# Sewage Sludge Disposal and Utilization Study

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# EXECUTIVE SUMMARY

This report looks at the use of municipal sewage sludge on land as a means of transforming an unpleasant and sometimes harmful waste into a natural resource. In Washington State digested or composted sludge is now being used for several purposes:

- silviculture
- agriculture
- land reclamation
- landscaping and miscellaneous uses

Certain risks are associated with the use of sludge due to its contamination with:

- heavy metals (such as cadmium, lead, arsenic and mercury)
- disease-causing organisms (bacteria, viruses, parasites)
- toxic organics (such as PCB's and pesticides)

As with other fertilizers, excess use of sludge can contaminate groundwater or surface waters with nitrates. Also, if sludge recycling is mismanaged, there can be nuisance factors such as noise, traffic or odor.

Careful management of sludge can minimize these risks and objections. Depending upon sludge quality, characteristics of the application site and the intended use of the material, some or all of the following safeguards may be needed:

- pretreatment programs to protect sludge quality
- monitoring of soils, groundwater and runoff
- limited annual and total heavy metal application
- appropriate site selection and choice of crops
- public information
- control of soil acidity
- limited public access to the application site
- heat treatment of the sludge (including composting)

Currently both the State Board of Health and the Department of Ecology have authority to regulate the use of sewage sludge on land. Local health departments are responsible for implementing these regulations. The legislature needs to ensure that the regulation and enforcement are effectively protecting public health and the environment. The legislature may wish to evaluate the roles of these agencies and their relationships with one another and the public. Further, the legislature might examine the enforcement of existing laws and regulations. It would also be useful to conduct further research into the potential of sewage sludge as a source of revenue to the public sector.

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# I. INTRODUCTION

Sludge is the solid material removed during the treatment of wastewaters. There are three kinds of sludge: sewage sludge from municipal treatment works, septage pumped from septic tanks, and industrial sludges. All three are a growing management problem in this state, and throughout the world. This report will discuss the management of municipal sewage sludge.

Washington State currently produces more than 2000 wet tons of municipal sewage sludge per day. This amount will be doubled in the next few years, due to stricter requirements for purifying wastewater before it is pumped into Puget Sound. Sewage treatment plants are classed as *primary* or *secondary*. There are also *tertiary* treatments of water, usually chemical, that are used in especially sensitive environments; these will not be considered in this report.

A *primary* treatment plant removes solids physically, by screening out larger objects and allowing grit and other materials to settle in settling tanks. This removes most solids, but leaves suspended matter and dissolved substances in the discharged water, or effluent. Under the pressure of federal laws, particularly the 1972 Federal Water Pollution Control Act and the 1977 Clean Water Act, and with the aid of federal grants, most primary treatment plants in the U.S. have already gone to secondary treatment. The exceptions are generally those which discharge into salt water, including Puget Sound. It was formerly thought that the volume of water in marine environments would dilute the effluent water enough so that no important pollution would result. However, research has shown increasing toxicity in fish and shellfish along both coasts of the country. Public opinion and government agencies have become dissatisfied with primary treatment, even for plants which discharge into salt waters. This is especially true for Puget Sound, which is more sensitive to pollution than the open ocean.

As a result, all of Washington State's primary treatment plants are now preparing plans to go to secondary treatment. Some cities (Lynnwood, Port Angeles, Bellingham, Des Moines and Anacortes) have appealed the state requirement to the Pollution Control Hearings Board. They claim that since they have comparatively little industrial pollution, their primary effluent is clean enough. So far, no waivers have been granted.

*Secondary* sewage treatment consists of bubbling air or oxygen through the water to encourage the growth of microorganisms. This is a biological treatment, like fermentation or composting. The "bugs" convert the dissolved and suspended materials into bacterial mass, essentially by "eating" (or "drinking") the substances. When the microorganisms finish growing and are allowed to settle out from the water, they take 85-95% of the contaminants with them. The result is not drinking water, but it is much less polluted than primary effluent. Metro (Municipality of Metropolitan Seattle), estimates that instituting secondary treatment at the Seattle West Point plant will reduce the amount of toxic materials flowing into Puget Sound by about 100 tons a year.

Although the methods are not used in Washington, many states recycle this water (primary or secondary effluent) after it has been treated—for irrigation purposes, to recharge ground water, or simply as “land treatment.” This method may be used when it is undesirable to discharge any effluent at all into nearby lakes or rivers. Irrigation with effluent provides some plant nutrients. Land treatment of wastewater must be carefully managed to minimize risks to public health and to the environment, but there are several successful programs. The Penn State Wastewater Renovation and Conservation Project has been irrigating forests with municipal wastewater since 1962. Also, a large scale project in Georgia, begun in 1981, transforms some of Atlanta’s wastewater into water of drinking quality for a nearby county.

Both primary and secondary treatments produce solids, or sludge. By 1991 Metro alone expects to produce 173,000 tons per year, more than double the current amount. There are many ways to treat this sludge so that it will not harm public health and the environment. Most commonly, the material is digested by microorganisms that grow well without air, under anaerobic conditions. This process kills something like 90% of the disease-causing organisms in the sludge, and stabilizes it, removing most of the odor and the tendency to further decay. Some treatment plants then treat the digested sludge by dewatering, heat treatments, adding chemicals, placing it in sludge lagoons, or composting. A few treatment works in other states irradiate sludge to kill off organisms; for example a research project in Boston uses high energy electrons from an accelerator. Theoretically high level nuclear wastes could be used for this purpose. Disadvantages are high cost, difficult technology, and problems of safety.

