sectors of decaying industry are important here.
3) Resistance to price increases while at the same time trying to help to improve Community farming practice.

Based on our entry into the EEC certain forecasts are possible. The National Economic Development Organisation have attempted such forecasts and these are discussed here, in relation to waste disposal.

**Cereals** An increase in cereal production in Britain is expected. Higher variable costs and fixed costs are likely but higher cereal prices more than counteract these, producing an expected net margin increase of 100%. This would lead to increased production to replace the 2.0 - 2.5 million tons imported from third countries and possibly a net export of grain.

Such a surplus production would necessitate Governmental purchase at intervention price requiring off-farm storage facilities.

The disparity between U.K. and E.E.C. cereal farms is unlikely to continue due to amalgamation grants and retirement and resettlement provisions for EEC small growers. It is therefore essential for the U.K. growers to continue research into improving
yields, quality, and disease resistance. As pointed out in Chapter 10, fertilising practice is at the economic optimum and, very nearly, the physiological optimum. Further use of nitrogen can easily lead to lodging problems. This shows itself as an "over-growth". Excess N boosts growth to such an extent that the crop cannot deposit lignins, etc. fast enough to support its head. During wind and rain the crop collapses and up to \( \frac{1}{2} \) the crop is lost as it cannot be harvested once flattened. Some farms are already dangerously near this state and fields can already be seen where part of the crop is flattened and useless.

In terms of run-off, this will improve the situation as the trend to increased fertiliser usage will halt. However, there may be a trend to soil erosion by intense monocultures and over-cropping. At present the soil is allowed to degenerate in preference to using costly methods of soil maintenance (Ch. 10) offering no short-term benefit and doubtful economic benefit at all.

**Milk** The CAP has resulted in the EEC being more than self-sufficient in milk and dairy products. Expansion in this sector will not therefore be rapid.

**Beef** The supply of Community beef is unlikely to match demand by 1977 and so there are attractive opportunities for U.K. producers.

Although the end price will be higher, production costs will also rise and a necessary increase in capital (higher calf and store prices, feed and fertiliser costs) will result in constant returns on capital.
However, one can predict a trend away from high-priced cereal-fed beef to grass-fed beef. Increased cereal prices may promote a move to grass or maize silage as a cheaper food. There is ample scope for increasing grass production (Ch.10) by increased fertiliser usage. Grasses respond linearly up to around 300 units N/acre and at present the use is around 150 units N/acre. This is so because it is not worth while producing more grass than is required as food. However, if beef units expand it is relatively simple to increase grass supply on the same land area to satisfy increased food demand. This, of course, will lead to problems of waste disposal as it is generally considered that 1 acre is required to absorb the waste produced by 1 cow-equivalent. The costs of increasing beef production are not, then, simply increased food (i.e. fertiliser) costs as arrangements will become necessary to export manure onto neighbouring farms or even Counties capable of absorbing the produce (Ch.10).

**Pigs** The EEC is self-sufficient in pig production and a highly competitive industry has developed. Denmark, Ireland, the Netherlands and possibly Belgium compete with U.K. producers for the U.K. market as these Countries produce a surplus. The U.K. farmer has certain advantages:

a) relatively low-priced feeding stuffs

b) competitive level of efficiency in pig production related to a low degree of self-sufficiency in bacon

c) low distribution costs owing to the close proximity of major markets.

In the fresh pork sector the U.K. producer is unlikely to face competition due to the freshness of the carcase being important and U.K. measures to minimise swine fever preventing
imports from the EEC until they are accredited disease free. However, there is strong competition in the bacon market, particularly from Denmark. Manufactured products such as sausages and pies are highly perishable requiring close proximity to the markets.

There is, therefore, scope and incentive for increased pig production, especially for bacon. This increase is perhaps best centered in East Anglia for two reasons. The traditional pig industry is strong in that region so the distribution and storage network is available. Norfolk, Suffolk and Essex are, moreover, able to absorb quantities of manure comfortably (Ch. 10) and possibly with benefit. This latter reason will reduce what could otherwise be costly waste disposal provisions.

