

PUBLIC HEALTH ASPECTS OF THE  
DISPOSAL OF MIXED WASTES TO LAND

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### Abstract

Mixing household waste with stored animal waste for discharge to land has been proposed as an alternative on-site sewage treatment. Little information is available on the effect this would have on public health. Potential hazards include parasites, bacteria, and viruses. Parasite transmission might be avoided by pretreatment of household wastes before mixing them with animal wastes or by not spreading mixed wastes on pasture land. No special bacterial hazards are expected. In a laboratory model study, D values (times for 90% reduction of titer) for inoculated poliovirus 1 were essentially identical (63 days at 5°C, 39 days at 15°C, and 18 days at 25°C) in phosphate-buffered saline and in septic tank effluent, but less than half as long (20 days at 5°C, 17 days at 15°C, and 7 days at 25°C) in septic tank effluent mixed with dairy manure slurry. Further work is in progress to determine how the virus is inactivated.



## PUBLIC HEALTH ASPECTS OF THE DISPOSAL OF MIXED WASTES TO LAND

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The question of the risks associated with mingling animal and human wastes comes to hand for reasons of legality and geology. In many instances mingling wastes is not legal although it represents a reasonable alternative for domestic waste disposal where geological conditions preclude disposal by conventional percolation. Currently, federal regulations governing the production of Grade A milk prohibit mixing domestic wastes with animal wastes. Changes in dairy management, advances in technology, and increasing scientific knowledge promote reassessment of these regulations. Other regulations governing waste disposal to land are created and enforced at the discretion of the individual state and vary widely among states. In Wisconsin, the disposal of domestic waste must follow regulations imposed by the Department of Natural Resources (DNR) and the Department of Industry, Labor, and Human Relations (NR113 and ILHR83).

Septage and holding tank waste, for example, may be surface spread on land used for forage crops (if done at least 8 weeks prior to the consumption of the forage by animals), but no application on land used for vegetable crop production is permitted. A 43-state survey on mixed waste disposal revealed that 67% of the respondents do not permit domestic waste to be mixed with swine, beef, poultry, or dairy manure (James C. Converse, unpublished survey, 1982). Some states permit disposal of mixed wastes only under specific circumstances. A problem common to many states is the lack of a central authority to enforce waste disposal policy. Legislation and compliance are two separate matters. A waste disposal system that is convenient encourages compliance with the law. This emphasizes the importance of ascertaining the public health hazards of mixing household effluent with animal manure for disposal to land as animal manure. Mixing waste has the advantage of providing an easily implemented, readily available means of waste disposal. The geology of Wisconsin often precludes the possibility of percolation of septic tank effluent through soil. State code prohibits drainfields on sites that have creviced bedrock near the surface, slowly permeable soils, or high water tables. On these sites the homeowner is required to use alternative systems such as holding tanks or

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mound systems. The disadvantage of a holding tank is that it imposes high operating costs, whereas the mound system imposes higher capital costs.

Mixed waste disposal is appealing in that it is easily implemented, involves simple design, includes efficient disposal, reduces use of clean water to dilute the manure, and avoids building a separate disposal system. It is logical to handle two similar items as one. In fact, storing household waste and animal waste together may decrease the hazards associated with its disposal to the land. The waste is spread once or twice a year instead of whenever the holding tank is full. Increased detention time causes increased retention and/or inactivation of pathogens. This enables storage of waste material until climatic conditions are favorable to pathogen inactivation (warm temperatures) and application to ground that is neither frozen nor soaked with rain. This modification would still be within the already established DNR regulations on disposal of septage and holding tank wastes (DNR, 1975).

#### Characterization of Microbial Pathogens in Waste

There are hazards inherent in handling waste. The specific concern is the potential effect on public health as a consequence of adding household waste to animal wastes and treating both as animal waste. Any land disposal of excreta may complete a cycle of transport of pathogens along the food chain. One problem with waste disposal to land is potential contamination of the land and associated water. Although it is not likely that pathogens from contaminated soil will be taken up and translocated into non-traumatized edible plant tissue, microbial pathogens may survive on the surface of food for extended periods of time (Bitton et al., 1980). The crop in the field may become hazardous to consume either directly (by man or beast) or indirectly (as when man eats beast). The potential contamination of surface water or groundwater is also a concern. Both chemical and biological contaminants must be considered.

Mixing household waste with animal waste would have little effect on the level or persistence of toxic chemicals in the system. Organic residues or heavy metals do not usually occur in household waste. Septic tank effluent may contribute small amounts of nitrogen and phosphate, both of which will serve as plant nutrients when properly applied to soil. It has been suggested (Soulsby, 1985) that the presence of detergents in domestic waste may alter microbial growth. Dilution of the household waste with several volumes of manure slurry should mitigate any such effects. Hence, the proposed mixed-waste system seems unlikely to entail any new problems of chemical pollution.

The biological hazards represent the more immediate concern, and may be categorized as viral, bacterial, or parasitic. Table 1 lists

