#6.10

SMALL SCALE WASTE MANAGEMENT PROJECT

Wastewater: Emergent Environmental and Health Issues

by

Dean O. Cliver

October 1981

UNIVERSITY OF WISCONSIN - MADISON
College of Agricultrual & Life Sciences
Agricultural Engineering
Food Research Institute
Soil Science
School of Natural Resources
Environmental Resources Center
College of Engineering
Civil & Environmental Engineering

Copies and a publication list are available at:
Small Scale Waste Management Project, 345 King Hall
University of Wisconsin - Madison, 53706 (608) 265 6595

WASTEWATER: EMERGENT ENVIRONMENTAL AND HEALTH ISSUES

Dean O. Cliver, Ph.D.

INTRODUCTION

The scope of this discussion is delineated by its title. For use in the present context, the key words are defined as follows: Wastewater means water that, having been used in a household, is on its way to or from a private or cluster waste treatment and disposal system. Emergent means new, recent or increasingly visible. Environmental (as an adjective modifying "issues") means having to do with people's physical well-being--internally effective. Issues means subjects on which people disagree. The issues addressed here generally defy classification as either environmental or health concerns: many can be either or both. Breadth is favored here over depth because many of these topics will be considered individually in later chapters.

WASTEWATER

A pervasive problem in the matter of wastewater treatment and disposal is the public's perception of wastewater. That is, a substantial segment of the public regards any water that has been through a sewer pipe or subjected to some fecal contamination as if its molecular structure had been irrevocably degraded (Figure 1). As this perception of wastewater has a politically significant influence, it may be that one of the most effective ways of dealing with public mental block would be to separate or eliminate toilet waste from the main volume of the wastewater. This is suggested because the generally muted reaction to the presence of such substances as polychlorinated biphenyls (PCB) and trihalomethane (THM) in urban wastes seems to indicate a higher public tolerance for three-letter contaminants than for the time-honored four-letter contaminant. Further, this phenomenon reveals a failure on the part of much of the public to discriminate between categories of contamination or pollution which represent a hazard to human health, and those that are merely a nuisance, or to recognize the importance of differences in degree of either.

Nevertheless, it might be well if alternatives to the water-carriage toilet could be developed to the point where they were acceptable to the public of the United States and other developed countries. Americans clearly are not the only people addicted to what we regard as our style of amenities--one sees the magic cipher "WC" even in countries in which the letter "W" does not occur in the alphabet of the local language. It should also be mentioned, however, that our as yet unpublished studies of greywater in the University of Wisconsin's Small Scale Waste Management Project (SSWMP) have revealed high levels of *Escherichia coli* in wastewater that was receiving no inputs from toilets. We are prepared to believe that this *E. coli* was ultimately of intestinal origin, but whether by way of bath water or laundry water remains to be determined. In any case, it appears that even greywater may contain significant amounts of "four-letter" contaminants. This point is belabored because practical alternatives to the water-carriage toilet generally are not instantly available, and some of those that have been proposed are not obviously preferable to consigning all of the U.S. population to use "kitty litter."

The reuse of water by means less indirect than evaporation-transpiration followed by precipitation as rain or snow is an emergent issue. Whether disposed to soil or to the surface, wastewater will need to be treated with a view to its eventual reuse, possibly for drinking. Furthermore, people will have to accustom themselves to the idea that the water they drink may already have been used since it fell from the sky.

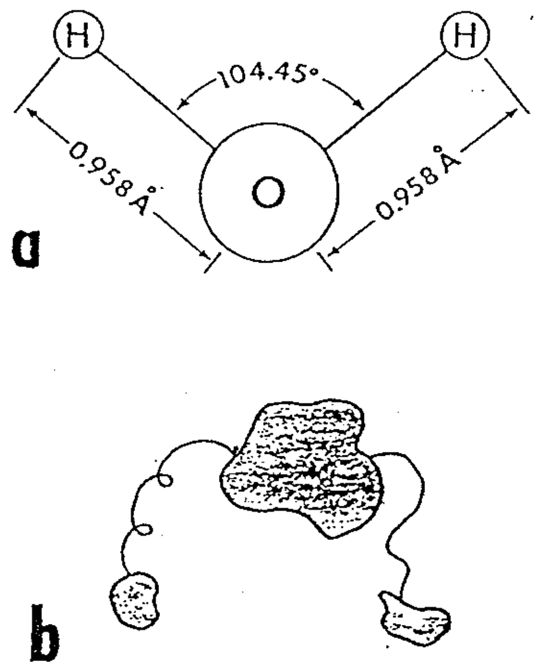

Figure 1. The water molecule: (a) general structure, (b) public perception of structure after use.