The CAP is aimed at rationalising and improving the Community's farms. The Mansholt plan (Clout, H.D. 1971) is trying in 20 years to do to the Community's farms what the Agricultural Revolution in 200 years did to British farms. Whilst this plan is being carried through British Farmers maintain a much higher efficiency of production. Cereals and beef are likely to attract the biggest increases as the Community is a net importer of these products. Dairy and pig production is likely to be maintained and to keep in step with demand at home to prevent imports of high priced dairy and pork goods from the as yet inefficient Community producers.

The volume of animal wastes produced as a direct consequence of entry into the EEF is likely to be relatively small arising only from beef enterprises. Pig enterprises are unlikely to face waste disposal difficulties due to their probable location
being in areas capable of receiving the increased volumes of manure.

12.3 INTERNAL FACTORS

According to Downing (Symposium on Eutrophication, 1970) the costs incurred as a result of the influence of eutrophication on algal growth could not be more than £2 million per year by the end of the century. This assumes a doubling of waste ejected into the waterways at present nutrient levels. Since the demand for potable water is increasing at around 3% per annum it is unlikely that more wastes or stronger wastes will be allowed to be discharged into inland waters, and this £2 million estimate is probably for the most pessimistic case. A similar bill for weed clearance is predicted. However, the costs incurred in keeping potentially troublesome wastes out of the rivers, and farm wastes must be included here, will be very much higher as legislation becomes harsher.

Legislation is likely to become harsher since public opinion against pollution has recently become so very vociferous. This is evident in National newspapers and an abundance of reports, case studies, and other books concerning pollution and other environmental damage.

Future legislation concerning water pollution is, however, unlikely to affect the farming community to a considerable extent. This has been shown in Chapters 8 and 11 where it was established that very few farms discharge waste liquors deliberately into watercourses. Underground aquifers may be in danger from leaching (Ch. 9) but these are difficult to monitor.

Farm wastes are of such a diffuse origin and relatively
innocuous on a volume/volume basis compared to other industrial wastes that little research is probable into farm waste disposal problems. The present maxim of "the polluter must pay" singles out the farmer as being responsible for waste disposal at his own cost. The technology for disposal is available (Ch. 4,5, 6,7) and so the farmer must choose his method, usually the cheapest. At present this is carried out satisfactorily making great use of the land and not the watercourses (Ch. 8 & 11), but a redistribution, or more even distribution, of the wastes may well be desirable.

The reduction and abolition of the fertiliser subsidy may have beneficial effects on animal waste disposal in that there will be an enhanced respect for the nutrients available in manures and they may well be used in preference to synthetics where transport costs are low.

12.4 SHORT TERM FUTURE

From the above discussion and by the very nature of agricultural practices, changes are likely to be slow. Each change will require at least a year to show as the industry is necessarily linked to the annual cycle. This mechanism protects the agricultural industry against sudden external influences (weather excepted) and this is most certainly true for waste production and associated disposal problems.

However, steady population increases produce steady increases in demand for agricultural output and hence steady increases in waste. As has been shown (Ch. 10), Britain can comfortably accommodate this waste using present land disposal techniques. The major problem in waste disposal in the near future is, therefore, simply the cost of transport and spreading. Both are
labour intensive processes and the cost of labour is likely to increase owing to inflation, demands for better living standards, etc. The rising costs will have to be absorbed into the farming budget and "the polluter pays" will result in increased food prices.

12.5 LONG TERM FUTURE

In the long run, the likely increases in distribution costs may force up the price of food to an unacceptable level. This will result in either or both of the following happening:

1) Substitution of traditional food by foods producing less waste or waste disposal problems. This influence can already be seen in the introduction of soya bean protein and other hydrolysed vegetable proteins into the diet.

2) A change away from labour intensive disposal methods to more capital intensive automated systems.

This latter case can also be seen at present and is likely to be influenced by non-economic factors. As seen in Ch. 10, it is foreseeable that the land will become incapable of absorbing more manurial or fertiliser wastes without pollution of water or other environmental damage. Legislation will, hopefully, prevent this occurring and Governmental sponsored research into new waste disposal technology confirms a suspicion that Parliament is at least aware of the long term problems of unrestrained agricultural growth unaccompanied by simultaneous waste disposal facilities.