Municipal sludge is a resource. Anaerobic digestion of sludge produces methane gas, which can be used as a supplemental energy source at treatment works. The solids contain nutrients of value to plants, as well as humus-like material which improves the capacity of poor soils to hold water and air. Unfortunately, industrial sources, including household wastes and urban runoff, introduce quantities of toxic materials into municipal sludge. Human waste also contains harmful organisms—disease-causing bacteria, viruses and parasites. Therefore sludge must be scientifically managed in its disposal and utilization.

## II. SLUDGE DISPOSAL

There are limited possibilities for disposal of wastes; we can put them onto or into the earth, in water, or into the air. In practice, none of the methods available to us is final: wastes discharged into the air settle out again as dust on city streets and farmlands; landfills leach into the groundwater or spill into rivers; and sewage sludge dumped in the ocean can wash up on beaches.

A few Washington cities incinerate sludge; EPA figures show 27% of POTW's (publicly owned treatment works) nation-wide used some form of thermal processing in 1980. Incineration has some disadvantages, including high cost. Burning sludge is a way of discharging wastes into the air, mostly as relatively harmless substances such as carbon dioxide and water. However, incineration does contain a potential for air pollution, including settling of dispersed solids downwind of the facility. In addition, a residue remains (approximately one/fifth of the original volume) which must in turn be disposed of.

Sludge can no longer be dumped into fresh water lakes and rivers. Ocean disposal of sludge has been quite important in the past, and is still being used on the East Coast (4% of all U.S. treatment plants in 1980). Most of this sludge is dumped a few miles off the coast, from tankers or barges. Some localities, for example, in California, constructed long pipelines so that the sludge could be discharged beyond the continental shelf into deep ocean. The environmental effects of this kind of dumping are less well known, and the practice is now illegal under the Clean Water Act. The Marine Protection, Research and Sanctuaries Act of 1972 regulates ocean disposal. Seattle's Metro dumped sludge into Puget Sound until 1972.

Marine disposal counts on ocean currents and the volume of receiving waters to dilute the pollutants. Most pathogenic bacteria probably die off relatively quickly, and some toxic substances can be transformed into harmless ones in water. However heavy metals and other toxins persist, and both pathogens and toxins may be taken up by fish and shellfish. With extensive dumping there can be even more dramatic environmental damage. In the New York Bight, offshore from New York City, 50 years of sludge dumping have created 50 square kilometers of dead sea floor.

Disposing of sludge in landfills is common in Washington State and was used by 15% of all U.S. treatment plants in 1980. The water content of most sludges makes it difficult to handle and increases the likelihood that the landfill will leach into the groundwater. When wet sludge is deposited in a landfill that also takes refuse, 7 tons of refuse is required for every wet ton of sludge, to prevent structural collapse and leaching problems. Sludge is also a source of methane gas, which is either a problem or a resource, depending on how it is managed. In Washington State methane from landfills can be a very serious problem. Finally, the scarcity of landfill sites and resulting expenses encouraged Washington jurisdictions to find other solutions to the ever-increasing quantities of sludge.

# III. SLUDGE AS A RESOURCE

The application of sewage to land as fertilizer is an ancient technique. In Europe, sewage was used for irrigation in Prussia from the 16$^{th}$ to the 19$^{th}$ centuries, and sewage farms existed in England and outside Paris over a hundred years ago. Melbourne, Australia, has been applying sewage to land continuously since 1896, and many U.S. cities did the same. Historically, the sewage put on crops was raw or untreated sewage, as it still may be today in some regions of the world. However, as awareness of the causes of disease and parasites grew, the technology of sewage treatment developed.

Records of land application of sewage are not complete, and it is difficult to estimate how widespread the practice was at any given time. However, there has probably been no time when there was no land application of sewage, in this country and in the state. In the last ten years, however, there has been renewed interest in utilization of wastewater from sludge, both because of the costs and disadvantages of disposal methods and because of new interest in recycling resources. The 1972 Federal Water Pollution Control Act Amendments specifically encouraged the land application of wastewaters and sludge, and provided for federal construction grants. At the same time, stringent regulations for effluent quality increased the amounts of sludge. Finally, rising fuel prices increased the costs of incineration, and of transport of sludge to distant disposal sites, as well as the costs of manufacturing nitrogen fertilizers. It was estimated in 1974 that 46 gallons of fuel oil would be burned to incinerate one metric ton of sludge, and another 26 gallons would be used in the replacement of the lost nitrogen by commercial fertilizer. The use of sludge on land promised to be a better choice.

There are four chief options for land utilization of municipal sludge: applying sludge directly to croplands, to forests, to disturbed lands as a means of land reclamation, and providing composted sludge for landscaping and gardening. The benefits of sludge are similar in all these uses. Sludge can provide all nitrogen (N) and/or phosphorus (P) for plant growth; potassium (K) supplements may be needed. Several micronutrients, such as zinc, copper, and iron are also available in most sludges. The added organic matter enhances soil quality, making clay soils more permeable to water and air, and increasing the water and nutrient-holding capacity of sandy or gravelly soils. The texture of the soil (tilth) is greatly improved.

