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Manure Disposal, Pollution Control, and the New York Dairy Farmer

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PRESENT MANURE HANDLING AND DISPOSAL PRACTICES

As the second largest milk-producing state, New York must dispose of large quantities of manure. At one time this manure was conserved and spread sparingly as fertilizer for field crops. Today the high cost of labor has made manure disposal a burden to many farmers.

To investigate the problems facing the dairy farmer and to evaluate the attitudes of farmers toward the economic and environmental effects of alternative manure handling and disposal methods, the authors visited 50 New York dairy farms in the summer of 1971 (tables 1, 2). Farmers expressed a large variety of attitudes and approaches toward manure handling and disposal.

Dairy farms fall into two distinct groups, those with a conventional barn, and those with a freestall barn. Conventionally-housed dairy cattle come inside only for milking during warm weather, spending most of their time outside in pasture. During winter months the cows remain mostly in the barn. On the other hand, farmers using a freestall barn permanently confine the cows in the barn and exercise yard or pasture to which the cows have free access; milking is done in a parlor. Some intermediates between these two groups exist where old buildings have been converted. For practical purposes, these can be put with either one or the other group based on the degree of cattle confinement.

Table 1. *Housing and manure systems**

System	*Farms*	*Average–cows*	*Range–cows*
	number		
Conventional	20	49	12–185
Freestall	27	135	31–300
Combined	3	153	50–360
Total	50	102	12–360
Liquid manure	8	169	25–360

**Based on summary of interviews with 50 New York dairy farmers in 1971.*

Table 2. *Manure disposal practices**

Practice	*System*	*Farms*	*Average–cows*	*Range–cows*
Manure piled during winter	Total	11	88	12–200
	Conventional	6	63	12–185
	Freestall	5	119	65–200
Manure dumped at rate exceeding 50 tons/acre	Freestall			
	solid	7	168	65–300
	liquid	1	360	–
	Conventional	0	–	–

**Based on summary of interviews with 50 New York dairy farmers in 1971.*

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These two situations are quite different in manure production and handling. Failure to recognize differences may contribute to later problems. Cows that go to pasture are their own manure spreaders most of the time. Cows continually confined present the farmer with a daily chore of one spreader load per day for each 30 to 50 cows (depending on the spreader size). In winter, manure from cows housed in a conventional barn will have a high content of straw or other bedding that increases the overall volume of manure compared with that produced by the same number of cows housed in a freestall barn. In the freestall barn almost pure manure will be produced all year.

Farmers are changing to confined housing systems with very little recognition that new manure disposal problems will arise. The farmer who has previously removed about one load of manure a week from his barn during the summer months is quite unprepared for manure handling under his new system. He has not the time or the area necessary for handling and disposing of this manure properly.

Table 3 shows some of the spreading rates currently used by farmers in New York. The average, winter, soil-spreading rate of manure on farms with a conventional barn was 10 tons/acre (22.4 M tons/ha) compared with 18 tons/acre (40.3 M tons/ha) for freestall barns. However, the summer spreading rate was very low for conventional operations, approximately 51/2 tons/acre (12.3 M tons/ha), whereas the freestall rate was 55 tons/acre (123 M tons/ ha). The farmer modernizing his operation by changing to a freestall system must be prepared for *summer* manure problems.

The 1971 survey shows most farmers felt that the benefits of manure for improved soil structure, soil aggregation, and nutrient availability, were great enough to make spreading all of their manure on cropland worthwhile. Most farmers considered manure to be worth the cost of spreading. However, a small number were making adjustments to fertilizer application rates to compensate for the fertilizer content of the manure (see table 4). Some farmers were convinced that the only economically rational approach to their manure problem was to dump it onto unused fields (spreading at rates greatly exceeding 50 tons/acre [112 M tons/ha] with no intention of recovering the nutrient value of the manure). Actual dumping rates may have exceeded the maximum 145 tons/acre (325 M tons/ha) estimated from figures supplied by the farmers. Many dumping areas were located in relatively inaccessible areas of the farm making transportation costs high. Also, manure was frequently dumped on soils subject to excessive runoff into nearby watercourses, or on soils with high infiltration rates such as sands and gravels. Farmers preferred sands and gravels since they were less likely to become waterlogged and pose problems with heavy machinery.

Table 3. *Manure spreading rates for summer and winter**

System		*Summer (May–Oct)*	*Winter (Nov–April)*
		tons per acre (M tons/ha)	
Conventional	average	5.5 (12.3)	10 (22.4)
	range	5–6 (11.2–13.4)	5–20 (11.2–44.8)
Freestall	average	55 (123)	18 (40.3)
	range	5–145 (11.2–325)	4–60 (9.0–134)

**Based on summary of interviews with 50 New York dairy farmers in 1971.*

Table 4. *Farmer attitude toward manure*

Farmers considering manure to have a favorable fertilizer/soil-building value in relation to the cost of spreading	42
Farmers who considered manure not worth the cost of spreading	6
*Farmers adjusting fertilizer rates to compensate for nutrients in manure	27
Farmers making no adjustment to fertilizer rates where manure is spread	21

**Nitrogen adjustment for manure nutrients averaged 6 lb. N/ton (3 kg/M ton), with a range of 1–13 lb. N/ton manure (0.5–6.5 kg/M ton).*

Table 5. *When manure was spread by crop*

Time	*Alfalfa*	*Corn*	*Fallow*	*Meadow*	*Pasture*	*Small grains*
			number of farms			
May, June, July	6 (1)*	6	1	18 (4)	14 (4)	0
Aug, Sept, Oct	9 (1)	0	1	17 (1)	11 (2)	3
Nov, Dec, Jan, Feb, Mar, Apr	0	46 (3)	0	1	1	0

**Number in "( )" indicates number of farms spreading at rates of 50 tons/acre (112 M tons/ha) or more.*

All of the surveyed farmers who were dumping manure onto unused fields were operators of freestall housing systems (table 2). The freestall system (total confinement) usually eliminates the need for most of the pasture grown on the conventional farm. Therefore, the farmer is able to put more land into cultivated crops such as corn and alfalfa, and solves the manure problem by dumping. Dumping is environmentally undesirable for many reasons including odor, flies, and possible pathogen contamination of surface and ground water. Table 5 indicates the use of the fields on which manure was spread at different times of the year. Manure can be spread on corn ground in late fall after silage has been cut, or later after grain harvest, or during winter months. If weather and soil conditions permit, winter spreading can be done up to planting time. In addition, light applications of liquid manure can be made to the growing corn crop. Alfalfa, however, is usually not considered by farmers or extension personnel to be a suitable crop for manure disposal because of the unfavorable effect of the manure's nitrogen on alfalfa. The authors have not been able to substantiate this assumption, except where manure application rates far exceeded the rates likely to be used in crop production.[1] New York farmers who had to spread manure on alfalfa were unable to detect any adverse effects and many were convinced of benefits.

Some farmers were growing small grains crops, mainly oats, in order to have a disposal area for manure in late summer. The straw is useful for bedding but otherwise these crops were not considered economical.

POLLUTION POTENTIAL FROM A DAIRY FARM AND SOME EXISTING REGULATIONS

Incorrect manure management may cause the following types of pollution:

1. Soluble organic material may lower dissolved oxy gen levels in water causing fish kills.
2. Both inorganic and organic nitrogen can be re leased as inorganic nitrogen after degradation, and fertilize undesirable growths of aquatic flora, and, with nitrite, can be toxic to man and animals when ingested in large enough quantities.
3. Phosphorus in both inorganic-soluble form and organic form may be released on degradation. Phos phorus is necessary for the growth of aquatic flora.
4. Suspended solids. Sediments cause siltation of wa terways and sludge banks contain organic solids that can cause oxygen depletion and the produc tion of noxious gases on decomposition.
5. Volatile materials such as hydrogen sulfide and organic compounds that cause undesirable odors.
6. Color and turbidity of water causing unaesthetic appearances.
7. Pathogenic organisms such as bacteria, viruses, and parasites in various forms and life stages that can be infectious to humans or other animals or both.
8. Pests such as rodents, flies, and mosquitoes.
9. Unsightly appearances which detract from rural amenities.

The summary above includes many items which are common to the pollution characteristics from any source such as industry or municipalities (Eckenfelder, 1966).