However, legislation cannot be effective without education of the farmers in better waste management techniques. A.D.A.S. is, in some respects, responsible for this education and the evidence is that programmes are being established and operated already. Indeed, the author has been present on several
occasions where A.D.A.S. lectures and demonstrations were given to local farmers in order to illustrate the beneficial uses of "waste" products and their successful, economic management.

Chapters 6 and 7 refer to the various advances in waste treatment and total disposal techniques. The conclusions reached are that, at present, the capital costs, and in some cases the running costs, are excessive. However, with harsher legislation, dearer labour, less available land and new management techniques the processes now under investigation may become economically attractive and hence popular practice. Of the treatment processes available it is likely that biological ones will be first to be used in significant numbers. This is due to their lower capital costs and their comparative simplicity. The latter point is of prime importance in that farm labour acting as supervisory staff is cheaper than the employment of skilled operatives. Some of the more sophisticated technological processes do, in fact, require permanent skilled supervision (e.g. Zimpro, micro-wave drying, furnaces).

12.6 CONCLUSIONS

From the discussion in Chapter 1 it is evident that agricultural practices are now aimed at a reduction of unit costs and this involves either intensivisation (livestock) or extensivisation (crops). New technologies and a competitive environment have necessitated changing practices for economic production. However, the wastes produced, not being "cash crops", have been insufficiently considered and hence the problems of today have arisen.

The large-scale collection of by-products and their disposal is of comparatively recent concern as is shown by the newness of
the legislation (Rivers (Prevention of Pollution) Act 1961, Deposits of Poisonous Wastes Act 1972). Agriculture has to some degree escaped the intensive policing that is applied to industry and the legislation discussed in Chapter 2 is indeed difficult to apply. This stems from the fact that agricultural discharges are nearly always diverse and diffuse in nature being both difficult to detect and difficult to prevent. Such point discharges as silage effluent are comparatively easy to contain and control.

The full economic impact of the Legislation has not, therefore, hit the agricultural industry. The publication of the Rivers Pollution Survey has drawn attention to the regions of the worst water quality and the establishment of the new Regional Water Authorities (Water Act, 1973) co-incides with an aim to upgrade all Class 3 and 4 rivers (i.e. grossly polluted) to cleaner Class 2 rivers (see Ch. 11). This necessarily means the enforcement of the legislation and the economic consequences to the agricultural industry may be great. However, the bulk of this pollution is of other industrial origin and farming practices may be immune for several years yet.

Reference to Chapter 3 indicates the constituents of the wastes and their uses and dangers. The dangers of misuse or carless disposal has been recognised for some time, but farming practices are generally slow to change. Traditional waste management practices still exist to a large extent - about 85-90% of farms - and it is difficult to envisage rapid changes here. However, with cleaner rivers and a growing human awareness to other forms of pollution, particularly smell, these practices must be modified or abandoned in the long run.
The mechanism for this change already exists and Chapters 4 to 7 discuss present and future disposal techniques. It is evident that most of the new techniques are costly (Ch. 6) in comparison to traditional disposal, but the pressures of legislation are forcing a trend towards confinement of wastes and at least partial treatment before disposal.

The responsibility for making the new methods open to the farming community rests squarely upon the Government as it is Governmental policy to control or curtail traditional disposal where pollution is possible. A.D.A.S. has accepted this responsibility and it is encouraging to see the farmers attitude to his waste products changing. Use rather than disposal is being encouraged by numerous demonstrations and lectures at Farmers' Clubs throughout Britain. Most of the techniques in Chapters 4 and 5 are readily available to farmers, and those of Chapters 6 and 7 are at least known by several farmers even if not easily accessible or available. This National education of the agricultural community in better waste management and an enhanced responsibility to the public is unlikely to have an effect in this generation as most of the methods involve large capital outlay and dubious returns. However, harsher penalties may produce a somewhat better return on capital by way of the incentive to avoid heavy fines for pollution.

