Plant Nutrients and Animal Waste Disposal

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One of the many functions which society must perform in order to survive is to dispose its waste. A substantial portion of that waste, even in urban Connecticut, is produced by animals that provide our eggs, milk, and meat.

Our concern is to examine how we may dispose animal wastes with the least damage to our environment. Following the function analyses suggested by Chairman Horsfall, it is obvious that disposal of animal wastes affects public health and the quality of our air, water, and land. However, let us assume that:

a) Existing public health standards are adequate to protect our health. The absence of outbreaks of disease attributable to improper waste handling makes this a reasonable assumption at the moment, although there is clearly a need for further study of methods of assessing the human health hazard of animal wastes.

b) Existing water quality standards will prevent downgrading the quality of our water. Examples of such standards include maintaining acceptable levels of dissolved oxygen, and avoiding the introduction of materials with undesirable color, odor or taste into receiving waters.

c) Existing or forthcoming air pollution standards will protect our air. Examples include the disposal of dead poultry by incineration in accordance with prescribed emission standards.

d) Existing or forthcoming solid waste disposal standards will protect our soil. An example here might be the disposal of incinerator residue by sanitary land-fill.

In my opinion, none of these regulations, or more precisely the methods of disposal, deal effectively with a very serious aspect of the problem, namely the impact on the environment of the plant nutrients in animal or human wastes.

Turning to human waste disposal as an example, we must realize that a conventional sewage treatment plant employing primary and secondary treatment is essentially a process for converting human waste

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[1] This document was prepared at the request of the Waste Disposal Panel, The Governor's Committee on Environmental Policy, and was presented in testimony to that Panel February 12, 1970. Many others have expressed an interest in the information in this report; hence it is published here with the permission of the Committee.

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into a rich liquid fertilizer. The effluent is chlorinated, so that pathogens are usually not a health hazard. Concentrations of nitrate are usually below the U.S. Public Health drinking water standard of 10 parts per million (ppm) N, so that nitrate poisoning of infants ("blue-baby disease" or methemoglobinemia) is unlikely. Other water quality criteria, mainly the requirement to maintain an adequate supply of dissolved oxygen in the receiving water, are also met. Moreover, we assume that the digested sludge is disposed by acceptable methods. The net result, however, is that abundant plant nutrients, particularly nitrogen and phosphorus, are released from various organic forms in human waste and made available for the growth of weeds and algae in the receiving water.

The consequences of this nutrient enrichment are increasingly familiar. Domestic water treatment plants are plagued with clogged filters, taste, and odor problems from decaying algae. Frequent treatments of reservoirs with copper sulphate or other algicides are necessary to keep the algae from exploding into a so-called "bloom." Such treatments for lakes and impoundments used for recreation are too expensive and, as a result, many Connecticut lakes are unfit for swimming, boating, or even lakeside cottages during the height of an algal bloom.

Conventional wisdom dictates that tertiary treatment of sewage effluent is required to solve this problem. Essentially, this involves the production of distilled water by some process akin to desalinization of seawater. At present, such methods are considered prohibitively expensive and may not be the ultimate solution.

To return to animal waste disposal, it is useful first to look at the magnitude of the problem. The accompanying table contains some estimates of total waste production by humans and animals in Connecticut, as well as estimates of plant nutrients from these and other sources. These estimates were obtained by combining census enumerations of people, animals, or cars with appropriate waste production rates and nutrient concentrations reported in the literature. Information on agricultural feeds and fertilizers was taken from recent USDA summaries. Nitrogen in industrial fumes was assumed to be 7/6 that from automobile exhausts, a ratio reported for the entire United States by the U.S. Public Health Service. Not all these sources are mutually exclusive: as an example, nitrogen from feed and fertilizer appears in both human and animal wastes.

First, it is evident that animals in Connecticut produce more waste than humans. Nitrogen in animal wastes is about equivalent to that from humans, while phosphorus is about half. This enrichment of human waste with phosphorus is in part attributable to detergents: some estimates indicate that as much as half of the phosphorus in domestic sewage comes from detergents. It seems clear from these data that if 3 million Connecticut citizens cannot afford tertiary sewage treatment plants, 1,500 farmers are not likely to install such facilities either.

