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An E.E.C. viewpoint on animal waste disposal

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Livestock management practices have evolved considerably in the E.E.C. during the last two decades. The development of intensive confined rearing without using litter results in the production of vast quantities of animal waste slurries, which create serious disposal problems. Yet these wastes possess a fertilizing value that should be used as much as possible to replace increasingly expensive chemical fertilizers. The Commission of the European Communities sponsored a coordinated research programme on livestock effluents to assess the levels of fertilizing elements in slurries and to establish mathematical models aimed at predicting environmental effects as well as specifying the economic aspects of the land spreading of slurries, and to enable livestock production management to be included in the context of planning and regional policies.

The main results obtained on the characterization of slurry and on its use for arable crops, grassland and forage crops are presented, together with some recommendations for administrative action.

Background information

In traditional farming, animal manures were used as the major source of nutrients for crop production and the two enterprises were closely integrated and mutually dependent. Animal manures were applied to land to grow crops, which in turn were used as animal feed. Animals were housed in sheds, the floors of which were littered with straw which served as a bedding material in addition to absorbing urine. This mixture of straw and animal manure was allowed to accumulate as a hand-pack and spread on land in the spring and autumn. Under such circumstances the farmer appreciated the nutrient value of the manure and neighbours raised few objections to malodours.

The advent of chemical fertilizers on a large scale resulted in a situation in which crop and animal production were no longer interdependent. Chemical fertilizers became the major source of plant nutrients with a consequent decrease in the demand for animal manures for their fertilizing value. There was a marked increase in both meat consumption and livestock production, and the latter was achieved against a background of a continuously declining agricultural labour force.

Concurrent with the trend to stream agricultural enterprises into two distinct routes, namely crop and livestock production, major changes in the housing of livestock were developed. Confinement feeding of pigs, poultry and veal calves is now standard practice. Modern housing methods, with the possible exception of broiler production, require the use of no bedding material whatsoever. Present-day housing techniques require animal manures to be dealt with in liquid rather than in solid form as hitherto. Having regard to the large volume of animal manure produced, a farmer with a 2000 place fattening unit, for example, must deal with approximately 3500 m^3 of manure per annum. Its management and disposal requires careful planning to minimize environmental problems.

The problem of animal manures is accentuated by the fact that most western European countries are densely populated. The population is in general engaged in non-agricultural employment and cares little for 'farmyard smells'. Moreover there is an increasing interest in open-air activities, an expansion of urban centres into rural areas, and an increasing concern on the part of the general public for the quality of the environment.

The biological data, when compared with those of municipal sewage, indicate the enormous water-polution potential of animal manures; a pig-fattening unit of 10000 places is equivalent in terms of biochemical oxygen demand to a town of 18000 inhabitants. The dry matter content of municipal sewage is approximately 0.03%, which is insignificant when compared with animal manures, approximately 9.5, 11 and 23% respectively for pig, cattle and poultry manure.

The nutrient content of animal manures is considerable and with a trend in standardizing of feeding rations there is a predictable nutrient content which, if utilized, could result in significant savings in chemical fertilizer costs to agriculture. The cash value, in terms of equivalent cost of chemical nutrients, per pig and fattening cattle place, was estimated in 1974 at £2.5 and £5 respectively per season (per annum for a pig place and per 5 months for a cattle fattening place). Having regard to the likelihood of a continuing increase in the cost of chemical fertilizers, it was considered that the utilization of animal manures in crop production would become highly significant in terms of the economics of both livestock and crop production.

The C.E.C. research programme on effluents from livestocks

Following these considerations a Research Programme 'Effluents from livestocks' was sponsored by the General Directorate for Agriculture, submitted by the Commission of the European Communities to the Council of Ministers and finally agreed (E.E.C. 1975). This programme lasted three years, from 1975 to 1978, and a follow-up to 1980 was then accepted (E.E.C. 1978). It was based on the following priority items.

(*a*) Study of the influence of physical, chemical and microbiological characteristics of manure, in particular its content in fertilizing elements, organic matter and polluting agents, on mainly:

> yield and quality of crop, soil characteristics and water quality, as a function of soil type, amount of manure and time of application in order to determine the maximum amounts of manure to be spread for optimum crop yields and quality, while creating minimum harmful effects on environment for any type of soil, climate, etc....