The re-organisation of Water Boards, Sewage Authorities, and River Authorities will bring public water abstraction closer to pollution prevention in the new Regional Water Authorities. The constant checks on potable supplies will, therefore, be available to pollution prevention Officers at short notice and long-term trends in water quality can be studied. With particular reference to nitrate concentrations (Chs. 9 and 10), this will
mean that monitoring of groundwater supplies may be coupled to a watch on agricultural practices. Suspected nitrate infiltration into groundwater supplies from agricultural waste disposal or over-fertilisation may result in prosecution of closure of premises. With potable water supplies reportedly fully exploited, any potentially polluting practices are likely to be under intense surveillance. This is already the case in some River Authority areas (personal communications, Thames Conservancy, Yorkshire River Authority).

The forthcoming changes may be slow, but evidence suggests that a watchful eye is being kept on pollution (Chs. 9 and 11) and changes must come about in waste management techniques.

The quantification of various facets has proved extremely difficult in some parts of this thesis and it is evident (Ch. 8) that farmers themselves attach little importance to the costs of waste disposal at present. However, being titled "The Economics of Farm Waste Disposal" necessarily requires some discussion of the costs if only to either guess or to point out that costs are simply not known. To say that costs are not known is not negative; it implies a gap in our knowledge which should be filled at some future date. This usually involves further experimental work or involves the quantification of several other factors before a cost or price can be deduced. It may not be beneficial, therefore, to quantify everything at this stage since, in the majority of these cases, sufficient data is rarely available. For example, the running costs of a biological unit may be practically impossible to quantify due to unquantifiable variables - the successful establishment of a biomass, the
weather, the virility of the floc, the susceptibility to shock, both physical and biological, and the competence of the operators. Where value can be derived from an estimated cost, this has been done.

The problems alluded to in this thesis are not new. Man has always known pollution and man has always had difficulty in establishing the optimum allocation of resources. It is likely that man will continue to have difficulty, but whether the difficulties will be greater or lesser is a matter of conjecture.

Charles Riley (formerly M.A.F.F. farm waste disposal, Guildford) has summed up the situation to the author on several occasions:

"We're always in it; it's only the depth that varies".
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APPENDIX 1 - Pitts P.V. Test
The oxygen absorbed by an effluent sample is usually measured by estimation of the amount of oxygen (provided by acid permanganate or dichromate) required to satisfy the demand by the effluent, the result being known as the P.V. or dichromate value. These estimations give an indication of the amount of oxidisable organic matter present in the sample.

To date, the estimation of the P.V. of effluents has been a lengthy procedure (4 hours) requiring, for reasonably accurate results, access to water baths and other equipment not necessarily available in the field. The three minute and the field test for P.V. assessments (Ministry of Housing and Local Government 1956) can only supply a rough estimation of the oxygen absorption, as the Ministry book (Methods of Chemical Analysis as applied to Sewage and Sewage Effluents 1956, HMSO) indicates "...It (the field test) aims at an approximate estimate of the probable range...". There is thus a need for a test that will give a more accurate assessment of oxygen absorption by the organic matter under field conditions. The following modification has proved satisfactory during an extended period of use.

Materials

The reagents for the test are those described in the Ministry's book (Methods of Chemical Analysis as applied to Sewage and Sewage Effluents 1956), and comprise:

1. Potassium permanganate N/80 solution
2. Sodium thiosulphate N/80 solution
3. Sulphuric acid: 1 volume concentrated acid to 3 volumes of water
4. Potassium iodide crystals
5. Sodium starch glycollate, 0.5% solution

Figure 1. Graph of P.V. against ml. thiosulphate required for titration.
Care should be taken to check the strengths of stored solutions by regular standardisation.

Two disposable 2ml syringes and one chemically clean 25ml. universal bottle (plastic screw cap) are required for each estimation. 5ml. permanganate solution and 10ml. distilled water are added to each bottle, these are termed the "experimental bottles".