The advantages of sludge for agricultural use have been extensively researched in other states and in Europe. Farmers are often very receptive to the application of sludge, especially after seeing the results on nearby farms. On sandy or clay soils, sludge can increase the yield of some crops as much as three times over the use of commercial fertilizers.

Recent experiments with timber production also show dramatic improvement in tree growth over unfertilized controls. Although not all tree species respond to sludge application, commercially important trees such as Douglas fir, and poplar or cottonwood grown for fiber, have done extremely well at the University of Washington's research project at Pack Forest.

The use of sludge in reclaiming strip mines has proved superior to previous techniques of adding topsoil, liming, fertilizing, and irrigating, and is much cheaper.  Washington's large coal strip mine at Centralia is reclaimed with the use of Metro sludge from Seattle, as well as sludge and septage from other localities.

Finally, composted or treated sewage sludge from numerous American cities, including Seattle, Tacoma, and several small communities in Washington, is given away or sold for landscaping or gardening purposes.  Most cities with such programs find that there is more demand for the product than they can meet.  Portland, Oregon is now composting sludge in a new facility for sale to the public.  This program is less than a year old, and is being carefully watched by other cities to see if it is a financially viable option.  Packaged sludge compost from the Midwest is available in Washington.

At this time only a few treatment plants have chosen to sell sludge.  Reasons given for this hesitation are the increased costs of treatment and packaging, and the complication of marketing.  There are also risk factors, which will be discussed in the next section.  Chicago had to recall its "Nu-Earth" some years ago when it was found to contain dangerous amounts of cadmium.  However, the market potential is there, for composted sludge as well as for use in agriculture, forestry and reclamation.

Utilization of sludge nearly always represents a savings over disposal costs.  The amount of savings is specific to each situation, since it depends, for example, on the costs of additional treatment of the sludge, relative distances to disposal or application sites, whether costs of application are paid by the consumer or the POTW, and the specific costs of alternate disposal methods.  Application of sludge may require specially designed heavy equipment, storage sites, and the building and maintenance of roads.  However, it is common for treatment plants to find the costs of sludge utilization to be less than the costs of disposal, even if the treatment plant pays some or all of the costs of transportation and application to the land.

# IV. RISKS TO PUBLIC HEALTH AND TO THE ENVIRONMENT

Along with the benefits of sludge, there are several problems which must be carefully managed to protect public safety and the integrity of the environment. The most serious of these are the harmful constituents of sludge: heavy metals, toxic organics, and harmful organisms (pathogenic bacteria and viruses, protozoa, and parasites, or worms). Even the nitrogen in sludge can become a problem if not managed wisely, and in excess it can contaminate groundwater or surface waters. (This is also true of manures and commercial fertilizers.) In some situations there may also be nuisance factors such as odor, traffic or noise, which could have an impact on land values. Public acceptance is also crucial to the success of any operation.

The most likely sources of problems in sludge are the presence of heavy metals, particularly cadmium, and the potential for infection by disease-causing organisms. Specific management practices and careful monitoring are required to mitigate these risks.

## Heavy Metals

Most research on land application of sludge has focused on heavy metal content and its management. Because of industrial sources, all the metals may be found in sludge of one locality or another. However, the metals of most concern are zinc, copper, nickel, lead, mercury, arsenic and, particularly, cadmium. Metals such as chromium and selenium are problems where industries discharge these into municipal wastewaters. Of the metals commonly found in sludge, cadmium, lead, mercury and arsenic are toxic to humans, and zinc, copper, and nickel are harmful to plants. Washington does not have high amounts of zinc, copper and nickel in its sludge, and these metals are not considered to be a problem here. They represent no public health problem, since plants react to these metals at a level far below any impact on human health.

**Lead, Mercury and Arsenic.** All three of these may cause acute and chronic poisoning of animals and human beings, including disabilities and death. Luckily these metals are not taken up by plants in any quantity, or are contained by the roots and not transported into edible parts, even on soils containing large concentrations of these metals. Thus, it would be rare for animals or people to be harmed by consumption of clean plant material from sludge-amended soils. One exception to this general rule is mushrooms, which do accumulate mercury and other metals to dangerous levels. Sludge compost should never be used in mushroom production. Tobacco also is a heavy-metal accumulator.

A more important source of danger for human health is the dirt and contamination that may enter the food chain directly, rather than through plant uptake. Sludge sprayed in liquid form on growing plants may dry and adhere very strongly to the plants, and is difficult to wash off even by rain. Metals from the soil may also be absorbed onto roots of plants, including edible roots such as carrots and radishes. Another important pathway for entry into the food chain is through grazing animals, which ingest from 1% to as much as 20 or 30% of their diet as soil, depending on weather and grazing conditions. The highest amounts occur in wet weather on overstocked fields, when forage is trampled into the soil. Animals ingesting heavy metals accumulate these in the liver, kidneys or bones.

Finally, certain adults and children deliberately eat dirt, in a condition known as pica, and this is a significant cause of poisoning for some individuals. Dirt can also be ingested in normal play activities, when young children mouth toys or their hands. Effects of chronic poisoning by lead, mercury or arsenic can include brain damage, behavioral problems, poor learning, irritability and depression.

Most metals are strongly held in soil, and in most uses of sludge very little, if any, will be leached into groundwater or lost into runoff waters. However, monitoring of water quality should be a part of every sludge application program. Contamination of the groundwater or surface waters becomes likely when effluent waters are added at high rates to sandy soils, for land treatment, irrigation or recharging of groundwaters. This is not a technique used in Washington thus far.