A review of the available literature on existing and proposed laws and guidelines on pollution control from livestock sources has been made. It is possible to discern a number of specific approaches to the problems of controlling the factors listed above. Although many of these approaches are still proposals and have not yet been included in actual legislation, this should not detract from the need to give them adequate consideration. If public pressure continues to increase and officials respond by becoming bolder, these proposals will undoubtably be given greater attention and possibly enacted into law. The possible approaches may be summarized as follows:

1. To restrict the amount of manure that can be spread on a unit of area in one year.
2. To restrict the spreading of manure to soils that are not excessively permeable or excessively imper meable.
3. To restrict the spreading of manure to flat or only gently-sloping fields.
4. To restrict the spreading of manure to areas greater than some acceptable distance from surface water capable of leaving the operator's property.
5. To restrict the housing of animals and the spread ing of manure to areas greater than some accept able distance from dwellings and public areas.
6. To restrict the spreading of manure to certain times of the year.
7. To require that a certain minimum land area be owned or controlled by the farm operator according to the quantity and type of animals kept.
8. To require that any form of manure disposal, other than land application, meet the same controls and standards as those required for industrial or mu nicipal effluent disposal.
9. To require that treatment, handling, and storage of manure be such that no disease, odor, insect, or rodent nuisance is caused.

NOTE: In the above list, it is assumed that "manure" refers to fresh, stored, or treated animal wastes.

Just what distances, permeabilities, slopes, and application rates may be used with these nine proposals is far from certain. One may argue that insufficient data precludes such determinations being made. While this may be partially true, one should remember that lack of data has not prevented many government agencies from issuing guidelines to accompany approval certificates for livestock operations.

A detailed discussion of each of the nine approaches follows:

1. Application Rates of Manure or Effluent to Soil

Application rates of manure or effluent may be related to:

1. Nitrogen and phosphorus contamination of ground water
2. Manure contamination of runoff water
3. Pathogen contamination of water
4. Breeding of flies
5. Unsightly appearances

1.1 *Nitrogen and phosphorus contamination of ground water*

Both organic and inorganic nitrogen and phosphorus exist in manure. Nitrogen in the ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-) forms is soluble and may

[1] See, for example, the work of Hensler et al. (1970) with manure and Lee and Smith (1972) with nitrogen.

pass through the soil in percolating water. Most nitrogen in fresh manure is in urea and other organic forms. Resistance to microbial decomposition of these other forms is variable. Under favorable soil conditions a large portion of organic nitrogen is converted to NH_4^+ and then to nitrite and nitrate. In these latter two mineral forms most leaching losses occur because they are anions and are negligibly adsorbed by the soil complex (Webber and Lane, 1969). Ammonium, however, is a cation and is somewhat adsorbed on the exchange sites of all clay micelles. Some clay minerals also have the ability to fix ammonium between the crystal lattices. Ammonium nitrogen is lost in leaching water but not as readily as the nitrate and nitrite forms.

Large quantities of nitrite and nitrate nitrogen in water to be used for human or animal consumption are considered a health hazard. The maximum recommended concentration for drinking water is 10 mg/1 nitrogen, which includes both nitrite and nitrate forms (Federal Water Pollution Control Administration, 1968). States are not bound by this limit and some have recommended their own limits at higher concentrations. Concentrations far exceeding 10 mg/1 can be found in percolating water from land heavily fertilized with nitrogen fertilizers or manure (Jones and Zwerman, 1972; Marriot and Bartlett, 1972). Large amounts of nitrogen can also be lost from unfertilized soils that are kept free of vegetation (Barnett, 1972). Witzel et al. (1969) have estimated that manure or fertilizer applications that allow more than 13.5 lb./acre/yr (15.1 kg/ha/yr) nitrogen to pass beyond the root zone are sufficient to result in toxic levels of nitrates in ground water under some conditions.

Nitrogen contents of manures vary depending on the animal, the feed, the age of manure, and the degree and type of treatment. The New York dairy cow is likely to yield a fairly constant nitrogen content in fresh urine and feces of approximately 115 g/day and 100 g/day, respectively (Grieve, 1971). This is roughly equivalent to 10 pounds of nitrogen per ton of fresh urine and feces mixed.

Nitrogen from manure sources is probably not so easily lost in leaching water as that from fertilizer sources, since the conversion of manure nitrogen to nitrate is dependent upon biological factors that closely parallel those governing plant growth. This allows greater opportunity for plant uptake before leaching can occur (Bouldin and Lathwell, 1968). Nitrogen lost by denitrification is not a pollution problem since it is mainly in the form of N_2 gas, which is the main constituent of the atmosphere. However, since this nitrogen is no longer available for crop growth, loss by denitrification is not desirable unless the nitrogen is in excess and has to be disposed of in a nonpolluting manner. Organic nitrogen in manure is likely to be lost by denitrification after mineralization has occurred, since nitrification produces nitrates that are equally subject to denitrification regardless of origin. Since denitrification bacteria need a supply of carbonaceous material, manure applications might actually increase denitrification rates.

Losses of nitrogen by volatization of ammonia cannot be considered as nonpolluting as denitrification losses are. The studies of Hutchinson and Viets (1969) indicate good reasons for rejecting ammonia volatilization as a means of acceptable loss because the risk of secondary contamination of surface water by ammonia absorption is great.

It is extremely difficult to determine the application rate of manure nitrogen which should not be exceeded. Much depends on time of application, crop, and type of manure applied. Marriott and Bartlett (1972) applied 0, 700, 1400, 2100, 2800, and 3500 lb. manure nitrogen/acre (0, 785, 1569, 2354, 3139, and 3924 kg/ha) to a crop of orchardgrass, injecting slurry manure into the soil at 4 in. (10.2 cm) depth during the summers of 1969 and 1970. They concluded that the first application of 700 lb./acre (785 kg/ha) was excessive and represented a pollution potential, and that further study was needed to find out what level below 700 lb./acre was acceptable. Weeks et al. (1972) showed that manure applications up to 600 tons/acre (1345 M tons/ha), about 6000 lb. N/acre (6726 kg/ha), did not adversely affect corn yields. Application rates up to 192 tons/acre (430 M tons/ha) were checked for nitrate and salt movement onto the subsoil. Both nitrate and salts were shown to be leaching down through the soil. At all application rates the concentration of NO_3^--N below the surface of the soil was considerably in excess of 10 mg/1, but crop uptake appeared to control the level of leaching loss for application rates up to 42 tons/acre (94 M tons/ha). Weeks et al. concluded that applying manure at rates greater than 20 tons/acre (45 M tons/ha) was not economical.

Murphy et al. (1972) found that application rates of manure exceeding 330 tons/acre (740 M tons/ha) depressed crop yields because of the accumulation of salts in the soil. O'Callaghan et al. (1971) predicted potassium toxicity at high rates of manure application. Berryman (1970) and Venn (1970) showed that decreases in crop yield can occur also from copper and zinc accumulations that may become toxic when heavy applications of manure are made.

Murphy et al. (1972) found that large amounts of nitrate accumulated at application rates exceeding 330 tons/acre (740 M tons/ha) but that leaching did not occur much below a depth of one meter. Their study was conducted in Kansas under very different moisture conditions from those in New York, where more leaching would be expected.

Adriano et al. (1971) studied the problem in California and concluded that spreading manure from 10 dairy cows on one acre (0.405 ha) resulted in excessive nitrate loss to ground water. They suggested that manure from 3 cows spread on one acre (0.405 ha) should be a maximum rate in order to prevent pollution by keeping leaching water to a nitrate level of less than 10 mg/1. This rate was estimated to contribute about 219 lb. N/acre (245 kg/ha). However, Webber and Lane (1969) estimated that the maximum level for "pollution control" would be 2 cows/acre (5 cows/ha) or 280 lb. N/acre (314 kg/ha). This estimate is for Ontario conditions which are not greatly different from those in New York. In contrast, Missouri's guidelines recommend 8 cows/acre (20 cows/ha) of pasture and 12 cows/acre (30 cows/ha) of corn and other cultivated crops. This includes milking center wastes and is for "100 percent disposal" (Missouri Water Pollution Board, 1971).