Procedure

1. Add 0.5ml. acid (by syringe) to experimental bottle.
2. Add 0.5ml. effluent sample.
3. Mix thoroughly by inversion.
4. Allow to stand exactly 15 minutes at room temperature or, if the test is made out of doors, in a coat pocket.
5. Carefully add crystals of potassium iodide until the solution turns and remains yellow i.e. iodide to excess.
6. Add 6 drops glycollate solution; invert bottle to mix.
7. Add thiosulphate solution drop wise from syringe until the mixture turns from yellow, through blue to colourless; record the volumes of thiosulphate solution required for this change.
8. Read from the graph (Figure 1) the P.V. of the sample tested.

The reaction time of 15 minutes was chosen because a time titration, carried out over 4 hours, showed that approximately half of the maximum P.V. was satisfied at 15 minutes. Figure 1 thus represents the P.V. calculated from the modified test thiosulphate titre, and then multiplied by 2 to give the correct P.V. as related to the 4 hour test.

This 15 minute test (the Pitts test), modified from the 4 hour test, is dependent on the temperature at which it is carried out. It was found that room temperature gave sufficiently reproducible results alternatively, the test could be performed out of doors by using a coat pocket as a suitable incubator.

The test depends on the operator's accuracy when using the syringe; a 0.1ml. error in thiosulphate volume leads to an error of 20 ppm. in the final results.

This test has been found to give reproducible results and is easy to manipulate. It has been proved ideal for use with farm effluents and would probably be equally suitable for sewage works or any establishment that requires to make such estimations, particularly if large numbers of estimations are required.

The upper limit of the test, as described, is 2000 ppm P.V., for stronger effluents the test may be modified by increasing the strength of the permanganate and thiosulphate reagents.

Acknowledgements

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APPENDIX 2 - Two Pits, One Pump, No Problem
TWO PITS and a pump seem to have solved muck disposal problems on 40-acre Vigers Hill Farm at Boldre, near Beaulieu, Hampshire, where a dairy herd of 74 Friesians threatened to clog the farm system with dung.

For three years or so muck and slurry from yards, walk-ways and cubicle sheds had been scraped into two pits each measuring 90 x 90ft, and each between 5 and 8ft deep. But by May, 1971 the pits were full and the outlook for the 1971-72 winter appeared bleak.

The summer of 1971 gave farm manager Mr Derek Pitt-Pitts some respite and he used the time to investigate ways and means of getting out of trouble. Specialist contractors quoted a price to clear the pits and to keep on top of the job thereafter, but their idea of a price and Mr Pitt-Pitts' idea did not coincide. It was suggested that the muck should be scraped into two pits each measuring 90 x 90ft, and each between 5 and 8ft deep. But by May, 1971 the pits were full and the outlook for the 1971-72 winter appeared bleak.

The existing system just survived the first of 1972, but by March of that year it was obvious that something had to be done.

Consequently Mr Pitt-Pitts welcomed a suggestion from Surrey University, Guildford, that Messrs S. L. Willetts and C. Bell expected the aerobic bacteria to break down large organic molecules and to produce small organic molecules as waste products.

The second lagoon was cleared of muck and its bottom re-profiled to give a level base and a working depth of 2.5 to 3ft of liquid. This was to be an aerobic lagoon, hence the large surface area in relation to depth. It was here that Messrs Willetts and Bell expected the aerobic bacteria to break down the small organic molecules which were the by-product of the anaerobic lagoon.

Finally the two lagoons were linked by a channel to allow liquid to flow from the anaerobic to the aerobic lagoon, and a 100yd long aeration channel was dug between the farm buildings.

Into this channel was to be pumped the contents of the aerobic lagoon, the idea being that it would travel full circle back to the aerobic lagoon having absorbed more oxygen (which would increase the activity of the aerobic bacteria) on route.

So far the system seems to be working well enough. The solid muck and the slurry is scraped into the anaerobic lagoon which has a capacity for holding 90 days' muck. Anaerobic digestion turns the solids into a liquid which seeps into the lower, aerobic lagoon at about 1,200 COD (crude oxygen demand).

When the aerobic lagoon had been emptied and re-profiled it was also topped up with river water and the COD was measured at 400. The COD has remained at this level ever since. A point of interest here is that the river is tidal. The salty water seems to have had no adverse effects on the aerobic bacteria.