Nevertheless, heavy metal loading of the soils of the state must be avoided, since once the metals are in the soil there is no known way to reverse the process. This requires long-term monitoring and record-keeping of all sludge applications so that excess amounts will not be added to any site.

**Cadmium.** Cadmium is another metal which has effects comparable to arsenic, lead and mercury. It is both a chronic and an acute poison, and there have been occurrences of widespread human illness and death from cadmium-contaminated soil, particularly in Japan. The metal accumulates in the kidney and causes irreversible kidney damage, as well as other symptoms. Cadmium is discussed separately, because it represents a special danger in sludge.

Plants do take up cadmium into their leaves and roots, especially green leafy vegetables such as spinach and chard, and root vegetables such as beets and carrots. More cadmium is taken up when the soil is acid, below a pH of 6.5, as most soils in Western Washington and Oregon are. Cadmium concentrations in soils and in human diet have been increasing for many years and, according to the World Health Organization, the amounts of cadmium that most people contain in their bodies worldwide may be approaching a critical level for sensitive individuals. Cadmium is very widely used in industry. It is also a contaminant in zinc, as well as in the phosphate rock used to produce commercial fertilizers. Solders used in plumbing contain cadmium. Much of the cadmium found in Metro sludge from Seattle comes from the plumbing of the city. Tobacco, a green leafy plant, takes up cadmium, and smokers are at a special risk.

Besides uptake into food crops for human and animal use, cadmium can also enter the diet directly from the soil, as discussed above.

Washington's sludge is comparatively clean, containing relatively low amounts of all the heavy metals, including cadmium. Even Metro's sludge is low enough in cadmium that the EPA would allow its use on food crops, if the soil were limed to minimize plant uptake.

Metro is committed to improving the quality of their sludge by encouraging and enforcing pretreatment of industrial sources that might otherwise add these dangerous metals to municipal sewage. Even with these measures, heavy metals remain a concern, because of their irreversible attachment to the soil and irreversible health effects.

## Pathogenic Organisms

Infectious organisms found in sludge include bacteria, viruses, protozoa and parasites (worms). Some treatment processes, for example heating sludge, proper composting, or irradiation, kill almost all pathogens. Sludge which is marketed for sale to consumers is generally treated in one of these ways. However, these are relatively expensive treatments, and composting especially must be skillfully done to be effective. Composting does not kill the eggs of intestinal parasites unless heat is added in the process.

Normally a site which has received digested sludge, which still contains harmful organisms, will be closed to public access for one year. Animals can be turned onto the land after one month, as discussed below. If sludge has been properly composted or treated to kill all organisms, it can be used more freely—although it should still be monitored for heavy metal content.

**Bacteria.** Most land application utilizes digested sludge, which contains live disease organisms and parasites. Up to 99% of harmful bacteria may be killed by common sludge treatment processes. That is, if there are a million live bacteria per gallon in the beginning, there will still be 10,000 per gallon in the final product. This means that even treated sludge has the potential to cause disease. Most bacteria die off in the soil after varying periods of time. The bacteria found in sludge which may infect animals are salmonella and bovine tuberculosis; a waiting period of 30 days is considered sufficient to inactivate these bacteria.

If liquid sludge is sprayed onto the site, bacteria and viruses could be spread as an aerosol, in droplets of liquid that are sprayed into the air and breathed in by people nearby. It is recommended that this exposure be avoided, even though most testing for pathogens in aerosols has indicated there is little danger.

Bacteria also survive for some time on plants. It is unlikely that there would be enough bacteria remaining on food plants to sustain an infection, but certain bacteria have the potential to regrow during food processing, and this could be a danger to human health.

There is little evidence of bacterial contamination of groundwater under sludge application sites. Bacteria are normally filtered out by the soil column, and there should be small risk unless the water table is high.

**Viruses.** Many viruses, including hepatitis A and poliovirus, are found in sewage sludge. Viruses are somewhat more likely, because of their small size, to be carried into groundwater than bacteria are. This problem is still not settled by the research results, although the risk to human health is considered to be low. It is difficult to monitor the presence of viruses in the environment. Only a few years ago it was not realized that viruses can survive in soil. Many viruses still cannot be cultured in the laboratory. There are unknowns, therefore, but after one year in the soil it is not considered likely that virus infections from sludge would be a danger.

**Protozoa.** Three species of protozoa found in wastewater are significant human health risks: the organisms which cause amebic dysentery, giardiasis and a rare dysentery called balantidiasis. Giardiasis is a persistent diarrhea which is becoming more common in the Pacific Northwest. It is also transmitted in surface waters—hikers and hunters often become infected by drinking from "pure" mountain streams.

Management techniques for preventing infection from bacteria and viruses are considered sufficient to protect against these diseases.

**Parasites.** The parasites include several species of human and animal roundworms, such as pinworms and hookworms, and tapeworms. The level of parasite infections in this country is commonly considered to be low. However, these worms cannot be ignored because their eggs are adapted to live for long periods of time in soil—some roundworms can remain infective for several years, and a single egg may cause infection. Digestion of sludge does not reduce the numbers of parasite eggs. Heat treatments, including some composting processes, kill the eggs. Ordinary composting sufficient to kill bacteria will not kill these parasites. It is still a research question whether land application of sludge might represent a significant risk of parasite infection of animals or humans.