Maine is the only state that explicitly recommends manure application rates. The only factor in determining these rates is the nitrogen involved (Maine Special Statewide Committee, 1971). Canadian Guidelines make a similar statement (Canada Animal Waste Management Guide Committee, 1972). O'Callaghan et al. (1971) insist that the application of nitrogen must be tied to the type of crop being grown and will be at a maximum at about 500 lb./acre/yr (560 kg/ha/yr) with intensive grass production. However, if barley is grown, for example, they feel that the nitrogen applications in manure may have to be limited to only 30 lb./acre/yr (34 kg/ha/yr) because of the low uptake of nitrogen by the barley plant.

The Maine recommendations limit the total annual nitrogen application to 600 lb. N/acre (673 kg/ha) where a crop is removed annually and 500 lb. N/acre (560 kg/ha) where no crop is removed. This corresponds to 60 and 50 tons/acre (135 and 112 M tons/ha) of fresh manure, respectively. Many soils are limited to lower rates than the maximums above depending on permeability, soil drainage class, and other factors.

Based on the information presented above, *it seems reasonable to restrict the application of manures based on the nitrogen content,* although not all nitrogen in manure is released. Kononova (1966) has shown that over long periods of cultivation the decline in soil organic matter can be reduced to negligible quantities if manure is added regularly – whereas without its application the organic matter continues to decline at about 1 percent per year. Other studies quoted by Kononova indicate substantial increases in soil organic matter levels where manure was applied regularly for 48 years.

Nitrogen and organic carbon in soil maintain the ratio of 1:12 quite constantly. Also fairly constant is the amount of organic carbon in the soil organic matter – 59 percent (Buckman and Brady, 1969). Since a certain portion of the existing soil organic matter can be expected to mineralize each year under normal soil conditions, Kononova's data indicates that a portion of the applied manure must be immobilized to form either an equivalent or a greater amount of soil organic matter (humus) to that mineralized. In New York the rate of mineralization is estimated to be about 1.2 percent of organic nitrogen content of the soil-plow layer per year (Bouldin and Lathwell, 1968), or about 42 lb. N/acre/yr (47 kg/ha/yr) for a soil with 3.5 percent organic matter. This is equivalent to approximately 4 tons (9 M tons/ha) of manure. When manure is applied to soil, a similar quantity can be considered as being used for soil humus maintenance.

Should manure applications be limited because of phosphorus? Phosphorus is immobilized in the surface layers of the soil and is normally not leached in significant quantities. Fresh dairy manure contains approximately 4.0 lb./ton (2.0 kg/M ton) organic phosphorus as P_2O_5 (Weeks, 1965). Phosphorus may be leached in either orthophosphate or polyphosphate mineral forms or in soluble organic forms. The total of all forms leached from the soil is usually regarded as only a trace (Buckman and Brady, 1969). Koelliker et al. (1971) found that 90–97 percent of the total phosphorus applied to a silty clay loam soil as anaerobic lagoon effluent was removed by a four-foot depth of soil. They found the following relationship between application rate and the concentration in drainage water:

$$\text{Total P (mg/1)} = 0.0011 \text{ (lb./acre P applied)} + 0.10$$
$$[= 0.00098 \text{ (kg/ha P applied)} + 0.10]$$

Goodrich and Monke (1971) however, point out that the ability of a soil to fix phosphorus is far from infinite and warn of possible phosphorus contamination of ground water from the incorrect design of soil waste disposal systems. The work of de la Lande Cremer (1972) indicates that phosphorus in liquid manure will readily penetrate sandy soils to depths of one meter or more. Recent unpublished results from manure studies at Cornell University's Aurora Research Farm indicate that fairly large quantities of phosphorus can pass through the soil under conditions of high rainfall and high application rates of manure.[2]

If phosphorus is removed from the field as soluble P in runoff or drain effluent, evidence shows that the distance it may move in stream flow is small. Kunishi et al. (1972) showed that 200 ppb of soluble phosphorus in runoff was reduced to 15 ppb P by both adsorption in stream banks and adsorption on soil particles from subsoil material as the water moved downstream. This adsorped phosphorus is considered to be unavailable because of the low equilibrium phosphate concentration associated with these sediments (Taylor and Kunishi, 1971).

Soluble *organic* phosphorus from manure sources carried in surface runoff may be resistant to adsorption on sediment particles. Taylor and Kunishi (1971) observed that soluble phosphorus of manure origin was more persistent in runoff water than phosphorus from inorganic sources. This seems to support the Cornell (Aurora Research Farm) findings. However, phosphorus contamination under application rates selected to avoid nitrogen contamination of ground water is unlikely. But treated manures and effluents that are low in nitrogen may not satisfy this assumption.

[2]Personal communication, S. D. Klausner, Agronomy Department, Cornell University, 1972.

1.2 *Manure contamination of runoff water*

When manure is applied to a field subject to runoff at certain times of the year opportunities occur for the movement of manure and nutrients into receiving bodies of water. The risk may be particularly severe when manure is spread on frozen soil.

Minshall et al. (1970) found that up to 20 percent of N, 13 percent of P and 33 percent of K applied as manure spread on frozen soil (with averages of 10 percent, 6 percent and 33 percent respectively) were lost during early spring runoff. When manure was spread in summer and incorporated into the soil, runoff losses of nutrients were less than losses from unmanured ground. The manure had a beneficial effect on reducing runoff by increasing water infiltration. Drielsma (1970) reported that manure had a significant effect on reducing the soil and nutrient loss from soils continuously cultivated for corn production. Zwerman et al. (1971) related this to improved water stable aggregation of soils and pointed out the apparent interaction of manure with fertilizer applications for improved aggregate stability. Loch (1971) demonstrated this.

Since runoff is highly dependent on degree and length of slope, both of these factors should be taken into account. For conventional, soil-loss, probability calculations, 100 ft (30.5 m) length at 8 percent slope has about the same soil loss potential as a 600 ft (182.8 m) length at 4 percent slope as found by the following equation (Wischmeier and Smith, 1965):

$$\text{Length and slope factor} = \sqrt{L}(.0076 + .0053s + .00076s^2)$$

where: L = slope length in feet
s = slope (gradient) in percent

Manure loss in runoff water can be affected by a similar relationship. Therefore it is safe to apply *maximum* rates of manure only to fields where the slope is less than about 2 percent, since below this value, the "length and slope factor" is almost never greater than 1.0.

The data of Minshall et al. (1970) suggest that the application rate of manure may be of little importance if the soil is not frozen and if the manure is incorporated into the soil before runoff-producing rains occur. Their study was conducted on a slope of 10 to 12 percent. These observations are supported by studies in Texas where up to 900 tons of manure per acre (2016 M tons/ha) were turned under by various machines and the runoff was acceptably free of pollutants (Redell et al., 1971).

No existing regulations or guidelines attempt to balance the effects of slopes and application rates except by simply prohibiting the application of manure to slopes greater than some specified gradient.

1.3 *Pathogen contamination of water*

The influence of application rates of manures on pathogen survival is far from certain. Those application rates and conditions that result in runoff losses of manure also present the risk that pathogens will be carried to water supplies. Pathogenic bacteria do not usually survive either drying or heat treatments (Fontenot et al., 1971; Hodgetts, 1971). Venn (1970) pointed out that grazing animals avoid their own manure, but manure that is spread, particularly liquid or slurry manure, does not permit the animal to avoid contaminated areas. Also, application rates that are great enough to cause the flattening or burial of vegetation increase the likelihood of pathogens being carried in wind blown particles after the material has dried. Application rates of slurry or liquid manure great enough to cause runoff of undiluted waste are particularly likely to contaminate water and transmit disease.

1.4 *Breeding of flies*

Under conditions where animal manure accumulates a marked change in the number and type of flies occurs compared with flies associated with manure deposited by pasturing cattle. Anderson (1966) found in California that as many as 40 fly species were breeding in the droppings of grazing cattle. Of those only two species that are mildly annoying to cattle were found, the remainder were coprophagous pasture flies of little concern to man or cattle. On the other hand, only seven fly species were found in piled manure around cattle feeding areas. The predominant flies were houseflies and stableflies, both of which are very objectionable to humans.

Conditions under which large applications of manure are made to the land closely resemble the piled manure situation. Light applications of manure that encourage rapid drying and leave much of the vegetation still growing are likely to attract flies in the same way as droppings left by pasturing animals. Therefore, light manure applications would help reduce the fly problem. This disposal method would also reduce one source of disease transmission from animal wastes to other animals and to man, since flies often carry bacterial infections (Bartrop, 1970).