Looking next at the sources of nitrogen and phosphorus that appear in animal wastes, we see that most nitrogen is imported into the state

ESTIMATES OF PLANT NUTRIENTS FROM VARIOUS SOURCES IN CONNECTICUT

Source	Tons material	Tons N	Tons P
People–3,000,000	1,500,000	13,500	4,500
Cows–100,000	1,500,000	7,500	1,600
Broilers–12,000,000	240,000	3,600	840
Layers–4,000,000	80,000	1,200	280
Dairy and Poultry Feed	444,000	13,300	3,100
Dairy Farm Fertilizer	26,100	2,500	1,300
Other Agricultural Fertilizer	29,100	2,100	1,000
Non-Agricultural Fertilizer	25,600	2,800	1,400
Protein Produced in Conn.	....	3,800	....
Protein Imported into Conn.	....	14,000	....
Automobile Exhaust	....	38,000	....
Industrial Fumes	....	44,000	....

in the form of concentrated feeds, rather than fertilizer. Since much of this nitrogen returns to the land as manure, manufacturers of dairy and poultry feeds perhaps should share the abuse currently directed at fertilizer manufacturers for polluting our waters.

Other agricultural uses of fertilizer in the state are about equal to the amounts applied to dairy farms. An item which provides additional perspective is shown as non-agricultural usage: note that this exceeds the amount purchased by dairy farmers. Since much of this is spread on suburban lawns, where no crop is harvested and removed, the suburban home owner may well be contributing significantly to nutrient enrichment of our waterways.

Given these various agricultural uses of feed and fertilizer, we might ask what proportion of the total protein consumed in Connecticut is produced by our agricultural efforts. These estimates are also shown in the table: Connecticut farmers produce fully 20% of the total protein consumed in the state, which is equivalent to feeding 600,000 people. Since this protein is produced by about 2,000 farmers, 300 Connecticut citizens depend on one farmer for their animal and vegetable protein.

Finally, the last two entries in the table are estimates of the nitrogen derived from NO and NO_2 (nitric oxide and nitrogen dioxide) in automobile exhausts and industrial fumes. These oxides originate largely in combustion at temperatures hot enough to cause nitrogen in the air (not the fuel) to react with oxygen. Although the fate of these compounds in the air is not completely understood, they are generally considered to react with atmospheric moisture and return to the earth as nitrate nitrogen. Clearly, these are sources of considerable magnitude when compared with others in the state, and we must learn more about them.

Although the magnitude of animal waste production as shown in this table is impressive, we might still ask why we have a disposal problem. Why not continue putting it on the land as farmers have done for centuries? The answers are several, but they all stem from a common cause: the tremendous economic pressure of the farm market place. To survive, farmers have increased the productivity of their units many-fold. As an example, the average dairy farm in Connecticut in 1935 had 13 cows producing 5,360 lbs. of milk per cow. In 1968, the average farm had 50 cows producing 10,300 lbs. per cow, so that the productivity of a dairy farm increased almost 8-fold in that 33-year period. The economic pressures are also evident in broiler production in the state: in 1935, 1.6 million broilers were grown and sold for 22.2 cents per lb. Production rose to over 25 million by 1955 although the farm price had reached only 26.5 cents per lb. Since then, the price has dropped steadily, and in 1967 it was 15.8 cents per lb. Farmers still produced over 9 million broilers in 1967, but received 30% less for them than in 1935!

The consequences of this pressure are most easily seen if we analyze a farm as a machine for food production, since this is essentially what we have created. I have analyzed the records of about 600 dairy farms in the Northeast for the period 1966-68: the results of these studies appear in a number of publications listed at the end of this report. The major findings are summarized below.