## Toxic Organic Substances

The concentrations of toxic organics in most sludge are expected to be low. Although certain persistent pesticides, for example, are found in sludges, they would not be in as high a concentration as in common agricultural use. The important questions are: What are the effects on human health and the environment of exposure to low levels of these chemicals? And are there any interactions of these substances with each other or with other pollutants that could increase their potential for damage? These are not questions unique to sludge use, however.

There are hundreds of thousands of organic substances produced by modern industry, from detergents to pesticides. Any of these can appear in wastewater. Some are known to be harmless, and many are known to be toxic. Most are very little known, in their effects, their transport through the environment, and in techniques for monitoring them. EPA now lists over a hundred organics as priority pollutants, but techniques for measuring even these, and knowledge of their interactions in soil, water and air, are still inadequate.

The treatment of sewage inactivates most of these substances (or volatilizes them into the air). Nevertheless certain toxic organics are persistent, such as the PCB's and several pesticides. Except for unusual discharges from industries, most organic substances are in low concentration in sludge, and the principal danger from them would be their potential to cause cancer or gene mutations in these low concentrations. There may be a danger from a spill or illicit dumping into the system.

Many organics are capable of uptake by plants. Toxic organics tend to concentrate in fatty tissues of animals, including milk. Contamination of groundwater and surface waters is possible, and should be monitored for, although, again, it is expected that there would be relatively small amounts to leach into the water. Research is continuing into the unknowns of the vast numbers of new organic substances now in the environment.

## Nitrates, Salts Etc.

Nitrate has been found to leach into the groundwater from sludge application sites whenever the amount of nitrogen applied is greater than that needed for fertilizing the plants. This is also true of commercial fertilizers and manure, if present in excess. A small or infrequent leaching of nitrates may be considered acceptable at some sites.

Some sludges could contain high concentrations of salts or other materials which would limit their use.

## V. Risk Assessment

The use of sewage sludge to improve soil cannot be shown to be a zero risk proposition. Pretreatment of sewage by industries can greatly reduce the amounts of heavy metals and toxins that enter the sludge, but these cannot be entirely eliminated. As mentioned before, an important source of cadmium in Seattle is the pipes themselves. Some household hazardous substances will still enter the waste stream, although educating the public and providing effective ways for people to dispose of household poisons could make a difference. Finally, treatments that kill all pathogenic organisms are expensive. Do we really need to kill all the organisms before using sludge in agriculture and silviculture? The answer, so far, has been no. With proper precautions, this risk is acceptable.

Most agricultural use of sludge, especially in the Northeast, has avoided use on crops for human consumption. Sludge is most commonly used on forage crops and grains grown for animals, ornamentals, turf, and in this area, for Christmas trees. There are other restrictions placed on agricultural use by most jurisdictions, and examples will be given in the next section. Food crops that could most safely be grown on sludge-amended soils are tree fruits and grains, which do not take up cadmium. So far, however, major food processors are reluctant to buy any food crops grown on sludge.

One area where few restrictions are presently found is in the use of sludge from giveaway programs. There are several reasons why risks in these programs might be lessened. Most sludge given free to the public has been composted, has been dried and/or has been in a lagoon for at least one year. Nearly all harmful organisms (with the exception of some parasites) die off after that length of time. Also, sludge from most cities with giveaway programs has low concentrations of heavy metals. For composted sludge, if the composting process heats the sludge sufficiently, the pathogenic organisms will be killed. Composting also reduces the concentration of heavy metals, by the addition of sawdust or wood chips in the composting process. However, at the same time it reduces the nitrogen, so more of the material might be used.

For these reasons, most communities have not felt it necessary to set up formal procedures to track this use of sludge, or even to inform the public of any remaining risks. They do not prevent use of the sludge on areas where young children play, or on vegetable gardens, and no records are kept to prevent over-use of metal-containing sludge on one site.

The questions for the public, their representatives, and for public and private agencies are:

- Given the benefits of recycling sludge, are the risks incurred acceptable? Shall we recycle sludge?
- What are the relative risks, costs and benefits for each of the recycling or disposal methods available? Which recycling or disposal process (or processes) shall we choose?
- How can we best manage the process chosen so that the balance of benefits, risk and costs is best for the community?

These questions do not have easy answers, but land application of sludge is increasing. Growing numbers of people and organizations have decided that the risks, as currently known, are acceptable. Most recycling of sludge is carefully managed and restrictions are built into the programs. This will be discussed further in the case studies in the next section.

# VI. EXAMPLES OF LAND APPLICATION

## Silviculture

The use of sludge in the commercial production of timber is just beginning in this state. At Pack Forest, in Pierce County, researchers from the University of Washington have been investigating this application for thirteen years. They are studying tree growth response, timber quality, and effects on wildlife, water, and on those foods which are traditionally harvested from forests: game, berries and mushrooms.

Metro sludge from Seattle is now being sprayed onto a 150 acre demonstration site at the Pack Forest. Metro also applies sludge to its own recently purchased forest lands (2300 acres), and has signed agreements with Weyerhaeuser, Boise Cascade and the Washington State Department of Natural Resources to supply sludge to their timber lands. Results from Pack Forest indicate that trees may grow as much as four times faster with the use of sludge, and these effects are still seen eight years later. In contrast, the application of urea as fertilizer must be repeated every three years. Metro is consciously building a market for this material, named “Silvigrow,” in its demonstration projects.