TABLE 1. Major Microbial Pathogens in Human and Animal Waste

VIRUSES		(0.025 - 0.100 $\mu\text{m}$ diameter)
Enteroviruses		
Poliovirus		
Coxsackievirus A		
Coxsackievirus B		
Echovirus		
Other enteroviruses		
Hepatitis A		
Rotavirus		
Norwalk-like Agents		
Adenovirus		
Reovirus		
BACTERIA		(0.5 - 2.0 $\mu\text{m}$ diameter)
<u>Salmonella</u> sp.		
<u>Shigella</u> sp.		
Enteropathogenic <u>Escherichia coli</u>		
<u>Campylobacter</u> sp.		
<u>Yersinia</u> sp.		
<u>Bacillus</u> sp.		
<u>Clostridium</u> sp.		
<u>Enterobacter</u> sp.		
<u>Staphylococcus</u> sp.		
<u>Leptospira</u> sp.		
<u>Brucella</u> sp.		
<u>Listeria</u> sp.		
<u>Mycobacterium</u> sp.		
PARASITES		
Protozoa		(7 - 50 $\mu\text{m}$ diameter)
<u>Entamoeba</u> sp.		
<u>Giardia</u> sp.		
<u>Balantidium</u> sp.		
<u>Toxoplasma</u> sp.		
Metazoa		(> 50 $\mu\text{m}$ diameter)
Nematodes (roundworms)		
<u>Ascaris</u> sp.		
<u>Trichuris</u> sp.		
<u>Toxocara</u> sp.		
<u>Ancylostoma</u> sp.		
<u>Necator</u> sp.		
<u>Strongyloides</u> sp.		
Cestodes (tapeworms)		
<u>Taenia</u> sp.		
<u>Echinococcus</u> sp.		

(Taken from Sobsey, 1984; Little, 1980; and Kowal, 1982)

the major microbial pathogens in human and animal wastes. The emphasis in this presentation is on the addition of septic tank effluent to animal manure for disposal as animal manure. The potential hazards of the disposal of animal manure remain in full force; they are not necessarily lessened by this addition. The addition of septic tank effluent to animal manure in surface storage units increases risk only in that it represents surface holding of domestic waste with minimal pretreatment. The usual precautions to detain the waste and prevent surface run-off or leakage into groundwater supplies are necessary.

#### Viruses:

The first category of microbes that we will consider is that of viruses. Viruses are submicroscopic packages of nucleic acids surrounded by a protein coat and sometimes a lipid layer. They may be considered to be obligate intracellular parasites. They are specific for a given species, and are completely dependent upon their host cell for replication. Consequently, upon release to the environment outside of the gastrointestinal tract, they will either persist or diminish in numbers, never increase. Viruses of concern in waste disposal are enteric viruses. Enteric viruses are characterized by the ability to withstand a pH of 3 and are transmitted by fecal-oral routes. Although viruses are not normal inhabitants of the digestive tract, once an infection has occurred it is estimated that feces may contain from  $10^6$ - $10^{10}$  viral particles per gram (Kowal, 1982). Consequently, if virus is present in wastewater, it is likely to be present in higher numbers. For example, Hain and O'Brien (1979) recovered from 800 to 7500 plaque forming units/ml of septic tank effluent. The infectious dose for viruses is reported to be as low as one viral particle and may cause severe and debilitating diseases, such as poliomyelitis, meningitis, and hepatitis. Consequently a substantial decrease in viral levels is needed as part of waste treatment.

The survival of virus in the environment is a function of many variables. Temperature, microbial activity, and the types of virus are the most influential determinants, while in soil, saturation, chemistry, and association with particles also play a role. Work by our group (Salo and Cliver, 1976; Green, 1976; SSWMP, 1978) indicates that temperature is a predominant factor in determining the inactivation rate of enteroviruses. Microbes in general, and viruses in particular, survive longer at lower temperatures, and conversely are inactivated by heat. Green (1976) found a 97% reduction in 28 days when poliovirus type 1 was held at 20°C versus a 57% reduction when it was held at 7°C. Lund et al. (1984) reported that the degradation of both porcine enterovirus and human enteric virus were primarily temperature dependent. They also noted that greater inactivation occurred in the presence of oxygen. Observations by Hurst et al. (1980) indicate that in soils appreciable virus inactivation due to microbial activity may occur only under aerobic conditions and moderate to high temperature.



Temperature and oxygen both strongly influence microbial activity, which, in turn, influences viral persistence. Microbial predators of enteric viruses include bacteria and protozoa. These microbes may produce metabolites that adversely affect virus particles or may use the virus capsid as a nutrient source. Sobsey et al. (1980) found shorter viral inactivation times in non-sterile suspensions of wastewater. Cliver (1978) found no significant differences between survival of P01 in sterile and non-sterile sand columns. Ward (1982) reports loss of viral infectivity in activated sludge due to microbial activity. Herrmann et al. (1974) found two enteroviruses were inactivated more rapidly in a lake than in sterile lake water. These authors found that poliovirus 1 is susceptible to proteolytic enzymes of some microbial species.

The survival time of viruses in waste systems is highly variable, but should be considered in terms of days, weeks, or months as opposed to minutes or hours. Enteroviruses are reported to survive for 3 to 170 days in soils of various compositions at various temperatures, and on crops from 1 to 23 days (Kowal, 1982). Substantially longer survival is expected at cold temperatures as human enteric viruses are routinely stored in the laboratory at 4°C for up to a year with only a one log decrease in infectivity. Prolonged detection is one key to the prevention of viral transmission. Work by our group (S. L. Stramer, unpublished observations) indicates that while there is some detention of solids-associated virus in a septic tank, resuspension occurs frequently if not regularly and most of the viruses go into the drainfield with the septic tank effluent. There is nothing particularly antiviral in the septic waste system. Viral inactivation is largely a function of post septic tank treatment. Consequently the potential of disposing virus laden septic tank effluent with animal manure via detention in an earthen storage basin looks most attractive. A mixed waste system represents increased detention time, increased microbial load, and exposure to temperatures which may be higher than in a septic tank, all factors which contribute to inactivation of the virus.