CONVENTIONAL SYSTEMS

At present, the most widely used system for onsite waste treatment is almost certainly that comprising a septic tank and soil absorption field [1]. This has come to be known as a "conventional" system, despite the fact that not nearly enough seems to be known about what it really does in waste treatment. "Failure" in such systems is usually recognized when waste that has received little or no treatment backs up into the home or surfaces on or near the absorption bed. This is, in fact, too limited a definition of failure for it does not address the question of adequacy of treatment of wastewater that is simply disposed, in the sense that the water goes away.

More important that the inadequacy of the definitions of failure in the performance of conventional systems is the lack of a comprehensive definition of success. For example, treatment of wastewater in the septic tank itself has largely been characterized with respect to the removal of solids and biochemical oxygen demand (BOD), but little has been done to determine the removal of pathogens from wastewater during treatment within the tank [2]. This means that the majority of treatment that affects pathogens, and perhaps some other important contaminants as well, is left for the aerobic treatment phase in the soil. The soil may indeed be the point where emphasis belongs, but so many variables in soil systems have yet to be evaluated that one wonders why the relatively predictable septic tank has been so ignored from this standpoint.

A great number of variables in soil that probably influence the effectiveness of wastewater treatment could be listed here. That the actions and interactions of these factors influence waste treatment is well known. The complexity of waste purification in soil systems, especially unsaturated systems, is so great that the comprehension of events in a single system is almost beyond hope; yet generalizations regarding the abilities of different soils at different sites to treat septic tank effleunts successfully are badly needed if adequate regulation of the installation and use of such systems is to be accomplished. Another neglected aspect of the soil treatment phase in "conventional" systems is the longer-term effect of high loading densities, such as situations in which many dwellings using such systems are built close together or effluents from several septic tanks discharge at a single sight.

Finally, one would wish to know much more about factors governing the useful life of a "conventional" soil system. That is, even if the septic tank is pumped with sufficient frequency, is every system doomed to eventual failure? This question has enormous potential significance both in the area of government regulation of onsite systems and in the financing of homes that use them. One hears of systems in which a 10-year life was assumed for a bed that failed in less than a year, and of other systems that have functioned without apparent impairment for more than 20 years, with no problems in sight. The first of these observations supports the assertion that there are many sites at which conventional systems have no business being installed; the second indicates that we need to know much more about the causes of the more obvious kinds of soil system failure if a more rational basis of the amortization of the cost of installation is to be achieved.

To conclude, the effectiveness of wastewater treatment by "conventional" systems is an emergent issue. One might say figuratively that both the life and death of these systems is in need of further study.

VIRUSES AND OTHER PATHOGENS

An important concern in onsite wastewater treatment and disposal is adequate removal or containment of viruses and other potentially waterborne pathogens, as mentioned above. The pathogens that are potentially transmissible as a result of disposal of inadequately treated wastewater are largely those that emanate from the human intestines, including viruses, some bacteria, and certain protozoan and metazoan parasites. None of these pathogens is normally found in the intestines of individuals in the U.S., so the pathogens are likely to be absent from most families and, therfore, from their septic tanks. If one or more members of the group whose wastes are being treated by a given septic tank shed virus for a period of time, some of the virus is likely to be found in the septic tank and its effluents, even after the infections have run their course. This probably does not represent a great threat to the health of other members of the household, even if the wastewater surfaces in the backyard are not being treated adequately. Virus infections spread within families with considerable efficiency without recourse to such indirect modes of transmission. However, improperly disposed septage or effluent from the tank could serve as the source of infection to others who had not been exposed directly to those previously infected. It should also be noted that the level of a pathogen entering a septic tank is likely to be highly relative to that in urban wastewater because the pathogens in the wastewater of large communities are present continuously, but are diluted with wastewater from households in which no infection is taking place at the time.