As in all land application of digested sludge, access to the land must be restricted for one year. Generally sludge is added to forest land no more often than every five years. Sludge is not applied to steep slopes (over 30°) and buffer zones are left along waterways. Groundwater, soils and runoff waters are monitored for nitrate leaching. Soils are monitored for heavy metals.

By the 1990’s Metro estimates that it will be producing 100 dry tons of sludge per day. Metro’s Sludge Management Plan calls for the use of 65% of its sludge on forest lands, 25% for land reclamation and soil improvement, and 10% composted for use in horticulture and landscaping.

Other communities which apply sludge to smaller forested sites include Tacoma, Woodland and Ridgefield. Bremerton recently ceased application to forest lands owned by McCormick Land Company, because the company now wishes to develop nearby lands. Bremerton is looking for other silviculture projects.

## Land Reclamation

The biggest land reclamation project in the state is WIDCO’s coal strip mine at Centralia. When the mine began operation in 1971, the company used saved topsoil and/or commercial fertilizers to encourage new vegetation growth on the disturbed land. Since 1978, the mine has been using digested sewage sludge injected under the surface of the ground, with excellent results. WIDCO’s reclamation efforts are now contracted to Solganics, which takes one-fourth of Metro’s sludge production and all of the sludge from the LOTT plant in Thurston County and from several smaller communities. Most of the land will be used for timber production, with a smaller amount possibly used for growing

Christmas trees.  Surface runoff is controlled and leaching is monitored.  Public access is limited.

Other reclamation projects in the state include mixing sludge with soil as a top cover for landfills at Cedar Hills, Duvall, and for Ryegrass Landfill in Kittitas County, all using Metro sludge.  Digested or composted sludge is also useful for smaller disturbed sites created by construction or roadbuilding.

## Agricultural Use

Both Spokane and Tacoma have well-planned programs for utilizing sludge on agricultural land.

Spokane has just finished a three-year pilot project program testing the results of sludge application on a farm which grows grain for animal consumption.  Spokane's sludge has low levels of heavy metals, and no problems have been identified in this use of the sludge. Grain yields have been encouraging, and enough farmers are interested so that there is no anticipated shortage of land for sludge application.  The sludge is supplied free to the farmers at this time, with a possibility of charging for it in the future.  Costs are expected to be approximately half the costs of disposal.

Spokane will require a contract by the user which will limit the uses of the sludge-amended land.  No food crop for direct human consumption will be grown for 18 months after the last application, and no animals used for meat or dairy products will have access to the land for one month.  Only cereal grains, forage crops, ornamentals or trees can be grown during sludge application.  Records of sludge use and metal soil values must be recorded on the property deed, along with the statement that no tobacco, root crops, or leafy vegetables should be grown on the land.

Tacoma also has instituted strict record-keeping and comparable restrictions on the land treated with sludge.  Most of the agricultural land currently utilizing sludge is used for pasture, flower bulbs, or grass.  Tacoma also has plans to go to a thermophilic (heated) sludge digestion treatment which would kill all organisms in its sludge (including parasites) and would allow more flexibility in its use.

## General Use:  Giveaway and Marketing Programs

A number of Washington communities have giveaway programs, where sludge is provided at no cost to individuals or companies who are willing to haul it away.  Tacoma allows the public to take dried sludge which is more than one year old.  An informative brochure is provided with the sludge, which advises precautions to lessen the risk of infection from harmful organisms.  The brochure does not mention heavy metals, nor does it recommend controlling pH to avoid metal uptake by plants.  Groco, Inc., contracts to compost Metro sludge for sale to the public.  Metro pays the contractor for this service.  Groco informs purchasers that the composted sludge is not recommended for use on root crops or low-growing vegetables and fruits. The company keeps records of use information and the purchaser's signature and address.

Most smaller communities make no attempt either to inform consumers or to keep records of sludge given away. As mentioned, the amounts of heavy metals in the sludge from smaller communities are normally quite low.

Portland, Oregon has built a novel treatment facility which composts all its sludge in enclosed vats. The treatment provides complete kill of pathogens. The facility has been in operation for one year. North American Soils, a subsidiary of the company which markets the composter (Taulman Company), sells the product to landscapers and to wholesale nurseries nearby, including some in southwest Washington. The compost can be substituted for peat moss. Due to a successful industrial pretreatment program, Portland has decreased the cadmium content of its sludge to one-fourth of its former value, and the compost is not unduly high in the metal.

## Other Uses

Metro sludge is also applied to stands of cottonwood or poplar trees grown for fiber, at Pack Forest. Sludge has been applied to several Christmas tree-growing sites in Washington. For example, Bremerton's sludge now goes through a contractor (Solganics) to a Christmas tree farm in Mason County.

One interesting use of sludge is along a powerline right of way maintained by Tacoma City Light. Sludge applied to clearcuts encourages the growth of grass and other herbs to such an extent that trees are unable to compete. Small rodents such as voles thrive in the thick grass, and girdle young trees. Deer are attracted to the richly fertilized plants, and also kill the trees by browsing on them. The result of this grass competition and browsing on the trees by wildlife is suppression of trees which is as effective as using herbicides. If the demonstration project is successful, sludge application could replace herbicides or mechanical clearing under powerlines. Only one application of sludge is needed. Groundwater, soil water and soils are being monitored on this site by University of Washington researchers. Soils are monitored for heavy metals.