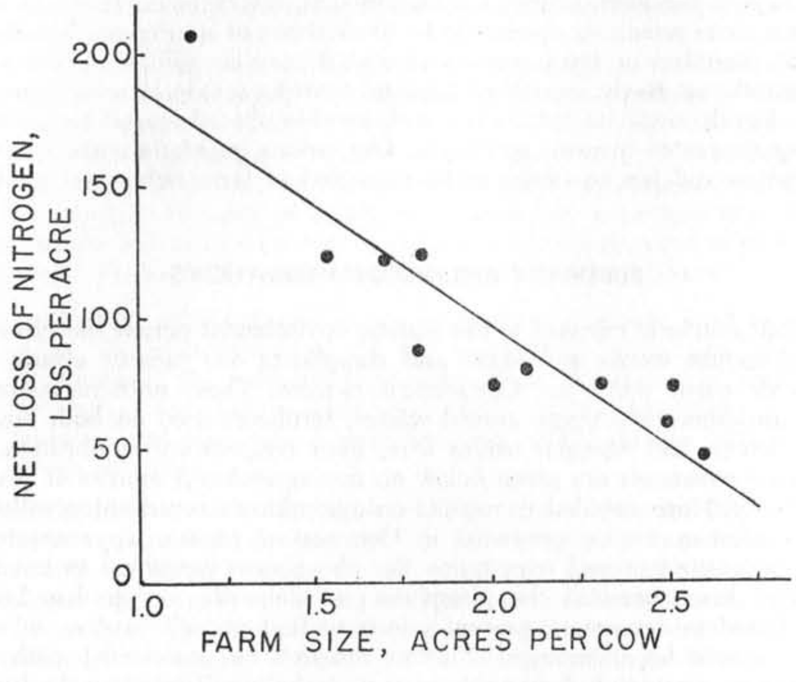
These highly specialized dairy farms were assumed to operate as machines for the conversion of dairy feed and fertilizer into milk. Considerable re-use occurs on the farm as nutrients pass through the cow, are applied to the field, taken up by the crop, and returned to the cow. Since no machine is perfect, some of the nutrients are lost and either accumulate in the fields or leave the farm by various paths.

Since phosphorus is readily fixed by soils in relatively insoluble forms, I assume that most of this nutrient remains on the farm. Nitrogen, however, is not readily retained by soils and much of the calculated loss will likely leave the farm and eventually appear as nitrate in ground water.

The magnitude of these calculated losses of nitrogen from dairy farms in the Northeast is shown in the attached figure. The data points represent averages for 6 states in 1966 and 5 states in 1968.

Obviously, the intensity of land use is a strong determinant in the loss of nitrogen to streams. As the available land per cow is reduced, the movement of nitrogen from the farm increases sharply. Moreover, calculations show that losses of nitrogen in excess of about 75 lbs. per acre per annum can cause concentrations of nitrate in the ground water under a single farm in excess of the drinking water standard of 10 ppm N. Analyses of ground water in the milk-producing regions of eastern Connecticut indicate, however, that this high concentration is rapidly diluted with ground water from low-nitrate sources.

Since Connecticut farms in both 1966 and 1968 had the largest calculated losses of nitrogen of any states shown in the figure, along with the smallest acreage available per cow, we apparently are crowding



our farmers to a greater extent than any of our neighboring states. Although Public Act 490, the "Open Spaces Act," was designed in part to provide tax relief for farmers, perhaps we need to do more in the way of encouraging farmers to keep adequate areas in crops.

In the case of poultry farmers, who long since have abandoned growing their own feed, even more novel approaches may be necessary to provide land for manure disposal. One possibility is the use of State Forests, where plantations of young trees, especially, would benefit considerably from fertilization.

If manure is to be disposed on the land, as seems likely for some time to come, several other factors must be considered even though land remains or is made available. Chief among these is the fact that nutrients, particularly nitrogen, are only removed by a growing crop. This is the principal reason why reduced farm acreage leads to high nitrogen losses, since farmers are forced to apply manure to the soil year-around. In addition, off-season prices have made it attractive to apply nitrogen fertilizers to the soil in the fall, again promoting losses to the environment.

There are also agronomic practices which could considerably increase the efficiency of removal of nitrogen by the crop. These include use of hybrids selected for high protein content, summer side-dressing, foliar fertilization, more extensive use of cover crops, and breeding of animals with improved efficiency of conversion of nitrogen in the feed to protein in meat, milk or eggs. These practices should reduce the total nitrogen imported to the farm and produce the same product with less damage to the environment. At the moment, the chief difficulty in applying these principles appears to be the logistics of storing and handling large quantities of farm manure so that it may be applied to the soil during the relatively short New England growing season. A related problem, largely aesthetic but no less real, involves the odors and occasional unsightliness of manure spreading. Our urban population has largely forgotten and has no desire to be reminded of farm sights and smells.

SUMMARY AND RECOMMENDATIONS

Plant nutrients released to the aquatic environment permit the growth of abundant weeds and algae and complicate our present efforts to provide clean water for Connecticut citizens. These nutrient sources include domestic sewage, animal wastes, fertilizers used on both farms and lawns, and nitrogen oxides from high temperature combustion.