The aeration ditch results in the liquid becoming completely saturated in oxygen, with the consequence that the aerobic lagoon itself contained 50% oxygen — which means that the aerobic bacteria can work at maximum efficiency.

Mr Pitt-Pitts is moderately pleased with results so far. He now has a product, at 400 COD, which can be sprayed on the land without too much fear of fouling the ground or the nearby river. The bogey of being obliged to pay for the solid results of three years of intensive cow-keeping has, he hopes, been banished.

However, the day will come when the aerobic lagoon needs to be emptied and it will be then that he will wish he had spent just a bit more than the £467 (lagoon emptying, spreading contents, levelling, digging aeration channel, buying pump and hose) he laid out in the first place.

The present design (less a design, more an "as it turned out") prevents easy access to the surface of the aerobic lagoon, hence it is difficult to remove surface scum. Eventually a heavy machine will be required to cast out the sludge — but the banks will not be sufficient to support its weight.

However, that day of reckoning is a long way off. Messrs Pitts-Pitts, Willetts and Bell now look forward to a hot summer which will both speed up the breakdown process and remove some of the liquid by evaporation.

As Mr Pitt-Pitts says: "We are in a better position now than we were three years ago. At least this system promises to work, and to keep us out of trouble for another five years."

Picture (left), which shows part of the aerobic lagoon at Vigers Hill Farm, illustrates the problem faced by farm manager Derek Pitt-Pitts. Between the spot where he stands (right) with Stephen Willetts from Surrey University and the glasshouses in the background runs a river which would quickly become polluted if the muck from the 40-acre farm's 74 cows was not treated.
APPENDIX 3 - Pilot Questionnaire
March 1971.

Dear ...........

I enclose the questionnaire which you so kindly agreed to complete. You will see that it is in the form of a flow sheet, and perhaps these notes will help you:

1. Select your largest waste problem and fill in the question boxes either by ticking "YES" (Y), or "NO" (N); or by ticking the relevant answer; or by inserting a figure if required.

2. Follow the arrow from the foot of Page 2 upwards, and this will lead to either Page 3 or Page 5.

3. In some cases the arrow you follow will depend on which answer you tick. For example, on Page 3 (Top, centre) you are asked if you separate liquids from solids. If you answer N, you will proceed along the "solid/slurry" arrow to Page 4; if you answer Y, you will follow both the arrow to Page 4 and also the "liquid waste" arrow which leads down Page 3.

4. In some cases there are boxes relating to capital and running costs of a particular treatment stage. It will be difficult to answer these exactly, but I would be most grateful for your best estimate.

I think you will agree that this questionnaire will take a little time and thought to complete, but your assistance will provide me with extremely valuable information for my research into the problem of farm waste disposal, which is becoming increasingly urgent to all farmers.

With many thanks for your help,

Stephen L. Willetts

Stephen L. Willetts.

Enc.
Use this questionnaire to deal with largest waste problem. Please specify:

- Cattle
- Pigs
- Poultry

Is all waste handled together? [Y/N]

- Additional water (including rain and wash water) [Y/N]

- Milking parlour and/or domestic farmhouse waste [Y/N]

Insert Figure

Total gallons for disposal per week
Direct drying/Composting
Muck direct to land
Digester tank
Lagoon without aerator
Filter
Activated sludge unit
Oxidation ditch/Lagoon
with aerator
Trickling filter
Other (3)

Liquid separation
N
Y

Slurry/Solid
Solid
Liquid

Holding tank
Y
N
Installation date
Capital Cost £

How often is disposal undertaken?
More than 1 per week
1 per week — 1 per month
Less than 1 per month

Disposal Method
Irrigation
Watercourse
Public sewer
Other (4)

Pipe and pump
Ditch
Mobile tanker
Gravity pipe

Installation date
Capital cost £
Av. weekly running cost

Consent conditions
B.O.D.
S.S.