# VII. Applicable Laws and Regulations

## Federal

Many federal laws affect sludge, including the 1972 Federal Water Pollution Control Act Amendments and the Clean Water Act of 1977. Both laws encourage resource recovery and recycling of sludge. The Resource Conservation and Recovery Act of 1976 likewise emphasizes recycling of waste materials, and EPA regulations under this law (published in the *Federal Register* on September 13, 1979) address land application of municipal sludge as a "solid waste" disposal practice.

It should be noted that most states, including Washington, previously managed sludge as part of a water quality program rather than as a solid waste. Sludge fresh from the digesters is, in fact, more than 90% water, and traditionally was disposed of in water as often as on land. However, following the federal practice, Washington has transferred the management of sludge to the Solid Waste section of the State Department of Ecology.

Other federal statutes governing aspects of sludge utilization are the Clean Air Act, the Toxic Substances Control Act, the Marine Protection, Research and Sanctuaries Act, the Federal Food, Drug and Cosmetic Act, and the National Environmental Policy Act. The Food and Drug Administration and the Department of Agriculture have not separately established limiting levels of cadmium or other toxic substances, such as PCB's, in food crops grown on sludge treated land. Both departments cooperated with the EPA in setting its 1979 regulations.

Current EPA regulations govern:

(1) the quality of sludge (fertilizing value and heavy metals content) to be determined by the treatment plant;

(2) soil characteristics, especially pH and "cation exchange capacity";

(3) other site factors, such as drainage patterns and crops grown; and

(4) application rates of plant nutrients and some metals (lead, zinc, copper, nickel and cadmium).

The EPA advises that local pretreatment requirements go beyond the minimum federal regulations, to control contaminants which interfere with the beneficial use of sludge.

In 1982 the EPA established a Task Force to consider additional regulations and to consolidate current regulations under Section 405 of the Clean Water Act. Resource recovery remains the emphasis of the agency. States will be responsible for assuring that federal regulations and guidelines are followed, and the EPA will keep its usual oversight role. The final technical regulations are to be issued in approximately one year, and will include guidelines for toxic organic substances as well as heavy metals. Further regulations for the distribution and marketing of sewage sludge products are also under consideration.

Some states, including both Washington and Oregon, have suggested that the EPA rules allow for regional flexibility. The most important consideration for the Pacific Northwest is a possible pH requirement that would be too costly for this region to implement. Several alternatives to a rigid pH requirement have been suggested, such as exempting "clean" sludges from the requirement, or allowing crops which do not accumulate heavy metals to be grown at a lower pH.

## Washington State

Washington statutes give responsibility for municipal sewage sludge to the Department of Ecology and to the State Board of Health.

RCW 43.20.050 gives the State Board of Health the authority to

> (b) Adopt rules and regulations and standards for prevention, control, and abatement of health hazards and nuisances related to the disposal of wastes, solid and liquid, including but not limited to sewage, garbage, refuse, and other environmental contaminants; adopt standards and procedures governing the design, construction, and operation of sewage, garbage, refuse and other solid waste collection, treatment, and disposal facilities.

Chapter 70.95 RCW, Solid Waste Management—Recovery and Recycling, directs the Department of Ecology to adopt minimum functional standards for solid waste handling (RCW 70.95.060). Solid waste is now interpreted to include municipal sewage sludge. Primary responsibility for solid waste handling under this statute is assigned to local government.

Chapter 70.95 establishes the following priorities in the management of solid waste:

(a) Waste reduction;

(b) Waste recycling;

(c) Energy recovery or incineration; and

(d) Landfill.

As discussed earlier, reduction of municipal sewage sludge is not possible because of water quality considerations. Recycling becomes the first priority, and energy recovery (as by methane production) the second.

In addition, Chapter 90.48 RCW may apply when sludge application endangers the purity of waters by runoff, spillage, or excess quantities of sludge.

The Department of Ecology is now in the process of rewriting its Minimal Functional Standards for Solid Waste Handling (Chapter 173-301 WAC). The proposed rules were published August 7, 1985 in the Washington State Register. As published, the rules were apparently incompatible with some current uses of sewage sludge in this state, particularly in silviculture applications. (For example, the rules seemed to require discing in of the sludge.) However, the current draft of the rules does not contradict current practices, and refers to the “Municipal and Domestic Sludge Utilization Guidelines” WDOE 82-11 (WAC 173-304-300(4) and (5)). These guidelines were issued October 1982, by the Department of Ecology’s Solid Waste Division in cooperation with the Department of Social and Health Services.

Under the guidelines, local health departments are responsible for approving and reviewing the utilization or disposal of municipal sewage sludge. The guidelines require that sludge be treated (for example, digested) before being used in agriculture, and that certain food crops may not be grown on sludge unless it has been further treated or composted to remove nearly all disease organisms. Public access to sludge-treated sites should be controlled for one year, and dairy cattle shall not graze on the site until one cropping cycle after application. Other animals may be permitted on the land after one month following application.

To minimize heavy metal (cadmium) contamination, current EPA standards are followed. Annual and total amounts of cadmium are strictly limited on food crops, and pH must be 6.5 or above. If food crops (other than animal feed) are not grown, requirements are less strict. The only toxic organic substances addressed are the polychlorinated biphenyls, or PCB’s. Sludge containing greater than 10 ppm PCB’s may be used, but must be incorporated into the soil.

