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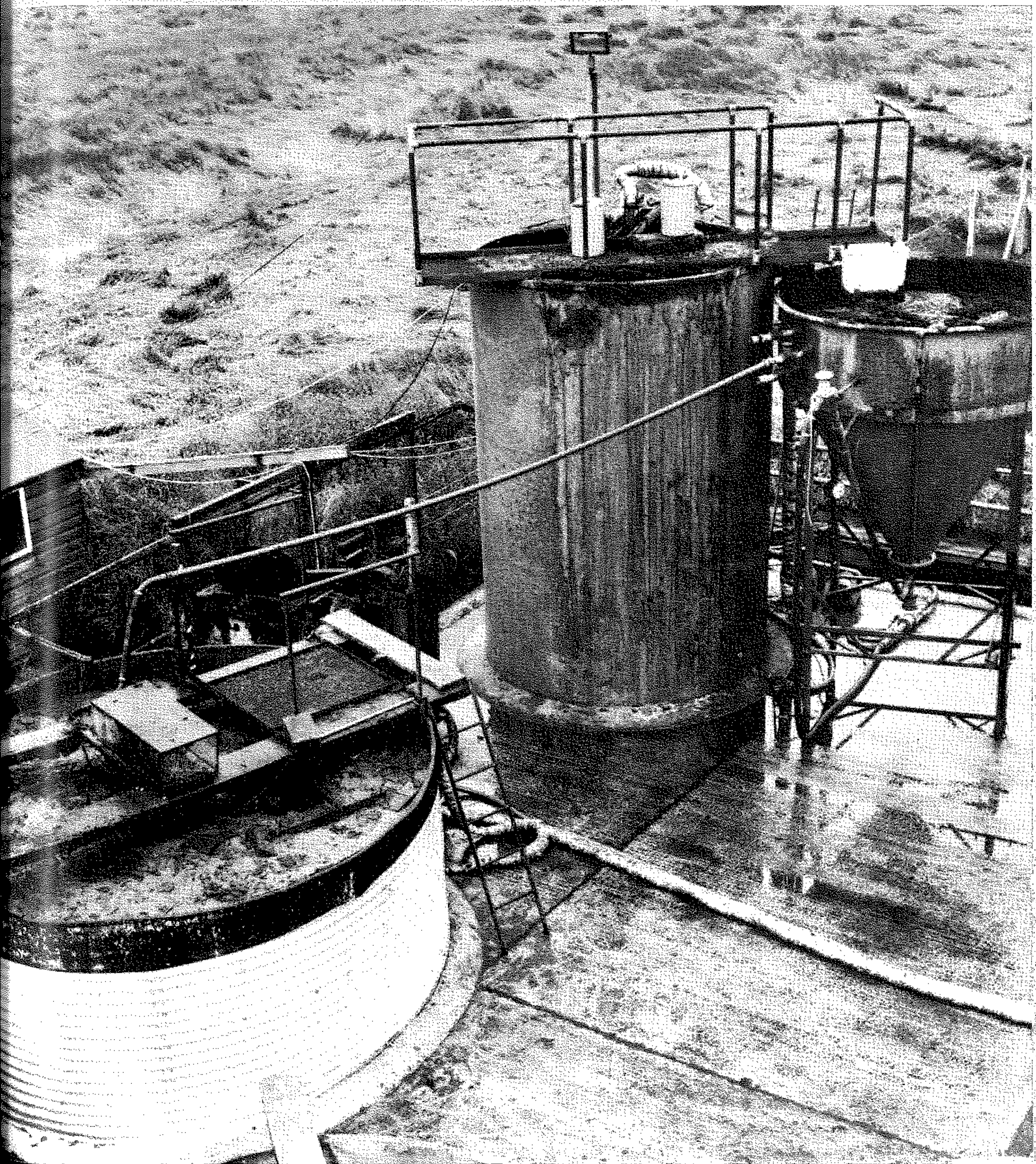

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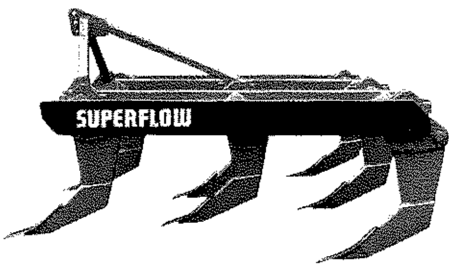

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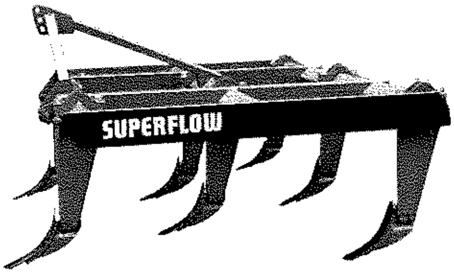

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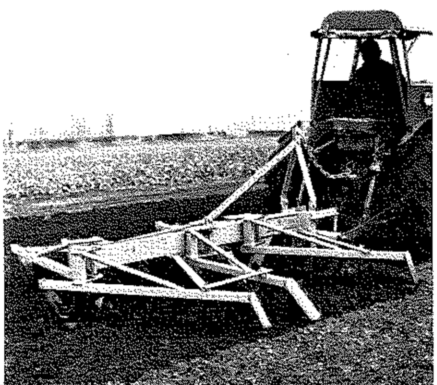

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Front Cover: Experimental slurry treatment plant at *NIAE* *(photo courtesy NIAE)*.

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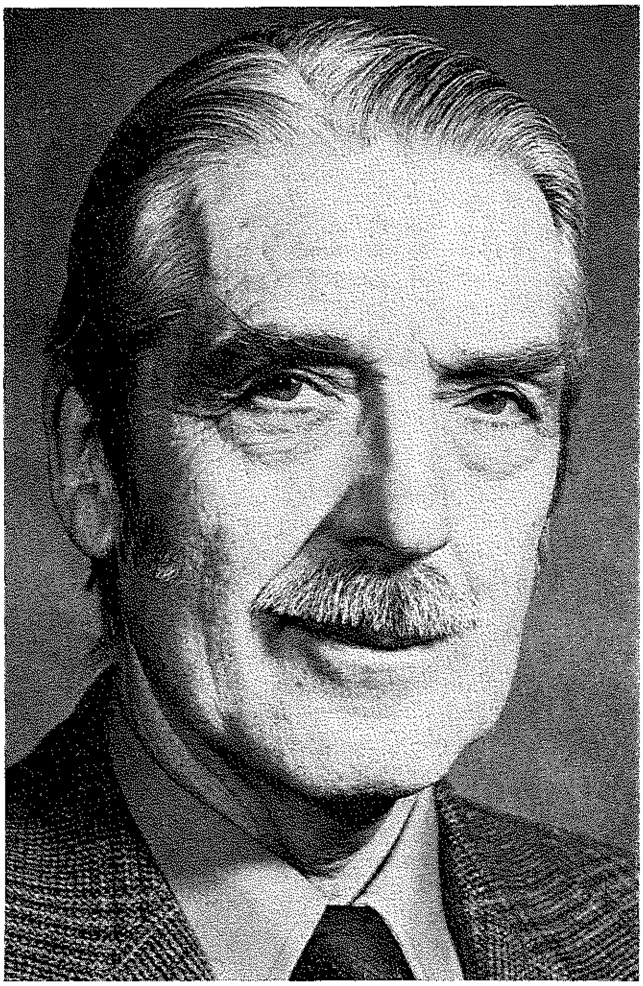

The Handling, Treatment and Disposal of Farm Waste

by J. C. Hawkins

MR A. J. DAVIES, in his introduction as Chairman of the opening session of the Annual Conference, said that farm waste covered a range of materials including animal and vegetable processing wastes, agricultural chemicals and solid rubbish as well as animal manures. The problems of dealing with all these would increase in the future as more animals were kept on less land, legislation against pollution of the environment was increased and the environmental lobby became stronger. Farm waste problems, however, must not be considered in isolation: they should be taken into account at the planning stage of any new enterprise. Too often the Advisory Service was consulted about waste disposal when the owner was already committed. In recent years, the Agricultural Research and Advisory Services had turned their attention more to dealing with farm wastes and the substantial amount of additional money provided for the work was now beginning to show results.

Dr K. L. Robinson, as Chairman of the afternoon session, opening the discussion on the four papers given during the day, emphasised that the speakers were working in a difficult field that was new and called for workers in a range of disciplines to collaborate to achieve progress. The necessary effort to bring together agricultural engineers, agriculturists, microbiologists, building specialists and others had been made by the *MAFF* and the *ARC* from 1970 to 1973 and they had provided the funds for their research. The results would normally have been published in many different journals and so not easily accessible. The *ARC* had, therefore, set up a small working party to write a bulletin on the subject in order to make the results more readily available to advisers, students and other research workers.

From the increased research effort described by both chairmen and the resulting interchange of ideas on farm wastes between research workers, advisers, farmers and manufacturers, two or three general conclusions are beginning to emerge. The first is that farm wastes are very different from domestic waste and so the equipment and techniques, developed for the handling and treatment of sewage, are not suitable. Farm wastes are about 20 times stronger, with dry matter contents of 10 per cent or more instead of the usual 0·5 per cent or so of sewage. From this situation comes the second conclusion that, in most cases, a mechanical separator is likely to be necessary in dealing with slurry. Division into a stackable solid and an easily pumped liquid makes handling easier, disposal on land safer, and is an essential part of any form of treatment. There is a pressing need for agricultural engineers to design separators suitable for farms together with a reliable method of feeding them with all types of slurry at the low rates required.

The third general conclusion is that the concept of treatment plants as a means of converting unpleasant polluting liquids into something clean and sweet, which can safely be put into a watercourse, does not apply to farm plants. Rather their purpose is to change smelly liquids and unstable solids into odourless and stable ones or to reduce the risks of transmitting disease to animals or man when slurry is put on land. An efficient farm waste treatment plant will probably produce no liquid effluent at all, only a stable de-watered sludge which can be stored with the solids from the initial slurry separation until it is convenient to put them on to land like farm yard manure.

These general conclusions suggest what the farming industry is likely to be wanting from the agricultural engineering industry in the future as legislation and pressure from the environment lobby make it necessary for farmers to take more precautions against polluting the environment. The need will be for a matched set of equipment from which it is possible to select the items required to meet any given farm situation. A dairy farmer with plenty of land away from houses may need simply a slurry separator to go with a small pump, 1½ inch bore plastics pipe and sprinklers to apply the liquid fraction to land and will use existing equipment or a contractor to deal with the solids when convenient.

If a farm is near a village or town or has houses nearby, smell may be a nuisance: so, in addition to the separator, pump, pipes and sprinklers, a simple form of treatment plant will be required to deal with the soluble *BOD* and produce a liquid which does not smell. For a pig or poultry unit with little or no land, a separator, a treatment plant and a sludge de-watering stage will be needed. This complete set of equipment, which will reduce slurry to a solid which can be stacked for storage, should be the target for agricultural engineers working in this field.

**Mr J. C. Hawkins has been with the NIAE for over 30 years and involved in all aspects of its work. He has specialised in research on ploughing and cultivations and on root and vegetable harvesting. He was awarded the RASE Research Medal in 1969. Mr Hawkins has been Head of the Farm Buildings Department since 1968.*

APPLICATION OF FARM SLURRIES TO AGRICULTURAL LAND*

by K. A. Pollock†

Introduction

Characterisation

THE expression "farm slurries" might reasonably be considered by the layman an imprecise term, but this is not inappropriate to the material, as it accurately reflects the attitude adopted by most farmers. In considering the application of slurries to agricultural land it is essential, however, to have a precise conception of their constituents, in order to limit harmful effects, and maximise possible benefits.

The fundamental material is faeces and urine from one or more classes of farm livestock. To this is added a variable quantity of water, which may be intentional dilution to facilitate handling, essential washing down water, or accidental supplementation from drinkers and rainfall. Many handling problems arise from sundry contaminants, in the form of feed, (grain or silage) bedding (straw or sawdust) and sundry large items (bricks, cans etc) which are reputedly inevitable additions. Should the availability of bedding at reasonable cost make its use feasible, the resulting farmyard manure poses few problems in storage or spreading, as the loading rates adopted are generally too low to cause damage or pollution.

Quantification of the effluent output of farm livestock has proven possible with some accuracy, providing one is measuring the undiluted, uncontaminated material (table 1).

Table 1 Quantity of Manure Produced by Farm Livestock (*after O'Callaghan et al 1973*)

Animal	Manure produced Per day kg	gallons	Per year kg	gallons	Manure produced from housed livestock m. gallons
Pig, fattening	4·54	1·0	1,660	365	2,300
Poultry, 100 layers	12·4	2·7	4,550	1,000	1,330
Cattle, cows	32·0	7·0	11,700	2,570	9,000

Note: Housed livestock includes all types of enterprise cattle housed for 5 months per year.

The volumes indicate the large scale storage and handling facilities required for an average enterprise and emphasise the need to avoid unnecessary dilution with wash water or rainfall. Quality is of significance (table 2) even where the land is to be used for disposal, the important measures being solids content. *NPK* levels, mineral and antibiotic supplements, and organic load measured by *BOD* and *COD*. These latter measures estimate the quantity of oxygen required to breakdown the organic matter, and render it stable in air or water.

The term slurry refers, of course, to the consistency of the material being applicable in the range 6 - 25 per cent solids and this is of importance for storage and handling.

Without dilution water, most wastes will not separate substantially in storage, although a hard crust may dry out on top. As dilution increases, separation takes place more readily, and the solids may either sink or partially float on the surface. Where the use of two handling systems is acceptable, this natural separation may be an advantage, but if the material is to be handled as a slurry, agitation of some nature is often required to achieve a degree of homogeneity.

Alternatives to Land Spreading

One may develop a strong preference for land disposal where possible by examining the major alternatives (fig 1) all of which are in present use or under investigation. Leaving aside the blatantly illegal possibilities, the use of local authority sewerage and treatment is only superficially attractive. The polluting concentration of waste encountered in agricultural practice may easily be one hundred times that of domestic sewage, resulting in very high treatment charges, which are based on the rates applicable to other trade wastes. Costs may be reduced to some degree by partial treatment on the farm, with only the impure, liquid phase being discharged to the sewer.

The next obvious alternative is to build a simplified domestic sewage plant on the farm itself, and treat the waste to a standard acceptable for river discharge. Despite extensive research, this can still be considered a very costly approach. Partial treatment is possible, with a liquid and a solid for separate land spreading, or alternatively, a liquid for spreading and a solid material which may be carted off the farm. Both schemes involve some complexity and generally high cost. Poultry manure, being of high solids content, invites high temperature drying, with the product being saleable to recoup some of the running costs. Incineration also involves high costs, but without a solid product of significant manurial value, and can thus be discounted in most cases.

Table 2 Quality of Manure Produced by Farm Livestock (*After O'Callaghan et al 1973*)

	Dry matter per cent	BOD mg/l	Total N per cent	Total N kg	Total P per cent	Total P kg	Total K per cent	Total K kg
Pig, fattening	9·5	21,500	0·63	10·5	0·16	2·7	0·19	3·2
Poultry, 100 layers	23·0	41,700	1·5	68	0·55	25·1	0·41	18·7
Cattle, cows	11·1	15,000	0·51	60	0·06	7·3	0·47	55

Land Spreading Basic Principles

The farmer is left with the traditional alternative of land spreading, in which his primary objective is disposal at minimum cost. It is becoming realised, however, that there are constraints which limit the technique, if it is to be regarded as a long term solution, resulting in no net environmental deterioration. These constraints concern crop, animal and soil damage, and air and water pollution.

To compensate for this restriction, the slurry has manurial value, due to its *N*, *P* and *K* content, as well as the less easily defined benefit of soil structural improvement. Within this framework, it is possible to build a spreading policy, which may be regarded as safe, cheap and of minimal nuisance to the farmer and general public.

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* *Presented at the Annual Conference of the Institution of Agricultural Engineers, held at The Institution of Mechanical Engineers, London SW1, on 8 May 1973.*

† *Department of Agricultural Engineering, The University of Newcastle upon Tyne.*

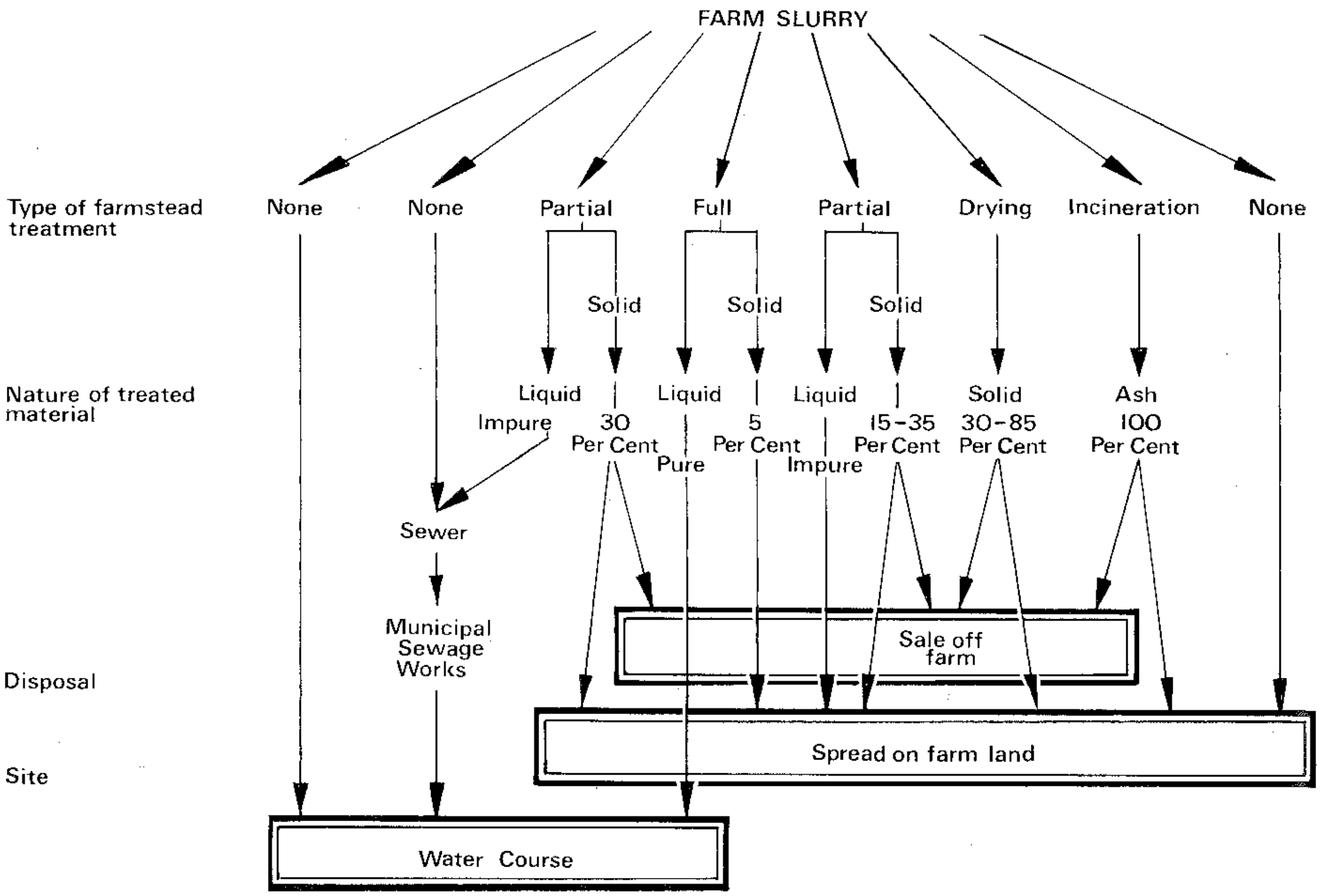

Fig 1 Alternative disposal methods for farm slurries.