Therefore, onsite waste treatment and disposal systems are only challenged intermittently as to their ability to contain pathogens, but the challenges are relatively severe. This might prove especially important in the case of a familial outbreak of infectious diarrhea, in which the infectious agent was being shed at high levels by several members of the family under conditions that would lead to frequent flushing of the toilet(s) and a prolonged hydraulic overload at the tank. For these reasons, more needs to be known about the fates of pathogens during onsite waste treatment and disposal.

Treatment in the septic tank is fundamentally a sedimentation process. Therefore, the degree to which a pathogen is removed in the septic tank will depend on the tendency of the agent to settle and be held in the sludge layer of a properly maintained septic tank. Such eggs and cysts are quite durable and are still likely to represent a threat at the time that the tank is next pumped. Some bacteria may also settle spontaneously, but most bacteria and probably all viruses settle only in association with other solids, which are likely to be predominantly of fecal origin.

We have found that [3] virus in feces in a sludge layer may be liberated from time to time, presumably as a result of degradation of the fecal solids and of stir-back through the evolution of gas in the sludge layer; the same thing probably happens with fecal bacteria in the sludge. Viruses and vegetative bacteria are not as stable as the eggs or cysts of the parasites, so the potential of either to cause infection by the time the sludge layer is disturbed by spontaneous processes or when the tank is pumped will depend on the time and temperatures to which they have been subjected since they entered the tank. No coherent model of the loss of infectivity by pathogens in septic tank sludges seems yet to have been devised.

Clearly, the phase of treatment that takes place insoil is critical to the fate of pathogenic bacteria and viruses in wastewater that is processed onsite. The metazoan and protozoan parasites should pose no problem with effluents from a properly maomtained and operated septic tank, but care should be taken where effluent is discharged to the surface or treated on a very coarse medium, such as gravel. Bacteria that are pathogenic are likely to be removed from water percolating through soil by the mechanisms of filtration, absorption and parasitism by the indigenous soil microflora, assuming that more or less normal aerobic conditions are maintained in the soil field, and that the rate of application of the effluent is not so high in soils of high hydraulic conductivity that the exposure of the wastewater to these conditions is momentary. Where viruses are concerned, neither filtration nor biological degradation seems to have any very significant effect [4].

If viruses are retained, they are held either by absorption to soil particles or by adhesion to biological materials formed in the treatment during wastewater treatment. Media coarser than sand are unlikely to be effective in removing viruses from septic tank effluents, and saturation of the medium appears to allow virus to persist and be transported over considerable distances in an infectious condition. Virus that is retained either by absorption or adhesion will gradually lose its infectivity as a result of physical and chemical effects of the environment. The rate of loss is especially dependent on the temperature of the soil.

Bacteria do not appear to travel as far as viruses through saturated or unsaturated soil; however, a properly operated, unsaturated soil treatment system should be able to contain both viral and bacterial pathogens.

Bacterial indicators of fecal contamination, when found in groundwater, signal a distinct possibility that bacterial pathogens may be present. However, these bacterial indicators appear to be poorly correlated with the incidence of viruses in groundwater, as has been proven of indicators and viruses in many other environmental contexts [5].

In conclusion, the ability of septic tank-soil absorption systems and alternative onsite systems to deal successfully with pathogens in wastewater is an emergent issue. Much more research will be needed to follow the fate of pathogens during passage of wastewater through the septic tank, and during subsequent treatment of the effluent in soil or by alternative techniques. The research will be neither easy nor cheap!

GROUNDWATER PROTECTION

As most of the wastewater treated onsite is probably disposed of beneath the surface, a major concern in evaluating adequacy of treatment and the containment of pathogens is the protection of groundwater. The complexity of groundwater hydrology and the relative irrevocability of contamination of groundwater make this a difficult and urgent problem.