1.5 *Unsightly appearances*

Manure applied at up to 100 tons/acre (224 M tons/ha) can completely cover the soil surface with 1–2 in. (2½–5 cm) of slurry. If minimum distances between manure spreading areas and public access are maintained, 100 tons/acre will not constitute a serious aesthetic problem unless spread on top of snow. If this application rate or greater is spread on soils close to roads or houses, unsightliness and odor may result.

2. Manure Applications to Soils of High and Low Permeability

The literature frequently refers to the need for considering soil types when predicting the pollution risk associated with a certain practice. Soil permeability – meaning a steady-state infiltration rate or in situ hydraulic conductivity (Soil Survey Staff, S.C.S., 1951) – is the most important factor. A soil of very high permeability is likely to allow the passage of waste liquids into the ground water with such rapidity that filtration, especially of pathogens, is inadequate. Gravelly soils and soils subject to "piping" are particularly risky. At the other extreme, soils of very low permeability, while being good filters, are subject to excessive runoff and pose a problem of surface water contamination.

Some proposed guidelines and regulations take into account different soil permeabilities. The Ontario guidelines, for example, list greater areas of land required for waste disposal for sandy soils than for loamy soils. The difference is approximately 40-50 percent greater land area for sandy soils (Ontario Depts. of Energy & Res. Mangmt., and Agr. & Food, 1970). The reason given is the greater risk of ground water pollution with nitrogen compounds on the sandy soil, a fact verified by Logan et al. (1972). The same reason is implicit in the differences in application rates of manure for different soils in the Maine guidelines. Illinois has proposed prohibiting fall applications of nitrogen in most cases to sandy soils (Anon., 1972).

The need to control nitrogen on sandy soils is somewhat questionable. Barnett (1972) presents some of Allison's data that show correct management and timing of nitrogen applications to a cultivated, loamy, sand soil can reduce leaching losses of nitrogen to as little as 18 lb./acre (20 kg/ha) where a total of 680 lb./acre (762 kg/ ha) was applied. The concern is not with nitrogen applications per se but the relationship between nitrate production and availability and the presence of excess water for leaching (Bouldin et al., 1970). Animal and human wastes, however, were shown by Hedlin (1971) to be contributing to high nitrate levels in ground water under sandy-textured soil on which these wastes had been concentrated *without* crop production. The problem did not occur, however, on medium- or fine-textured soils.

Soil efficiently filters most bacteria from wastes because of the dynamic relationship between many bacteria and clay particles, particularly the clays with high surface areas such as the montmorillonite group (Garcia and McKay, 1970). However, aerobic bacteria (E. coli) have been shown to travel distances of 10 ft (3 m) in sandy soils (Caldwell, 1938) and up to 35 ft (10.7 m) in sandy soils underlain by an impervious stratum from a source of manure to which little or no liquid had been added (Caldwell and Parr, 1937). Anaerobic bacteria (Clostridia welchii) were shown to have moved at least 50 ft (15.2 m) in sandy soils. Once pathogenic organisms reach an aquifer, they can move distances of several hundred feet and may live as long as five years (Romero, 1970). Evans and Owens (1972) found that large increases in fecal bacteria occurred in drain-tile effluent from sandy loam soil for two or three days after swine slurry had been spread. The problem is not restricted to bacteria since studies have shown that viruses can move through soils. Retention of viruses by soils can be characterized by linear adsorption isotherms, the degree depending on soil properties such as clay content, pH, and cation exchange capacity. In neutral soils with low clay content, adsorption is at its lowest level (Drewry and Eliassen, 1968).

We conclude that the risk of ground water contamination by pathogenic organisms exists if these organisms find their way into the subsurface layers of highly permeable sandy or gravelly soils. These soils correspond to those classified as "rapidly" permeable by the Soil Survey Manual (Soil Survey Staff, S.C.S., 1951). They have permeabilities greater than 5 in./hr (12.7 cm) or greater than 6.3 in./hr (16 cm) under the system adopted by the most recent Soil Survey to be completed in New York (Hutton, 1972).

Soils that have been either tile drained or have dried out can allow unfiltered wastes to be lost to streams. Worm holes and cracks in the soil can act as conduits for slurry straight into the tile drain (Berryman, 1970). Therefore tile-drained or highly permeable soils should not receive large quantities of manure, especially in the form of a liquid effluent or when large volumes of leaching water are expected. Effluents from animals known to be shedding infectious organisms should particularly be avoided on these soils.

3. Applications of Manure to Sloping Land

Runoff and soil loss usually increase with increasing slope. Losses of nutrients and organic matter will also increase if manure is spread on sloping soil, unless the manure is incorporated into the soil thus increasing infiltration and decreasing runoff (Minshall et al., 1970). Zwerman et al. (1971) found that runoff and soil loss were decreased somewhat by manure applications, but losses of nitrogen and phosphorus were not decreased. Where fertilizer and manure were applied together, runoff and soil loss were lower and nutrient losses were greater than where fertilizer or manure alone were applied. Hensler et al. (1970) have presented evidence which agrees with Zwerman et al. with regard to runoff, but they did not find any significant increase in nutrients in the runoff water with manure applications.

The significance of these observations depends on whether the runoff water can enter a water course. Sloping fields isolated from drainage-ways by vegetated land of very little slope may be of no concern as a pollution source.

At this time only Maine has attempted to include slopes in its recommendations. All manure spreading is prohibited on slopes in excess of 25 percent (Maine Special Statewide Committee, 1971). The Illinois proposals prevented spreading manure on slopes greater than 5 percent within 660 ft (201 m) of a stream or lake when the soil is *frozen* (Anon., 1972).

We conclude that no great problem from spreading manure on sloping soils occurs provided that minimum distances are maintained. By following the dictates of basic hydrology and standard soil and water conservation practices control can be maintained (Robbins et al., 1971).

4. Applications of Manure Adjacent to Water Courses

The risk of nutrients, organic material, and pathogens contaminating water bodies and public water supplies is greatly increased if manure is spread adjacent to streams, waterways, and lakes. The presence of animals grazing within short distances of a stream or where they have access to a stream can have the same effect. Robbins et al. (1971) found in studies of different waste management systems in North Carolina, that a beef herd grazing on the banks of a stream resulted in larger losses to the stream of total nitrogen, total phosphorus, and organic carbon per animal than manure spread adjacent to a stream. BOD_5 was also higher per animal than with the manure spreading. Goggens (1962) reports that children became infected with leptospirosis after playing in a stream draining a pasture in which diseased cattle had been grazing.

Several states have proposed controls on spreading manure near water capable of leaving a farmer's property. Maine standards require that no manure be spread within 25 ft (7.6 m) of the outer edge of the normal high water mark of a watercourse. They also require a distance of 100 ft (30.5 m) between spreading areas and wells, springs, or lakes (Maine Special Statewide Committee, 1971). Wisconsin has a proposed limit of 200 ft (61 m) from water bodies that applies only from December 1 to April 1 (State of Wisconsin, 1972). New laws in Iowa and North and South Dakota suggest that animal confinement areas which are more than a certain distance from a watercourse need not register or obtain permission for the operation of the enterprise. The distance for dairy cattle is 3 ft (0.9 m) in Iowa and 2 ft (0.6 m) in North and South Dakota (Agena, 1972; Lutz, 1972). Nebraska standards require livestock confinement operations to be more than 550 ft (168 m) from a watercourse, and in Wisconsin they must be 100 ft (30.5 m) from navigable waters (Lutz, 1972). These requirements imply that this distance is adequate to avoid pollution from animal operations. Similar types of controls can be found outside the United States. For example, Saskatchewan requires registration and approval for livestock operations within 1000 ft (305 m) of any body of water capable of leaving the operator's property. Newfoundland prohibits the spreading of manure within 250 ft (76 m) of any source of drinking water supply (Hore, 1971).

A vegetated strip of land between the point of manure application and any surface water should act as a "soil-plant filter," and any runoff reaching the stream or lake may be well filtered of sediment, organic matter, and pathogens, if not of nutrients. Britain has used grass filters in this way for improving sewage treatment effluents to make them acceptable for discharge into streams, therefore meeting the 20 mg/1 BOD, 30 mg/1 suspended solids "Royal Commission" standards (Farrow Irrig. Ltd., undated; Young, 1969). Different slopes and vegetation conditions affect the degree of filtration obtained. A close-growing crop like grass will have a far greater filtering efficiency than a cultivated crop like corn. If a field is cultivated to the edge of a watercourse greater widths should be left un-manured than if it is not.