Constraints on Land Spreading of Slurry

The constraints placed upon land spreading of slurry may be usefully viewed from the standpoint of the farmer. He is primarily concerned with three questions: Where can one spread? When can one spread? How much can one spread? The constraints effectively answer each of these questions in turn.

Trafficability

Should one intend to use a slurry tanker for spreading, it is obviously essential that it should be possible to move over the land without becoming immobilised through sinkage. Most farmers would consider that before this constraint applied, unacceptable crop damage was being inflicted.

Crop Damage

Visual inspection will probably prevent too great damage of crops by tractors and spreaders. Of greater interest and of significance also with organic irrigation, is the subsequent damage to the growing crop, shown by plant kill or poor yields. Work in progress at Trawscoed, Bridgets and Great House *EHFs*, and at the *NIRD*[2,3,4,5] shares a common concern with the crop damage due to heavy winter dressings of pig and cow slurry. As a tentative summary of the current indications, levels up to 2440 tonnes/ha have been used, with various effects ranging from complete kill of the sward due to physical smothering, to response in subsequent years, showing valuable, if inefficient, utilisation of the manurial value. To avoid excessive runoff and prevent serious sward kill, it would appear that a limit of around 12·5 mm depth of slurry (equivalent to 125 tonnes/ha) per spreading should be set, with a total winter application of 1000 tonnes/ha for grass being a generous upper limit. Greater applications could be countenanced if the sacrifice of the crop to facilitate disposal was acceptable. Further complications may, however, be associated with this and other techniques involving high application rates, some being associated with animal health.

Animal Health

Concern about animal health usually stems the spread of pathogens in slurry, where this is not adequately prevented by palatability restriction as encountered in grazed areas. The figure of six weeks normally quoted may be regarded as a combination of grazing acceptability and a tolerable level of risk from pathogens. The fact that Johne's disease *mycobacterium* has been found to survive for 249 days on pasture, does not mean that this should be the minimum rest period after spreading[6], while recently reported work at the Institute for Research on Animal Diseases indicated no evidence of infection if grazing were delayed for one week after spreading[7].

Animals are also at risk, however, from high levels of nitrogen and potassium in herbage, either grazed or conserved, and this may result from heavy slurry spreading. Applications of bagged *N* beyond 500 kg/ha result in increased storage of nitrogen as nitrate, which is lethal to 50 per cent of exposed animals at levels in excess of 0·6 per cent[8]. Raymond and Spedding[9] concluded that nitrate poisoning would not be a significant danger where nitrogen is applied to the limit of economic response, which is 450 - 500 kg/ha a[10]. When disposal is the chief aim of slurry spreading, levels well in excess of this may occur, with a maximum of 3150 kg/ha being reported in an experiment at Bridgets *EHF*. Under these circumstances, toxic nitrate levels are to be expected in subsequent crops.

The risk to farm animals from excessive ingestion of potassium is well known. Levels over 1·6 per cent in herbage dry matter give no yield benefit, but may reduce magnesium availability, resulting in hypomagnesaemia[11]. Following application of pig slurry to grassland during the summer of 1972, in a field trial conducted by *ADAS* and Newcastle

University, a maximum of 3·83 per cent *K* was detected in regrowth, although the control level was between 2·60 and 3·00 per cent. McAlister[12] has reported similarly high levels of *K* following slurry application and these were associated with sward kill in the winter and early spring.

A further threat to animal health arises from the use of copper in pig diets. The application of slurry contaminated with copper may result in high levels in herbage. Smith[13] has reported levels in excess of 20 ppm copper in grass, when there was no prophylactic use of copper in the diet. Continued ingestion of such concentrations by young lambs could be dangerous.

Soil Damage

It may be said that the influence of slurry on soil is only of significance inasmuch as the changes brought about may affect current or subsequent crop growth. In consequence, the soil my be considered as a complex of inorganic and organic matter including living fauna and micro-organisms, which provides a suitable medium for root growth and plant anchorage. Recent work undertaken by the *NIRD* and Reading University has confirmed the commonly held belief that a layer of slurry may restrict soil aeration, to the extent that accumulation of products of incomplete oxidation, such as methane and ethylene, may account for sward kill. Such accumulation is accompanied by low oxygen and high carbon dioxide conditions, and may also be associated with breakdown of soil aggregates, thus affecting aeration in the longer term. A similar structural degradation may result from the heavy dressings of large droplets associated with organic irrigation rain guns. Short term saturation may result in kill of worms with deleterious effects, but total aerobic bacteria counts in the Reading work were found to increase in response to the extra food source from slurry[5]. A related phenomenon has been reported by McAlister[12]. Successive application of slurry makes it unnecessary for grasses to root deeply to find adequate water supplies and McAlister reports grass being uprooted during grazing, although this effect is also correlated with the high *K* concentrations mentioned earlier.

Ideally, these soil problems could be partially overcome by immediate incorporation into the soil, as is mandatory in Sweden. This would obviously restrict the use of grassland for disposal unless the slurry is deposited under the sward as may be achieved with some continental and American equipment. Severence or roots and smearing of soil are problems as yet to be solved with these techniques.

Air Pollution

The Swedish regulations are designed to overcome two problems which may be regarded as air pollution, and which are often treated lightly by farmers. The first is that of fly infestation, which may be annoying or even a health hazard if near human habitation, but is inherent in the use of land spreading at certain times of the year. The second concerns the more readily recognised nuisance of odour. The conscientious farmer will seek to minimise this aggravation by avoiding fields close to human habitation, avoiding days when the wind is likely to carry odour toward dwellings, and minimising the number of days on which nuisance may occur. Such general principles are likely to pertain for some time, as the sort of predictive modelling based on weather data investigated by Nordstedt and Taiganides[14] requires the evaluation of numerous coefficients relating to odour release.

Such principles may not always eliminate nuisance, and in those cases some pre-treatment may be necessary. Aerobic schemes will be mentioned in later papers, while commercial deodorisers and masking agents are also available at a cost which encourages sparing use. In such situations, it is probably wise to eschew the "little and often" principle, settling rather for a major spreading programme of short duration, perhaps two or three times a year.

Water Pollution

There exists a further constraint upon land spreading of slurry, usually least considered by the farmer, but often imposing the greatest limitation upon the permissible spreading rate (fig 2). The dumping of slurries directly into surface water courses and water bearing strata is illegal, but initial placement upon land does not necessarily prevent illegal contamination of water. Leaving aside direct overflow from areas around the farmstead, slurry may run off the surface of agricultural land, if the latter is saturated and/or sloping. Also, subsequent rainfall may wash off slurry otherwise considered safely adhering to the soil or crop.

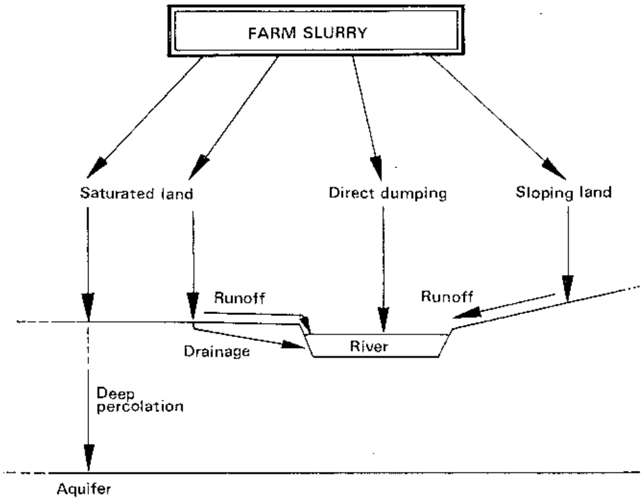

Fig 2 Methods of slurry disposal rendered unsuitable by the possibility of illegal water pollution.

Slurry draining through the soil to water courses and aquifers may also not be sufficiently purified to prevent pollution, and the cause is similar to that arising from surface runoff. The Royal Commission advisory standard is 20 mg/l for *BOD* and 30 mg/l for suspended solids, and these values are commonly applied by river authorities. Bearing in mind the very high contaminant load in raw slurry, it is clear that a high efficiency of purification is required from the filtering and biological breakdown mechanisms occurring in the soil.

Nitrogen and phosphorus present a different threat to water quality, in that, rather than killing plant and animal life through immediate deaeration, they are associated with stimulation of plant and algal growth. The resultant phenomenon of eutrophication may bring about the same end result, as the algal blooms or excessive weed growth can eventually deplete the dissolved oxygen to the extent of self-destruction. Such a problem is generally associated with long retention times as found in lakes such as Lake Erie or those of Ireland[15]. While conclusive evidence of the precise stimulation of algal blooms is lacking, eutrophication has been linked with runoff of agricultural slurries in a number of locations.

A Policy for Land Spreading

Against this background of limitations, one may now construct a positive policy for land spreading of farm slurries. This will be concerned with answering the three basic questions of where(?), when (?), and how much(?), bearing in mind the three significant slurry constituents of (a) organic material (b) chemical nutrient elements and (c) water.

Where May Slurry be Spread?

Three areas may be identified as unsuitable for land spreading. Firstly, sloping ground presents the serious hazard of surface runoff on application or after subsequent rainfall, resulting in high *BOD* organic matter and chemical nutrients causing water pollution.

Secondly, certain soil types are particularly susceptible to de-aggregation following the temporary saturation involved in heavy slurry spreading, and are thus unsuitable for land disposal.

Thirdly, areas of poor grazing, or paddocks close to the animal houses are sometimes treated as sacrifice areas, from which no crop is expected. Under such circumstances, organic matter may be adequately stabilised, but all the chemical nutrients may not be fixed. During subsequent periods of saturation, the excess chemicals, plus other amounts released during vegetative breakdown will be leached into the groundwater and drains. Alternatively, the high levels remaining may result in toxic concentrations in subsequent crops.

When May Slurry be Spread?

The overriding consideration limiting the times at which slurry may be spread is that the organic and chemical constituents likely to cause pollution should be immobilised. This means that the translocating medium, water, present initially in the soil or slurry should be insufficient to cause saturation and hence runoff or drainage. Loss of water by evapotranspiration will successfully leave the organic matter to be broken down and the chemicals to be absorbed by the roots.

This requires spreading of slurry in the growing season, generally limited to the summer six months, during which time a soil moisture deficit will normally exist. The spreading programme may effectively reduce the average deficit, but should be arranged to avoid any period of saturation.

How Much Slurry May be Spread?

Given these timing and locational constraints, one may now estimate the permissible level of spreading. For the organic load, it is difficult to estimate rates of soil microbial breakdown, and the maximum load is best estimated on the basis of avoiding physical smothering and deaeration. Results from the Newcastle University trial would indicate that 12·5 mm slurry spread on a thick sward after cutting for silage can be tolerated two to three times in a dry summer, with only minor setbacks. Heavier loads per spreading could well be detrimental.

Turning to chemical nutrients, a long term spreading policy would require no accumulation over a period of years, and hence the principle that only as much chemical should be applied as can be removed in the crop during that season. Given that only two-thirds of the nitrogen in slurry is available to crops in the first season[16], then a limit of 500 kg/ha of available *N* should be set. In most cases this will result in satisfactory *K* dressings and only minor accumulation of *P*[1].

The limits to hydraulic loading during the summer period may be calculated using a modified Penman method for evapotranspiration and historical rainfall[17]. Results for three widely different locations give an appreciation of the influence of level and variability of rainfall (table 3). The large variation in average level, as shown by the standard deviation, would indicate that facilities should be designed on an average rather than "worst case" year, to avoid overcapitalisation. Emergency measures to avoid pollution in wet years would probably prove a cheaper alternative.

The Possibility of Winter Spreading

It is clear that prohibition of winter spreading would be very unwelcome, and that not all winter rainfall results in leaching. It would thus appear possible to spread some slurry in the winter, using the evaporative capacity of the winter sun and wind. Ideally this could be so, but in the light of earlier analysis, three problems remain.

The first is associated with rainfall which on balance greatly exceeds potential transpiration during the winter period (table 4)[18]. In consequence the average maximum

Table 3 **Maximum Permissible Hydraulic Loading Rates on to a Sacrifice Area in Three Locations**

Year	*Durham (Durham City)* l/ha x10⁻³	*Essex (Vanges Reservoir)* l/ha x10⁻³	*Cardigan (Gwyddffynon)* l/ha x10⁻³
1	278	418	325
2	580	511	302
3	348	302	139
4	395	511	372
5	348	418	232
6	487	465	302
7	372	488	209
8	372	418	139
9	232	465	186
10	441	395	139
11	255	372	186
12	232	418	186
13	255	232	186
14	348	511	162
15	325	465	162
Mean	352	426	215
SD	98	77	75

Table 4 **Average Total Winter Rainfall and Potential Transpiration**

	Durham	*Essex*	*Cardigan*
Rainfall	470	201	862
Potential transpiration	60	71	72
Excess rainfall	410	130	790
Saturation deficit	20·6	21·2	16·1

Note: Values relevant to average county height below 1,000 ft
averages for winter six months
all values in millimetres

saturation deficit is very small, and not easy to utilise. If one could predict long dry spells, then spreading could go ahead to safely dispose of the liquid.

The two other problems remain, namely that low temperatures in the winter will mean much slower stabilisation of organic matter, and similarly very slow or non-existent, uptake of nutrients by the generally dormant crop.

In consequence, the two major pollutants will be mobile when subsequent rainfall saturates the land. A further difficulty which has commanded the attention of North American farmers is concerned with periods when the ground is frozen. No spreading should then take place, because of runoff dangers, and during this period storage will be necessary in any case.

Can Separation Ameliorate the Situation?

Separation techniques have been widely investigated with the intention of simplifying aerobic treatment, and it has been suggested as a pretreatment before land spreading. The solid material may be stable in air, without odour, and easily stacked, before spreading with conventional equipment. The liquor, produced daily, is intended for spreading through small bore irrigation pipes. The efficacy of the technique is based on the ease of immediate liquor disposal all through the year. In the light of the previous discussion, daily spreading could be accepted if the material itself constituted no pollution threat. It is clear, however, that the water pollution mentioned above results more from the soluble organic matter and chemical nutrients than from the suspended particulate matter removed in separation. Hence, the liquor contains a high *BOD* and much of the soluble *N*. Some of each may be absorbed by the soil, but both are liable to washing out by subsequent rainfall.

To avoid periods of frozen ground, one must provide temporary storage for perhaps four to six weeks to add to the separation equipment, and two sets of handling machinery for the liquid and solid. In many cases, it may be preferable to settle for long term storage and summer disposal by tankers. The latter are generally less liable to atomisation of the slurry liquor, and hence the nuisance of wind drift associated with rain guns and irrigation sprinklers.

The principle is not absolute, depending as it does upon concentration of pollution and hence rate of spreading. In the Newcastle trial, some highly contaminated material was collected in the drains immediately after spreading, but this was normally washed out within 24 hours. In an Irish trial[19], pollution resulted from rainfall two to three weeks after slurry spreading. It might be possible to spread at a rate low enough to make pollution insignificant, but this would probably prove uneconomical, through the high labour and capital required.

Table 5

Cash Value of Animal Manure
(after O'Callaghan et al. (1971)

	Manure produce per season	*Available nutrient content in season's output of manure*			*Total cash value of manure*
		N	*P*	*K*	
	kg	*kg*	*kg*	*kg*	*£*
Pig	1660	3·8 - 8·64	0·76 - 2·27	2·86 - 3·86	0·6 - 1·3
100 Poultry layers	4550	44·9 - 70·9	11·3 - 19·5	18·6 - 43·1	6·7 - 11·4
Cattle	4880	18·4 - 32·9	2·22 - 2·36	8·5 - 38	2·4 - 3·4

1971 prices: 1 lb N £0·04: 1 lb P £0·076: 1 lb K £0·02.

Fertiliser Benefit From Slurry

It is worth contrasting the positive benefits from slurry application in winter and summer. Winter spreading tends to take on the character of disposal with minimum damage, whereas summer spreading on to a growing crop may be viewed as a fertiliser treatment. Figures have been published (table 5)[17], that indicate a worthwhile return from animal slurries, even taking account of the low utilisation rates.

Inasmuch as one ton of inorganic fertiliser requires six tons of coal equivalent in its manufacture, the price of this large item of farm expenditure is very closely linked to the cost of energy. The expected rise in the latter in the near future could make the re-use of organic fertiliser on the farm a more attractive economic proposition.

Conclusions

The foregoing discussion leads to a general basis for land spreading, which enables it to become a productive and beneficial part of the farming cycle.