The initiative to conduct onsite treatment in a manner that will minimize groundwater contamination presents a dilemma. If wells in an area are not contaminated, those who live there are likely to believe that they have no problem. On the other hand, if wells in the area are contaminated, it is too easy to blame the problem on something other than onsite waste treatment or on the waste disposal practices of a less-enlightened past. Of course, there are now areas of the U.S. where the groundwater is in a condition too severe to ignore, and where all possible sources of contamination are being regulated closely. One would hope that the public's enlightened self-interest would lead to greater consciousness of the problem before that condition occurs in other areas.

The removal of viruses and other pathogens discussed in the preceding section is obviously part of the question of groundwater protection. In addition to human sources through onsite waste treatment facilities, it has been suggested that animal feces may be a significant source of groundwater contamination with pathogens. As it happens, few of the bacteria emanating from the intestines of nonhuman species, and virtually none of the viruses, are infectious to humans. This means that animal feces are probably not a significant source of agents that may infect humans by way of groundwater. However, animal feces may be a significant source of coliform and fecal coliform organisms that would indicate a health hazard if found in someone's well. Unfortunately, there is really no way to tell whether these indicators are of animal or human origin once they are found in a wellwater sample. Only a few bacteria (other than the pathogens with which one is most concerned) are sufficiently species-specific to implicate humans as the source of contamination in such instances. Viruses, when present, could be used for this purpose if one wahted to go to the trouble and expense. Unfortunately, viruses are so likely to be absent from individual onsite treatment systems, for the reasons discussed above, that a negative result of a test for viruses infectious to humans would not rule out contamination of human fecal origin.

Nitrates are another contaminant of groundwater that has health significance. Nitrate in drinking water at levels in excess of 10 mg/l is judged a health threat to infants because of its tendency to be reduced to nitrite and cause methemoglobinemia. Much higher levels are well tolerated by adults, [6] and may be blamed on animal wastes as well as on agricultural fertilizers. There is no doubt that both animal wastes and inorganic agricultural fertilizers can be important sources of nitrate under some circumstances, but it now appears clear that onsite waste treatment and disposal can also contribute to the problem, particularly in areas of high dwelling density. In this connection, it is unfortunate that phosphates have been removed from most detergents in favor of agents such as nitrilotriacetic acid (NTA). Phosphate does not seem to be either a threat or a nuisance as it might occur in groundwater, whereas NTA is a potential source of additional nitrate.

Excess sodium in drinking water also has been thought to be a threat to the health of some consumers, particularly those who are supposed to limit their sodium intake because of high blood pressure or related conditions. The salt used to de-ice roads can be a significant source of sodium in such areas, but salt used for water softening is a concern anywhere that swelling densities are great enough to exceed the dilution capacity of groundwater receiving effluent from onsite waste treatment. This is somewhat a circular problem in that homes deriving their household water from wells are likely to have to soften the water and thus would contribute to the contamination of their future supplies.

For these reasons, groundwater protection can be considered an emergent issue. In addition to the microbial pathogens and the inorganic contaminants that have been discussed here, organic contaminants seem likely to attract increasing attention in the future, especially when onsite treatment of wastes that are not of household origin are considered more closely.

REGULATION

At one time, in many parts of the U.S., there was essentially no regulation of onsite waste treatment and disposal. People could treat and dispose of their wastes in any manner they themselves felt they could tolerate. It seems clear that times have changed and that there is likely to be more regulation of onsite waste treatment than in the past. Even so, it is important that the regulations be right if they are to accomplish their intended purposes.

As regulation of onsite treatment expands, two continuing issues are: (1) How much regulation is needed? and (2) Who will pay for it? Where a property owner, an installer, some level of government, and the public at large are involved in various ways, the question of cost allocation derives from the question of whose interests are primarily served. That is, the property owner being protected from the effects of ill-advised interaction between the property owner and the installer, or is the property owner being protected from his own folly? All these possibilities exist, and their very existence could be used to justify putting the financial burden of regulation on either the property owner (directly or by way of the installer, who will inevitably pass his costs along) or through the public through taxes. Since there is no one right answer, it seems reasonable for the general public and the property owner to share costs, as often as is done at present.