Crops
Acres/week
Root crops
Grass
Cereal
Others:

End of Questionnaire. Thank you for your valuable help.
Waste not processed on farm

Discharged directly:

- On own land
- Watercourse
- Public sewer
- Contractor

Muck spreader
Mobile tanker
Pipes (and raingun if used)

Gravity pipe
Pipe and pump
Ditch

Disposal on own land
Pay contractor
Be paid by contractor
Free disposal by contractor

Consent Conditions
B.O.D.
S.S.

Installation date
Capital cost £
Av. weekly running cost £

End of Questionnaire. Thank you for your valuable help.
APPENDIX 4 - Final Questionnaire
Department of Humanities and Social Sciences
In conjunction with the University of Southampton

SIW/ML November, 1971

Dear

A survey of a number of farms in the South East region of England is being undertaken by the above two Universities. Our terms of reference cover the costs of disposal of animal wastes.

A short questionnaire will follow and may we ask you for your help by trying to complete the questionnaire as soon as it arrives, and posting it back for analysis.

About three hundred farms have been selected on a purely random basis, and the survey of these farms is independent of any other organisation, of immense value to us, and, we hope, of interest to the farms. The answers will provide strictly confidential information, the analysis of which may help to benefit farmers in the future.

If you are using "sophisticated" methods of animal waste disposal we would very much like to visit your farm for the benefit of your experience in the workings of your particular method. Some questions refer to costs of processes and we would be most grateful for your best estimate if an accurate figure cannot be quoted.

May we thank you once again and ask for your co-operation on this project.

Yours sincerely,

Stephen L. Willetts

Stephen L. Willetts B.Sc. F.R.H.S.
Department of Humanities & Social Sciences
University of Surrey.
We are interested in finding out what farmers do about the waste produced by their animals. Many farmers find that waste disposal is an increasingly urgent problem, but little is known about which methods are best in particular circumstances. This questionnaire is laid out as a flow sheet, these notes will help you complete it:

1) Select your largest waste problem and fill in the question boxes by ticking "YES" or "NO", by ticking the relevant answer, or by inserting a figure if required.
2) Follow the arrow from the FOOT of page 2 upwards.
3) In some cases there are boxes relating to capital and running costs of a particular treatment stage. It will be difficult to answer these exactly, but we would be most grateful for your best estimate. Your answers will provide strictly confidential information about a very important topic.

Thank you.
Do you directly dry, or biologically treat, or deliberately compost the waste?

Yes

No

Below ground sump
Above ground tank
Heap
Midden
Other (2)

Installation date
Capital Cost £
Average weekly running cost £

Is waste stored?

Yes

No

Handling
Pump and pipes
Manual/Mechanical
Gravity pipe
None or none necessary

Installation date
Capital Cost £
Average weekly running cost £

Method
Slats
Scraping
Flushing
Continuous belt
Other (1)

Installation date
Capital cost £
Average weekly running cost £

How often is waste removed from animals?

1 - 7 days
7 - 28 days
28 days or over
### Treatment Method

- Direct drying
- Composting
- Digestion Tank
- Lagoon without aerator
- Filter
- Activated sludge unit
- Oxidation ditch/Lagoon with aerator
- Other (3)

#### Discharged directly:

<table>
<thead>
<tr>
<th>On own land</th>
<th>Watercourse</th>
<th>Public sewer</th>
<th>Contractor</th>
</tr>
</thead>
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<td></td>
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</tr>
</tbody>
</table>

- Muck spreader
- Mobile tanker
- Pipes (and raingun if used)
- Gravity pipe
- Pipe and pump
- Ditch
- Pay Contractor
- Be paid by contractor
- Free disposal by contractor
- Consent Conditions
  - B.O.D.
  - S.S.
- Crops
- Acres
- Root Crops
- Grass
- Cereal
- Others

#### End of questionnaire. Thank you for your valuable help. Please add any comments or remarks on page 4.
Please use this page for any comments or remarks you may have either concerning the questionnaire or concerning farm waste disposal generally.
February 1972.

Dear Farmer,

Some time ago I sent out some questionnaires relating to the costs of disposal of farm wastes, and many of these have been completed and returned. Since the problems discussed are of a very important nature, especially bearing in mind Mr. Peter Walker's recent £130 million "environment cleaning programme", I am taking an opportunity to ask you to complete the questionnaire.