1. Avoid unnecessary dilution and contamination, so that handling may be simplified, and manurial content predicted.
2. Avoid spreading on to sloping or saturated land to minimise water pollution.
3. Avoid spreading on to unstable soil, or with large droplets which may damage soil structure.
4. Avoid spreading odorous slurry frequently, or with an atomising jet or under windy conditions, wherever smell nuisance may arise.
5. Restrict spreading to the growing season, when the soil is generally unsaturated, and restrict spreading rate to leave the soil unsaturated.
6. Restrict spreading rates to a maximum of 12·5 mm/dressing, to avoid a solid mat accumulating on the surface.
7. Restrict spreading rate, so as to utilise all the available nutrients, in the season of application,

Following these principles should result in safe and cheap disposal which may be continued indefinitely without fear of agricultural or environmental deterioration.

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Principles of Treatment of Animal Slurries*

by S. Baines, M. R. Evans, R. Hissett† and R. Q. Hepherd††

Introduction

THE traditional methods of rearing animals for the production of meat, milk and eggs allows for the natural distribution of the fresh excreta from the animals on grazing land for part of the year. The material voided during the periods when the animals are housed is collected with bedding, usually straw, wood shavings or sawdust and composted over several months to form farmyard manure. The manure is then spread on land, either grassland or arable land for its fertiliser and soil conditioning value. The organic matter present is degraded by the soil microflora providing plant nutrients and other innocuous inorganic metabolites. The soil also acts as a physical and biological filter and thus drainage water discharged to water courses does not give rise to pollution. Organic pollution can occur if liquid wastes such as urine, wash waters and drainage from the composting manure are discharged directly to water courses.

The techniques of storage, transport and distribution of farmyard manure are relatively straightforward because of the high dry matter content. The storage period is essential for microbial breakdown of carbohydrate—present in the bedding materials—to reduce the carbon/nitrogen ratio, thus avoiding microbial utilisation of nitrogen in competition with crops, when the manure is applied to land. During composting the intense microbial activity causes heating and this together with the long storage period results in the virtual eliminatiion of pathogenic micro-organisms.

The system therefore provides a means of complete recycling of animal excreta, normally on the farm where it is produced with little risk to animal or human health or of social nuisance.

Economic pressures have led to increasing intensification of livestock production. The number of animals, and therefore the quantity of excreta, per hectare is increased and because of the shortage and/or cost of straw the use of bedding materials is reduced or eliminated. The material to be dealt with consists of excreta with varying amounts of added water and has come to be known as slurry. Developments in animal housing allow the slurry to be collected by scraping from solid floors or in channels under slatted floors. The animals are provided with a clean, non-bedded area in cubicles, pens or battery hen cages.

Most of the problems concerned with slurry arise from attempts to deal with it in much the same way as farmyard manure. Obviously the solids content is much reduced and slurry cannot be stored in heaps; it is normally pumped as a liquid and applied to land either by tanker or through pipelines and rain guns. Because of intensification there is a reduction in the area of land available, particularly in pig and poultry enterprises. Pigs and poultry are housed all the year round and a combination of less land and longer housing periods tends towards a greater frequency of application. This creates difficulties in accessibility with tractors and tankers and in the addition of large volumes of liquid to ground that may be already wet. In almost all instances slurry is therefore subjected to storage in tanks or in under-slat channels for periods varying from two or three weeks to several months. The conditions of storage rapidly become and remain anaerobic. Unlike the beneficial storage of farmyard manure during composting, the changes which take place are undesirable. Such storage is uncontrolled anaerobic treatment. Anaerobic microbial degradation progresses slowly giving rise to metabolites which are objectionable in odour and which become extremely evident when the stored slurry is disturbed during pumping and spreading. Noxious gases may be produced and cases of the asphyxiation of pigs, housed on slats over slurry, have been reported.

Pathogens have been shown to survive for long periods in stored slurry and therefore give rise to animal and public health risk when discharged to land. Grazing animals are at risk due to contamination of the herbage and pathogens can be transmitted through the land drainage system to water courses within a very short time of the application of slurry. The methods of application either from tankers or through rain guns produce aerosol conditions which may promote the atmospheric dissemination of pathogens.

Much of the organic polluting material (*BOD*) is in solution in slurry and this may cause pollution of water courses by rapid transmission through land drains following application. In extreme conditions, surface run-off may give rise to gross pollution. The degree of pollution depends on rate and frequency of application, flow rate of drainage water, soil type and topography of the area.

It would appear therefore that reliance on the natural microbial processes in the soil to eliminate the risk of pollution is not justified in all cases when attempting to deal with slurry.

The general public awareness of the need to control environmental pollution together with a greater degree of legislative control over the discharge of agricultural effluents has pointed the need to investigate and develop efficient systems for treating slurry in such a way as to minimise social nuisance, pollution of water courses, and the risks to animal and human health. The constraints inherent in any such system include a regard for the cost and technical difficulties of installation, operation and maintenance. The most efficient systems are therefore likely to be those which include the largest element of conservation of the valuable components of slurry and result in the production of materials which can be utilised.

In short, the term waste disposal is ill-chosen since slurry should not be regarded as waste and its disposal, as opposed to its utilisation in whole or in part, should be regarded as at least partial failure.

The evaluation of treatment systems to meet the objectives defined presents a challenging and a unique opportunity. Although the problem has similarities with the urbanisation and industrialisation of the human population which led to the development of sewerage and sewage treatment technology, there remains the important difference that slurry, when compared with sewage, consists

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largely of animal excreta with little added water and few toxic materials. It is not surprising that attempts to utilise domestic sewage treatment systems, in simplified form because of the need to reduce costs and the requirement for operational technology, meet with little success. The dilution of slurry to the strength of domestic sewage would create a demand on water resources so great as to increase rather than alleviate pollution problems. The requirement is for a system which condenses in space and time the natural microbial processes that take place in soil and may be regarded as intensive microbial husbandry in controlled environments. Such an approach emphasises the need for a productive rather than a purely destructive process.

The Characteristics of Slurry

The amount and composition of slurry varies according to species of animal, age, physiological state eg gestation and lactation, diet (including consumption of water) and amount of added water.

The figures available cover a very wide range (table 1) and in most cases the absence of details of housing, added water, diet etc, make it impossible to use them for design purposes.

Table 1 Slurry Production, Dry Matter Content and BOD5

Type of slurry	*Daily production per animal.1*	*Dry matter* $g\ l^{-1}$	*BOD5* $g\ l^{-1}$
Dairy cattle	35 - 55	85	16
Beef cattle	6·5 - 17	50 - 140	10 - 30
Pigs	4 - 25	25 - 140	8 - 40
Poultry	0·1 - 0·22	100 - 350	50 - 70

Physical and Biochemical Characteristics

Since it is apparent that slurry is a complex mixture both physically and biochemically, it is desirable to obtain an apportionment of the *BOD* and dry matter in different components. The experiments at the West of Scotland Agricultural College are based on the following four components:—

(1) Coarse solids — material retained by a 0·2 mm mesh

(2) Fine solids — material sedimented by centrifugation for 20 min at 9,000 g

(3) Colloids — materials retained on an ultra-filtration membrane with a nominal cut-off at a molecular weight of 30,000

(4) Solutes — material passing the ultra-filtration membrane in (3)

The percentage dry matter and BOD_5 in each fraction are given in table 2. The three kinds of slurry each have almost

Table 2 Percentage Dry Matter and BOD of Fractions of Slurries

Type of slurry	*Coarse solids*	*Fine solids*	*Colloids*	*Solutes*
	Percentage dry matter			
Pig	46	37	6	11
Beef cattle	49	25	10	16
Poultry	46	34	5	15
	Percentage BOD_5			
Pig	13	52	7	28
Poultry	17	50	8	25

50 per cent of the total dry matter content in the coarse solid fraction which contains 13 - 17 per cent of the BOD_5. About half the BOD_5 is contained in the fine solids fraction constituting 25 - 37 per cent of the total dry matter. The solutes contain 11 - 16 per cent of the dry matter but the proportion of BOD_5 is 25 - 28 per cent.

Biological Treatment

Although wide variations exist, the treatment system must deal with a relatively high solid content and a high *BOD*. Biological systems are considered more suitable for recycling purposes, minimising the possibilities of added toxic chemical residues entailed in chemical treatment. Physical treatment cannot meet all the objectives and is primarily concerned with disposal such as incineration or dumping.

Biological treatment depends on the controlled growth and activity of micro-organisms, chiefly bacteria which may be expressed in the following simplified equations.

$$\text{Organic matter} + O_2 \xrightarrow[\text{Bacteria}]{\text{Aerobic}} \underset{+++}{\text{Bacterial mass}} + CO_2 + H_2O + NO_3^-$$

$$\text{Organic matter} \xrightarrow[\text{Fermentative bacteria}]{\text{Anaerobic}} \underset{++}{\text{Bacterial mass}} + CH_4 + CO_2 + NH_4^+ + \text{oxidisable organic matter}$$

$$\text{Organic matter} + \text{Nitrate} \xrightarrow[\text{Denitrifying bacteria}]{\text{Anaerobic}} \underset{+}{\text{Bacterial mass}} + \text{gaseous nitrogen}$$

The rate and nature of the reactions depend on oxygen, available substrate, temperature, pH value and toxic materials. Any one of these factors may become limiting and result in (a) termination, (b) change in the rate, or (c) change in the nature of the reaction.

Oxygen Limitation

When oxygen is non-limiting the reaction will be aerobic. If, in a nitrifying aerobic system, oxygen becomes limiting then anaerobic respiration resulting in denitrification will occur as a temporary phase. Continual oxygen limitation will result in anaerobic fermentations.

Substrate Limitation

Substrate limitation can arise from the absence or exhaustion of components essential for the continued metabolism of constituent micro-organisms in the mixed flora.

Temperature — In general, microbial activity will increase up to the optimum growth temperature of the dominant organisms which themselves will vary according to the prevailing temperature. Extremes of temperature would inhibit activity.

pH value — Changes in pH value arise from microbial activity and will have a selective effect on constituent members of the mixed flora. Excessive production of acid or alkali may result in feedback inhibition of microbial metabolism.

Toxic materials — Toxic materials, which may be present originally or produced as metabolites, will inhibit or reduce microbial activity.

The composition and activity of the microflora and consequently the nature of the end products will therefore vary according to the conditions under which a biological treatment system is operated.

A stable system, in which a state of equilibrium exists can only be achieved in a continuous rather than a batch system. In the latter, different factors become limiting in turn resulting in sequential changes in substrates, dominant microbial species and end-products of metabolism including toxic metabolites. The operating conditions must therefore be controlled to give the end-products which are determined by the original objectives of treatment. These objectives, which should be regarded as short term or intermediate with respect to the ultimate objectives of recovery and recycling of utilisable components, may be stated as follows:—

1. removal of smell
2. reduction of water pollution risks
3. reduction of risk of transmission of animal and human disease
4. ease of handling.

Anaerobic fermentation under controlled conditions and at an elevated temperatrue (30°) will bring about the degradation of slurries with up to 50 per cent net reduction in suspended solids over a period of about 28 days. Methane is produced and forms a utilisable end-product. The residual sludge is relatively inert, odour-free and may have manurial value. The liquid phase of the digested material remains high in *BOD*, has an unpleasant smell and requires further (aerobic) treatment to remove these undesirable characteristics. This process as applied to slurry from pigs is being investigated by Hobson and his co-workers at the Rowett Research Institute and the North of Scotland Agricultural College.

The results discussed below arise from investigations of aerobic systems for the treatment of slurries mainly from pigs, but also from cattle and poultry, at the West of Scotland Agricultural College and the National Institute for Agricultural Engineering.

Continuous aerobic systems for the treatment of whole slurries from fattening pigs, beef cattle and battery hens have been evaluated in laboratory-scale units.

The cost of any commercial treatment unit is largely determined by the size and capacity of the aeration vessel. The capacity is determined by the rate of supply of substrate, ie loading rate, to the micro-organisms in the mixed liquor, assuming the quantity of slurry produced to be constant in a given animal-rearing enterprise. Therefore, most of these studies have been concerned with the effect of loading rate on the operation of the experimental units. Two possible approaches have been attempted.

1. The operation of the system with the suspended solids of the mixed liquor in the aeration stage controlled at 5 g/l, ie similar to that in activated sludge type systems for the treatment of domestic sewage. Because of the high solids content of slurries, maintenance of the suspended solids in the mixed liquor requires frequent desludging, by removal of mixed liquor followed by separation and return of the liquid fraction. As a result, the residence time of the liquid in the aeration stage is longer than that of the solids. In the absence of improved separation methods and/or drying methods, a residual sludge of approximately the same suspended solids content as the original slurry is the only product of the system. By contrast the treatment of domestic sewage entails a sludge return and the main product is the liquid effluent discharged to a water-course. In this case the residence time of the solids is longer than that of the liquid.

2. A system, analogous to a laboratory chemostat, in which the concentration of suspended solids in the mixed liquor is controlled largely by the concentration of suspended solids in the input slurry. The residence time of both the liquid and solid components is the same.

The capacity of the aeration vessel in the first type of system will usually be larger than in the second because of the high suspended solids concentration in animal excreta. However, because of the difficulty in supplying oxygen and obtaining oxygen transfer in thick suspension, the slurry must be diluted, or stirred at a rate which restricts flocculation of the bacteria in the mixed liquor. The latter might cause difficulties in post-aeration separation by gravity if that were desirable.

Because of difficulties of handling small volumes of slurry in the laboratory it was not possible to provide continuous loading of slurries thicker than 20 g 1^{-1} SS. One unit was operated by loading once daily with a slurry containing 50 g 1^{-1} SS. The loading rate experiments were carried out mostly at 15° and oxygen was supplied in excess. Evaporative losses from these mixed liquors were prevented.

Studies of the fractions described under Biochemical Characteristics above suggest that the *BOD* of the soluble fraction can be almost entirely removed along with complete removal of smell in a system operating with a liquid residence time of three to five days. At the high loading rates required, no net reduction of solids would take place, also the residence time of the solids, and consequently the bacteria, in the aeration vessel, will be insufficient to allow nitrification to occur.

Results and Discussion

The effect of loading rate is shown in table 3.

Soluble BOD

In laboratory-scale systems, and probably also in field-scale units, the separation of sludge from the liquid effluent is difficult, particularly at higher loading rates. Thus the concentration of suspended solids in the liquid effluent tends to increase and consequently the *COD* and *BOD*. To overcome these problems the supernatant *BOD*, measured after centrifugation of the mixed liquor, was obtained at low and high loading rates. It is apparent that at the high loading rate of cattle slurry (0·91 g SS/g MLSS.d) the soluble *BOD* (125 mg/l) is much higher than at a low loading rate of 0·10 g SS/g MLSS.d (30 mg/l *BOD*). The increase in loading rate of pig slurry from 0·17 to 1·30 was also accompanied by an increase in supernatant *BOD* from 27 mg/l to 250 mg/l.

Table 3

The Effect on Loading Rate on the Aerobic Treatment of Slurries

Type of slurry	*Type of system*	*Daily loading rate* g SS/g MLSS	g BOD/g MLSS	*Temp*	*pH*	*per cent SS*	*Output/input COD*	O_2 *consumption mg* O_2/l.d	*Supernatant* BOD_5 *mg/1*
Pig	1	0·14	0·06	15	5·3	70	64	—	—
Pig	1	0·17	0·07	15	5·9	73	—	—	27
Pig	1	0·30	0·12	15	6·8	96	54	—	70
Pig	2	0·76	0·30	15	7·0*	109	94	—	—
Pig	2	0·88	0·35	15	8·5	105	90	—	—
Pig	2	0·91	0·36	15	7·0*	102	—	—	160
Pig	2	1·30	0·52	15	7·0*	93	87	—	250
Beef cattle	1	0·10	0·03	15	5·8	73	74	252	30
Beef cattle	1	0·12	0·04	15	5·3	106	84	229	—
Beef cattle	2	0·23	0·07	15	7·9	99	86	—	—
Beef cattle	2	0·91	0·27	15	8·0	97	90	—	125
Poultry	1	0·10	0·05	15	5·7	49	39	495	—
Poultry	1	0·15	0·07	15	5·2	59	36	475	—
Poultry	2	0·34	0·17	20	7·6	67	43	—	—
Poultry	2	0·34	0·17	20	7·4	42	51	—	—

**pH controlled*

pH value

These results show that at low loading rates (<0·2 g SS/g MLSS.d) the uncontrolled operating pH ranges from 5·2 - 5·8. Nitrification also occurs in these systems and may be responsible for the low pH. As the loading rate is increased the pH rises and at rates over 0·8 g SS/g MLSS.d is over 8·0. Nitrification is absent and the high pH is probably due to the presence of ammonia. Similar results were obtained with slurry from pigs, cattle and poultry.

Net Reduction in Solids

The net reduction in solids is greatest at low loading rates (increased residence time of solid fraction). Whereas the reductions obtained in pig and cattle slurries were similar at about 25 - 30 per cent at low loading rates a much greater reduction of the order of 40 - 50 per cent was obtained in the treatment of poultry slurry. The reduction was 33 - 58 per cent when the loading rate was 0·34 g SS/g MLSS.d for poultry slurry whereas at these and higher loading rates there was no reduction of suspended solids with pig and cattle slurries.

Net Reduction in COD

Increasing loading rates caused an increase in output/input *COD* from about 60 per cent to 90 per cent in the treatment of pig slurry and 75 - 90 per cent with cattle slurry. Poultry slurry gave percentages of about 50 - 67 over the loading rate range 0·10 - 0·34 g SS/g MLSS.d. It appears therefore that the slurry from poultry is more readily degradable than that from pigs or beef cattle, a fact borne out by the greatly increased oxygen consumption figures obtained in the treatment of poultry slurry compared with those from the treatment of cattle slurry, loaded at 0·11 - 0·15 g SS/g MLSS.d.

Temperature

The probable effect of temperature is to modify the rate of metabolism of micro-organisms and since, in practice, a treatment plant is subject to seasonal fluctuations in temperature the loading rate and therefore the capacity of the plant may be determined by the lowest operating temperature. The performance of the experimental systems was therefore compared at 5°, 10° and 15° using low loading rates. Although at high loading rates it is apparent that the degree of degradation achieved is less than at lower rates, the capacity of the system is so much smaller that it is possible to consider maintaining it at a higher temperature to increase the rate of degradation. System 2 was therefore tested at 25°. The results are shown in table 4 alongside those obtained at 15° for similar loading rates.

A reduction in temperature from 15° to 10° or even 5° had little effect on the net reduction in suspended solids or in the supernatant *BOD*. Nitrification, however, was inhibited at 5° resulting in a rise in pH value in the system. It appears, therefore, that at these low loading rates the system is substrate limited, even at 5°.