The matter of how much regulation is very much in flux at this time. The need for closer supervision of subdivisions and other high-density developments where onsite treatment is used is not widely disputed, although there are certainly some who would like to see even this go away. On the other hand, there are those who feel that there should be exemptions from virtually all regulation for farms and other extremely isolated sites. If those who were the source of the waste were the only ones to be affected by it, a good case might be made for exemption from regulation. However, many farm owners are now selling their road frontage land for development, which means that the old farm is not as isolated as it once was. Other sites may be isolated only temporarily; unless the home in question is on a large parcel of land and has a stipulation added to the deed that would preclude subdivision, there is no guarantee that other homes will not be built later within the range of effluent from the site, unless the owners of contiguous properties agree to restrictions on the future use of their lands as well. Finally, there are a great many hydrologic unknowns at this point that make it almost impossible to define the term "isolated," as it has been used here, in a way to ensure that adjacent sites will not be affected.

The main focus of regulation to date has been on preinstallation supervision. This seems appropriate because it is much more difficult to identify and correct problems once a system is in the ground. However, there have been disagreements (which will continue) regarding the degree of supervision and what level of government should perform the task. At a time when local control, or none, is being proposed as an alternative to so-called "big government," it seems appropriate to point out that local control, or none, has been egregiously inadequate in the area of regulation of onsite waste treatment. Inequity and ineptitude have both been conspicuous problems.

A major problem with respect to preinstallation regulation has been that of site evaluation, both with respect to the validity of the criteria and to the ability of the evaluators. Criteria for site evaluation have focused on surface features and on the percolation test, with little regard for factors deeper than three feet below the proposed infiltration surface [2]. Controversy surrounds the attention being paid to soil mottling and perhaps other indications of pertinent conditions that have existed at times other than that at which the evaluation is being performed. However, still not included in the site evaluation are hydrologic conditions and other factors at deeper levels that may have a great deal to do with the long-term success and impact of the system proposed for installation. Obviously, broadening the scope of a site evaluation would add materially to the required investment of time and effort. Much study is needed before this can be recommended. Meanwhile, the question of the capability of the soil tester or site evaluator remains, and is intimately related to the adequacy and appropriateness of the criteria applied. Those who do site evaluations must not be left with so much latitude that they are obliged to make decisions for which they are not professionally qualified. If site evaluation criteria are fairly rigorous in the sense of defining requirements precisely, the onus will be on those who formulated criteria, rather than on those in the field, where they may be subjected to untoward pressures. Clearly, there are no explicit guidelines available to establish how rigorous site evaluation criteria should be, but the principle seems valid that the onus should be on those who write the criteria, rather than on those who must use them in the field.

Regulation of existing systems seems to have been largely neglected, in that a system that is in the ground can be whatever the occupant of the dwelling is willing to tolerate, unless a neighbor files a complaint. This is no longer sufficient in many places, however, and means are now needed to monitor systems for routine maintenance and for correction of failures. The availability of innovative systems, to be discussed below, means that those whose systems have failed now have alternatives to living with the nuisance. This does not mean that people will accept the alternative systems (or even know they exist) unless institutional arrangements are made for this purpose.

Innovative methods for onsite wastewater treatment are needed to deal with the limitations of sites that will not accomodate conventional systems [1]. Included among innovative methods are those employing water conservation or re-use waste segregation, evapotransipiration, interceptor drains, mounds, and other pressure distribution systems, aerobic treatment, surface discharge, cluster systems and many more. Some of these are already better studied than the "conventional" septic tank-soil field system. While none of them seems more likely to serve all purposes at all sites than does the conventional system, most evidently do have their place.