It is you, the agriculturalist, that can help us compute the costs of present day waste disposal. Please give your co-operation and complete the questionnaire.

With many thanks,

Stephen L. Willetts

Stephen L. Willetts.
Dear Farmer,

My questionnaire prompted a very encouraging and interesting response from a large number of participants. I would, however, like to make the survey as complete as possible. May I finally ask you to complete your questionnaire.

With many thanks.

Stephen L. Willetts
Dept. of Humanities
University of Surrey, Guildford, Surrey.
APPENDIX 5 - Coded Questionnaire
We are interested in finding out what farmers do about the waste produced by their animals. Many farmers find that waste disposal is an increasingly urgent problem, but little is known about which methods are best in particular circumstances. This questionnaire, laid out as a flow sheet, these notes will help you complete it:

1) Select your largest waste problem and fill in the question boxes by ticking "YES" or "NO", by ticking the relevant answer, by inserting a figure if required.
2) Follow the arrow from the FOOT of page 2 upwards.
3) In some cases there are boxes relating to capital and running costs of a particular treatment stage. It will be difficult to answer these exactly, but we would be most grateful for your best estimate. Your answers will provide strictly confidential information out a very important topic.

Thank you.

- Farm Acreage
  - Grassland: 6-9
  - Woodland: 11-14
  - Wasteland: 16-19
  - Arable: 21-24

- Head of
  - Cattle: 26-29
  - Pigs: 31-34
  - Poultry: 36-39

- Is all waste handled together?
  - NO: 9
  - YES: 41

- Use this questionnaire to deal with largest waste problem. Please specify:
  - CATTLE: 1
  - PIGS: 2
  - POULTRY: 3

- Additional water (including rain and wash water)
  - YES: 1
  - NO: 2

- Milking parlour and/or domestic farmhouse waste
  - YES: 3
  - NO: 4

- Insert figure

- Total gallons for disposal per week
  - 47-50
Do you directly dry, or biologically treat, or deliberately compost the waste?

- YES
- NO

Is waste stored?

- YES
- NO

Handling

- Pump and pipes
- Manual/Mechanical
- Gravity pipe
- None or none necessary

Method

- Slats
- Scraping
- Flushing
- Continuous belt
- Other (1)

How often is waste removed from animals?

- 1 - 7 days
- 7 - 28 days
- 28 days or over

Installation date

- Capital Cost
- Average weekly running cost
Waste not processed on farm

<table>
<thead>
<tr>
<th>Treatment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct drying</td>
</tr>
<tr>
<td>Composting</td>
</tr>
<tr>
<td>Digestion Tank</td>
</tr>
<tr>
<td>Lagoon without aerator</td>
</tr>
<tr>
<td>Filter</td>
</tr>
<tr>
<td>Activated sludge unit</td>
</tr>
<tr>
<td>Oxidation ditch/Lagoon with aerator</td>
</tr>
<tr>
<td>Other (3)</td>
</tr>
</tbody>
</table>

Discharged directly:

<table>
<thead>
<tr>
<th>On own land</th>
<th>Watercourse</th>
<th>Public sewer</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Muck spreader 1
Mobile tanker 2
Pipes (and raingun, if used) 3

Gravity pipe 4
Pipe and pump 5
Ditch 6

Pay Contractor 7
Be paid by contractor 8
Free disposal by contractor 9

Consent Conditions

<table>
<thead>
<tr>
<th>B.O.D.</th>
<th>S.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root Crops: 69-71</td>
<td></td>
</tr>
<tr>
<td>Grass: 72-74</td>
<td></td>
</tr>
<tr>
<td>Cereal: 75-77</td>
<td></td>
</tr>
<tr>
<td>Others: 78-80</td>
<td></td>
</tr>
</tbody>
</table>

Installation date
Capital cost £
Average weekly running cost £

End of questionnaire. Thank you for your valuable help. Please add any comments or remarks on Page 4.
APPENDIX 6 - River Pollution Survey