# VIII. POLICY IMPLICATIONS

## Regulations

There is a broad consensus among researchers, public agencies and concerned citizens that municipal sewage sludge should be considered a natural resource rather than a waste. There are many well-managed sludge application projects in Washington State. There is even a market potential for the use of sludge, and some interest from the private sector. This fits in with the legislative encouragement of RCW 70.95.020(5) that local governments "use the expertise of private industry and contract with private industry to the fullest extent possible to carry out solid waste recovery and/or recycling programs." Although many cities in the United States (Seattle, Portland, Los Angeles, Philadelphia and Milwaukee, among others) do market their sludge, in most cases revenues do not cover the costs of treating, distributing and marketing the product. A comparative study of these programs would be desirable, with emphasis on revenue possibilities in the Pacific Northwest—including revenue from silviculture applications.

Although the benefits of municipal sewage sludge are well established, the risks and problems involved are equally well established. Research findings at this time indicate that the risks are manageable and acceptable. Certain sludge treatments (heat drying or composting) kill almost all pathogens in the sludge. Pretreatment of industrial wastewaters can greatly reduce heavy metal and toxic organic contamination in sludge. Even digested sludge that has not been further treated to kill disease-causing organisms may be used safely with certain restrictions, such as keeping people off the site for one year, and allowing no food crops to be grown for 18 months.

Most knowledgeable people in Washington State believe that current regulation of sludge use does not involve unacceptable risk to the environment or to the health of the people of Washington.

All concerned agencies are in the process of expanding their regulation of sludge. This is particularly true of the Environmental Protection Agency. Many more detailed technical regulations will be forthcoming from this agency within a year. There is local concern that some of these regulations may be inappropriate for this region, especially for the use of sludge on forest lands. It would not be possible, for example, to incorporate sludge into the soil in a growing forest; application of sludge to clearcuts has been found to encourage the growth of grass rather than trees. Raising the pH of forest soils to pH 6.5 is likewise inappropriate and expensive, as would be requirements for fences to keep people out. It is essential that regulating agencies keep firmly in mind the purpose of the regulations, while remaining flexible in the means of achieving this purpose.

At the same time there are several questions which require further study, and may lead to more stringent regulation of sludge use in the future. What are the long-range effects of increasing heavy metals in the soils of our state? What are the effects on wildlife? On the harvesting of wild mushrooms for food? What are the effects of sludge on mushroom populations, and therefore on the forests? (Mushrooms are essential partners with trees. In effect the mushroom "roots" gather nourishment for the trees.)

Are there potentials for disease that we are not yet aware of that may be a danger in sludge? In particular, we know very little about the survival of viruses in the environment. Is it possible that parasite infestation will increase in animals or people as a result of certain uses of sludge?

And finally, we know very little about the effects of the toxic organics in sludge. Which of these substances persist in soils or water? How do they break down, and are the breakdown products harmless or poisonous? How do they interact with each other? How can they be monitored? An interesting suggestion for monitoring, by the way, is to analyze earthworms. Earthworms eat soil/sludge and in some cases concentrate certain substances in their bodies. They are easier to analyze chemically than the soil or sludge itself.

The least regulated use of sludge is the marketing and distribution of sludge to the public. In contrast to the larger projects, records are not kept of the use of the sludge, and the people using it may be less informed as to the risks and necessities for management. There are few or no safeguards to prevent children from playing in the sludge and being exposed to harmful levels of heavy metals and toxic organics. These sludge products may also be used for gardens, including the growing of root crops and leafy vegetables which concentrate cadmium. The public is not always informed that liming acid soils will help prevent plant uptake of these metals. Sludge products available to the public must be kept low in cadmium and other toxic substances, and information must be provided.

A related use is the application of sludge by municipalities in parks, schools, and other places where children play. It may be that further restriction of these uses of sludge would be desirable.

## Enforcement

This study was not designed to investigate enforcement of any of the regulations in Washington State. Nevertheless there were suggestions that enforcement may vary enormously from time to time or from place to place. The immediate responsibility for what happens to sludge belongs to the local health departments, and these range from one half-time person for a county to departments with big city resources. There is a need for further investigation into dumping of both municipal sewage and septage. There are indications that some of these sites may have been selected informally—if not illegally.

Another difficulty of enforcement is to control accidental or illicit spills of toxic chemicals into the sewer system. Every treatment plant operator can tell stories of a mysterious blue dye or of the soap suds that swallowed the facility one day. Events such as these can seriously impair the quality and safety of the sludge produced on a given day. Monitoring that occurs every three months (for example) will not identify these problems. Quality control is a real need if sludge is to be a useful product and no longer simply disposed of.

# CONCLUSION

Washington State is fortunate to have many dedicated and conscientious people managing sludge application and concerned with the problems and opportunities of this resource. The University of Washington researchers are highly respected in the field, deeply motivated, and determined to communicate successfully with sludge managers, regulators, and consumers. There is a developing partnership among private interests and public agencies to discover the best uses of sludge that will safeguard our health, economy and environment. Although I hope this report has not overlooked any of the substantial risks intrinsic to this material, I would like to express confidence that Washington State can be a leader in the successful recycling of this natural resource. The key to the beneficial use of sludge is intelligent and watchful management.

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