5. Minimum Land Areas

The concept of requiring a minimum land area to be owned or controlled by the livestock farmer has proved a popular one with some legislators and control boards. Such a requirement helps to avoid the problem of feedlots, poultry operations, or similar enterprises in proximity to other developments, with no control on the farmer's part over subsequent land use in his immediate vicinity. A far greater probability of animal wastes being spread on the soil exists if the necessary land area is available. Most of these regulations, however, avoid the explicit directive of covering all the required land with manure, so it is not certain that wastes will be disposed of in a nonpolluting way. The Canada Animal Waste Management Guide (1972) states:

> It is important that continuous blocks of productive agricultural land be maintained in close proximity to these animal concentrations for the disposal and utilization of wastes.

Swedish law requires a minimum of 8 acres (3.2 ha) be kept per 10 cows for 12-months manure disposal in liquid form. If cows are confined only for 8 months, the requirement is 5 acres (2 ha)[3]. In Ontario the guidelines suggest approximately 5 acres (2 ha) per 10 cows of loam soil and 7.5.acres (3 ha) per 10 cows of sandy soil; the actual requirement is given in a table and refers only to tillable area (Ontario Depts. of Energy & Res. Mangmt., and Agr. & Food, 1970). The guidelines show some variation with number of animals, that is, a slightly lower number of acres per animal as the number of animals increases. This type of sliding scale may have some merits since the economic feasibility of using some method of waste treatment and disposal other than land disposal will increase as the size of operation increases.

The United States has shown less interest in the minimum land area approach, except as it is implied by maximum manure or nitrogen application rates. As long as effluent standards are met little reason exists for discouraging the treatment of wastes from large-scale operations if land areas are already available for adequate isolation, unless one wants to conserve plant nutrients. Manure sale off the farm, refeeding, and other nonpolluting uses also may be quite feasible for some operations.

[3] Personal communication, Eric Johansson, College of Agriculture, Uppsala, Sweden, 1971.

6. Manure Applications at Inappropriate Times of Year

Bryant and Slater (1948) show that without manure a high loss of nitrogen may be expected during winter runoff. This loss was up to 89 percent of the total runoff loss of nitrogen for the entire year under a corn-alfalfa rotation. But soil loss during winter was only 5 percent of the total for the year, even though 69 percent of the year's runoff occurred during this time. Nearly all the remaining soil loss occurred in one August storm. Bryant and Slater report that the high-runoff losses of nitrogen during winter appear to come mostly from the leaching of dense organic material on the soil surface.

It appears that losses of nitrogen might be expected from winter-spread manure, but not necessarily losses of manure solids. Similar results have been attributed to the spreading of manure on frozen soils (Hensler et al., 1970; Midgley and Dunklee, 1945; Miner and Willrich, 1970; Minshall et al., 1970). Just what constitutes a "frozen" soil is open to question. The type of cover may have considerable effect on the degree to which a soil freezes (Dunford and Weitzman, 1955). For the purposes of this paper, a soil can be considered as frozen if the temperature at 2-inch (5 cm) depth or deeper is at 32 F (0 C) or lower.

It is difficult to determine when the soil will be frozen because of the wide temperature variation both within any given year and from year to year. From the 12 years of data for New York collected by B. Pack, Cornell University, frozen soils occurred in the first week of December only 4 percent of the time. For two northern locations, however, the occurrence was 17 percent while at four central, New York locations the occurrence was zero during this same period. The same problem arises in the spring, when in the second week of April the soil was frozen in northern locations 68 percent of the time, in central locations only 4 percent of the time.

If it is necessary to ensure that manure is not spread on frozen soils throughout the state, spreading manure should be prohibited from the second week of December to the third week of April. Prohibiting spreading at any time when the soil is actually frozen is another alternative. This involves the need for a precise definition of what constitutes a frozen soil. A soil may be unfrozen in the top few inches yet remain impervious to water infiltration on account of a frozen layer at a somewhat greater depth. The probability of runoff is particularly severe in this case.

Other times when the runoff problem may occur are in early spring and in fall, although storms may cause intermittent runoff at any time of the year. The spring runoff peak usually occurs before the season of freezing risk is over. However, high runoff losses may continue into May (Zwerman et al., 1971). Preventing spreading when the soil is frozen but allowing the entire winter accumulation of manure to be spread immediately after the soil thaws should be questioned. During October and November both runoff and deep percolation are high and application of manures at this time can result in large losses of nutrients. Maximum use of nutrients contained in the manure will occur only during the growing season between mid-May and mid-September, the same period during which evapotranspiration exceeds rainfall, and runoff and deep seepage losses are at a minimum (Bouldin et al., 1970).

Some proposed regulations on spreading manure in winter can be summarized as follows: proposals for Wisconsin include the requirement that manure not be spread within 200 ft (61 m) of a watercourse between December 1 and April 1 unless it is incorporated into the soil immediately (State of Wisconsin, 1972). Swedish law prohibits spreading manure on frozen soil.[4] Illinois proposals prohibit spreading manure or fertilizers on frozen soils of 5 percent slope or greater within a distance of 660 ft (201 m) of a watercourse.[5]

7. Distances from Public or Private Property

A number of attempts have been made to reduce nuisance problems by preventing the construction of animal confinement operations and (or) spreading manure in the vicinity of homes, roads, and other places of public access. Odors, flies, rodents, disease problems, and unsightliness are minimized when adequate isolation of livestock operations is maintained. The nature and method of spreading manures need to be considered. For example, anaerobical-ly stored manure is likely to emit offensive odors when first spread and hence should either be spread by a machine capable of covering or burying the manure immediately, or be spread as far downwind as possible from homes and public roads. If rain-guns are used for irrigating liquid wastes or effluents, the fine particles are likely to drift in the wind, subjecting those downwind to offensive odors and risk of infectious diseases such as leptospiro-sis and Q-fever (Rankin and Taylor, 1969).

Animal housing can be a source of odors, flies, rodents, and noise that can be disturbing to neighbors and can reduce property values. Nuisance type litigation arising from complaints can be greatly reduced by locating buildings away from other property and land that might be developed.

Ontario guidelines require that new buildings be located at least 1000 ft (305 m) from dwellings on adjacent property, 2000 ft (610 m) from any land zoned for residential development, and 300 ft (91 m) from public roads. Solid manure must not be spread within 600 ft (183 m) and liquid manure within 1000 ft (305 m) of neighboring dwellings, unless it is incorporated into the soil within 24 hours (Ontario Depts. of Energy & Res. Mngmt., and Agr.

[4]See note 3, page 8.

[5]Personal communication, Dr. S. R. Aldrich, Illinois Water Pollution Control Board, 1972.

& Food, 1970). Swedish law also requires covering manure within 24 hours.[6]

Minimum distances of animal confinement operations from dwellings and other property are required by most of the Provinces of Canada. Some states in this country have this type of regulation, although 16 have none at all. Most have provisions for registration of certain livestock operations with subsequent approval of facilities which meet Public Health Department and other requirements (Schwiesow, 1971).

8. Waste Discharge to Watercourses

In the United Kingdom determining the treatment a waste should receive before being discharged is relatively simple. All discharges must meet the "Royal Commission" standard of 20 mg/1 BOD and 30 mg/1 suspended solids (Jones and Riley, 1970), and checking these criteria is relatively easy. In this country, however, the tendency has been to require effluents and discharges to be such that the quality of the stream into which the waste is discharged is not degraded below some specified level (Bernard, 1969). This approach has economic advantages over that of Britain by forcing an economic relationship between upstream and downstream discharges. The less treatment undertaken by the upstream polluter, the more will be necessary for the downstream discharger if the stream quality is to be maintained at the minimum level. Whether or not economic interaction takes place between polluters as a result of this approach is open to question. It does, however, tend to encourage the maintenance of stream quality at or near the minimum acceptable level. But, the law does not require a discharge to be treated if the quality of the water into which it is discharged, after mixing, is not below the required level.[7]

The system of classifying streams and stating quality criteria used in most states, including New York, makes the task of determining the degree of treatment necessary for an animal waste discharge extremely difficult. The degree of treatment will be determined by the classification of the stream, the existing quality of the stream, the flow rates of the stream, and the flow rate of the discharge. A discharge to a stream classified as suitable for drinking water supply must have no floating or settlable solids or oil and no taste or odor-forming substances. All sewage or waste effluents must be "effectively" disinfected. The pH of the stream must remain within the range of 6.5 to 8.5, and dissolved oxygen must stay above 5 ppm if it is a trout stream and above 4 ppm for others. No substances may be added in a quantity great enough to be injurious to fish life or make the water unsafe for drinking. Specific maximum stream levels are given for ammonia, cyanide, ferro- and ferric-cyanides, copper, zinc, and cadmium. On the other hand, a stream classified as suitable only for waste disposal or transport need only be maintained at a level of dissolved oxygen and floating material such that no "public nuisance as defined under the Penal Law" occurs (New York State Dept. of Health, undated).