We began our studies by measuring rates of viral inactivation in a laboratory model of a mixed waste system. A dairy farm in northern Wisconsin has unsuitable (slowly permeable) soil through which to percolate the household wastewater. Under an approved variance from the state code the effluent from the septic tank (approximately 180 gal/day from a 4-member family) is being pumped into a clay lined earthen basin, which also contains the barnyard waste from one hundred head of cattle - manure, milkhouse waste, and bedding. This slurry (@10% solids) is approximately 15% (by vol) septic tank effluent and 85% (by vol) barn waste; 1380 gallons/day might be generated and held in a storage unit approximately 27,000 to 54,000 cubic feet in size. Common agricultural practice is to hold these wastes for a variable length of time (usually up to 6 months) and then dispose of them to land via subsurface injection or surface spreading; an event which usually occurs two to three times

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each year. Manure slurry is typically in the pH range of 6.1--7.7 with a BOD of 86,000 to 100,000 mg per liter (Berry, 1967). Average temperatures reflect the ambient atmosphere, with variation from surface to bottom. The average temperature in manure lagoons studied in South Dakota was below 18°C (Berry, 1967). Freezing is limited to the surface.

Our laboratory model for virological study consisted of three different mixtures held at three different temperatures (5, 15, and 25°C) to which we added  $10^6$  plaque forming units/ml of poliovirus type 1 (an attenuated vaccine virus). Rates of viral inactivation in (1) septic tank effluent were compared to rates in (2) mixed wastes (15% septic tank effluent and 85% cow manure slurry) and in (3) phosphate buffered saline. Each solution (200 ml) was placed in an Erlenmeyer flask and covered with mineral oil (to represent the anaerobic conditions of a manure basin). Portions (20 ml) of these three mixtures were frozen and stored for later use. They were thawed on a weekly basis and used to replace the 20 ml portion that was removed. This was done to mimic the fresh influx of wastes to the manure basin as well as to draw a sample for analysis. Initial characterization of the mixed wastes revealed typical values: pH of 7.78 and 6.56% of total solids. Fecal streptococci values were  $3.2 \times 10^6$  colonies per 100 ml, and fecal coliform counts were  $4.4 \times 10^7$  colonies per 100 ml. This is in comparison to samples drawn on the farm site: pH 7.65, fecal streptococci counts of  $4.3 \times 10^6$  colonies per 100 ml, and fecal coliform counts of  $7.1 \times 10^7$  colonies per 100 ml.

In the laboratory model there were duplicate flasks of each mixture at each temperature, from which duplicate samples were drawn. A sample was assayed every 21 days for 4 months for levels of viral infectivity. Each 5 ml sample was mixed with diluent, and the pH was adjusted to 9 with 1.5 N NaOH. Twenty minutes of sonication in an ice slurry was followed by centrifugation (16,500 g for 1 hour). The supernatant was decanted, adjusted to pH 7 and filtered through a 0.2  $\mu$ m filter. This procedure extracts the virus from the solids and removes bacteria which may otherwise inactivate the virus. An elaborate procedure is necessary to detect viral activity. Confluent layers of Buffalo green monkey kidney cells were grown on 25 cm<sup>2</sup> tissue culture flasks. The sample was diluted and three successive 10-fold dilutions were used to inoculate 0.5 ml each into duplicate cell cultures. After rocking the cultures at 37°C for an hour, an agar medium was added, allowed to solidify, and the cultures were incubated at 36°C. The flasks were observed daily for the formation of plaques (areas of lysed cells). After allowing for dilution, the plaque forming units per ml may be calculated. The changes in viral infectivity with time are plotted in figures 1, 2 and 3.

At all three temperatures the phosphate buffered saline and the septic tank effluent had similar rates of viral inactivation - a D value (time, in days, for 90% reduction in virus titer) of 63 at