In the high loading rate system an increase in temperature from 15° to 25° brought about little change in the output/input percentages of solids or *COD* but the supernatant *BOD* was reduced from 250 mg/l to 150 mg/l at loading rates over 1·30 SS/g MLSS.d. This presumably reflects a greater degree of degradation of the soluble *BOD* due to increased metabolic activity.

Toxic Materials

Copper, fed as a growth promoting substance to pigs,

Table 4

The Effect of Temperature on Aerobic Treatment of Pig Slurry

Temperature	*Type of system*	*Daily loading rate* g SS/g MLSS	g BOD_5/g MLSS	*pH*	*per cent SS*	*Output/input COD*	*Supernatant* BOD_5 *mg/1*
5	1	0·10	0·04	8·2	78	—	35
5	1	0·20	0·08	7·0*	67	—	30
10	1	0·10	0·04	6·2	71	—	30
15	1	0·17	0·07	5·9	73	54	27
15	2	0·91	0·40	7·0*	102	—	160
15	2	1·30	0·50	7·0*	93	75	250
25	2	0·77	0·30	7·0*	83	75	180
25	2	1·46	0·60	7·0*	90	90	150

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10	1	0·10	0·04	6·2	71	—	30
15	1	0·17	0·07	5·9	73	54	27
15	2	0·91	0·40	7·0*	102	—	160
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gives rise to concern because of the possibilities of long-term toxicity to crops and animals. The copper present in the faeces of pigs does not have any inhibitory effect on the microbial activity in the treatment systems described, but accumulates in a non-available form in the solid fraction. The danger arises from the slow release of available copper compounds in the soil over a long period of time and the validity of such dietary additions is therefore in question.

The relative ease with which soluble *BOD* can be removed by aeration during a limited period suggests that there may be advantages in removing, by separation, the coarser and less degradable solids before treatment. In field-scale units and under operating conditions on the farm such a process, if practical, would reduce the mechanical problems encountered for example, in the operation of pumps. Provided the separation method produced sufficient dewatering, the solid fraction could be stored in heaps, ie composted, and handled as farmyard manure for discharge to land. However, the aerobic treatment of the liquid fraction gives rise to more solids, in the form of bacterial floc and these must be removed by a second separation system if a clarified liquid effluent is the objective of the treatment. It may be possible to pump the treated liquid including the bacterial floc on to land by small-bore pipes and sprays as an alternative to the vacuum tanker or rain gun systems.

A system employing primary separation may leave sufficient soluble *BOD* in the solid fraction to promote (anaerobic) fermentation (and smell) unless the solids are sufficiently dry.

The operation of field-scale units treating whole slurry from pigs and from beef cattle has been successful using oxidation ditches where the feed into the ditch is by gravity.

At the West of Scotland Agricultural College similar results to those predicted from the laboratory-scale units have been achieved. Long-term operation has been limited largely due to the difficulty in maintaining a constant suspended solids level in the mixed liquor. Post-aeration separation can give rise to a residual solids fraction which drains readily and has little residual soluble *BOD*.

Successful operation will depend on the amount and type of fibre and extraneous solids in the slurry and primary separation may be necessary in some cases.

If treatment is to be by a biological filter then primary separation is essential to avoid frequent blockage of the filter medium. In this stage of treatment the bacteria developing to form the solid fraction during aeration are largely retained as the active filter film. Thus batch experiments can give remarkably high percentage removals of *COD* and *BOD* although in continuous operation over a period there will be a continual sloughing of excess film thereby increasing the solids concentration in the material for final discharge to land.

It is beyond the scope of this paper to consider the various methods of aeration. The choice of the method will depend on the cost of installation, operation and maintenance.

At present, any economically-viable method will only succeed in so altering the characteristics of the slurry as to make its discharge to land easier in terms of handling, in reducing the risks of pollution due to soluble *BOD*, and in removing odours. The risk of disease transmission by pathogens passing through the drainage system might be reduced by the removal of pathogens to the sludge in a flocculating system. These pathogens, if present, would still present a risk to animals grazing on land to which residual solids had been recently applied.

The biological treatment of slurries must therefore be integrated into a system of animal housing, slurry collection, treatment and handling to meet the requirements and objectives in each individual case. Factors to be taken into account include the topography and climatic conditions, in addition to the area of land and its availability for the application of the material in either the treated or untreated form.

In the immediate future, further investigations will be directed towards more profitable utilisation of the components of treated or untreated slurry alongside the development of operational systems which still require agricultural land as the final treatment stage.

Equipment and Methods for the Solid/Liquid Separation of Slurries*

R. Q. Hepherd[†] and J. C. Douglas[††]

Summary

THIS paper describes the work carried out at the *NIAE* and West of Scotland College to assess the performance of commercially-available and experimental processes or mechanisms for separating coarse solids from slurries from pigs, poultry and dairy cows, and to determine the handling and storage properties of the liquids and solids produced by them. Some preliminary experiments on the de-watering of sludges from treatment systems are also described.

Introduction

The methods of livestock housing which have developed during the last two decades in general involve the use of minimal quantities of bedding, the general theory being that manure disposal can then be an easier, cheaper, and less time-consuming operation than when using the traditional method of bedding-down with relatively large quantities of straw. The overall cost of handling animal dung and urine as farm yard manure appears to be on average about double that for slurry handling, and moreover a system based on handling as *FYM* often makes an additional demand on the limited labour available on most holdings. However, bedding-down produces a material that is fairly easy to handle and spread and is very easy and cheap to store, a considerable advantage under many conditions.

Under many farm circumstances, systems based on handling as a slurry are successful in practice for the smaller or the less intensive livestock farms. However, present-day methods of slurry handling, storage and disposal are often inadequate to overcome the management problems that are being encountered increasingly by the larger or more intensive types of holding and particularly those having having heavy rates of stocking in relation to the area of land available for manure disposal.

It appears almost inevitable that the stocking rates per unit area of land will continue to rise wherever housed livestock are a major enterprise on a holding, and therefore the waste management problems are likely to become more acute on such holdings than they are at present. Moreover, more accurate control of rates of application and dosages will be required as the quantities to be spread on given areas of land increases with stocking rate.

Problems when Using Conventional Slurry Disposal Systems

Wherever slurries are produced, the management problems that often occur when using tanker or pipeline disposal systems are usually due to one or more of the following factors:—

1) Undiluted slurries contain between about 8 and 14 per cent of dry matter, thus they often do not flow readily and are difficult to pump (except for short distances).
2) Cattle and poultry slurries in particular contain sufficient relatively coarse material (eg undigested fibre, wasted fodder and bedding, feathers, egg shells or grit) to cause stratification in tanks into layers of different density and to lead to pump or pipeline blockages.
3) In general, the capital costs of slurry storage are relatively high because some form of tank or walled compound is required. In contrast, the capital cost of farm yard manure storage is normally minimal, and also the point of storage can be changed at will and without difficulty to suit other organisational requirements.
4) It is frequently necessary to dilute the thicker slurries to render them pumpable for long distances with at least equal quantities of water. Although the provision of diluting water may not present any problems, any dilution increases the size of storage container required (or the frequency of emptying) and therefore increases overall handling costs. Additional costs for water also may be incurred.
5) It is often impracticable to run tankers on the land when it is wet or to use tankers or organic irrigation when land is cropped, and therefore long-term storage is often an essential part of existing slurry disposal systems.
6) Particularly where organic irrigation systems are used in winter, the risk of run-off to ditches or down into land drains can be high. Relatively high flow rates and rates of application (not less than 13 mm/h and usually much higher) must be used because of the large pipes or orifices required in order to pass the solids through the system even where choppers or macerators are used prior to pumping.

Objectives of a Separation Process

A separation process is a vital stage in the experimental slurry treatment processes currently under investigation on a pilot scale at the *NIAE* and the West of Scotland Agricultural College. However, it also seems probable that separation processes will ease the problems of applying untreated slurries to land.

Separation of Untreated Slurries Prior to Land Spreading

Separation of an untreated slurry can convert it into a solid and a liquid, both of which are much easier to store and to apply to land in a relatively controlled manner than the slurry from which they are derived.

An undiluted slurry contains a relatively small proportion of coarse solids: for example, in a cattle slurry containing about 10 per cent of dry matter, only about 10 per cent of this dry matter exceeds 1 mm in diameter, but about 50 to 70 per cent has a diameter of less than 75 microns. It is however the coarse fraction of a slurry that makes it a difficult material to pump, to store, and to apply to land.

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Experiments at the *NIAE* have shown that both the coarse solids and the liquids produced by suitable types of separator can be easily stored and handled, and that no dilution of the liquids is required prior to pumping to land.

Typically, a satisfactory separator will produce a moist solid that can be stacked and handled easily (in the case of cattle slurry, the dry matter content of the solid should not for this purpose be much less than 16 per cent) and also a liquid having a relatively high dry matter content (4 to 7 per cent) but very little material over 2 mm in length.

The process of coarse solid separation has made it possible to use alternative techniques and equipment experimentally for applying slurry to land, since the liquid can be pumped for long distances through relatively small bore pipes. In one experiment at the *NIAE* the liquid was pumped to four sprinklers fitted with 4·8 mm nozzles through 800 m of 38 mm pipe with an additional 30 m of 25 mm lateral pipe to each sprinkler. The pressure at the nozzles was approximately 280 kN/m^2 (40 lb/in^2) and the pressure drop between the pump and sprinklers was approximately 140 kN/m^2 (20 lb/in^2)[1]. The precipitation rate was approximately 5 mm/h (0·2 in/h), but by adding a standard time clock to control the pump, it was possible to apply at an average rate of 0·6 mm/h (by running the pump in relatively short bursts during the working day). At the sprinkler spacing used, the four sprinklers covered an area sufficient to accept the liquid slurry output from about 40 cows or 400 pigs in one day.

Since sprinkler types and numbers (and therefore application or precipitatiion rates) can be varied relatively easily to suit farm conditions, within the limits imposed by crop and soil condition, the intelligent use of sprinkler systems should make it possible to control slurry application more easily than can in practice be done with existing tanker or organic irrigation systems.

Since there is some evidence that the most rapidly biodegradible fraction of slurries is in the liquid and very fine colloidal fractions[7] the rate at which these pass through the aerobic surface layer of the soil can be minimised by intermittent sprinkler application. Thus the soil is likely to remove these substances more efficiently than if slurry is applied in a single heavy application which passes relatively rapidly through the surface layer. This aspect of slurry application appears to merit further study by microbiologists and soil scientists.

Where intermittent sprinkler application is used, greater advantage can be taken of the evaporation that will normally occur from water, leaf or soil surfaces even in winter. The total evaporative loss per day is likely to be greater if slurry is applied as a succession of light "doses" over a relatively long period than in one single application. Thus the chance of run-off to ditches or percolation to drains should be reduced (particularly the former, since a near-saturated soil is more likely to accept a series of light applications).

Moreover small-bore pipelines, pumps and other equipment should be relatively cheap and easy to instal, and easy to move in the field even when full of liquid. A less obvious advantage is a reduction in the slurry storage capacity required per head of livestock (or reduction in frequency of emptying) because there is no need to provide storage for the diluting water essential where conventional organic irrigation systems are used.

Separation as a Stage of Aerobic Biological Treatment

The coarse fibrous materials contained in animal slurries are normally strongly resistant to breakdown by the organisms which populate aerobic treatment systems[2,7]. They must therefore in practice be removed from the treatment process at some stage but it is not yet certain whether it is better to remove them from the slurry prior to biological treatment or during the treatment process. Much depends on the type of slurry and the design of treatment plant used.

Experience at the *NIAE* with cattle slurry from a cubicle house system have shown that separation prior to treatment is essential to prevent blockages where biological filters are used, and highly desirable for the particular types of activated sludge processes so far investigated. (An oxidation ditch and a bubble- or jet-aerated tank). Experience with pig and poultry slurries indicate that biological filters are likely to block in the long term unless a preliminary separation is carried out,[3,6] but that other types of plant can be operated satisfactorily in this respect, provided that the solids are removed from the aeration stage, and provided that no very long material is allowed to enter the plant. An experimental high-rate filter tower at Reading University treating hen battery house slurry[3] and an oxidation ditch system treating pig and cattle slurries at the West of Scotland Agricultural College both operate on the latter principle.

Separation Prior to Treatment

Separation prior to treatment has some practical advantages over separation during biological treatment. In addition to improving the flow properties of thick slurries, it also reduces the quantity of bio-degradable material to be treated. The dry matter content of the coarse solids is relatively low (between 16 per cent and 30 per cent depending on the type of separator used), and therefore they contain a considerable quantity of liquids and fine solids which would have to be treated if allowed to enter a treatment plant. For undiluted cattle slurry, up to 40 per cent of the slurry by weight can be stacked as a solid.

The disadvantage of separation prior to treatment is that much of the equipment available for solid/liquid separation in the sewage treatment and other process industries is unsuitable for undiluted animal slurries, unless modified or adapted to suit farm conditions, whereas some will separate out coarse solids in a relatively dry conditiion (about 10 - 15 per cent d.m) from the relatively dilute liquid in a plant. For this reason the development of specialised machines is currently in progress at the *NIAE* and elsewhere.[4,5]

To sum up, separation of untreated slurry produces:

(a) a coarse fibrous solid which can be stacked and applied to land with farmyard manure handling equipment. This has not undergone any biological treatment but will normally undergo biological changes in the stack similar to those occurring in stacked farmyard manure, or at the higher dry matter contents (say 25 per cent), in composting processes.

(b) A liquid that can be applied easily to land, but which is also in a physical condition suitable for feeding into a biological treatment system.

Separation During Treatment

If the slurry is fed direct into a biological treatment system and the coarse solids subsequently separated from the liquids and fine solids undergoing treatment, separation then produces coarse solids which are in a more biologically stable state. The disadvantage of this technique is that the risk of blockages in the plant is greatly increased, particularly when treating cattle or poultry slurries, which almost invariably contain long wastes such as hay or feathers.

Disposal of Liquids From Treatment Processes

The liquids discharged by simple aerobic treatment processes are mixtures of liquid and fine solids which are easily pumped to land or spread by tanker, and, being biologically treated, do not cause smell problems during spreading.

If a slurry cannot be disposed of to land (for example, because of insufficient land being available), the possible alternatives are to carry out a biological treatment process aimed at producing a relatively solid-free liquid for discharge to a watercourse and a wet sludge which requires less land for disposal, (the conventional domestic sewage process which as yet has not been successful for farm wastes), or alternatively, to de-water the sludge to convert it into a solid and to produce a relatively solid-free, odourless liquid from the de-watering process for re-cycling or land application. The main problem to be overcome is that the sludges contain a very high proportion of particles which are too small to be trapped by the screening or other

Table 1

Summary of Separator Performances—Cattle Slurry

Machine type	Machine setting	Slurry Type	Slurry dry matter per cent	Solids output kg/h	Solids dry matter per cent	Liquid output kg/h	Liquid dry matter per cent	General condition of solids
Rotary screen	Screen mesh with 4·8 mm apertures fitted. No backwash with water	Cattle; diluted	5·6	1170	8	1170	3	Wet; not stackable
Rotary screen	Screen mesh with 4·8 mm appertures fitted; but with 360/kg/h backwash	Cattle; diluted	5·5	1210	7·5	1490	2·7	Wet; not stackable
Brushed screen	3·2 mm round-hole screen fitted	Cattle; undiluted	7·1	350	8·7	370	4·8	Wet; not stackable
Brushed screen	3·2 mm round-hole screen fitted	Cattle; diluted 1:1	3·7	490	9·1	2210	2·5	Wet; fairly free draining
Brushed screen with roller press attachment	3·2 mm round-hole screen fitted	Cattle	9·6	not recorded	18·5	not recorded	4·5	Stackable, moist
Vibrating screen 18 inch	1·5 mm mesh screen fitted	Cattle	10·1	not recorded	15·2	not recorded	10·2	Wet; fairly free-draining
Vibrating screen 44 inch	120 BSS screen fitted	Oxidation ditch liquid from cattle slurry	1·2	270	9·4	2160	0·8	Wet; fairly free-draining stackable
Rotary screen press	3 mm screen	Cattle	9·7	162	22·6	658	7·0	Stackable moist; very easily handled
Horizontal solid bowl centrifuge	Set for highest dm in solids	Cattle; diluted about 1:1	6·1	112	26·0	770	3·2	Stackable moist; very easily handled
Horizontal solid bowl centrifuge	Set for lowest dm in liquid	Cattle; diluted about 1:1	7·1	530	14·9	1000	3·0	Just handleable as a solid

simple mechanical processes so far used experimentally. The alternatives are therefore:

(a) to increase the particle size by flocculation, either naturally (by biological means) or by the addition of chemicals, and then filter them out by relatively simple means, or

(b) to develop new equipment suitable for use under farm conditions which is capable of removing very small particles from suspension.

In the short term, approach (a) appears the simplest and is the one currently being investigated at the *NIAE*.

Separation Trial Results

A few of the results of trials at the *WSAC* and the *NIAE*[1,5] are given in table 1 to illustrate the characteristics of various basic physical processes in terms of the products to be handled after separation. A diagram illustrating some of the types of machines used is on page 81.

Only four of the machines discharged solids in a sufficiently dry condition for stacking, when treating undiluted slurries. However, some of the screens could be used successfully to produce rather wet but stackable coarse fibre provided that the slurry was diluted with five to ten times its volume of relatively solid-free liquid before it entered the separator. This dilution was quite easy to achieve when the separator was a part of a treatment system (by recycling liquid from the system), but it was difficult to arrange where slurry was to be spread direct to land, particularly when the slurry was undiluted with waste water.

Storage Properties of Solids From Untreated Slurries

To date, the procedure at the *NIAE* has been to tip trailer loads of fibre onto a small area of waste ground from which it has eventually been loaded and spread with conventional equipment on agricultural or horticultural land.

At dry matter contents between 15 and 18 per cent, the solids from cattle slurry were in a condition in which they can be stacked but a little seepage from the heap could be expected. At dry matter contents over 18 per cent the fibre was easily stacked and no seepage occurred and at about 20 - 25 per cent dry matter, conditions within a heap of fibre appeared to be aerobic because spontaneous heating occurred to temperatures of at least 50°C, the solid composting itself into a brown material rather like moist peat in general appearance. In general, the handling properties of the coarse solids after stacking were very good at any of the range of dry matter contents over 15 per cent encountered.