The New York requirements are administered under a set of rules, one of which directs that sampling and determinations must be made after "reasonable" dilution and mixing of the discharge with the receiving body of water has taken place. As a result many agricultural holdings on large streams may be legally permitted to discharge raw wastes into the streams; it is very difficult to determine whether or not the law is being violated.

Nebraska's criteria for intermittent streams (Bernard, 1969) are similar to many states' laws. Being intermittent streams implies that periods exist when the flow is made up essentially of undiluted effluents. The criteria call for a limit of 20,000 coliform group organisms per 100 ml, less than 30 mg/1 suspended solids, and less than 30 mg/1 BOD. These criteria are similar to the British Royal Commission standards. No mention is made in either set of criteria of the nutrients nitrogen and phosphorus, the usual cause of accelerated eutrophication in water bodies.

A very large number of alternative methods and processes are available for the treatment of animal wastes. Some have been found to be more successful than others. Few are without problems, and most require further research before widespread use could be recommended (Loehr et al., 1973). Presently the likelihood of effluents from on-farm treatment processes being of a quality suitable for discharge, even under the minimum criteria discussed, is very small. The high strength of animal wastes and the economic problems associated with their treatment are two reasons for the relatively low quality of effluents from farm treatment installations (Butchbaker et al., 1972; Loehr, 1971).

9. Diseases, Odors, Insects, and Rodents

Odors, flies, and rodents frequently can be attributed to poor cleaning and storage practices around livestock facilities. The only practical controls for such problems are enforcement of public health laws, use of private lawsuits based upon the common law concepts of freedom from nuisances, and seeking injunctions to prevent the nuisances from being continued (Levi, 1972). Since fly populations change in nature and increase when manure is piled around buildings, a legal requirement that manure be removed from buildings and stored or spread in a particular manner might reduce these problems.

Odors are often generated in otherwise well-managed systems because of the nature of the storage or treatment method used. Anaerobic storage facilities release large

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[6] See note 3, page 8.

[7] This, actually, would appear to violate the Federal Water Pollution Control Administration (now Environmental Protection Agency) guidelines of 1965 requiring that no treatable waste should be allowed to be discharged without the "best practical treatment or control" (Bernard, 1969).

quantities of offensive odors when the contents are agitated or pumped out into spreading vehicles. The problem is repeated when the material is spread unless it is covered immediately by "plow-cover" or subsoil injection methods. Requiring certain distances between spreading areas and homes is one way to minimize these problems. In Sweden farmers are allowed to spread anaerobically stored manure only when there is little wind and it is blowing away from the nearest dwellings or village.[8]

Anaerobic storage facilities located close to residential developments should be prohibited. Such a requirement would force a farmer to either spread manure daily or use some form of aerobic storage or treatment. Chemical deodorizers and masking agents have been found to help relieve the problem, but they are not considered entirely successful (Ludington, 1971). Odors also come through with ventilation systems for confinement housing of animals. Adequate isolation of the buildings is probably the most effective way to ensure that this problem is minimized. As previously discussed, most state regulations require some minimum distances to other buildings.

The problem of disease is more complicated. Diseases may be transmittable to either man, other animals, or both.[9] Bacterial, viral, fungal, and parasitic diseases may be transmitted by the improper handling and disposal of manure (Deisch, 1970; Rankin and Taylor, 1969). Salmonella infections are among the most common of bacterial diseases transmitted to man from animals. In the United States about 20,000 cases are reported each year and 2-3 million actual cases are estimated. Pastures, cow-barns, and abbatoirs have been implicated as sources of salmonella organisms where infected herds were known to be in the watershed of the contaminated stream (Gibson, 1965; Hooper, 1970; McGaughey et al., 1970). Salmonellae have been found to survive from 77 to 345 days in liquid manure, depending on serotype and temperature among other factors (Rankin and Taylor, 1969; Strauch and Hahn, 1968).

A less common but more serious bacterial infection is leptospirosis. Survival times for leptospires are generally shorter than for salmonellae — a few hours in dry soils to 183 days in a saturated soil (Okazaki and Ringen, 1957). This organism has the ability to infect humans through skin contact so that bathing in infected waters is sufficient to result in infection. A number of leptospirosis outbreaks have been traced to bathing areas on streams passing through pastures or farms where infected cattle were kept (Diesch, 1970).

Unfortunately, cattle may shed the leptospire organism before their own infection is evident, making the prevention of fresh contamination difficult to control. Furthermore, the organism has survived for at least 61 days in an oxidation ditch and up to 5 days in the effluent and sludge of a settling tank at summer temperatures (Diesch, 1971). Therefore it is reasonable to require special treatment and handling of manures, slurries, and effluents from infected cattle.

Other bacterial infections that may be spread by manure and streams are anthrax, tularemia, brucellosis, erysipelas, tuberculosis, tetanus, and colibacillosis. Some, such as the brucella bacteria can survive for over two years, while anthrax bacteria (Bacillus anthracis) can remain viable for 60 years. Pastures on which manure containing this organism have been spread can be considered to be permanently contaminated (Diesch, 1970; Rankin and Taylor, 1969).

The behavior of viruses in manures and effluents is not entirely understood. Although over 500 animal viruses are known, relationships between them and human health are not well explored. Enteroviruses, respiratory-enteric viruses, herpesviruses, adenoviruses, and myxoviruses are known to be excreted in animal feces. Though evidence is inconclusive, water and soil contaminated by manure may be a source of viral infection in animals and man (Diesch, 1970). An example of the latter is foot-and-mouth disease, caused by a virus that may survive in soil for up to 347 days (Magaha, 1964). As with some of the bacterial infections, viruses are excreted before infection in the host is evident. This period can be up to 5 days in the case of foot-and-mouth disease (Barrows, 1968). Infection has also been suspected from feeding hay and silage contaminated in a previous outbreak of the disease. Newcastle disease is a viral infection transmittable to man from poultry; hog cholera is one infecting other hogs only.

Man is susceptable to a number of fungal and parasitic diseases. Histoplasmosis and ringworm are examples of the former, "swimmers itch" and balantidiasis are examples of the latter. Treatment of infected animals and avoidance of contamination of soil and water with manures from infected animals are probably the best methods of control.

Regulation of practices to control disease transmission by animal manures and effluents have not been widely reported. Some organisms such as the hepatitis virus are not destroyed by normal chlorination or pasteurization (Diesch, 1970). Chlorination may be required in some situations — in the duck industry of Long Island for example. Such animal waste applications are likely to involve large numbers of organisms, and chlorine demands are likely to be high and expensive (Lawrence, 1971). Consideration may need to be given to the special treatment of wastes from certain infected herds. Discharge without adequate chlorination may need to be prohibited.

Land applications of infected wastes are not always acceptable. The data of Evans and Owens (1972), for example, suggest that such applications to soils that are drained with subsurface tile or mole drains are not safe. Also, in poorly drained soils water may collect around

[8] See note 3, page 8.

[9] For a listing of potential disease problems, see Appendix.

stock watering tanks and leaking irrigation hydrants. Such water may harbor and maintain the viability of leptospirosis organisms for 10 days or more after infected cattle have had access to them (Gillespie et al., 1957).