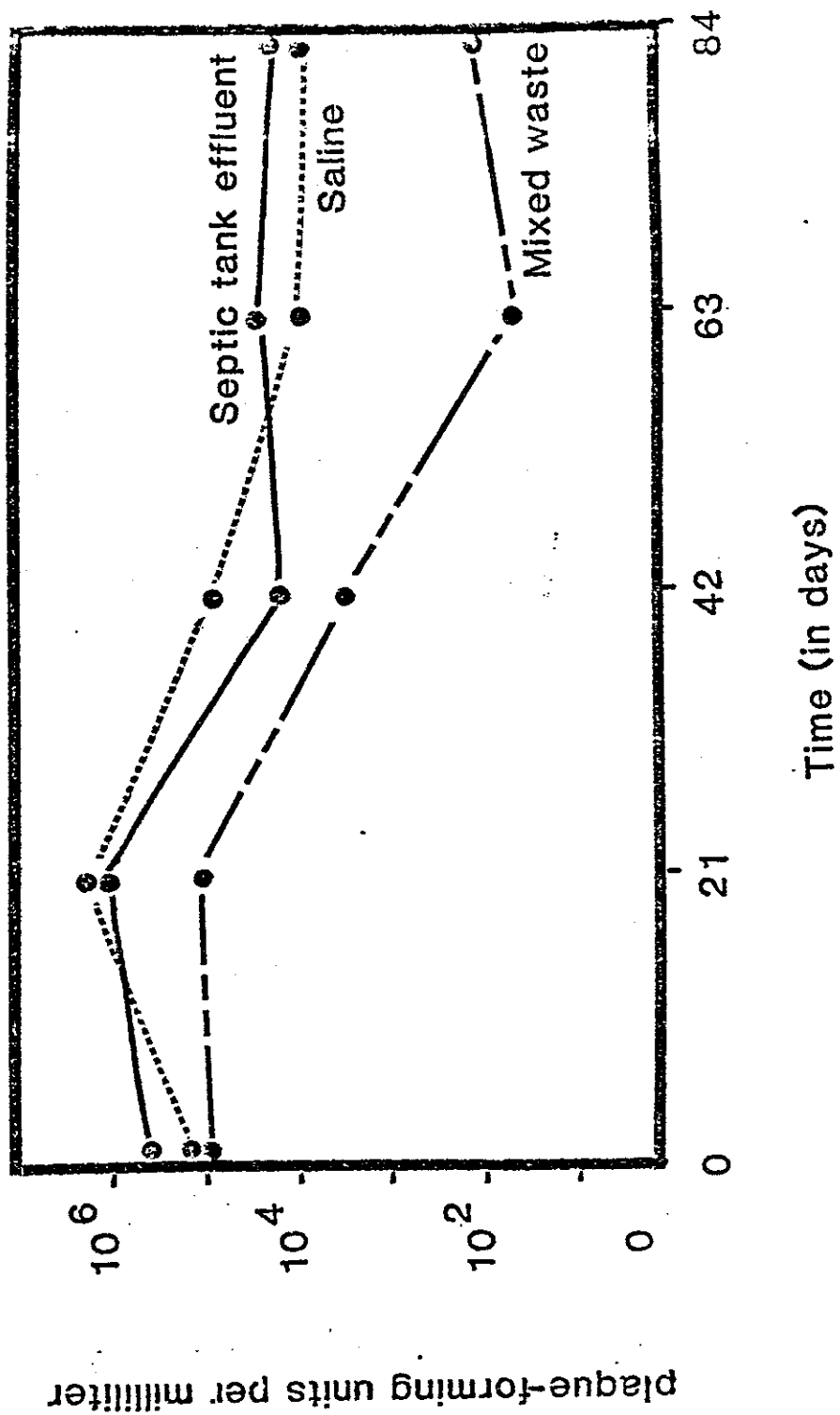


Figure 1: Decrease in Viral Infectivity with Time at 5°C

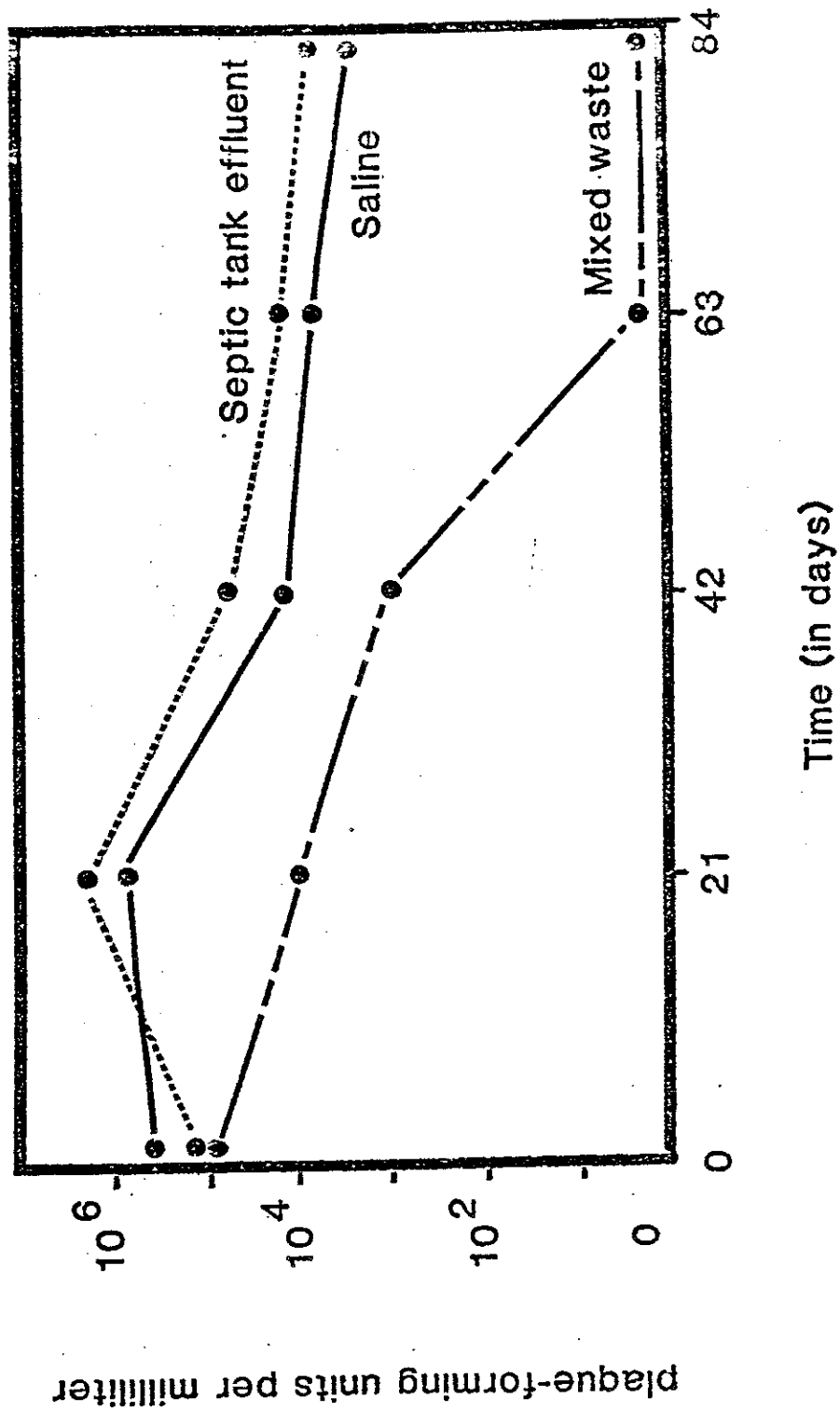


Figure 2: Decrease in Viral Infectivity with Time at 15° C

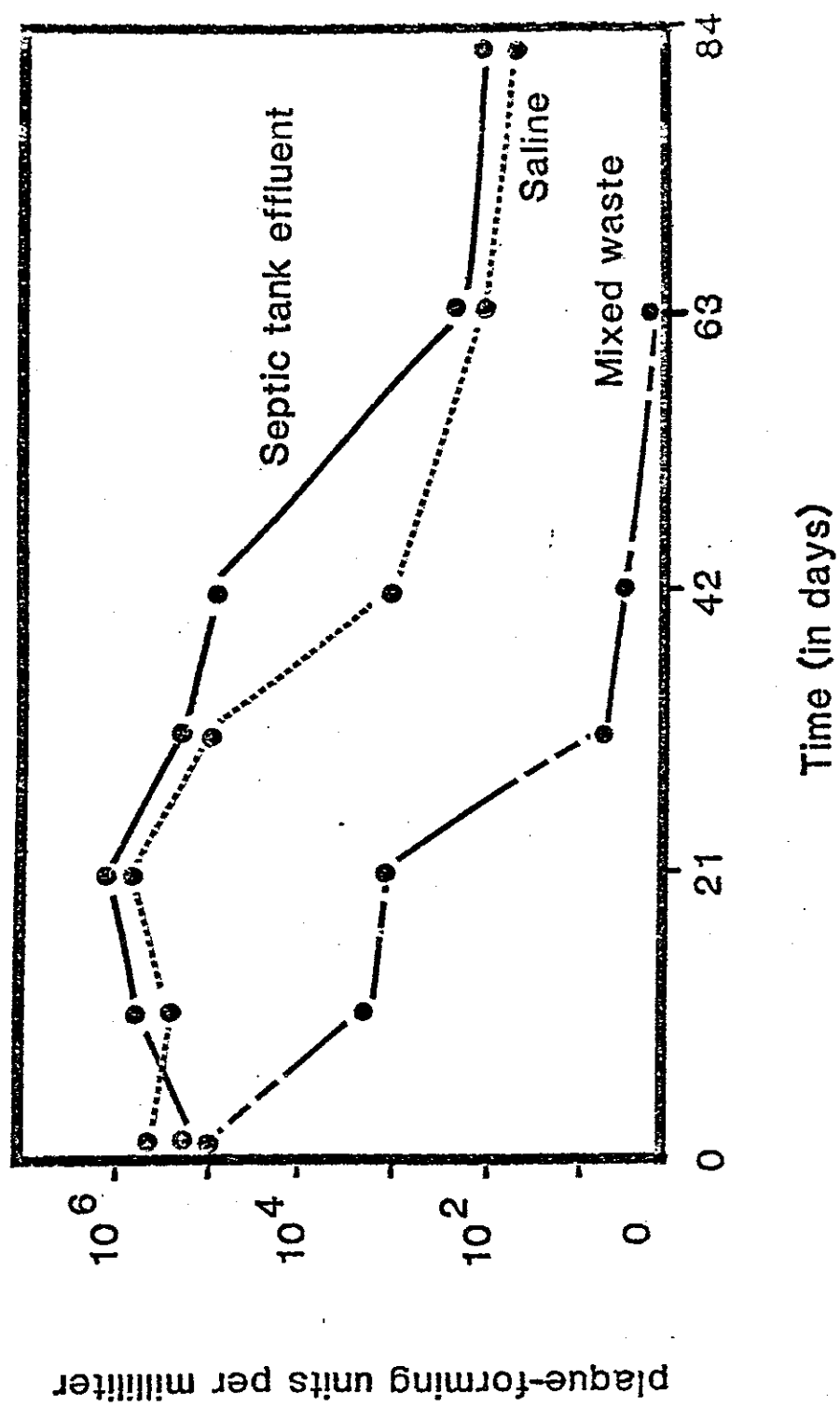


Figure 3: Decrease in Viral Infectivity with Time at 25° C

TABLE 2. Rates of Viral Inactivation\*

Solution	Temperature in °C		
	5°	15°	25°
Phosphate Buffered Saline	63	39	18
Septic Tank Effluent	63	39	18
Mixed Wastes	21	17	7

\*Expressed as D values: time (in days) for 90% reduction of virus titer.

5°C, 39 at 15°C, and 18 at 25°C (Table 2). This is in keeping with previously reported values. Virus activity in the mixed waste solution decreased more rapidly than the analogous controls, with D values of 21, 17, and 7 days at 5, 15 and 25°C, respectively (Table 2). The difference is most dramatic at the highest temperature, but is pronounced at all three temperatures; there is increased inactivation of virus when septic tank effluent is added to animal waste. The predominant influence upon virus viability is temperature, increasing inactivation with increased heat. But Wisconsin temperatures tend to be cool, preserving virus. Retention and inactivation are the keys to blocking virus transmission. This experiment clearly demonstrates a higher rate of inactivation of virus in the mixed waste system.

Microbes are known to have great influence upon viral activity. In a second experiment 8 logs of bacteria were removed from a sample of mixed waste via 4.5 Mrad of gamma irradiation. The resultant mixture was virtually bacteria free. With this irradiated sample we were able to design an experiment to determine if the microbes that are present in a mixed waste system are capable of inactivating the virus under anaerobic conditions. The irradiated slurry of septic tank effluent and dairy manure was inoculated with poliovirus type 1. This was compared to untreated mixed waste containing bacterial counts of over  $10^8$  colony forming units/ml, and the sterile solution of phosphate buffered saline which were also inoculated with virus. The flasks were sampled weekly; total bacterial counts (aerobic and anaerobic; figure 4), pH (figure 5), and viral activity were recorded. No bacteria were recovered from the flask of sterile phosphate buffered saline. The bacterial level of the irradiated mixed waste remained low or undetectable until the forty-second day when counts of  $3 \times 10^7$  cfu/ml were recovered. This may have been due to accidental contamination, or survival of latent spores. The