Innovative systems may solve site limitation problems where conventional systems already have failed, or they may be used in new construction. A good deal more controversy has attended the latter application than the former, in that site limitations have formed a basis for preventing development of tracts that would be opened if innovative systems were permitted. Clearly this is one form of land use control, but it cannot be called land use planning. I believe it is the prerogative and the duty of communities to plan for land use, but I believe that this is entirely a political area of concern and should be dealt with as such, rather than by resting the case on technological constraints. For example, one frequently hears that innovative waste treatment systems may promote "urban sprawl." I personally would have thought that rising fuel costs and transportation difficulties would have thwarted the centrifugal tendencies of those who have lived in cities, but the impetus to exploit solar and wind energy at the individual household level seem to me quite likely to lead to more disperse living patterns than city-dwellers otherwise would elect. If so, "urban sprawl" may acquire a new, less pejorative title.

To conclude, the entire area of regulation of onsite waste treatment is fraught with emergent issues, some of which are health-related, and may of which are environmental in nature. In particular, I see matters of site evaluation before new construction, monitoring of systems environmental in nature. In particular, I see matters of site evaluation before new construction, monitoring of systems that are already in existence, development and application of innovative technologies, and land use impacts as those that will create the most controversy.

SEPTAGE

The material pumped from septic tanks during routine maintenance is often called "septage." An analogous, but usually more dilute, waste material is that which is pumped from holding tanks. In either case, the waste is likely to be relatively rich in pollutants, including pathogens in some instances, subject to the probability limitations discussed above. These wastes may be disposed of at urban treatment systems on some occasions, but much more frequently are discharged on surfaces. As neither the septic tank-soil absorption system nor the holding tank is intended to be a surface discharge system in general, it is noteworthy that so much of the waste usually ends by being disposed in this way. It has been observed in the State of Wisconsin that pumping records are seldom entirely accurate and that probably not all the material that is collected is discharged at approved sites. The rising cost of fuel can be expected to reinforce the incentives for pumpers not to haul septage as far as the regulations require, so even greater problems are to be anticipated in the future. It seems clear that the disposal of septage will continue to be necessary inasmuch as the septic tank is here to stay. Closer scrutiny of septage disposal, including perhaps the development and application of an economical and effective method of disinfection, seem likely to be emergent issues.

SUMMARY AND CONCLUSIONS

Several emergent issues in the area of onsite wastewater treatment and disposal have been identified, most of which defy categorization as exclusively related either to health or to the environment. The first of these is the wastewater itself, from the standpoint of the public's perceptions of it and the need to reuse it. The second is the function and demise of the conventional septic tank-soil system, which has not been studied as thorougly as many of the more innovative techniques of waste treatment. Studies in this area to date have not yielded a coherent picture of the processes occurring in the actual field systems. A fourth issue is the protection of groundwater, not only from the pathogens that were just mentioned, but from other contaminants that may emanate from onsite treatment systems and have adverse health effects or be nuisances. A fifth issue is regulation of onsite waste treatment, including evaluation of sites before construction, monitoring of systems after construction, development and application of innovative waste treatment techniques, and the associated problems of planning and controlling land use. A final issue is determining that septage, and perhaps other products of onsite waste handling systems, are disposed of in such a way as not to create the same hazards that regulation of onsite treatment is intended to avoid. This list is certainly not exhaustive, but it does include enough topics to make a challenging agenda for the future. Many of these topics are covered in greater detail in other chapters of this book.

REFERENCES

1. U.S. Environmental Protection Agency. "Management of Small Waste Flows," EPA-600/2-78-173, National Technical Information Service, Springfield, VA (1978).

2. U.S. Environmental Protection Agency. "Onsite Wastewater Treatment and Disposal Systems," EPA-625/1-80-012 Water and Waste Management, Office of Water Program Operations, Washington, D.C. (1980).

3. Stramer, S. L. Draft Ph.D. Thesis, University of Wisconsin, Madison, WI (1981).

4. Green, K. M., and D. O. Cliver. "Removal of Virus from Septic Tank Effluent by Sand Columns," in Proc. Nat. Home Sewage Disposal Symp. (St. Joseph, MI: American Society of Agricultural Engineers, 1975), pp. 137-143.

5. Berg, G., Ed., Indicators of Viruses in Water and Food (Ann Arbor, MI: Ann Arbor Science Publishers, Inc., 1978).

6. Safe Drinking Water Committee. Drinking Water and Health (Washington, D.C.: National Academy of Sciences, 1977), p. 424.