Solids from cattle slurry were relatively odour-free when produced, but those from poultry or pig slurry had a very strong smell, particularly when the slurry had been in store for some time. Small-scale (0·3 m^3) stacks of such solids from pig or poultry slurry became almost smell-free whenever spontaneous heating occurred.

Experiments with poultry slurry at Reading[3] also showed that it was possible to mechanically separate the gross solids from poultry slurry undergoing treatment in a high-rate biological filter system. These solids were also relatively dry and very easy to handle and store.

Separation of Solids From Liquids as a Stage in Biological Treatment Processes

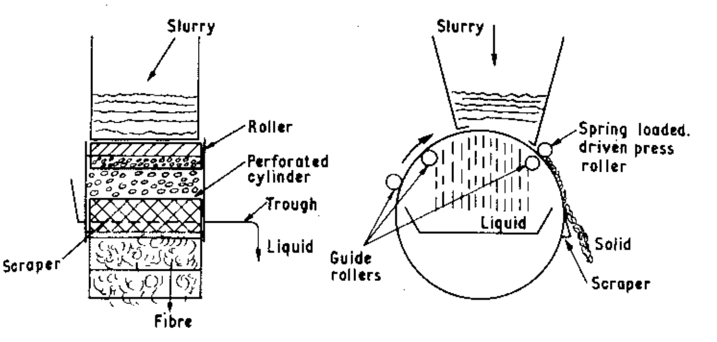
Gravity Filtration

(a) Removal by bale tank filters. Although none of the separators tried by the *NIAE* effectively removed fine solids from slurries or sludges, some pilot-scale trials of tanks with walls made from baled straw (associated with a high-rate filter plant treating a diluted pig slurry) showed that solids removed as a wet sludge were self-draining to an odourless moist solid if stored for a week or two.[6] When stored in the same manner, the original pig slurry did not drain freely to a condition in which it could be handled without difficulty with a front loader, and moreover contained biologically unstable substances that broke down anaerobically, and this resulted in the semi-drained slurry remaining extremely smelly.

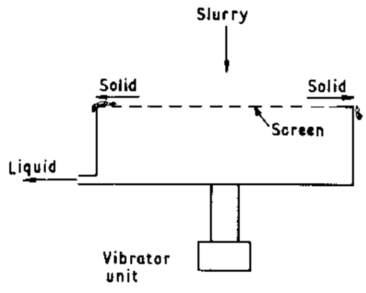
Subsequent experiments at the experimental oxidation ditch system at the *GRI* at Hurley showed that bale tanks were an ineffective means of separating the liquids from the solids in cattle slurry or from the type of sludge discharged from this particular treatment system. The use of a mechanical separation process prior to or during treatment did not improve the rate of de-watering.

However, similar results to those with pig slurry could be obtained if a flocculant was added to render the sludge relatively free-draining. Pilot-scale trials at the *NIAE* are showing that it is technically possible to de-water sludges by this method so that they can be handled and stored easily, but the technique has not yet been developed to the stage at which it is possible to assess flocculant costs.

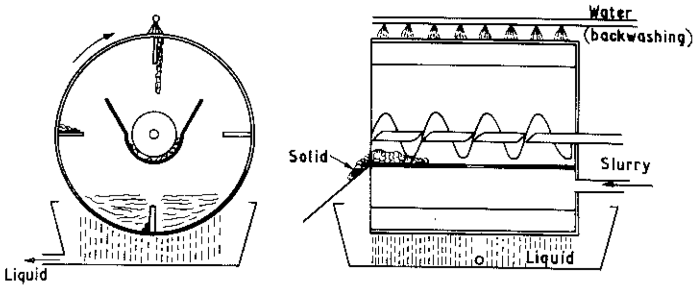
(b) Removal by drying beds. These were already available at the West of Scotland Agricultural College and various attempts had previously been made to operate these as a means of de-watering ditch mixed liquor. The filtration rate was slow and because of the large volumes involved when using mixed liquor, experiments were then conducted in conjunction with other equipment on their use for draining a concentrated slurry. Using the underflow from a hydrocyclone (40 g solids/l), and by using hessian, fly ash, paper pulp, sand or paper as filter aids, it was possible to de-water this liquid. The most promising results were obtained



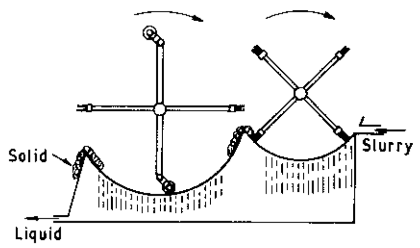
Rotary Screen with Press Rollers



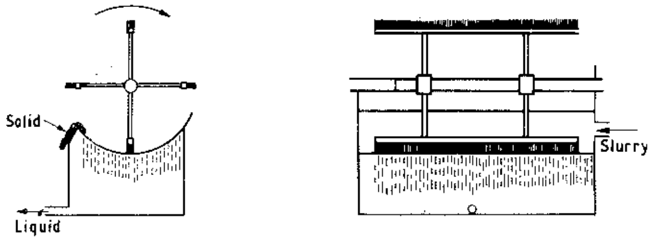
Vibrating Screen



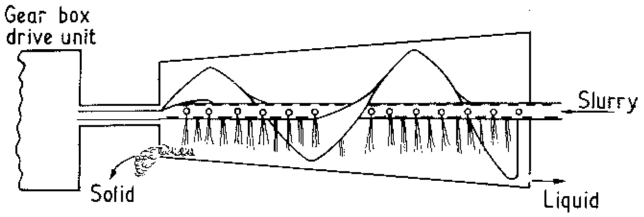
Rotary Screen



Combined Brushed Screen and Roller Press



Brushed Screen



Note: both bowl and scroll rotate in same direction: speed difference about 50 rev/min

Solid Bowl Centrifuge

with hessian. The disadvantage was that on standing for a few days the material underwent anaerobic decomposition and the smell was objectionable when the material was disturbed when emptying the bed. Due to the large area required, the high labour requirement, and the smell problem it was not considered that drying beds in themselves were a suitable means of de-watering mixed liquor.

The following separation processes and machines were assessed at the *WSAC*, when separating the liquids (mixed liquor) from an oxidation ditch.

Continuous Gravity Filtration

A simple type of continuous gravity separator widely used in domestic sewage de-watering, usually with a squeeze roller on the last stage, was tried at the West of Scotland Agricultural College on oxidation ditch mixed liquor derived from a slurry from fattening pigs. It was a single cell machine with a 1·7 m^2 screening area fitted with a 100 *BSS* nylon screen but had no squeeze roll. The total solids content of the ditch mixed liquor was 20 g/l at the start of the experiment and 12·8 g/l at the end of the two-week trial period (25.5.71 - 8.6.71). The solids content of the "plug" was 11·2 to 11·8 per cent w/w and the filtrate solids content 9·0 g/l. The output of "cake" (dry weight) was 5·5 kg/cell/h and the volume of filtrate was 1009 to 1045 l/h.

The main disadvantage of this machine was that the screen tended to "blind" with pig hair and/or a film of slimy material. When this happened the liquor would spill out over the previously produced solids.

The results obtained showed that only the coarse solids and the floc in physical association with these were being removed and no separation of the main bacterial mass was being achieved. For this reason it is suggested that this machine might have a limited application as a primary separator for treated liquor but its tendency to "blind" would make this unlikely.

Pressure Filtration

(a) By "Meta" filter. This is used in industry to remove very fine particles from a liquid, the final clarification of beer being one example. The method entails the formation of a pre-coat on the filter surface by pumping a filter aid followed by pumping in the liquor to be filtered either alone or with additional filter aid. It was found that for the ditch mixed liquor both the pre-coat and filter aid in the liquor were needed in the ratio of one part filter aid/part total solids in the liquor. Since the filter aid cost £150 - £200, the process was clearly uneconomical.

On an industrial scale and if a very pure effluent were required, then this method might be suitable for final clarification of an already relatively clear effluent, since *BOD* figures as low as 20 were obtainable with virtually no solids present in the filtrate.

(b) By *VC* filter. This was a pressure filter with a secondary membrane element to provide a hydraulic squeeze after the first pressure filtration through a filter medium had formed a cake. It is used in industry for dye stuffs, clays and other fine slimy materials. Tests were carried out at the manufacturer's works but no cake could be produced. This was almost certainly due to the fact that no filter aids were used and it would very probably have worked if filter aids were used. However, the costs of the latter were again likely to be high.

Vacuum Filtration

(a) Tipping pan vacuum filter. This was chosen as the simplest example of vacuum filtration and was found to work for cake thicknesses of 1 - 2 cm. Above this thickness the filtration rate decreased very rapidly and eventually stopped. Due to the low capacity imposed by the thin cake it was not considered suitable for de-watering mixed liquor.

(b) Rotary vacuum filter. This machine proved satisfactory for de-watering mixed liquor but the essential part is the filter cloth and only one of the many tested gave satisfactory results. This was a polypropylene felt type and had been developed for domestic sewage. A second cloth, which was a polyester woven cloth with a smooth callendared surface to facilitate cake removal, also appeared to be satisfactory in removing solids but analysis of the results showed that a large proportion of the fine material was in fact passed by this cloth. The mixed liquor contained between 1 per cent and 4 per cent of dry solids, the cake between 2 per cent and 14 per cent dry solids, and the filtrate between 0·2 per cent and 0·3 per cent dry solids, depending on the operating conditions. The cake production rate varied between 4 and 19 kg/m^{2}h.

A disadvantage of this equipment was that it was complex, requiring expensive plumbing, vacuum receivers, vacuum pumps etc. and would not really be suitable for on-the-farm use. The main disadvantage however, was that the cloth required to be thoroughly washed and tests showed that four parts of wash water per part filtrate was required. This wash water was contaminated and would require treatment. It would however be possible to use a recycled water for this purpose in a large installation.

Liquid Cyclones (Hydrocyclones)

In general the hydrocyclone has been used to remove solids from an oxidation ditch mixed liquor derived from a fattening pig slurry. Using single stage process, an underflow (discharge from the bottom of the cone) with 40 - 50 g/l of solids could easily be produced from mixed liquor having 10 g/l solids and the total solids in the ditch were held between 9 and 11 g/l over a period of three months. Using a two-stage process, with suitable operating conditions it was possible to obtain an underflow from the second stage of 80 g/l.

Detailed examination of similar results for the same ditch and hydrocyclone system fed with slurry from beef cattle showed that the free-floating bacteria were preferentially concentrated in the overflow and hence were returned to the ditch. If the underflow is to be discharged to land to maintain a constant solids content in the ditch during prolonged operation, this may mean that non-flocculating bacteria will be concentrated preferentially in the ditch system and the flocculating types discharged from the system. However, there was no evidence that drastic changes in ditch performance had occurred during the three-month period mentioned above when operating on pig slurry, or during a subsequent similar period when treating beef cattle slurry. Hydrocyclone tests have been carried out on the filtrate from the vibrating screen (table 1) using very small nozzles (1 to 3 mm) and it has been found possible to get solids concentrations of up to 8 per cent.

All of the work described was exploratory and was not intended to do more than indicate which principles of separation and which types of machine would justify further study. The results showed that the development of existing machines and principles of separation was likely to lead more rapidly to data and equipment of value to farmers than the design and development of new separation processes based on the physical, chemical and biochemical properties of the slurries and treatment plant liquids, partly because the latter are still ill-defined. For the present therefore the *NIAE* will continue to develop systems based on screening and then pressing the solids from slurries into a stackable condition, prior to land spreading the liquids and solids separately (with or without treatment of the former). The work on gravity filtration of treated slurries will also be continued.

The West of Scotland Agricultural College will continue the work on the separation of solids from the mixed liquor in treatment plants, particularly the application of vibrating screens and hydrocyclones to this problem.

Design Problems Still Requiring Solution

Methods of Feeding Untreated and Undiluted Slurries to Separating Machines

Most existing machines must be fed by pump or other conveying means such as elevators or augers. The requirements for such pumps or feed devises are broadly as follows:

(i) Since they must run largely unattended, they must be virtually free from blockage due to the contamination under farm conditions of the slurry with waste fodder or bedding, baler twine, plastic sheeting, wood and other similar materials. Such contamination is inevitable under farm conditions, particularly where slurry is mechanically scraped into a slurry holding tank.

(ii) They should be resistant to the abrasive materials (eg fine grit, plant silica) which are invariably present, particularly in cattle or poultry slurries.

(iii) They should have a relatively low output (up to about 5000 l/hour) since the total daily flows are not likely to exceed 4000 litres/day, even on the largest size of dairy unit at present in existence in the *UK*.

(iv) They should have a low power requirement, to minimise running costs.

There are certain types of pump on the market that will meet requirements (i) and (ii) above; however, they have much higher outputs than are required (about 50,000 l/h), and are expensive (both in capital and running cost).

Certain pump and chopper/conditioner combinations meet requirements (i) and (iii) but have a relatively high cost, high rate of wear, and high power requirement.

Low-capacity augers and conveyers meet requirements (iii) and (iv), but problems of wrapping occur where long hay or straw or twine is present.

Thus the development of separation systems must include work on the means of conveying to the separator. One solution which is theoretically attractive is the development of low-capacity (1 or 2 kW) submersible pumps with impellers, etc. specifically designed for farm slurries. So far as the authors are aware, no such pumps exist at present.

Another approach is to design separators so that they can be gravity fed. The only machines of these listed in table 1 which was suitable for installation in a channel were the brushed screen and the *NIAE* roller press. Methods of controlling gravity feeds to these and other types of separator from channels or from surface or underground tanks are currently being investigated at the *NIAE*.

Improvements to Existing Separators

The development of specialised separators for farm use is at an early stage. A number of very promising machines are under development or at the early stages of production, most of which incorporate a means of pressing excess liquid out of the coarse solids. None has however been in use for long enough to be generally accepted as being a reliable means of removing fibre from untreated and undiluted slurries under all farm conditions. Nevertheless, there is no technical reason why well-proven machines should not be available in the fairly near future. When this stage is reached, the development of low-volume small-bore systems for application of slurries, etc, to land can be carried to the stage at which it can be used experimentally under normal commercial farm conditions to prove the systems for wider use. The use of biological treatment processes under farm conditions is also unlikely to develop rapidly until reliable separators are available to remove the coarse solids from slurries before or during treatment.

To sum up, the main requirements for a separator are:—

(a) reliability and general robustness,

(b) simplicity in detail design to reduce maintenance and the incidence of mechanical failure,

(c) versatility (either within separator types or over the range of types available) to cover a wide range of farm slurries and farm conditions,

(d) adequate output—the ability to deal with the slurry output from say 150 - 200 cows in an eight-hour day is probably the minimum future requirement for general farm use.

Conclusions

1. Separation processes are very probably a key to the development of successful alternatives to present-day methods of slurry handling and disposal.
2. Given that suitable separators to remove coarse solids will soon become available, it will then be possible to convey slurry to land more easily and probably with fewer air or water pollution problems than is the case with conventional systems based on the use of tankers or organic irrigation, under those circumstances where management problems are arising when using conventional equipment.
3. The products of such separation processes are far easier to handle than slurries and the coarse solids in particular may have some commercial value off the farm (eg as an alternative to farm yard manure or peat in horticulture or for composting for mushrooms or other crops).
4. Small-scale trials suggest that it may be possible to store the liquids from separated cattle slurries for long periods, and then pump or tanker them to land with difficulty.
5. Biological treatment systems, either for odour control or for control of water pollution, are likely to become more simple in basic design and much more trouble-frree in operation if they include a separation stage to remove coarse solids. Mechanical separation is again likely to be the most reliable method under farm conditions, because of the variable results and difficulties often experienced when gravity separation of slurries is attempted.
6. The sludges are likely in many cases to form the greater part of the output from farm slurry treatment systems, and therefore separation processes aimed at reducing their volume or turning them into handleable solids, or possibly even converting them for re-use as fertilizer or feed supplements will have to be considered for those situations where the aim of a treatment processes is to solve the disposal problems of livestock units with little or no land on which to dispose of wastes.
7. The efficient separation of the liquid fraction from the solids in the sludges from treatment systems is difficult with types of separator at present being used to remove coarse solids. Although it is technically possible to achieve good separation with simple equipment (eg dosing with flocculants followed by draining the sludge in a bale tank), these techniques at present have disadvantages for farm use. There is therefore scope for research and development into existing methods and also into a range of possible alternative methods that have not yet been tried.

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The Design of Buildings and Concrete Areas for Handling Farm Waste*

by C. Dobson†

1. THE design of buildings and concrete areas for handling farm waste can be divided broadlly into the following aspects:—
   1. slatted tanks used as storage
   2. slatted ducts used to convey slurry to another point
   3. above ground passages and areas requiring regular cleaning
   4. deep littered yards and pens cleaned infrequently.

Only the first three aspects are discussed in this paper.

2. Slatted Tanks Used as Storage

Requirements

1. Adequate storage capacity after ignoring 250 mm immediately below slats.

	90kg pigs	*Sheep*	*Adult cattle*
Amount produced	0·056 m³/week	0·002 m³/week (approx)	0·042 m³/day

2. Individual slat and gap dimensions that ensure all waste enters storage duct but does not damage animals.

Stock	*Width mm* *Slat*	*Gap*
Yearlings	100-125	38
Adult cattle	125	38
Sheep	25-75	18
Growing pigs	25-75	13-17
Sows	75	20

3. Overall design and slatted dimensions should be large enough to ensure that all waste falls on the slats.
4. Liquid content of slurry is not over diluted or allowed to drain away through cracks in the walls or floors. Over dilution simply increases the bulk to be pumped and/or transported. Too dry a slurry is more difficult or impossible to pump or suck out into a tanker (see 4).
5. Prevention of slurry flowing from one area to another and exuding above the slats.
6. Slat surface should not damage animals' feet.

If we exclude 900 mm wide channels behind tied cows then designs based on a continuous flow of cattle slurry have not been generally successful.

3. Slatted Ducts Used to Convey Slurry to Another Point

Undiluted pig slurry has been successfully conveyed on many farms in ducts immediately under slats. It would seem that pig slurry from any class of stock fed either dry or wet feed is capable of being conveyed in this way. Research work is being carried out by the Building Research Station on some of these aspects. Until results are available it would appear that the basic requirements are:

1. Adequate stocking density to ensure sufficient slurry to maintain slurry movement.
   Suggested maximum slat areas/pig.