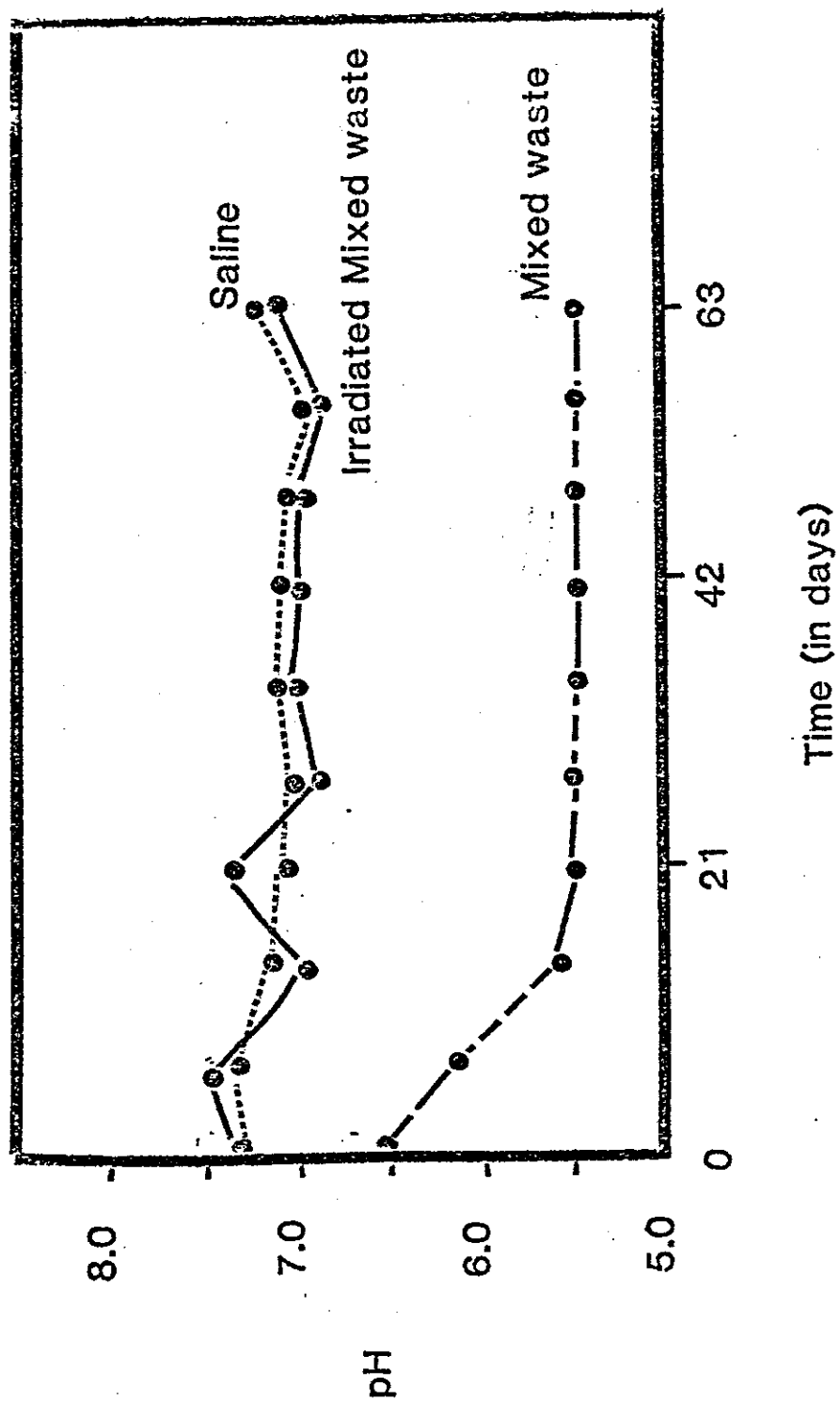


Figure 5: pH profile of Mixed Waste, Irradiated Mixed Mixed Waste, and Saline (15° C)