Some comments are given below on non-agricultural sources of plant nutrients. More detailed comments on agriculture's contribution follow.

a) Human wastes produced in Connecticut contain approximately as much nitrogen and over twice the phosphorus contained in animal wastes. Since one-half the phosphorus in domestic sewage has been attributed to detergents, present efforts to find phosphorus-free substitutes should be encouraged. Further research on economical methods of tertiary treatment of domestic sewage, including disposal on the land, should be supported. Existing water quality standards of the State Water Resources Commission which specify that waste be treated to the extent that is technologically feasible seem adequate if nutrient pollution is recognized as an additional threat to the environment.

b) Almost 40% of the fertilizer nitrogen sold in the state is used for non-agricultural purposes. Perhaps we could tolerate an occasional yellowing of our lawns if we realized the consequences of excess fertilizer reaching our waterways.

c) Nitrogen from high-temperature combustion appears as an enormous item in the rather crude nitrogen budget calculated for Connecticut, amounting to over twice all other sources combined. Either the estimates of this source are in error, or it does not all return to earth, since the amounts are so large that the fertilization response would be obvious. Nevertheless, we certainly should learn more about this source of nitrogen before encouraging the proliferation of high-temperature incinerators.

d) Animal wastes, as noted above, contain about as much nitrogen and half the phosphorus as human waste. Present methods of domestic sewage treatment are inadequate for the removal of nutrients in animal wastes and are also considered prohibitively expensive unless the cost can be subsidized in some fashion. Thus, disposal on the land will probably continue to be the most satisfactory technique. Where high concentrations of animals are involved, waste treatment plants may be required, and research to develop adequate methods should be encouraged. Unless tertiary treatment is included, however, putting animal manure into a waste treatment plant would, in my opinion, be a step backward.

Although the economic return from the plant nutrients in farm manure is marginal at best, we can no longer afford the consequences of regarding manure simply as waste to be disposed. Rather, methods must be developed for handling and storage so that it may be applied to a growing crop and not to bare or frozen soil. In addition, crops and animals with improved efficiency of uptake and conversion of nitrogen to protein will enable us to reduce the total amount of nitrogen required to produce our food. To this end, I make the following recommendations:

1) Continuing efforts should be made to keep adequate land area in crops. The effectiveness of PA 490, the "Open Spaces Act," should be examined and additional measures taken if necessary. The fertilization of state-owned lands with animal wastes, particularly young forest plantations, should be encouraged where private land is no longer available.

2) Methods of assessing the human health hazard from the disposal of farm wastes should be examined, so that the farmer is not harassed unduly by forced compliance with standards devised largely for the disposal of human wastes. In particular, fecal coliform bacteria counts are probably more reliable indicators of pollution than total coliform counts, since many coliform bacteria do not originate from human or animal wastes. Attention should also be given to the present standards for nitrate concentrations in drinking water, since they are based on rather limited observations, and may well be too high or too low.

3) Research on methods for storage and handling farm manure should be continued, with the ultimate aim a storage and distribution system so that manure is applied to growing crops and not to bare or frozen soil. Present cost estimates of such a system to provide 120 days storage for a 100 cow herd at 2 cubic feet per cow-day range from $9,600 to $14,000, with additional costs for spreading equipment of $3,000-$3,500. Increasing the storage capacity to 6 months would nearly double the cost and make such a system impossible for many farmers. Possibly, farmers with "adequate" waste treatment facilities could be provided a price differential for their milk within the present federal milk marketing orders. No such pricing system exists within the poultry industry, however, and more direct subsidies might be necessary.

4) Research should be continued on new agronomic practices to improve the uptake by the crop of the nutrients in the applied manure. These include selection of crops for high protein content as well as yield, studies of the effectiveness of summer side-dressing and foliar fertilization, and effective use of cover crops following harvest. As a necessary corollary, animal geneticists should strive for improved efficiency of conversion of nitrogen in the feed into protein in meat, milk, and eggs.

In recent years, Americans have become understandably wary of claims that research is going to solve all of our problems, and I hesitate to close this report with a list of research recommendations. However, I have attempted to identify specific problems and suggest profitable ways of examining them, in contrast to vague pleas for "further research." Others may disagree with my choice of priorities, but I firmly believe that studies of the problems I have indicated will aid considerably in our struggles to improve the quality of our environment.

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