15 — 35kg	35 — 90kg	90 — 135kg
0·2 m²	0·3 m²	0·55 m²

2. Fall designed to prevent separation of solids and liquids and conversely to prevent backing up. Field trials indicate that a slope of 1 in 50 meets both requirements.
3. Slurry exit from duct must be proof against air movement into the duct. Failure to prevent air movement could upset house ventilation and possibly cause toxic gases to enter the house. These dangers are more serious in an "extraction" ventilation system.
   A flexible curtain or adjustable slide should meet this requirement.
4. As for 2.2.2
   2.2.3
   2.2.4
   2.2.5
   2.2.6

4. Waterproofing Below Ground Ducts and Tanks

Most farm constructions are based on a variety of concrete blocks. All blocks are subject to fairly high shrinkage movements with variations in moisture content so much so that it is not possible to build a 225 mm thick wall which does not crack longer than 6·00 m. Any renderings attached to the wall whether waterproofed or not move with the wall and also crack.

Where no precautions are taken to waterproof the whole construction the result is that either:

(a) in a free draining sub soil liquids drain away through the cracks or

(b) in a high water table situation water flows into the duct or tank.

A fairly simple solution is to line the whole of the excavation with a flexible waterproof material such as butyll and build the tank inside the lining. Sufficient spare butyl must be provided to allow for folds and creases that occur during backfilling. Backfilling between walls and excavations

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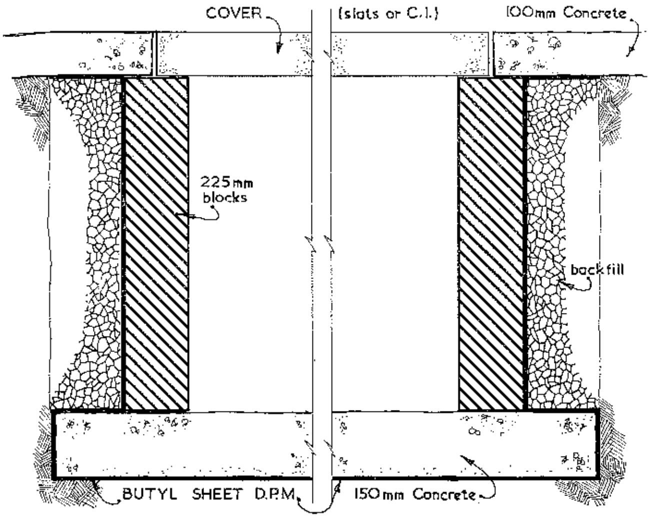


Fig 1 Waterproofing ducts and tanks.

is used to press the lining against the outside of the wall. Once the walls and floor have become saturated there should be no further moisture loss from the slurry and no increase in dilution from ground water (fig 1).

5. Strength of Walls

Long shallow tanks and ducts up to 1250 mm deep do not usually present any structural engineering problems. Neither do rectangular tanks up to about 2·4 m cube but a combination of length and depth gives rise to fairly high lateral and vertical bending moments. In these situations designs should be checked for structural stability.

6. Design Loading for Slats

Assuming vehicular traffic cannot pass over slats then the design loads should be:

Sheep + Pigs < 90 kg	Pigs > 90 kg + calves	Adult cattle
2·5 kn/m²	5 kN/m²	25 kN/m²

7. Slat Finish

It is now accepted that rough finishes on the top wearing face of pig slats are undesirable. To obtain a smooth finish on precast concrete slats means either a two part mould or special care in trowelling off one part mould products. The former is preferable for accuracy, consistency and hardness of the finish.

The evidence for or against smooth finishes for cattle slats is not conclusive. If slats are to be used in conjunction with a bedded lying area or cubicles then the dangers of damage to cows teats etc are are obviously reduced and there is probably a greater tolerance in the quality of the finish. Conversely where cattle are confined entirely to slats for longer periods then animal comfort will be increased by the provision of a good quality finish, with accurate spacing and an absence of sharp arises.

8. Above Ground Passages and Areas Requiring Regular Cleaning

In the field of livestock buildings there are a number of situations that come into this category. The most important being:

1. hand scraped pig dunging passages
2. tractor scraped pig dunging passages
3. tractor scraped cattle cubicle passages
4. tractor scraped cattle feeding areas
5. roads around buildings
6. parlour assembly areas
7. parlour dispersal areas.

9. Hand Cleaned Pig Dunging Passages

The numbers of new finishing houses being erected with solid narrow passages is small but new tethered sow houses are often built with solid dunging areas. In the latter case the dunging area usually acts as a central service passage for feeding etc.

The requirements can be summarised as follows.

1. The length of stall, stall step and dunging area should aim at maximum sow cleanliness (the parallel with old tie up cowsheds is worth noting).
2. Free urine should be drained off if it is not to have an adverse effect on house temperature etc.
3. Floor profiles should be suitable for small scrapers.
4. The central area of a common passage serving two rows of tail to tail areas should be clean and dry. (This is necessary if pigmen are not to be asked to walk through pools of urine.)
5. Floor finish should be smooth, non-slip and easily cleaned.
6. Slurry being scraped in one pass should be confined to the width of the blade.

With conventional passage width of 1500 mm it is difficult to meet all these requirements as (1), (2), (3) and (4) are conflicting to some extent. One possibility is to increase the passage width from the accepted 1500 mm to about 1900 mm. Then the old type of cowshed floor section can be used (fig 2).

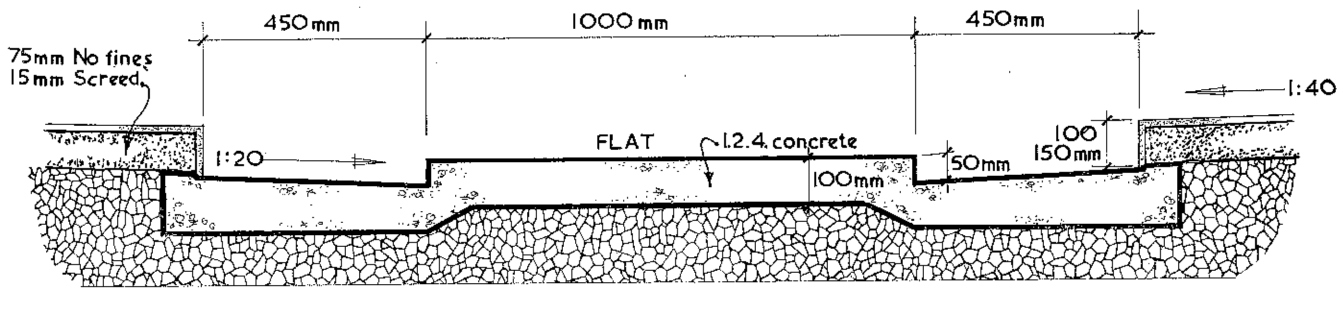
With a longitudinal fall of about 1 in 50 to 1 in 70 on sow beds, dunging channels and centre strips the requirements 1 - 6 should all be met. An analysis of systems using slotted drains in the centre of a 1500 mm passage will show that (4) and (6) cannot be met and that the additional cost of drains will be similar to increasing the width by 400 mm.

10. Tractor Scraped Pig Dunging Areas

A typical situation is shown in fig 3. Basic requirements are.

1. The area should be the width of either (a) tractor scraper width for a single line of troughs (1800-2350) or (b) pigs feeding tail to tail (2100 to 2250).
2. There should be no projections into the area to be scraped eg water bowls, gate posts etc.
3. The floor should not be dished or crowned but be either flat or fall uniformly to one side. (Few scraper blades can clean efficiently unless the floor surface is in one plane.)

Fig 2 Centre passage for thered sow stalls.



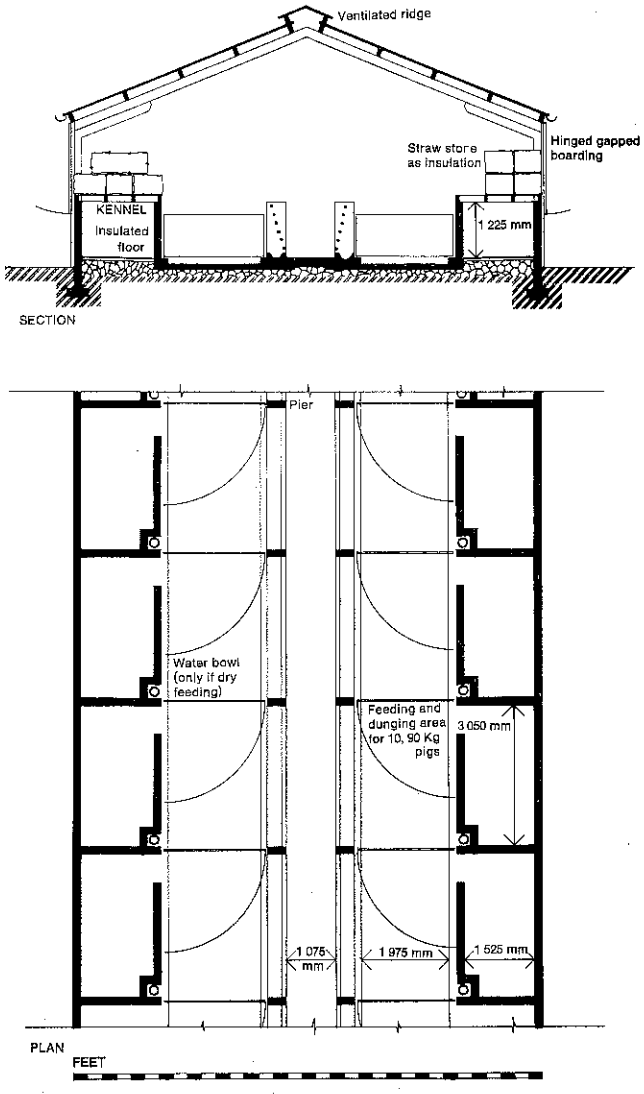


Fig 3

4. Longitudinal fall on roofed areas can vary from flat to 1 in 30 (there is virtually no run off of liquids due to treading and mixing by pigs' feet).
5. Damage to pen claddings and other fragile fittings must be reduced by provision of scraper kerbs projecting beyond vulnerable materials.
6. The floor should not contain any half round or similar channels, grooves, trapped gullies etc. (All would rapidly become blocked with slurry and render them ineffective.)
7. Adequate turning space at the ends of passages for tractors and scrapers. (This would be less than that required for tractors and trailers for feeding functions.)
8. The floor level of adjacent troughs, pens or stalls should be high enough to prevent slurry flowing into them during scraping operations.
9. The floor should be non-slip and smooth.

11. Tractor Scraped Cattle Cubicle Passages and Feeding Areas, and Roads Around Buildings

These have similar basic requirements as 10.1 to 10.9 except:

1. Suggested width of cow cubicle passages — 2100 mm.
2. Suggested width of feeding areas (excluding troughs) 3000 — one line; 5400—tail to tail.
3. Roads and areas around buildings and other unroofed areas should normally have a longitudinal fall to drain off rain and surface water. This requirement usually leads to a change of level (step or ramp) at entrances to cubicles and feeding areas. Ramps if poorly sited can be a serious obstacle to scraping. If they are unavoidable then they are usually best sited inside the passages and not projecting into the road to be scraped. This small change of siting can often save up to ten man hours per week.

The longitudinal fall will also ensure that all surface water runs to the low end. This water often needs intercepting to prevent it running into tanks or above ground dung stores. A simple uniform cross fall to one side of the road makes this easy to achieve (fig 4).

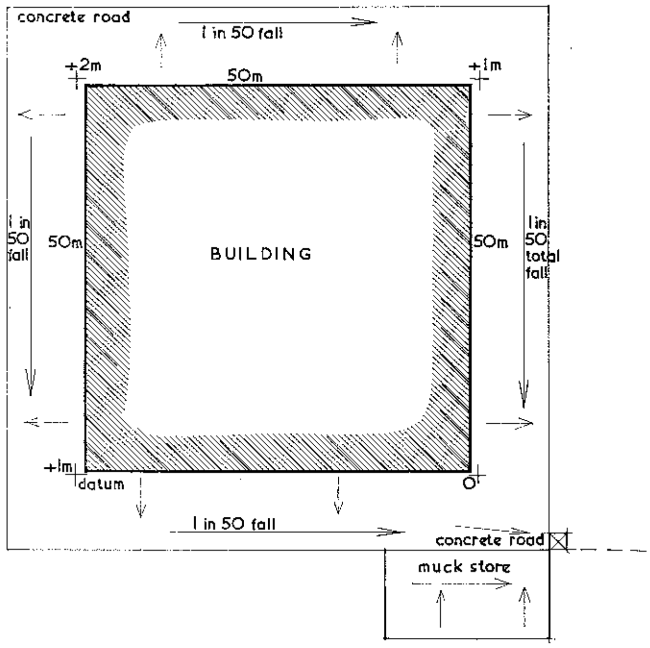
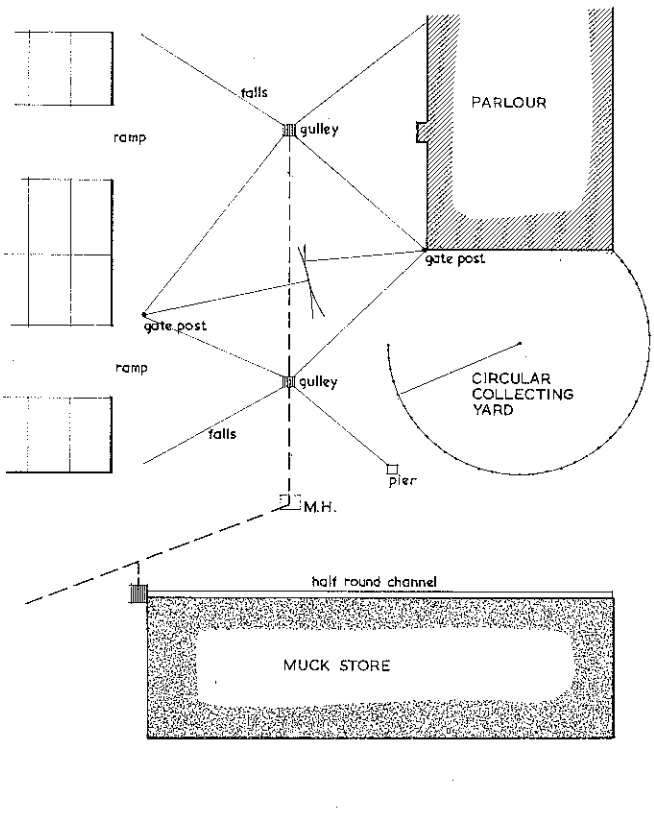


Fig 4 Falls on external areas.

Fig 5 Typical errors.



12. Parlour Assembly and Dispersal Areas

These can be cleaned in a number of ways, the most common is ascending order of labour required are:

1. Hosing
2. Tractor scraping
3. Hand cleaning.

In some areas circular type collecting yards have been adopted to improve cow flow into the parlour. When considering this type of plan its effect on cleaning costs should also be considered. As a general rule circular yards are only suitable for cleaning by hosing. With other methods the time saved on cow collection is often more than offset by the extra time taken to clean a circular area. A number of typical errors are shown in fig 5.

13. Effect of Rain on Unroofed Polluted Areas

The need to reduce building costs often results in not roofing many of the areas listed in 8.0

Apart from initial cost other factors to be considered are.

1. Would dilution of the slurry reduce the efficiency of the storage and disposal system?
2. Can run off be diverted to a satisfactory disposal system without danger of polluting watercourses?
3. How would it affect human and animal environment?
4. What will be the effect on food quality and wastage.

Probably the only systems that would not suffer losses of efficiency from dilution are those based on below ground tanks and pumps. Here at least 1 : 1 dilution is usually necessary.

In this situation the run off can often be drained into the slurry tank without too high a risk of over dilution.

The table 1 below gives some guidance on the effect of leaving areas unroofed.

Assumptions: 50 per cent of waste products falling on unroofed area (0·021 m^3d).

Table 1A

Number of Cows	*Unroofed areas to give 1:1 dilution (m^2)*				
	Rainfall per week (mm)				
	10	15	20	25	30
50	735	490	367	294	245
100	1470	980	735	588	490
150	2205	1470	1102	882	735
200	2940	1960	1470	1176	980

The effect of scale is important. Most layouts dictate fixed areas of concrete at ends of buildings and the dilution effect of rain on such areas will generally decrease as scale increases.

Eg: if in a cow layout an unroofed feed area of 2·5 m^2 per cow is adjacent to unroofed gable aprons of 200 m^2 and both areas would dilute tank contents then:—

Total area required for 50 cows = (50 × 2·5) + 200 m^2
125 + 200
= 325 m^2

From table 1—Max area to allow 1:1 dilution = 245 m^2

Total area required for 100 cows = (100 × 2·5) + 200
= 450 m^2
= 490 m^2

From table—Max area to allow 1:1 dilution = 490 m^2

The waste from 50 cows would be overdiluted with 30 mm rain/week but not from 100 cows.

Conclusion

As scale increases and expected rainfall decreases the risks of overdiluting liquid slurry storage decreases. So much so that if a liquid system is used the need to roof open areas does not usually depend on the need to exclude rainwater. Other factors such as fodder saving, livestock and human environment could become more important.

14. Siting of Slurry or Dung Stores

Some of the main factors to be considered are:—

1. Method of moving slurry from source to store
2. Acceptable dilution levels in the store
3. Location of areas giving maximum slurry production

4. Time of year when slurry is produced
5. Effect of statutory regulations, planning and pollution controls
6. Need for isolation of dung from potentially diseased animals eg isolation pens etc
7. Water table level during the storage period
8. Proximity of watercourses
9. Nuisance risk
10. Disposal method and access for disposal vehicles
11. Size of storage area required
12. Finished site levels
13. Movement lines from source to store
14. The need for further extensions to stock buildings etc

With such a wide range of variables it is not possible to give recommendations for all situations.

15. Some General Suggestions

1. If there is sufficient litter in the dung to bind it for use of conventional solid disposal machinery then the store need not be downhill from the slurry source.

   The converse applies to piped or ducted slurry depending on gravity to convey slurry to the store. Here the store must be at the lowest point on the side unless pumps are used to lift slurry from intermediate stores to the main store.
2. Slurry movement, particularly above ground, should as far as possible be confined to straight lines with the minimum of changes of direction (usually one).
3. During summer months slurry from dairy units is usually confined to the milking parlour area. Quantities per cow are not high but the slurry store should be near enough to satisfy 14.5 and 15.2.
4. Slurry movement lines should not cross routes for general farm traffic otherwise vehicle wheels will pick up slurry and spread it onto clean areas. This could either be at least a messy nuisance or possibly at worst a disease carrier.
5. In difficult situations such as extensions to existing scattered buildings a reasonable solution can lie in combining various methods of moving slurry eg pumps and ducts and tractor scraping, gravity ducts and tractor scraping.

These methods need not be confined to liquid stores for it is always possible to add binding straw to the store instead of at the slurry source.

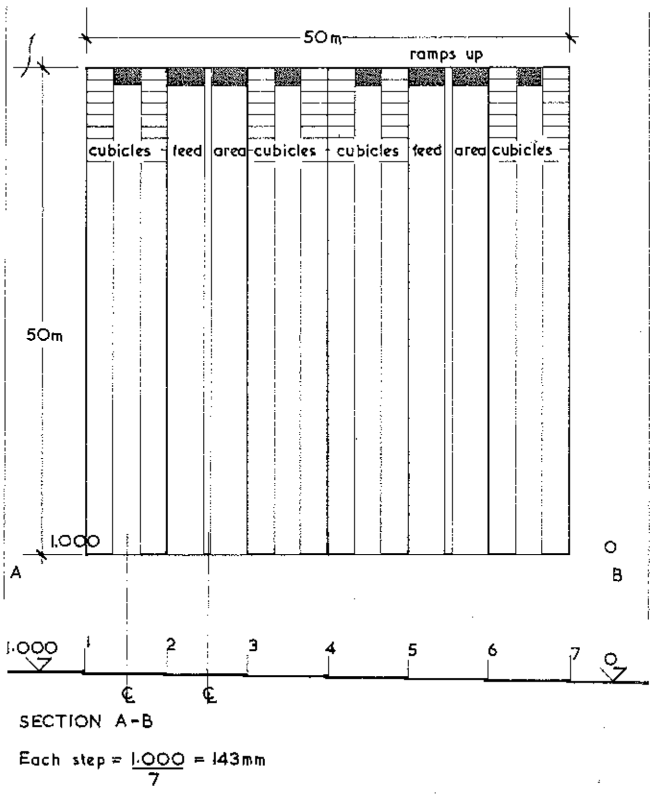


Fig 6 Setting out parallel buildings.

16. Summary

Advantageous existing site falls on unroofed areas should be made use of rather than resorting to indiscriminate levelling by earth moving equipment. The falls on parallel concrete areas should generally be identical even if the areas are 50 - 100 m apart. This will simplify the setting out of changes of level at doorways and ensure that prefabricated buildings can be erected without the need for expensive modifications to post lengths or foundations (fig 6 and 7).

The inability of normal scrapers to follow irregular planes

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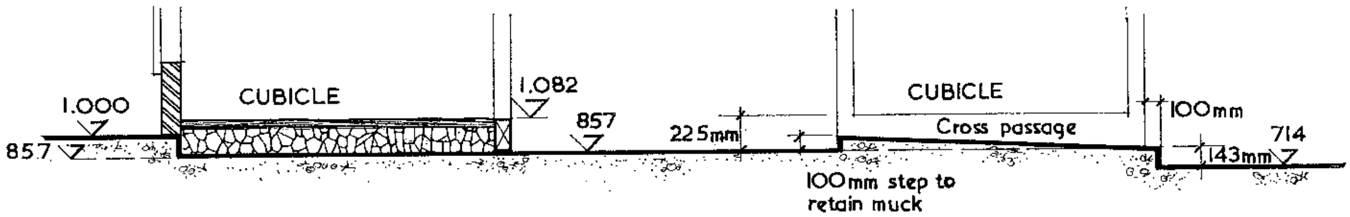
Fig 7 Setting out levels in parallel cubicles and feed areas.



THE HANDLING, TREATMENT AND DISPOSAL OF FARM WASTES

Edited Summaries of Discussions

I Application of Slurries to Agricultural Land

Dr I. J. Cook (Gascoigne, Gush & Dent) asked if it were possible to depart from a maximum slurry application of half an inch, quoted by Mr Pollock, and whether this figure applied only to grass. Further, did it apply only to complete slurries or would some form of solid/liquid separation allow it to be exceeded?

Mr K. A. Pollock said that his figure for a maximum application of half an inch of slurry applied to grass and similar crops such as winter wheat. This quantity was for a slurry with seven to eight per cent of solids and one with less than this would permit more to be applied.

Mr A. J. T. Sly (*NFU*) asked how the maximum permissible hydraulic loading rates given by Mr K. A. Pollock in table 3 were determined.

Mr. K. A. Pollock replied that they were calculated from the actual evapotranspiration and historical rainfalll to give a soil moisture deficit in any one year.

Mr G. Spoor (National College of Agricultural Engineering) listed some of the main forms of possible damage to soils by slurry application as impact damage to the surface, a reduction in permeability, structure breakdown and retention of excessive quantities of nutrients and wanted to know if any tests had been used to evaluate the level of damage being caused.

Mr K. A. Pollock knew of no simple in-situ tests that were suitable and said that there was a need for them. In their Cockle Park experiments, they were hoping to check on soil property changes by conventional laboratory determinations.

Mr A. J. Davies agreed that simple in-situ tests were badly needed.

Mr K. A. Pollock felt that it might be difficult to develop such tests, because you were working at unsaturated levels which was more difficult than working under saturated conditions.

Dr K. L. Robinson (Agricultural Research Council) pointed out that research on the effects of slurry applications on soil structure is currently being undertaken by the Department of Soil Science at Reading University in collaboration with *NIRD*.

Mr G. Shattock (Consultant) wanted to know if any work had been done on the time that should elapse before grassland, to which slurry had been applied, was acceptable to the various species of livestock.

Mr K. A. Pollock was not aware of any scientific work on this subject and had been given widely differing opinions by farmers. The *ARC* work at Compton on disease transmission, via slurry applied to grass, involved grazing within a week, so presumably the animals did not refuse to eat. A period of four to six weeks was usually quoted by farmers and advisers, but this was probably related to regrowth.

II Principles of Operation and Design of Farm Waste Treatment Plants

Dr I. J. Cooke referred to the relatively small effect of temperature on the rate of aerobic treatment and mentioned that research work in Germany has lead to the availability of high temperature treatment plants.

Mr S. Baines in reply, stated that Dr Gray was working on high temperature treatments at Birmingham University.

III Equipment and Methods for the Solid/liquid Separation of Slurry

Mr G. Shattock was in agreement with the idea of repeated light applications to land of the liquid fraction from separated slurry, so using the soil as a treatment plant. He took issue with Mr Hepherd, however, on his statement that in slurry separation there was no need to produce a high dry matter solid fraction. He considered that the heating which occurred in a stack of high dry matter solids was a good process for killing pathogens.

Mr R. Q. Hepherd felt that a high dry matter solid that would heat readily and so lose its smell was often important with slurry from pigs and poultry; but he was not so sure that it was needed for cattle. In his experience, a 16 per cent dm solid from cow slurry was inoffensive. It must always be remembered that, with a low dry matter solid, you have correspondingly less liquid to dispose of or treat.

Mr T. Sherwen (Consultant) recalled that he had visited the Filtration Unit at Mander College Farm constructed by using bales and wondered how they were handleld in this wet state. He also asked for more details of the centrifuge separation unit shown on one of the slides.

Mr R. Q. Hepherd admitted that he did not find straw bales particularly suitable but at present there were no better materials available. Other materials have been used, including paper and fibre glass. Mr J. C. Douglas has tried hessian on filter beds. The greatest difficulty experienced with straw bales was in handling. Straw had not yet been tried on a farm scale.

Mr R. Q. Hepherd went on to explain that the centrifuge was of the solid bowl type for sorting solids out of slurries and sludges. Although technically efficient, its main disadvantages were high cost and high power requirements.

IV Design and Layout of Buildings for Efficient Farm Waste Handling and Disposal

Mr A. J. T. Sly asked for comments on the future use of automatic scrapers in livestock buildings.

Mr C. Dobson stated that future developments in this direction depend up the intended objective. If the objective is economic, then the increasing cost of labour in the next few years may well justify the installation of automatic machines in several cases. It has been suggested that farm labourers' wages could rise to £5,000 in five years if recent rates of wage increase are maintained. Automatic machines may also be introduced as a means of reducing unattractive work tasks if the objective is to overcome the shortage of labour problem.

Mr M. R. Evans asked how, when the dm content of slurry varied in practice, it was possible to accommodate its different flow characteristics in building designs or in diluting for flow rate or pumping.

Mr C. Dobson agreed that diet, for example, had an effect on the flow characteristics of slurry, but that the range that he had found in practice was not wide enough to invalidate the data given in his paper.

Dr I. J. Cooke asked for comments on the amount of fall necessary to ensure slurry flow in slatted systems.

Mr C. Dobson stated that where slurry is retained in a storage space beneath the slats for several weeks, then the floor can be flat as in many cattle and pig installations. To lift slurry from beneath pig houses into a lagoon, then pumping is necessary incorporating a shallow duct at a fall of 1 in 50. Mechanical scrapers can be used to overcome the difficulty in getting cattle slurries to flow and for some installations the use of salt glaze or pvc pipes may be appropriate, keeping the pipe fairly full to improve the flow of the material and using a fall of 1 in 40. It is, however, difficult to give precise details on this aspect and some practical development of a particular method may be required.

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is an important consideration and so is the need to move above ground slurry in straight lines free from even minor obstructions.

Before deciding on concrete levels, dimensions, falls and finishes the constraints imposed by the livestock and the cleaning machine should be carefully studied.

V General Discussion

Mr P. Wakeford (Electricity Council) suggested that constraints on what farmers could do with waste were provided by existing Acts, but these were not being put into effect because of the cost to farmers. Would the *ARC* report, therefore, take costs into account? He felt, too, that the sprinkler shown by Mr Hepherd had a high trajectory and wondered if it could be reduced. He would also like to have a definition of "eutrification."

Dr K. L. Robinson said that the *ARC* bulletin would have a consolidating chapter dealing with the economic aspects and that there was a growing acceptance that such research should take economics into account.

Mr K. A. Pollock defined eutrification as the stimulation of the growth of plant life in water courses and lakes to a level which used up all the available dissolved oxygen and so excluded other forms of life.

Mr R. Q. Hepherd said that it was difficult to get reliable costs from experimental equipment. Much of the work was, however, now approaching the stage where trials on farms could start and these should provide more accurate cost data. He felt, too, that he should remind the audience that existing "conventional" methods of slurry disposal cost money, even if they only meant digging a large hole in the ground and employing somebody to empty it occasionally.

Mr C. Dobson considered that it was too early for economic assessments to be made. There were many factors to consider, but the techniques were available for doing this when the time was right. He was hoping to be able to start collecting data this year for a cost study of farm waste handling and treatment.

Mr R. Hissett requested comments on the possible adverse effects of repeated applications to the land of effluent which contains metallic compounds.

Mr S. Baines replied that the practice is undesirable and in respect of the problem of copper compounds in pig slurry, trials have been conducted at Aberdeen, where pigs were given copper free feed with little difference in terms of weight gain being observed.

Mr. R. Q. Hepherd commented on the use of chemical flocculents and stated that aluminium chlorohydrate was being used as a flocculent in small quantities at present with no noticeable effect. Pig slurry may be conditioned without the use of agents.

Attention was drawn to the risk of metallic compound concentration build-up in the event of feeding processed effluent to pigs which are also receiving copper in their feed. The fixation of these compounds in the soil was regarded as an important factor.

Dr K. L. Robinson pointed out that two research programmes were in progress looking at the short and long term effects of copper in soil.

Mr Simms was concerned about the future of intensive pig farmers with no land. What did they do with the liquid fraction of their slurry and how did they treat it to Royal Commission standards?

Mr S. Baines pointed out that it was possible to treat the liquid to produce an effluent to Royal Commission standards, but this was not desirable because it was uneconomic. The problem of solids disposal was similar to that of sewage works, which sold them to farmers. If dry enough solids were produced, it might be possible to compost them to supply a limited market in horticulture.

Mr R. Q. Hepherd felt that the solution was to design treatment systems which produced no liquid effluent at all, only solids which could be disposed of relatively cheaply and easily. From our present knowledge, this looked to be possible.

Mr S. Baines made the further comment that land to put slurry on might soon become so expensive that treatment plants would become economically justified.

Mr C. Brutey (*NFU*) observed that the speakers had emphasised the problems of slurry as a means of effluent disposal. There is also a problem of straw disposal which is frequently used, where available, as a bedding material. He asked whether the speakers thought that if an equivalent amount of time and effort had been devoted to handling animal wastes as a solid, then it would have been possible to solve two disposal problems at the same time. He recognised that different localities for cereal and animal production could create transport difficulties.

Mr S. Baines emphasised the transport problem and suggested that the intensification of animal production in certain areas had made less land available for spreading solid effluent. There were also difficulties in exceeding the acceptable amounts of effluent on land adjacent to its production.

Mr. K. A. Pollock predicted that transport was likely to represent one of the largest future cost increases which would make the transport of straw from arable to animal production areas uneconomic. It may, however, be economically acceptable to transport slurry. He also suggested that one of the important reasons why the existing methods have been developed in recent years is due to the amount of technology and derived equipment available for separate solid and liquid processing and handling. In view of the recent development of techniques for handling wet concrete it may well be possible to use this experience to develop methods of handling mixed farm waste materials again in the future.

ADMISSIONS AND TRANSFERS

THE following candidates have been admitted to the Institution or transferred from one grade to another.

ADMISSIONS

MEMBER

Apau, N. A.
Fung, C. E.
Goodacre, R.
Lewis, A. H.
Maitin, P. E.
McCleery, D. H.
McNulty, P. B.
Rickman, P. E. A.
Shepherd, A. E.
Webb, B. H.
Wetherell, P. C. S.
Wooding, G. J.
Wosu, A. R.
Zarinchang, J.

GENERAL ASSOCIATE

Agboka, V. K.
Arshad, K. B.
Barham, D. C.
Bevan, T. G.
Curtis, P. J.
Dasanayaka, C. L. B.
Davies, A. T. J.
Davies, B.
Edmondson, C. R. J.
Fernando, S. T.
Ford, M. J.
Green, G. A.
Grosvenor, H. R.
Hill, J. G.
Kemp, C. H.
Key, G.
Lawal, B. A.
Marshall, D.
Mitchinson, J. J.
Payze, R. A.
Pusey, M. A.
Rock, I. G.
Saaiya, M. Y.
Stuckey, B. C. N.
Taylor, N. O.
Teather, P. J.
Tebbit, M. D.
Thanki, S. B.
Waggitt, P. W.
Warrilow, E. L.
Welstead, D. J.
Wharton, F. N.
Williams, D. J.
Wilson, E. J. G.

TECHNICIAN ASSOCIATE

Barnard, H. B.
Brooks, P. R.
Broughton, M.
Burr, G. L.
Cunningham, R. I.
Marsh, M. J. S.
Renton, D. B.
Roach, S. H.
Taher el Issati, A. M.
Thelwell, N.
Whitehead, D. P.

GRADUATE

Booth, R.
Butcher, F. J.
De Silva, J. A.
Gough, J.
Hasell, S. J.
Harris, S. D.
Huzzey, M. D.
Kernahan, T.
Lam, C. T.
Major, M. T. W. C.
Miller, S. M.
Moore, J. E.
Scurlock, R. V.
Sriskandarajah, S.

STUDENT

Comben, P. W.
Cooper, H. D.
Davies, R. B.
Evans, P.
Ford, N.
Fraser, M. J.
Freed, G. R.
Gaydon, A. C.
Gunstone, R. K.
Hodgekiss, A. G.
Horsfield, J. A.
Jayawardena, S. P.
Jeganathan, K.
Johnson, I. A.
Kathirgamathamby, B.
Ofori, E. T.
Shaw Stewart, A. J.
Sothiratnam, A.
Teagle, T. J.
Tharmakulasingham, K.
Wallis, T. J. R.
Walton, J. M.
Welwood, J. C. L.
Young, N. W.

TRANSFERS

FELLOW

Carpenter, J. L.

MEMBER

Braithwaite, P. G.
Douglas, M. P.
Duggleby, T. J.
Glass, D. G.
Hancox, W.
Judson, C. A.
Keeble, B. M.
Khoo, T. C.
Lake, J. R.
Matthews, M. D. P.
Mayne, I. T.
Pearson, M. J. C.
Powdrill, C. L.
Reisner, J.
Shaw, G. J.
Shipman, J. G.
Thomas, R. J. O.
Wilson, K.

TECHNICIAN ASSOCIATE

Evans, W. H.
Mason, J. W.
Phillips, A. J.
Russell, P. J.

GRADUATE

Barnard, R. J.
Cutler, H. M.
Landers, A. J.
Leeds-Harrison, P. B.
McNicoll, A. A.
Ollier, L. B.
Pollock, J. M.
Reed, C. R.
Rowe, E. P. H.
Whiteford, R. C.

AROUND THE BRANCHES

East Anglia Branch

THE annual dinner dance of the East Anglian Branch was held at the King's Head Hotel, Diss, Norfolk, on 16 February 1973, and attracted about 85 members and their friends.

Guests of the Branch included Mr W. J. Garnett, Principal, Norfolk School of Agriculture and Mrs Garnett; Mr W. R. B. Carter, *ADAS* Advisory Officer, Norfolk, and Mrs Carter; Mr and Mrs W. Akester; Mr and Mrs A. V. Gardiner and Mr H. Weavers, *IAgrE* Secretary, and Mrs Weavers.

Mr Brian Bell, Branch chairman, welcomed the guests, saying that Mr Garnett and Mr Carter both gave continuing support to the conference each year. Mr Akester had been influential in launching the *Farm Machinery Instruction Book Writers' Guide* and Mr Gardiner had assisted in its preparation. He thanked the other members of this study group for their work in preparing this document.