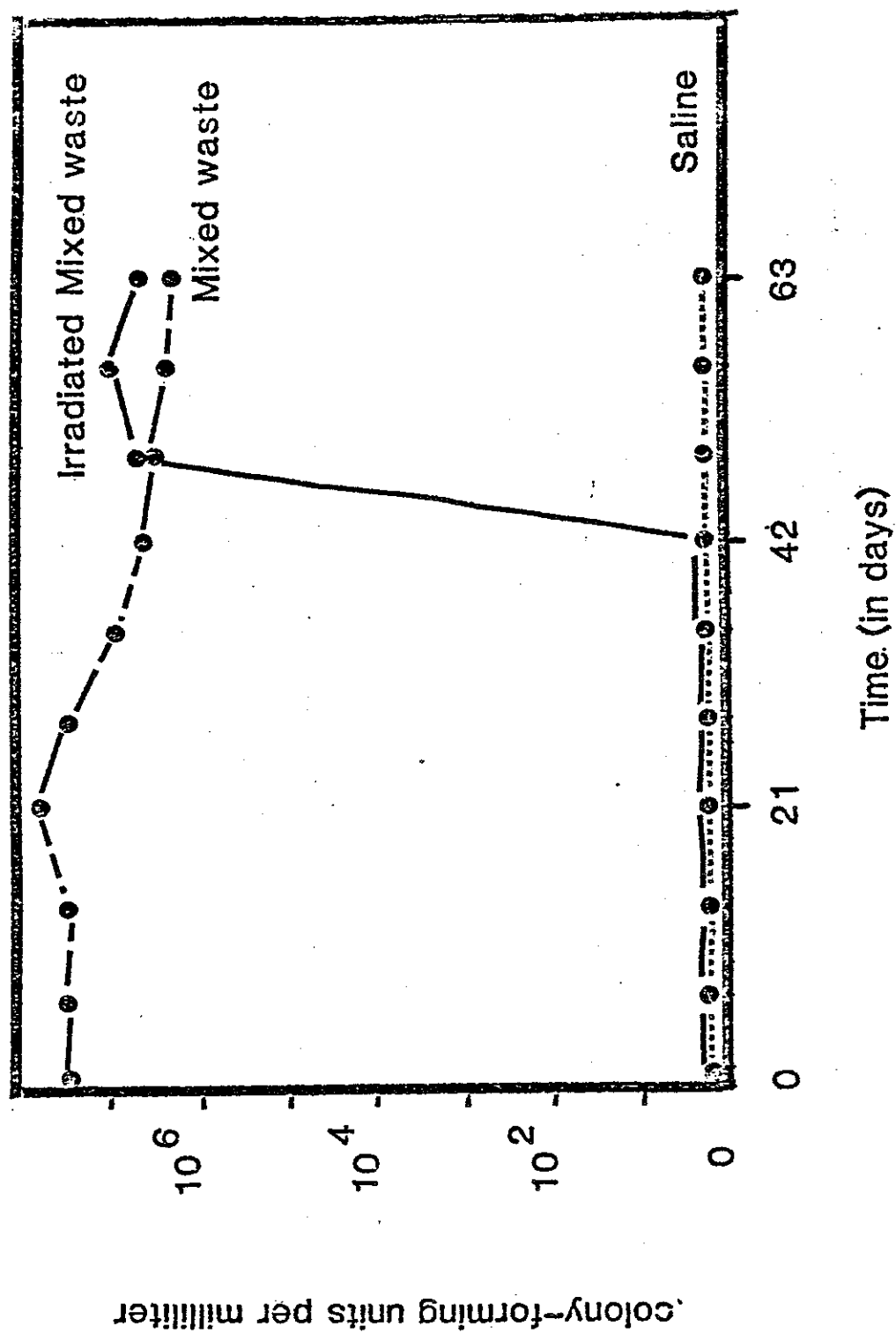


Figure 4: Bacterial Profile of Mixed Waste, Irradiated Mixed Waste, and Saline (15° C)



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typical mixed waste slurry contained counts of  $5 \times 10^7$  colony forming units/ml initially which decreased to  $10^6$  by the end of the 63 days. These numbers are in keeping with the bacteriological profile in storage of manure in a lagoon, where a slight decrease in numbers is followed by a leveling off in numbers (Miner, 1972). The pH of the irradiated mixed waste and the phosphate buffered saline were both stable at an average of approximately 7.2 through the duration of the experiment (figure 5). The typical mixed waste had a slightly lower pH than that of the irradiated mixed waste (6.5 vs. 7.3). It also dropped a full pH unit in 28 days. This is probably due to the buildup of organic acids that are metabolic byproducts of the bacteria. This pH change does not exert significant influence upon the viability of enteric viruses as they are stable down to pH 3.

The associated change in viral activity has undergone preliminary analysis. The untreated mixed waste system seems to have followed the usual pattern of a 2-3 log reduction over 12 weeks at 15°C. There appears to be little reduction in the phosphate buffered saline and an intermediate amount of change in the irradiated mixed waste. This indicates that the bacterial load in mixed waste systems plays a key but not exclusive role in the reduction of viral activity.

We anticipate continuation of this work with a field study. A semipermeable tube filled with a known amount of virus will be suspended in a basin filled with mixed waste. At periodic intervals samples will be withdrawn and assayed for viral activity. The activity in mixed wastes from animals other than dairy cattle (e.g., beef cattle, swine and poultry) also needs to be examined.

#### Bacteria:

It is not likely that the addition of household effluent to barnyard waste will increase the bacterial hazard of the waste. Bacteria present in animal slurry constitutes a diverse and numerous population. Animal wastes contain an enormous quantity of bacteria. For example, 159 samples of swine effluent and sludge were examined yielding total bacterial counts from  $7 \times 10^6$  to  $3 \times 10^{11}$  cfu/ml. This included 142 strains of E. coli and 106 strains of Salmonella which were pathogenic to man (Strauch, 1980). Dudley et al. (1980) developed a comprehensive screen for the enumeration of pathogenic bacteria from sewage sludge which includes over 40 different species.

Substantial work has been done in the United Kingdom to document the persistence of Salmonella and Brucella under a variety of conditions. In short, survival periods for hazardous organisms range from 30 minutes to several years (Reddy, 1981). The actual risk is reduced by appropriate waste disposition; for example, Salmonella in "buried soil" dies very rapidly (one log decrease in

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less than 2 weeks; Pike, 1985). Further protection is afforded because grazing animals are not easily infected; large numbers ( $10^5$  microbes and greater) of Salmonella must be present in the forage to result in an infection. Prudent recommendations such as storage of the slurry for at least 1 month, no grazing animals for 1 month; barring special precautions for young animals; no application to crops eaten raw by humans (or a 12 month delay prior to planting); and avoiding surface run-off should represent sufficient protection from bacterial hazards. In general matching the type of sludge to the type of land use and imposing appropriate time restrictions is necessary and sufficient. The use of lagoon storage or cold anaerobic digestion removed greater than two logs of Salmonella (Pike, 1985). While manure slurries must be handled with respect, the addition of septic tank effluent hardly contributes any additional burden to this microbiological collection. Those bacteria which are specific for livestock species represent no additional threat to public health in a mixed waste system (as they cannot infect humans). Those few bacteria of exclusively human origin (V. cholerae and Shigella) cannot infect animals and die off rapidly outside their host. They do not survive well outside of the gastrointestinal tract because of the lack of necessary nutrients and because of the presence of competitive bacteria. They tend not to multiply, though they may survive for weeks (Miner, 1972). The bacteria which represent a threat to human health in this context are those that are not species specific, and these are already present in the manure of the livestock. Hence, this system represents naught but an advantage for waste disposal.