The results of these studies should contribute to the data input for system analyses, which will lead to an improvement in the next item.

(*b*) Establishment of mathematical models for the whole system with all essential factors such as manure characteristics, soil types, different climatic factors and crops in the input. One of the aims of the model is the prediction of ecological effects, economic aspects, etc., to enable the management of livestock production to be included in the context of planning and regional policies.

(*c*) It was agreed that research on production and storage of pig manure would also be a first priority. The control of bad odour emitted directly from the farm or during storage as well as during manure spreading is a problem of utmost importance.

Results

Slurry characterization and its use for arable crops

(*a*) *How much manure can be applied without harm to the vegetation?*

Long and shorter term fertilizing effects must be distinguished. With increasing amounts of manure applied over periods of 10–20 years, the N content of the manure will limit the dressings that can be used without harm to the plants. However, the application of large quantities of manure over many decades will be limited by the content of other nutrients such as phosphate, copper and calcium, or organic matter.

Too much N leads to the following difficulties: with cereals, lodging and/or decreasing yield; with sugar beet, decreasing sugar content in the roots; with potatoes, decreasing nitrate content in the plants; with grassland, scorching of the grass; with forests, too rapid decomposition of the humus and litter. In the long term, other nutrients can also have a negative influence on the growth of plants and plant quality, and their significance becomes evident when one looks at the nutrient levels that are applied to the soil with specific quantities of N. The nutrient content of slurries and the relation between amounts applied and plant uptake will vary somewhat, but in general, with pig and poultry manure, too much phosphate will be applied. Poultry manure also supplies excess calcium; pig manure too much copper and cow slurry too much potassium. The enrichment of the soil with phosphorus and copper after 4 years of application of 90 m^3 slurry ha^{-1} showed that, with continued application, the phosphorus and copper contents of the soil can reach critical levels. Furthermore, high organic loadings can produce unfavourable physical topsoil conditions because the soil can become too porous.

The amounts of slurry applied can be increased by using a longer time between the application of the slurry and the beginning of crop growth.

The optimal amounts of slurry increase from least for cereals to most for grassland, with root crops, potatoes to maize, being intermediate.

(*b*) *How much manure can be applied without risk to surface water and groundwater?*

For the year of application, N limits the amount of slurry that can be applied without risk to water quality. With continued application, N leaching into deeper soil layers increases with the number of dressings, as does the amount of phosphate leached, particularly if large slurry dressings are used for two or three decades.

Nitrogen concentrations in the groundwaters of heavy soils are similar, or sometimes a little higher than in sandy soils, but the amount of N leached from heavier soils is generally less than from sandy soils, because there is less drainage water. More phosphate moves downwards into deeper soil layers on sandy soils than on heavier soils. In wet regions, more N is leached than in drier regions with low precipitation rates; dry summers with high evapotranspiration rates lead to more leaching in autumn and winter than after wetter summers.

The N content of the groundwater is increased less when slurry is applied nearer to the start of the crop growth. When the same amount of N is applied, more N is leached from organic manure than from fertilizer. With continued applications, similar amounts of N are leached from farmyard manure and from slurry. More N is leached from organic manures than from fertilizers, because the time of application is not always related to the time of nutrient demands by the plants.

The risk of loss of nutrients by leaching is lessened when growing crops are present. For example, on grassland, where the crop is present all the year, smaller amounts of nutrients are lost by leaching than from arable land. Various authors have obtained similar results, and over a prolonged period leaching from farmyard manure would be expected to be the same as from slurry. A very important point to note is that the order of magnitude is almost the same in all the experiments.

(*c*) *How much manure can be applied economically?*

Applying large amounts of organic manure causes the amount of nutrients used from the slurry to decrease from year to year, because of the residual effects of the earlier slurry dressings. The nutrients in the slurry are utilized better on heavier soils than on sandy soils for the first few years. The amounts of slurry required for crop production are smaller, the nearer is the application time of the slurry to the start of crop growth. For the first few years, more N can be applied as farmyard manure than as slurry, although the amounts of available nitrogen as ammonium are the same for farmyard manure and slurry. With application for several decades, the potassium content of both cattle slurry and farmyard manure can limit the optimal rates. The same is true for phosphorus and copper for pig slurry, and for phosphorus and calcium for poultry manure and slurry. Least N is required for cereals, more for potatoes and sugar beet, and most is needed for grassland and maize.