Cattle have become infected with salmonellosis from grazing where infected slurry was sprayed onto the herbage 3 weeks earlier (Jack and Hepper, 1969). Hahn (1967) suggests that holding manure from cattle infected with salmonella bacteria for 2½ months is not adequate to kill the organisms. The Ministry of Agriculture in Britain now recommends that 6 months should pass after applications of liquid manure to pastures before they are grazed (Jack and Hepper, 1969). Rain-guns are a particular risk where potentially contaminated slurries and effluents are involved (Bartrop, 1970). Regulations limiting the use of rain-guns within certain distances of dwellings would be applicable. When confirmed infections are present, it would be desirable to prohibit this method of disposal altogether.

PRESENT AND FUTURE CONTROL MEASURES

The futility of relying on conscience to control pollution has been shown by Hardin (1968), leaving economic incentives and legislation as the only feasible methods of control. Economic incentives include taxes and subsidies and are frequently preferred by economists because they are supposed to bring about a reduction of pollution within the framework of a free market (Goase, 1960). Such incentives need to be carefully chosen to discourage disposal systems that are both socially undesirable or pass the costs of "pollution intensive" items on to the consumer (Federal Water Pollution Control Administration, undated). However, the costs involved in negotiating and policing these arrangements are often greater than the benefits they produce (Demsetz, 1964; Johnson and Connor, 1971; Turvey, 1963). Perhaps taxes and subsidies could be used to enhance and support legislative controls, thus making those controls more easily enforceable.

Most recent legislation to control pollution has dealt with discharges — identifiable, point sources of waste or other contamination. Agricultural operations are rarely identifiable as point sources of pollution and have therefore generally escaped direct control. Only where farm wastes are concentrated into distinct discharge channels, or disposed of through a well to the ground water can controlling authorities exercise any real power under existing laws (Fish, 1970). To remedy this situation, many legislative bodies have gone on record as having the intention of controlling environmental hazards that might be caused by agricultural practices. Others have set up boards of local officials and experts to formulate acceptable standards for agricultural operations in their region (Hore, 1971; Schwiesow, 1971).

Until very recently litigation involving the external effects of the agricultural community has been based on the complaints of an aggrieved party about some nuisance allegedly caused by an agricultural practice. Common Law, principles allow damages to be paid and enjoinment of the guilty party from continuing the nuisance. Problems ranging from the control of odors and flies to the chemical contamination of water supplies have been handled by this approach (Willrich and Miner, 1971). It is, however, costly, inefficient, and unpredictable (Levi, 1972; Walker, 1970). With suburban development encroaching upon traditionally agricultural land, the incidence of such litigation is increasing. Furthermore, changing farming practices are sometimes allowing greater opportunity for impairment of public and private resources.

It is not surprising that legislative bodies are anxious to enact regulations that may force farmers to maintain suitable standards and thus reduce the incidence of agriculturally related pollution and nuisance complaints. Indeed, legislators are under a mandate in this country, as a consequence of the Water Quality Act of 1965, to implement water quality standards adopted under the Act. These standards apply as much to agriculture as to any other cause of reduced water quality (Bernard, 1969; Johnson et al., 1972).

The task of writing a law to control pollution from a nonpoint source such as runoff or percolation from dairy manure disposal areas is extremely difficult. Few legislatures have attempted to do this except in very indirect terms. Measures have been taken by some states to control identifiable discharges of wastes from farms. Of the 27 states producing 82 percent of this country's milk, 7 states require registration or permits to be obtained for operation to continue; of these, 5 require permits only if a treatment facility is operated or if an identifiable waste discharge point exists (Johnson et al., 1972). These regulations, then, apply to large operations such as processing plants and animal confinement systems in which land is probably not being used for waste disposal. Such agricultural pollution sources are not very different from industrial or municipal sources in principle, though they may have quite different waste characteristics. Therefore they lend themselves to similar legislative controls.

Control of the usual agricultural nonpoint sources of pollution by setting discharge standards is, for all practical purposes, impossible. Many people think that control of certain practices, under conditions that are likely to result in undesirable consequences, is the best way to correct this situation. A large number of states, provinces, and countries are either proposing or enacting regulations or codes of practice that would restrict the choice that the farmer currently has in his waste management practices. Appendix tables 2 and 3 present a summary of proposed or enacted regulations by states.

In addition to the use of legislative regulations, the concept of "Administrative Codes of Practice" is popular, particularly where Control Boards are reluctant to have quantitative limits written into the law. Their hesitancy is understandable, for it is no easy task to be required to represent experience and intuition in terms of numbers which might later be proved erroneous. A code of practice carries with it no enforcement provisions, but compliance implies that the farmer is doing his best to avoid pollution and nuisances. Compliance makes him somewhat immune from prosecution by the state and helps eliminate the risk of punitive damages being awarded against him in private litigation (Levi, 1972).

Registration requirements are also widely used for animal operations. Usual registration of a livestock enterprise is required only if it exceeds some specified size or is located within some specified distance of a lake or stream. Once registered, the choice of waste handling or treatment facilities is usually left with the operator, who must have his plans approved before proceeding. In this instance the operator has the opportunity to choose his methods. Some states, however, require the construction of some specified minimum facilities before registration or approval is granted (Johnson et al., 1972).

Another approach of some importance is zoning. Zoning does not actually prevent pollution, but may reduce nuisance-type litigation. The creation of zones, however, can present considerable problems. If an existing agricultural operation is included in a zone intended for some other purpose, the result may be the closure of the operation by injunctive order (Levi, 1972), regardless of attempts by the operator to prevent any nuisance. Other types of zoning could be based on such factors as soil types and the way in which they relate to certain practices such as lagooning for animal waste disposal (Walker, 1970).

Most of the present legal procedures are of little value in controlling the downward movement of contaminants through the soil and into the ground water. Proof of both the source of the contaminant and the causative negligence is extremely difficult to establish for most agricultural pollution, although this type of pollution should certainly be controlled. Presently, however, little agreement on the details of suitable controls has occurred. Attempts are being made to standardize and quantify such controls, but the most common approach is still to leave the decision with some appropriate authority as to whether a particular farmer's practice or proposed practice is acceptable.

Writing legislation to control agricultural pollution should include the points of view of the farmer, the legislator, the administrative agency, and the environmentalist. The authors have identified, for the purposes of this study, the following primary objectives of legislation:

1. To prevent or reduce pollution — biological, chemical, visual
2. To conserve material nutritional to plants and animals
3. To encourage the formation of stable soil tilth or physical conditions
4. To maintain favorable relationships between farmers and the public

These objectives might be achieved by a combination of one or more of the following approaches:

1. To prohibit certain practices under conditions that make them undesirable, as would be the case if any of the four objectives were violated.
2. To make easy identification possible of farms with the potential to cause pollution, so that compliance with the law can be readily established.
3. To make compliance with the law desirable and attractive to the farmer in order to reduce the need for enforcement.
4. To make the farmer responsible for proving compliance with the law.

It is probably not desirable to construct rigid regulations that force a farmer to adopt methods and procedures that are not optimal for his operation. The objective of reduced pollution may be achieved many ways. Farmers should be encouraged to use all the ingenuity at their command to achieve these objectives, rather than to simply comply with a uniform set of conditions prescribed by a pollution control board.

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APPENDIX

Appendix table 1. *Major diseases transmittable by manures or other animal wastes**