South-Eastern Branch

A JOINT discussion between the Essex Farm Management Association and the South-Eastern Branch of the Institution was held in February.

Mr Arthur Longbottom, Head of the Farm Management Department at Writtle Agricultural College led the discussion which was on the subject of investment in mechanisation. He suggested that most managers had an existing "on-going" situation, that they wished to support or develop. He listed two main reasons for spending:

(1) Replacement cost of taxation, obsolescence, end of useful life, increasing maintenance costs etc.

(2) A change in mechanisation policy. Mr Longbottom suggested a change in policy might result from the wish to:

- (a) cut costs overall;
- (b) add a new enterprise or extend an existing one;
- (c) substitute for disappearing resources, eg casual labour;
- (d) displace available labour for use elsewhere;
- (e) improve timeliness from speed of operation;
- (f) increase speed of operation to get a better quality product, eg use of a mower/conditioner for grass cutting;
- (g) maintaining resources, eg ditch cleaners or heavy trimmers;
- (h) improve working conditions.

After this introduction, Mr Longbottom was joined by a panel, comprising:

Institution of Agricultural Engineers

AUTUMN MEETING 1973

"IRRIGATION FOR AGRICULTURE AND HORTICULTURE IN THE 70's"

The meeting will be held on Thursday 27 September 1973 at the National College of Agricultural Engineering, Silsoe, Bedford. The papers presented, and the discussions on them, will examine trends and possibilities for the future in the farming and engineering aspects of irrigation.

In addition to considering United Kingdom practice, there will be component parts on equivalent practice overseas. During the course of the one day meeting irrigation equipment manufacturers and contractors will display hardware and techniques for irrigation purposes.

The programme, details below, starts at 10 15 and closes formally at 16 15 but College premises will remain open for those who wish to make further examinations of equipment and projects.

10 15 Reception and coffee

10 45 The President of the Institution introduces the theme of the meeting and the Chairman of the sessions.

Morning Session

Chairman: E. A. G. Johnson CBE CEng FICE FIWE (Consultant, Sir M. Macdonald & Partners)

10 50 Paper 1
"The irrigation policy, practice and economics of two companies farming in Essex and Suffolk" by Major J. A. Comyn MBE FCIS (a director of Lord Rayleigh's Farms Inc. and of Strutt and Parker [Farms] Ltd)

11 15 Paper 2
"Water for Irrigation"
by R. Huntingdon BSc MICE FIWE FIPHE (Water Conservation Engineer, Essex River Authority)

11 40 Discussion on Papers 1 and 2, opened by C. N. Prickett MICE AMICE (Deputy Chief Engineer, drainage & W.S. arm, *ADAS, MAFF)*

12 30 Luncheon
During the luncheon interval there will be opportunities to visit irrigation equipment manufacturer's demonstrations

Afternoon Session

Chairman: Dr H. L. Penman OBE PhD FinstP FRS (Head of Physics Dept, Rothamsted)

14 00 Paper 3
"The evolution and evaluation of irrigation practices in Britain" by W. B. J. Withers BSc MICE (Senior Lecturer, National College of Agricultural Engineering)

14 20 Paper 4
"Trends in irrigation development overseas" by P. H. Stern MA FICE MIWE (Water development consultant to the Intermediate Technology Development Group)

14 40 Discussion on papers 3 and 4, opened by E. J. Winter MS MSc (Scientific Liaison Officer, National Vegetable Research Station)

15 20 Paper 5
"Equipment available for use in agriculture and horticulture in the United Kingdom" by J. Ingram NDH (Deputy Director, Luddington Experimental Horticultural Station)

15 45 Discussion on paper 5, opened by W. T. A. Rundle and Dr A. Iveny PhD (respectively Managing Director, and Head of Research and Development section of Wright Rain Ltd)

16 15 Tea and dispersal

Mr G. C. Mouat, Head of the Farm Mechanisation Department, Writtle Agricultural College
Mr A. Sansom, managing director of Ernest Doe & Sons Ltd
Mr T. Creese, senior management advisor to Strutt & Parker
Mr K. McClean, *ADAS* mechanisation advisor, Chelmsford

The result of the panel discussion? Managers and engineers agreed that investment in machinery had really only one purpose—peace of mind.

South-Western Branch

THE South-Western Branch of the Institution have enjoyed an excellent series of winter meetings. Using the general theme of *Grass Conservation,* meetings have been held in many parts of the Branch area. The October meeting held at Liskeard, Cornwall, entitled *The Farmers Requirements* was given by Mr F. A. Uren, lecturer in agriculture at the Cornwall Technical College.

November saw the venue move to Crediton for an excellent paper with the title *Grass Harvesting Machinery Current Trends* given by Branch member Mr J. G. Parker *FIAgrE,* a director of Western Machinery and Equipment Co. Ltd.

January's meeting given by Mr G. Newman of Howard Harvestore Ltd, at Exeter under the heading *Tower Silo* fully explored grass conservation by the tower method. This was followed in February by a paper on *Barn Hay Drying* given by a Branch member Mr A. J. Armitage *MIAgreE,* mechanisation advisory officer of *ADAS,* held at Taunton.

The final meeting in the series at Exeter was entitled *Mechanised Livestock Feeding* and was given by Mr R. G. Mortimer, Head of Agriculture at the Harper Adams Agricultural College.

The series of meetings was very well attended, over sixty members and friends being present on each occasion.

Scottish

THE Scottish Branch of the Institution of Agricultural Engineers are to make an annual award—the "Weir Shield" —for the agricultural engineering company having indentured the most successful apprentice of the year in the Scottish Section of the Agricultural Mechanics City and Guilds Course Number 015. In addition, the apprentice will be offered books or tools to the value of £10.

The first award will be made at the Branch's annual conference, Dunblane, on 27 February 1974 following the results of the June and December examinations.

The Shield and prizes are to be presented by Mr James Weir, the South of Scotland Electricity Board, after whom the award is named as an appreciation of his past services to the Branch over many years as either hon. secretary or chairman.

West Midlands

THE speaker at the meeting of the West Midlands Branch on 8 January was Dr N. Pleshanov, assistant agricultural counsellor at the Soviet Embassy in London, who gave his audience many interesting facts and figures about farming in the Soviet Union. He admitted that some aspects of farming in Russia were not as satisfactory as they would wish, but they were working hard to improve upon them.

He mentioned that large factories for the manufacture of wheeled and crawler tractors, combined harvesters and farm equipment of all kinds were situated in major cities throughout the various republics of the Soviet Union and in the main each plant specialised in producing machinery required for the particular farming activity carried on in its own area. He said that over 100 new tractor and combined harvester plants had been set up since the war and a further 16 factories were planned. In 1940 the Soviet Union produced 84 types of tractors and farm machines, and in 1972 this had increased to 1,025 different types.

●

ON 5 February at the Massey-Ferguson Product Training Centre, Mr C. L. Cawood, who is also press officer of the Yorkshire Branch, gave a survey of imported European tractors. He illustrated his talk with slides and technical details of many foreign tractors, which included Italian, German, French, Austrian, Polish, Russian, Hungarian, Czech and Rumanian, and said that a threat to British makers on the home market could be a 4-wheel drive Rumanian copy of an Italian Fiat machine now being sold in Britain for almost half the price of a comparable *UK* product. He said that he did not see much cause for concern about European penetration of the home tractor market, but did see them providing great competiton to British-made products in the developing countries of the Far East and Africa, where price and simplicity were more important than superior quality engineering and sophistication.

In his opinion three things were vital to all farm tractors—4-wheel drive, a gear box where one could change gear on the move like a car, and power steering.

Prof. J. D. Ivins presenting the West Midlands Branch Technical Award to the first winner, Mr A. Grice.

●

THE annual general meeting and dinner of the West Midlands Branch was held at the Manor Hotel, Meriden, on 13 April. A motion by the Wrekin Sub-Branch to complete steps to obtain full Branch status in their own right was warmly supported by the West Midlands Branch members.

Branch officers elected are chairman—Mr John Alcock (sales director, Bomford & Evershed Ltd); vice chairman—Mr S. D. Burley; secretary—Mr M. J. Bowyer; and hon. treasurer—Mr S. F. Howell.

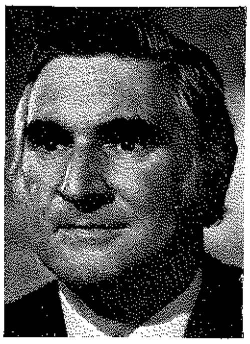
Professor J. D. Ivins was the guest of honour and it fell to him to present for the first time the West Midlands Branch Technical Award to Mr A. Grice of Culworth, Northamptonshire, for his hitch to convert a fully-mounted multi-furrow plough to a semi-mounted plough with draft control and independent lift at front and rear.

Yorkshire

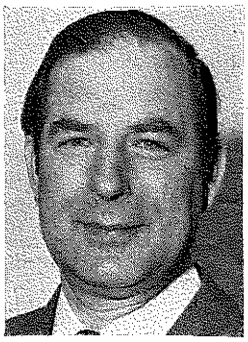
THROUGH the advertised speaker at the Yorkshire Branch meeting being cut off by deep snow drifts, it fell to the lot of Mr Charles L. Cawood, press officer to the Yorkshire Branch, to give a survey of the history of the agricultural tractor, at the Yorkshire Branch meeting on 17 February. He illustrated his paper with slides taken from his vast collection of photographs of tractors old and new, and in his inimitably colourful style left his audience in no doubt as to his intimate knowledge of all aspects of his subject, whether the tractors be European, American, or from the Eastern Bloc.

PERSONAL

W. T. A. Rundle



J. H. H. Wilder



D. Walker

A PAST president of the Institution of Agricultural Engineers, and a former member of the Governing Body of the National Institute of Agricultural Engineering and its deputy chairman for some years, is the newly elected president of the Agricultural Engineers Association. He is **Mr J. H. H. (Tim) Wilder OBE BA(Cantab) FIAgrE FRAgS**, a director of John Wilder Ltd, Wallingford and Reading, and managing director of the subsidiary company John Wilder (Agricultural) Ltd. Mr Wilder is chairman of the *BSI* Agricultural Machinery Industry Standards Committee and was recently appointed to the Engineering and Buildings Board, one of the five boards set up by the Joint Consultative Organisation for Research and Development in Agriculture and Food.

Another Fellow of the Institution, **Mr W. T. Alan Rundle**, chairman and managing director of Wright Rain Ltd, Ringwood, Hants., is the first vice-president of the *AEA*. Mr Rundle trained at the Henry Ford Institute of Agricultural Engineering and joined Wright Rain 17 years ago. His other appointments include director of Birmid Qualcast Wrought and Engineering Products Division; chairman of Wright Rain subsidiaries; and vice-president of Riego Wright.

Second vice-president of the *AEA* is Institution member **Mr Douglas Walker**, managing director of John Deere Ltd, Langar, Nottingham. Born in Edinburgh in 1928 he studied at the East of Scotland School of Agriculture. He joined John Deere in 1965 and became managing director four years ago.

Mr William G. Cover receiving a retirement gift, a camera, from Mr E. M. Bond-Smith

Mr WILLIAM G. COVER, a Fellow of the Institution of Agricultural Engineers and chairman of the East Anglian Branch of the Institution from 1964-65, member of the Council from 1962-66, chairman of the Finance and General Purposes Committe from 1964-65, and a vice-president from 1964-66, retired in April after 50 years in business, 48½ years of these being with the General Electric Company. Mr Cover was a director of Simplex of Cambridge Ltd before he retired at the age of 64.

At a ceremony held at the company's works he was presented with a camera from the directors and members of the staff and works of the Simplex organisation. The presentation was made to him by chairman and managing director **Mr E. M. Bond-Smith.**

Mr W. T. A. RUNDLE FIAgrE, chairman and managing director of Wright Rain Limited, has been awarded an *OBE* for service to export.

In 18 years with Wright Rain, Mr. Rundle has steered the company to many successes, which included in 1967 the Queens Award to Industry for export achievement, the first Royal Agricultural Society of England Gold Medal for Agricultural machinery of outstanding merit, and this year the award of the Royal Warrant as manufacturers of irrigation equipment to Her Majesty the Queen.

SCHOLARSHIP AWARDS IN AGRICULTURAL ENGINEERING

Dunlop Scholarship Award

THROUGH the generosity of the Dunlop Rubber Co. Ltd, the Institution is able to offer a scholarship valued at £250 tenable in 1973/74 for a post-graduate course at the National College of Agricultural Engineering or for a course leading to the National Diploma in Agricultural Engineering, whichever is more appropriate to the successful candidate.

Applicants for the scholarship should either have obtained or be about to obtain, for entry to the National College post-graduate course, a degree or Higher National Diploma or equivalent professional qualification, or for entry to a course leading to the *NDAgrE*, a degree in agriculture or horticulture; national or other approved diploma in agriculture or horticulture; degree or equivalent in engineering or technology; Higher or Ordinary National Certificate or Diploma in Engineering; City and Guilds 260 or 261 certificates or City and Guilds 293 certificate (part II).

Forms of application are obtainable from the Secretary of the Institution of Agricultural Engineers. Interviews will be held during September.

Shell-Mex and BP Bursary Awards

THE generosity of Shell-Mex and BP Ltd enables the Institution to offer bursary awards valued at £50 each available for the 1973/74 courses of study for the National Diploma in Agricultural Engineering.

The Writtle Agricultural College, Chelmsford, Essex, and the West of Scotland Agricultural College, 6 Blythswood Square, Glasgow C2, offer courses leading to the *NDAgrE*.

Applicants for the bursaries should either have obtained or be about to obtain a degree in agriculture or horticulture; national or other approved diploma in agriculture or horticulture; degree or equivalent in engineering or technology; Higher or Ordinary National Certificate or Diploma in Engineering; City and Guilds 260/261 certificates; or City and Guilds 293 certificate (part II).

Forms of application are obtainable from the Secretary of the Institution of Agricultural Engineers. Interviews will be held during September.

Classified Advertisements

Situation Vacant

Versatile, Competent Engineer for interesting work erecting Industrial and Agricultural Silo's by a Revolutionary new system.

Should be prepared to travel extensively throughout United Kingdom.

Salary up to £1,500 per year depending on qualifications plus expenses, plus bonus based on work completed after initial training.

H.G.V. licence an advantage but training will be given.

This is a great opportunity for advancement for all engaged in this new system not before used in this country and which will rapidly expand.

Full details to: C. F. Lander,
Simplex of Cambridge, Sawston, Cambs.
Tel: 022-03 3281 (13 lines).

Education

Kesteven Agricultural College

Caythorpe Court, Grantham

One year certificate and three-year diploma courses of training in:

AGRICULTURAL ENGINEERING

ARABLE FARM MECHANISATION

These courses lead to the new City & Guilds 030 examinations, which entitle holders to the Full Technological Certificate of City and Guilds of London and to Graduate Membership of the Institution of Agricultural Engineers; the Arable Farm Mechanisation course leads to the Advanced National Certificate in Arable Farm Mechanisation.

Full particulars from:

The Principal.

INSTITUTION OF AGRICULTURAL ENGINEERS

Penn Place Rickmansworth Herts

APPOINTMENTS REGISTER

This service is available to members who wish to learn of vacancies in specific branches of agricultural engineering and the related services; it is also designed to assist organisations and employers to bring any such vacancies to the attention of persons who have a direct interest. It will operate in the following way:—

MEMBERS

Broad areas of interest have been categorised and identified by a letter as shown below:—

A. Design/Manufacture
B. Administration
C. Technical representation for manufacturer
D. Technical representation for distributor
E. Service for manufacturer
F. Service for distributor
G. Farmbuilding
H. Field Engineering
I. Education
J. Advisory

OTHERS

New categories will be included as and when it proves necessary.

NB: Members may wish to include details of qualifications and any other information which, it is felt, could help in ensuring that suitable information is forwarded; but this is optional. Any information will be treated as confidential.

Members wishing to use the scheme should write to:

J. Turner, Ryecotewood College, Thame, Oxon (Tel. 2501) indicating the types of vacancy on which they would like information and enclosing some stamped addressed envelopes, up to ten in number, suitable for A4 or foolscap size papers.

As vacancies are notified, photocopies of particulars will be forwarded to members who have expressed interest in the particular type of post involved.

This service will continue and the penultimate stamped addressed envelope, returned to the member, will contain a reminder that the supply of s.a.e's is almost exhausted. If the member wishes to continue the service, more s.a.e.'s should be sent. Particulars of vacancies will continue to be sent until either the supply of s.a.e.'s is exhausted or the member writes asking that the service be discontinued.

ORGANISATIONS/EMPLOYERS

Details of vacancies should be sent to:—

J. Turner, Rycotewood College, Thame, Oxon (Tel. 2501) in a form suitable for copying by the thermal photocopying process. Copies of information will be sent to members who have expressed an interest in the type of work in question.

There will be no charge to either party for the service.

BP announce the time saver

New BP Super TOU

Few farm people have time to waste. Especially on lubrication. BP now save you time and trouble with a newly-formulated multi-purpose farm oil. New BP Super TOU covers all these farm requirements...

For all farm engines

including tractor engines with a Series 3 requirement. New, high performance engines need an oil which minimises carbon deposits. BP Super TOU, based on new lubricants technology, keeps pistons clean. Wear is reduced and power output maintained.

For oil-immersed disc brakes

No more need to worry about special wet brake additives. New BP Super TOU lubricates wet brake transmissions and contains a friction modifier to alleviate squawk.

For transmissions

on tractors, combines, planters, harvesters, balers, conveyors, elevators, etc. New BP Super TOU is a high load-carrying oil which offers maximum resistance to wear.
(Exceptions: IH and John Deere tractor transmissions; all semi-automatic transmissions; Land Rover axles; some other machinery. See BP Farm Lubricants User's Guide.)

For hydraulics

Use new BP Super TOU for hydraulic systems combined with tractor transmissions and others, including combines. This new oil keeps hydraulics efficient and responsive. It also fights corrosion – especially important on machines in store such as combines. Rust-vulnerable components such as servo valves and control mechanisms are effectively protected by new BP Super TOU.

New BP Super TOU saves you time by simplifying lubrication. And keeps down machine down-time because it more than meets the protection demands of modern, high performance farm machines. If you have a mixed fleet including modern machines, you must have new BP Super TOU. For older machines, regular BP TOU is still available. Contact your BP Farm Service distributor or your agricultural traders.