The use of slurry for grassland and forage crops

Slurry can be used effectively on grassland, but there are a number of problems and risks that need special attention. In the short term, slurry greatly in excess of crop needs can be applied. In the medium term, problems of water pollution will arise and, in the longer term, crop nutritional and animal health problems may develop with increased amounts of phosphorus and potassium.

Nutrients can be lost from grassland both by leaching and surface runoff. Nitrate losses by leaching are of primary importance, and results indicate that in general losses from grassland will be smaller than from arable soils. Where surface runoff occurs, the major losses will be as biochemical oxygen demand, ammonia and phosphate.

One consistent result of major importance is the low availability of N in cattle slurry when applied to grassland. The reasons for this are not clear, though there are several possibilities such as the volatilization of ammonia, denitrification, slow release of organic N, and coating of slurry on the grass surface. The availability of N in cattle slurry and percentage recovery were often less than 20% and in a few cases cattle slurry actually depressed yields of grass.

Grass usually responds well to the N in pig and poultry slurry, with an availability of 50% or more being obtained. This difference in the availability of N in the slurry from ruminants and from monogastric animals should be studied and explained. Clearly in the E.E.C. large quantities of N in cattle manure are being lost each year. Perhaps this expensive loss could be reduced if we had a better understanding of what is happening.

Of course, all the manures are valuable sources of phosphorus and potassium for maintaining grassland fertility, although large amounts of cattle slurry can give high potassium percentages in the herbage, and pig and poultry slurry can increase the content of phosphorus in plants. Application of slurry in summer increases yields of grass least.

Slurry can increase some species of soil fauna and decrease others. But the results do not indicate a positive or a negative effect of these changes on grassland production or utilization.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

It would be interesting to study the effects of slurry on the fauna of soil under arable crops. The short duration of the experiments (3 years) could not show what the long-term effects of high nutrient levels in the soil might be. In the absence of information on the long-term effects of large applications of slurry on the soil and the environment, the suggestion is made that no more than double the amount of nutrient required by the crop should be applied in one year. This is proposed as a short-term guideline until further information becomes available. Present results indicate that large concentrations of phosphorus from manure in the soil give rise to serious problems when they occur in the catchment areas of inland lakes and other waters.

Pasture used for grazing can only accept a limited amount of slurry because of the high proportion of nutrients that are recycled. Therefore it is proposed that most of the manure on grassland will be recycled to grass cut for hay and silage. However, the results of the work showed that, although slurry can be used on pasture for grazing, poor animal performance was obtained with cattle slurry. Good animal performance was obtained from pasture when poultry and pig slurry were applied. Silage produced from grass treated with slurry was significantly less good when measured by animal performance than silage made from grass with fertilizer, though silage quality was not affected. The slurry was applied in spring and summer less than 2 months before cutting the grass for silage. Application of slurry in the autumn may avoid this problem. The overall results indicate, particularly with cattle slurry, that caution is necessary, when spreading slurry on the grass surface, to avoid damage to the sward and contamination of the grass.

Modelling nitrogen from slurry

There is a need for good principles for land spreading and the development of models. This would require the ability to use the nutrients in the slurry effectively, avoiding pollution of water and problems with odours. These aims raise the ideas of the optimum use of slurry and the protection of the environment. To meet both aims there is a need for knowledge of what is happening when slurry is applied to land. Two types of models are required:

(i) systems models that allow the practical problems to be quantified;

(ii) process models that describe the processes occurring when slurry is applied.

Other points that could be raised are the problems of the distribution of slurry and the land available for its disposal. The costs of transport are likely to be less than the cost of treatment if distances are less than 30 km. If longer distances are involved the cost of transport may be greater than the value of the slurry. The effects of slurry on the structure of soil need further investigation. This should be studied in the field as well as in the laboratory by using available techniques for estimating the effects on soil micromorphology.

In any event, slurry must go back onto the land. A hundred cows equal a thousand people for purposes of purification of slurry. It is necessary to relate the animal and crop production within the region. Models are required to allow use to be made of superfluous slurry within the region. Simplified models are needed rather than simple models. This may be a difference of degree rather than of kind, and allows two approaches. The first is the empirical development of simple models and the second is the use of mathematical models to quantify and to simplify.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Recommendations for administrative decisions

Attention should be focused on the following conclusions.