Disease	*Cause*	*Transmissibility to man*	*Transmissibility to animals*	*Description*
Anthrax	Bacteria	Yes	Yes	Acute disease of all warm blooded animals, characterized by septicemia and sudden death.
Balantidiasis	Protozoan parasite	Yes	Yes	Parasite found in intestines of swine, cattle, sheep, horses, and occasionally man. May cause severe diarrhea and/or fatal dysentery.
Brucellosis	Bacteria	Yes	Yes	Causes abortion and infertility in cattle, swine, goats, and sheep. In man infection causes 'undulant fever,' a chronic illness with malaria-like symptoms.
Colibacillosis	Bacteria	Yes	Yes	Characterized by diarrhea of newborn and young animals (including man); may terminate in fatal septicemia.
Erysipelas	Bacteria	Yes	Yes	Primarily a disease of swine, that may occur as acute septicemia with rapid death, or as chronic disease causing arthritis. Lambs and calves may be affected with arthritis. Birds (turkeys, ducks and chickens) may die of acute septicemia. In man, infection occurs usually through a skin injury when infected material is handled and results in painful swelling of hand and arm. In man this disease is known as 'erysipeloid.'
Foot and Mouth	Virus	Rare occurrence	Only cloven footed species	An acute, highly contagious debilitating disease of cloven footed animals, particularly cattle and swine, characterized by formation of vesicles in the mouth and on the feet.
Histoplasmosis	Fungus	Yes	Yes	Can occur in most animal species, and may be acute, subacute or chronic, localized or disseminated. May cause liver enlargement, anemia, diarrhea, and emaciation.
Hog Cholera	Virus	No	Swine only	This is an acute, highly contagious disease with high mortality rates, manifested by high fever, loss of appetite, vomiting and diarrhea, cutaneous hemorrhages, and nervous symptoms.
Leptospirosis	Bacteria	Yes	Yes	Particularly affects rats, mice and moles, dogs, cattle, and swine. Their disease organisms are shed in the urine and most species, including man, can be affected. Causes fever, jaundice, and anemia and pregnant animals may abort. In man, influenza-like symptoms result. May be fatal in all species.
Newcastle	Virus	Causes conjunctivitis	Only avian species	Varies from very mild outbreaks with low mortality to severe outbreaks with high mortality. Predominant signs are respiratory distress usually followed by nervous symptoms.
Q-fever	Rickettsia†	Yes	Yes	Febrile disease in man with symptoms like those of influenza. Is not apparent or mild illness in cattle, sheep, and other species, but may cause abortion. The organisms are also excreted in the milk of affected cows and may withstand ordinary pasteurization.
Ringworm	Fungus	Yes	Yes	Skin disease characterized by appearance of inflamed lesions which spread centrifugally with damage to and loss of hair in affected areas.
Salmonellosis	Bacteria	Yes	Yes	Septicemic disease occurring in many species, man included; characterized by fever, weakness, diarrhea, and abortion.
Swimmers Itch	Parasite	Yes	Yes	Dermatitis caused by larval stage of schistosome fluke where normal definitive hosts are certain species of aquatic birds.
Tetanus	Bacteria	Yes	Yes	Most species may be affected but horses are the most susceptible. Disease organisms enter body through wound contamination and produce a toxin which attacks the nervous system causing muscle spasms and finally death through respiratory failure.
Tuberculosis	Bacteria	Yes	Yes	Progressive, destructive disease that may affect most species and man, causing weakness, wasting, and emaciation. Frequently associated with a chronic cough when lungs are involved.
Tularemia	Bacteria	Yes	Yes	Highly contagious disease, causing a severe septicemia and a high mortality rate. Occurs in various rodents, particularly the wild cottontail rabbit, water rats, and beaver and may spread to farm animals, cats, and dogs. Man may become infected on handling the carcasses of infected animals or from contacts with water contaminated by the bodies or feces of infected animals.

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†Organisms intermediate between bacteria and viruses. Commonly found in tissues of anthropods.

Appendix table 2. *Summary of existing and proposed state regulations to control livestock related pollution**

Situation type		
1	Existing laws requiring registration of certain livestock operations	Arizona, Colorado, Florida, Indiana, Iowa, Kansas, Minnesota, Nebraska, North Dakota, Oklahoma, South Dakota, Texas † ‡ §
2	Existing laws to control wastes from livestock operations but with no registration requirement	Illinois, Ohio, Wisconsin † ‡
3	Registration requirements for waste discharges	Maine, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, Florida ‡
4	Discharge requirement without registration	Almost all states, other than those listed under 3 above.
5	Waste disposal administrative codes	Arizona, California, Colorado, Indiana, Iowa, Kansas, Maine, Missouri, Massachusetts, Minnesota, Nebraska, Oklahoma, Texas ‡
6	Other proposals	Unknown total number.

* *Not necessarily complete as these regulations are constantly changing.*
† *Lutz, 1972.*
‡ *Johnson et al., 1972.*
§ *Schwiesow, 1971.*

Appendix table 3. *Examples of existing and proposed state regulations to control livestock related pollution**

Situation type	*State*	*Application criteria*	*Conditions*
1	Iowa †	1. >1000 head of cattle in confinement. 2. If runoff contributes to a watercourse draining an area of 3200 acres or more *and* confinement less than 2 ft (0.61 m) per head of cattle from this watercourse. 3. If runoff from confinement lot or from retaining lagoon flows into a drain conduit, any type of well, or into a sinkhole. Applicable to any operation where there are at least 100 head of cattle, or where density is greater than 1 animal per 600 square feet (56 m^2).	Retention ponds and terraces must be able to contain at least 3 inches (7.6 cm) of runoff water from all waste contributing areas. Settling basins must be provided for solids separation before runoff reaches retention ponds. Waste treatment may be permitted with permission of Dept. of Health. Retention ponds must be emptied as soon as possible after runoff. *Proposed:* Approval of waste disposal practice based on information supplied as to soil types, use of land between confinement and stream, slope of land, infiltration rate, control of waste discharges in relation to stream flow and distance to dwellings. Wastes may be spread on land surface, irrigated, or mixed into soil in such a way as to prevent runoff of wastes. All other methods subject to individual approval.
3	Florida ‡	Any livestock or animal waste abatement installation considered a potential source of water pollution, and all firms with waste systems handling more than 500 lbs (227 kg) BOD_5.	Subject to approval.
5	Maine §	*Applies to:* Total annual animal and poultry manure production after removal from the barn or storage area. *Covers:* Manure use by crop production; disposal of excess by land spreadings, stockpiling, burying in landfills, composting, lagooning, irrigation, drying.	1. No spreading on frozen‖ ground, except in upland soil with less than 3% slope where limit is manure or waste with nitrogen content of 250 lb./acre (280 kg/ha). 2. Tabulated nitrogen applications for each soil type in the state are limit for total nitrogen *including* fertilizer. 3. No waste less than 25 ft (7.6 m) from water body. 4. No waste less than 100 ft (30 m) from spring, well, or lake. 5. No spreading near lakes if runoff probability high. 6. No spreading on slopes greater than 25%. 7. No spreading in depressions which carry water during snow melt or heavy rainfall. 8. Tabulated maximum nitrogen applications to crops from fertilizer or waste (crop must be harvested) – example corn – 250 lb./acre (280 kg/ha); oats – 50 lb./acre (56 kg/ha), and so on. 9. No dumping on floodplain unless waste is plowed under. 10. Dumping may be done at rates up to 600 lb./acre (673 kg/ha of nitrogen if a crop is removed. Otherwise limit is 500 lb./acre (561 kg/ha) nitrogen. 11. Stockpiling only allowed on certain soils.

Appendix table 3. *(continued)*

Situation type	State	Application criteria	Conditions
			12. Stockpiled wastes must be removed within one year. 13. Stockpiling of wastes cannot be on slopes greater than 8% or within 300 ft (91 m) of water bodies, streams, wells or springs. 14. There are many conditions relating to composting, burying, and so on. 15. Every soil in the state has been classified and limits applied for each of the activities listed above.
6	New York** Proposals (Guidelines)		Limit liquid and solid manure applications to nitrogen need of crop. Semi-solid manure (13–18% dry matter) limit 30 tons/acre (67 M ton/ha). Spring or summer plowdown – 100% of maximum rate; spring and summer topdressing – 24% to 100% of maximum depending on soil slope; fall and winter applications – 8% to 100% of maximum depending on soil slope, depth, and drainage class (given in a table).
6	Illinois †† Proposals (Legislation)		Nitrogen – 50 lb./acre (56 kg/ha) in fall; 30 lb./acre (34 kg/ha) in fall, on fall seeded crops only, on sandy soils; none on slopes greater than 5% when frozen; maximum rates at other times of year depending on crop and soil type, and whether irrigated or not, for example, corn 160 to 225 lb./acre (179 to 252 kg/ha). Phosphorus – none if slope greater than 5% and soil frozen; 50 lb./acre (56 kg/ha) limit on organic soils (soils with greater than 20% organic matter). Manure – no spreading on soils with slopes greater than 5%, within 40 rods (201 m) of a stream or lake, when soil is frozen; none in natural drainage or waterways. Other limits for sludge and effluents.

Not necessarily complete as these regulations are constantly changing.
† *Agena, 1972.*
‡ *Johnson et al., 1972.*
§ *Maine Special Statewide Committee.*
|| *Undefined.*
** *Personal communication, S. D. Klausner, Agronomy Department, Cornell University, 1973.*
†† *Anonymous, 1972.*

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