#### Parasites:

The third category of biological pathogens are parasites, and may be subdivided into the groups of protozoan and helminth organisms. Protozoa are single celled parasites of the gastrointestinal system, including species such as Giardia lamblia and Entamoeba histolytica. The helminths, multicellular parasites of the gastrointestinal system, such as tapeworms and roundworms, are best represented in this association by the Taenia and Ascaris species. Organisms of concern include those that have stages in their life cycle that are adapted to long survival in the outside environment. These include eggs of helminths and cysts of some protozoa. Like viruses, these organisms either persist or die, they cannot multiply when they are outside of their mammalian hosts. Hence, detention in an earthen basin represents a means to decrease infectivity. Anaerobic mesophilic digestion completely destroyed the infectivity of I. saginata ova as did 28 days of storage in a lagoon (Pike, 1985). In general, this category of microbes tends to be quite persistent. Sarcocystis miescheriana has been reported to survive in animal manure for at least 6 weeks (Burger and Wilkins, 1984). Taenia eggs may remain viable for 16 days in city sewage, 33 days in river water, 71 days in liquid manure, 159 days on pastures (Soulsby, 1985). Ascaris has been reported to survive for 5-7 years

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in garden soil (Little, 1980) The occurrence of parasites in septic tank effluent has not been studied (Little, 1980). Only a little work has been done on parasites in animal slurries, although parasitism in animals may be considered enzootic. Eggs and cysts of numerous parasites from a variety of host animals, were found in urban sludge in all 27 of the waste treatment plants studied. The prevalence of parasites varies geographically. Parasites may appear wherever and whenever a vector carries them; transmission often occurs where sanitary disposal of feces does not occur (R. Grieve, personal communication).

The addition of septic tank effluent to animal wastes does not represent an increased hazard to the safe disposal of the slurry. In most instances, the domestic animals are the primary reservoir of the disease; household waste would contribute little more. While up to  $10^6$  parasites/gm may be shed in human feces, only a fraction of this number will reach the storage basin because of their propensity to settle into the septic tank sludge. Recent work (Soulsby, 1985) indicates that sludge is not considered an important vector in the transmission of parasites (flies for example, carry the disease with high efficiency and rapidity).

The chief concern in this mixed waste disposal is the completion of a cycle that is necessary for the survival of the Taenia species. This species is of special concern because it must pass through man prior to becoming infective for a particular domestic animal (such as cattle, pigs, or cats). Those eggs that are carried over in the septic tank effluent, survive storage in the earthen basin, are applied to land where cattle are prematurely permitted to graze, are a textbook example of the successful completion of a cycle of disease transmission.

Hence, we propose to study the persistence of Taenia, Ascaris, and Giardia as representative parasites of public health concern in a modeled mixed waste system. There is evidence that detention in a lagoon may enhance rates of inactivation (Pike, 1985) - another plus for the disposal of mixed waste. Rates of persistence in conjunction with other data should help to determine what constitutes "good practices" for the disposal of mixed waste to land.

### Summary

Land disposal of animal waste or domestic waste, but not a mixture of the two, is legal in most states under specified conditions. Disposing of mixed wastes presents several advantages including encouraging compliance with the law by providing an easy, inexpensive, logical method of waste disposal. The microbiological hazards of the disposal of both human and animal waste have been well documented. More information is needed on the survival of microbes under specific conditions of waste disposal. A good deal

TABLE 3. Minimum Guidelines for the use of Animal Slurry

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- (1) Slurry should be used on tillage crops (excluding crops for fresh consumption), wherever possible.
  - (2) If slurry is spread on grassland then:
    - (a) use on pasture for conservation, wherever possible
    - (b) if on grazing land -
      - (i) storage of all slurry for minimum of 60 days before spreading;
      - (ii) delay of 30 days before grazing;
      - (iii) graze with adult or non-susceptible animals.
  - (3) Utilization of slurry should be related to plant nutrient requirements.
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(From: Kelly, 1978, as cited in Bürger, 1982)

of research on the safety of land disposal of mixed wastes remains to be done. The mingling of wastes does not increase the risks associated with the disposition of either household or barnyard waste. There is some evidence that combining the wastes may enhance microbial degradation. Our group has documented a faster rate of viral inactivation in a laboratory model of a mixed waste system. This is in contrast to the lack of antiviral activity in septic tank effluent. Virus inactivation appears to be related, at least in part, to the bacteria in the slurry and perhaps to the organic acids as well. Enteric bacteria do not survive readily outside of the gastrointestinal tract. Their decline is encouraged by exposure to the elements. Single- and multi-celled parasites may exist wherever a vector carries them; hence their prevalence varies. Some parasites may remain dormant but viable for years. The risk of transmission of parasites through domestic waste is diminished by simple sedimentation. Furthermore there is some evidence that detaining parasites in sludge diminishes their viability.

It continues to be important to match land use and waste disposal carefully. For example, neither cysticerci of Taenia nor Sarcocystis were detected in calves fed dried grass pellets from land that was irrigated with purified sewage. All calves that grazed on pasture irrigated with wastewater (200 litres/m<sup>2</sup>) 5, 9, and 17 weeks after irrigation were infected with Taenia and the majority had Sarcocystis infections as well (Wilkins, 1980). Minimum interim guidelines for the use of slurry were formed by a working group of the Commission of the European Communities (Kelly, 1978 as cited in Burger, 1982). They state clearly (Table 3) that slurry should be preferably used on tillage land and used only in a restricted manner on grassland. Effective minimum storage times are

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still subject to debate pending availability of more data. The disposal of a mixture of household and barnyard waste to land represents an easy, effective, efficient and safe disposal of waste. Mingled wastes appear to enhance the demise of microbial pathogens that are a threat to human health; this disposal technique may diminish the hazards associated with manure. The risk of re-entry of fecal borne pathogens into the food chain is diminished by the ease with which a mixed waste system may be implemented. An easy effective waste disposal technique encourages compliance and reduces the risk of inappropriate and hazardous disposal.

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