(*a*) Water quality is not adversely affected when slurry is spread at optimal rates for crops at the best times.

(*b*) In most E.E.C. countries the total nutrient requirements of crops are greater than amounts produced as animal manures and more nutrients in the form of animal manures could be applied for crop production.

(*c*) The amounts of organic manure giving optimal crop yields are also economically viable. The value of the nutrients in the animal manures is sufficient to make storage profitable, allowing slurry to be spread at the best time. Also, transport is justified over some distance from regions with overproduction to regions requiring nutrients.

(*d*) The most important reasons why slurry is not spread at optimal application times are:

(i) insufficient storage capacity;
(ii) lack of slurry tankers able to distribute slurry on to the land evenly and exactly;
(iii) too much damage to the soil by the big wheels of heavy slurry tankers;
(iv) odour emission during slurry spreading.

With regard to environmental pollution, and with the exception of the malodours, the main problem remains the prevention of water pollution caused by run-off of animal slurries and manure. Run-off can occur in many regions in the E.E.C. If this causes eutrophication of the surface water the following measures can be taken with respect to the land spreading of animal manure.

(*a*) Land spreading of manure between October–November and spring is not allowed. Spring is supposed to begin after the frost period as soon as the land is passable for the manure-spreader or tank. In regions where the arable land has to be cultivated before wintertime, land spreading before winter is acceptable if the manure is ploughed in as soon as possible.

(*b*) Ploughing-in and injection of the manure reduces the contact with run-off water. This measure can be advised if run-off occurs during the growing season. On land bordering on surface water a minimum distance for spreading of e.g. 2 m can be considered.

(*c*) As run-off water from soils rich in phosphorus contains more phosphates, the amount of manure to be spread should be limited to the manure produced per hectare per year by 1.5 milk cows, 8 pig places, 80 layers or 160 broilers.

(*d*) Run-off water from areas heavily contaminated with manure has to be collected in the storage pit for manure. The same holds for waste water from cleaning the stables, the milking parlour and the milking machine.

(*e*) To fulfil these guidelines the storage capacity for manure should be sufficient for half a year.

Conclusion

During the last decades, important changes have been observed in livestock management. Intensive confined rearing has become a current and reference practice and modern designs of housing of the animals exclude all forms of litter; this implies that animal wastes and excreta have to be manipulated in the liquid state rather than in the solid form. This represents a great volume of slurry production and its elimination needs to be predicted with special care with

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

regard to protection of the environment. This problem is accentuated by the fact that most of the western European countries have a heavy density of population.

One must consider two approaches to the problem:

(*a*) to find economic and practicable solutions for the farmer;

(*b*) to avoid pollution of the sources of drinking waters and malodours coming from the farm itself, from storage and from the use of the slurries produced.

Research activities have to take into consideration not only these aspects but also the specific Community interest of ensuring that national and Community regulations should be based on objective criteria established on a common agreement.

Bibliography (Bourdeau & L'Hermite)

Scientific details may be obtained in the proceedings of the seminars organized by the Commission of the European Communities within the scope of the research programme on Effluents from Livestocks.

Brogan, J. C. (ed.) 1981 *Nitrogen losses and surface run-off from landspreading of manures.* (471 pages.) The Hague: Martinus Nijhoff/Dr W. Junk. (EUR 6898.)

Catroux, G. & Hucker, T. W. G. (eds) 1981 *Phosphorus in sewage sludge and animal waste slurries.* (433 pages.) Dordrecht: D. Reidel. (EUR 7112.)

Gasser, J. K. R. (ed.) 1979 *Modelling nitrogen from farm wastes.* (195 pages.) London: Applied Science. (EUR 6361.)

Gasser, J. K. R. (ed.) 1980 *Effluents from livestock.* (712 pages.) London: Applied Science. (EUR 6633.)

Voorburg, J. H. (ed.) 1977 *Utilization of manure by landspreading.* (732 pages.) Belgium: Commission of the European Communities. (EUR 5672.)

References (Bourdeau & L'Hermite)

E.E.C. 1975 Council Decision of 22 July 1975. No. 75/460/EEC (O.J. L 199).

E.E.C. 1978 Council Decision of 30 October 1978. No. 78/902/EEC (O.J. L 316).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES