HEALTH EFFECTS OF APPLICATION OF WASTEWATER TO LAND

by

James D. Goff

ABSTRACT

There is a renewed interest in land application of treated effluent in both the states of Arizona and Nevada. Conservation of water and energy can be obtained by this treatment method. Data generated by the design engineer includes health effects related to heavy metals, bacteria, and aerosal spray. Examples of recent nuisance and consequences are noted. The application of this practice requires a case by case engineering and management analysis.

INTRODUCTION

In the arid regions of the states of Arizona and Nevada, land application of wastewater effluent should be considered in all wastewater system management plans. Land application of effluent is ideally suited for reasons of being: (1) low in energy requirements, (2) generally less expensive than other wastewater treatment processes, and (3) an indirect method of groundwater recharge. These treatment processes are consistent with water resources planning in that it encourages the reuse and recycle of wastewater (Goff and Horsefield, 1976). The three basic types of land application systems are: (1) overland flow, (2) rapid infiltration, and (3) slow rate process (Boyle Engineering Corporation, 1977). The health effects of applying wastewater to land has received very little attention in the past; therefore, it is of great interest to public health officials.

PRELIMINARY SITE ASSESSMENT

The process of selecting sites for land-application systems is an iterative process, starting with the evaluation of very broad criteria and refining the selection on the basis of more restrictive criteria as it relates to specific systems and sites. The initial evaluating criteria should consider general location as it relates to the existing wastewater system and its compatibility with proposed land usage in the general proximity (Goff and Ewing, 1977). Other aspects that should be analyzed in the overall site selection process are the general environmental setting of the potential sites which emcompass such things as climate, topography, soil characteristics, as well as the identification of historically and archaeologically sensitive areas (Boyle Engineering Corporation, 1976a). Groundwater conditions must be considered if such a system is undertaken by a community utilizing groundwater as a water supply source.

SLOW RATE PROCESS

The most common method of land application of treated wastewater is the slow rate process, also called crop irrigation (Pound and Crites, 1976; Sullivan, et al, 1973). This method applies wastewater to the land by the controlled discharge of effluent by spraying or surface spreading to both support plant growth and provide additional treatment of the applied wastewater. The effluent is lost to evapotranspiration and to the groundwater by percolation. Treatment of the applied wastewater is accomplished by physical, chemical, and biological processes as the liquid passes through or over the soil. This type of a system serves several purposes: (1) avoids surface water pollution by the reduction of nutrients, (2) recycles water and nutrients and obtains an economic return by producing marketable crops, and (3) conserves water when lawns, parks, or golf courses are irrigated (Boyle Engineering Corporation, 1976b).

Senior Engineer, Boyle Engineering Corporation
Newport Beach, California

RAPID INFILTRATION SYSTEMS

Rapid infiltration systems apply wastewater to the soil by discharge to specific basins. The treatment of the effluent is similar to that of the slow rate process except that it is allowed to infiltrate at a relatively high rate, thereby reducing land area requirements. The major portion of the wastewater percolates to the groundwater while a smaller quantity is lost to evaporation. The purposes of rapid infiltration systems are to: recharge the groundwater, renovate effluent, and often to recover the renovated water by the use of wells or underdrains.

OVERLAND FLOW SYSTEMS

The third method of land application is overland flow. This technique is probably the least used. It consists of applying wastewater, usually by spraying, on the upper reaches of sloped terraces of relatively impermeable soils and allowing it to flow through vegetation. The wastewater is ultimately collected as runoff at the bottom of the slope minus that amount lost to evaporation and percolation. Renovation is accomplished by sheet flow through the vegetation. The purposes of this type of a system are to provide additional treatment prior to discharge to surface waters and the reuse of collected runoff.

GROUNDWATER

Land treatment of wastewater can have a significant effect on both groundwater quality and quantity. Land treated wastewater can either be a pollutant or a means of improving groundwater quality, depending on the quality of the natural groundwater. In areas of extremely high total dissolved solids content, wastewater can improve this factor sufficient to make the groundwater suitable for irrigation and other purposes (Goff, 1977). Conversely, high quality groundwater used for domestic purposes could become contaminated by wastewater application if adequate controls are not exercised (Berry and Shaffer, 1978).

TRACE METALS

Although some metals, usually in small quantities, are essential for plant growth, most are not. Indeed, many metals are acutely toxic to plant life and microorganisms at even low levels, particularly citrus crops. The major problem resulting from heavy metals is their long-term accumulation in soil. Heavy metals are retained in the soil matrix by absorption, chemical precipitation, and ion exchange. In general, copper, nickel, and zinc comprise the largest portion of total heavy metal content in effluent.

Boron is an essential plant nutrient at low levels, but is toxic to many plants at dosages of 2 mg/l. To a limited extent, boron can be removed in the rapid infiltration treatment method by fixation to the soil in the presence of iron and aluminum oxides. Sand and gravel will not remove boron; clay, however, is an excellent fixant (Ragone, et al, 1975).

Results from the rapid infiltration system at Flushing Meadows, Arizona, show that copper and zinc are removed by the soil to a great extent. Cadmium and lead appeared to be relatively unaffected by rapid infiltration. Mercury removal was about 40 percent. One observation was that extended underground travel of the applied effluent does not result in additional removal of heavy metals (Boyle Engineering Corporation, 1977).

The slow rate process appears to be the most effective means of metal removal, with plant uptake comprising the primary removal mechanism. Irrigation removes 95 percent of applied trace metals; overland runoff removes 60 percent to 90 percent; and rapid infiltration removes 50 percent to 90 percent, depending upon the type of soil.

The important metals appear to be cadmium, copper, molybdenum, nickel, and zinc. The accumulation of these metals may pose a hazard to plants, animals, or humans under certain circumstances (Wolman, 1977).

Experience already shows that a more successful control of heavy metals lies in major reduction of these objectional materials at their source.

PATHOGENIC ORGANISMS

As increasing use is being made of land application treatment methods, more and more attention is being paid to the public health effects of such action in relation to bacteria and virus spreading. In general, the potential hazard associated with the application of wastewaters to the land is low, and in fact, is less than that associated with their discharge to surface waters (Benarde, 1973). However, certain potential public risks associated with the use of wastewater for land application do exist. Therefore, as a matter of good public health practice, effluent applied to land should first receive secondary treatment.

Rapid infiltration on land offers an excellent means of virus destruction. Studies indicate that no viruses are present in effluent after infiltration through 200 feet (61m) of soil. California authorities permit such water to be used not only for irrigation, but for recreational purposes as well. At the Flushing Meadows project in Arizona, total coliforms decreased to a level of two organisms per 100 ml at a distance of 30 feet (9m) from the point of application. The application method consisted of flooding the basins for one day, followed by a drying period of three days (Gilbert, et al, 1976).

Crops receiving wastewater effluent applied as irrigation water may, in turn, become contaminated with bacteria and viruses. In spite of reductions due to desiccation and die-off in the ground, large numbers of pathogens may still survive to constitute a health hazard in crops. Bacteria do not appear to enter healthy and unbroken vegetables; they may, however, enter broken, bruised or damaged plants (Sorber, 1974). Pathogens may travel in aerosols a distance of up to 200 feet (61m) from a sprinkler spray nozzle.

If wastewater applied to land passes through 5 to 10 feet (1.5 to 3m) of continuous fine soil before entering a groundwater system, then microbiological contamination of the groundwater should not usually occur (Kocerba, 1973). Even if bacteria do enter groundwater, they can only travel a few hundred feet horizontally. However, in the case of gravels and coarse soils, viruses and bacteria may travel long distances underground. Viruses in wastewater infiltrating through the soil are removed by absorption to the soil particles. There is, however, much information that is lacking concerning the effects upon public health of direct or indirect groundwater recharge (Lance, 1975).

Aerosols are small particles of liquid having a size range of 0.01 to 50 microns and suspended in air. As of 1975, specific studies of biological aerosols emitted by spray irrigation of secondary wastewater effluents had not been found in literature. It appears that destruction of bacteria in aerosols occurs through evaporation of the droplet and desiccation of the bacterial particle.

Investigations of aerosol evaporation rates show that the majority of bacteria die within three seconds. The remaining bacteria, protected by chemical additives which inhibit evaporation, die at a decreasing rate over time (McNabb and Dunlap, 1975).

The bacteria of primary concern in wastewater, Escherichia Coli, generally has a very short life span in aerosol form. On the other hand, Klebsiella, a pathogen affecting the respiratory tract, can form a protective capsule to prevent desiccation while in the air (Bryan, 1975).

Love reported that pathogens can travel over fairly large distances in aerosols from sewage or sludge spraying, but seldom travel very far in soil. He stated, "The greatest hazard would probably result from disrupting good treatment or sanitary practices. Despite associated disease outbreaks, the practice of land application of effluent can function safely. The limited quantities of essential chemicals and water available to produce food makes it necessary to find a safe use for wastewater and sludge." (Love, et al, 1975).

Rapid infiltration systems also show very good removal efficiencies for viruses. The Santee, California system was tested with polio virus; none were found after the water traveled 200 feet (61m) through the alluvial stream bed.

Virus studies have also been conducted at St. Petersburg, Florida. In one test, over 12 million virus units were applied per day; the viruses were detected infrequently at both 10-foot (3m) and 20-foot (6m) depths.(Dugan, et al, 1975).

Buffer zones of 50 to 200 feet (15 to 61m) in width should be provided around any land application site. In the case of spray application, prevailing winds have a great effect upon the distance aerosols may travel. For example, experiments have shown that a 7 mile (11km) per hour wind can cause aerosol-born bacteria to travel 500 feet (152m) from the spray nozzle. The maximum distance of travel has been estimated to be 1,000 to 1,300 feet (305 to 396m) in the case of an 11 mile (18km) per hour wind (Burbank, 1975).

The various land application methods provide a very high degree of bacteria and virus removal (90 to 99 percent). Removal efficiencies of Escherichia Coli by infiltration percolation are usually excellent (Pound and Crites, 1973). Table 1 presents a comparison of Escherichia Coli concentrations in applied effluent and the resulting renovated water for three such systems.

TABLE 1

ESCHERICHIA COLI REMOVAL EFFICIENCIES FOR

RAPID INFILTRATION

Location	Type	Fecal Coli Concentrations (MPN/100 ml) Applied Effluent	Fecal Coli Concentrations (MPN/100 ml) Renovated Water	Distance of Travel (feet)
Flushing Meadows, Arizona	Sand	1,000,000	10	100
Hemet, California	Sand	60,000	11	8
Santee, California	Gravel	130,000	10	200

According to the Corps of Engineers Cold Regions Research and Engineering Laboratory, "Virus, pathogenic bacteria, and coliform are completely removed by percolation through a 5-foot (1.5m) depth of soil under controlled slow infiltration design conditions. Survival times are typically a maximum of three months for organisms retained on soil particles. It is important that pathogens be removed, for the wastewater reuse cycle may be shorter with land application than with a point source river discharge. Consideration must be given to die-away rates in storage ponds and to the removal capacity of the receiving land." (Uiga, 1976).

CONCLUSIONS

In the arid areas of Arizona and Nevada, effluent applied to a properly designed land application system should cause no adverse health effects provided health regulations are followed, and normal operations are provided. As a matter of good public health policy, all public water supplies should receive proper disinfection to inactivate any pathogens that might be present. Although there are questions still unanswered regarding health effects, land application of effluent and reuse of the water are far better methods to employ than the practice of discharging partially treated wastewater into stream beds that may serve as recharge areas to groundwater supplies. The engineering capability is available today to properly plan, operate and monitor on a site specific basis land application of wastewater in a manner as to cause no adverse health effects.

REFERENCES CITED

Benarde, M. A. 1973. "Land Disposal and Sewage Effluent: Appraisal of Health Effects of Pathogenic Organism", Journal of the American Water Works Assoc., 65(6):432-440.

Berry, James W. and Shaffer, T. B. 1978. "Viruses: Monitoring is the Key", Water and Wastes Engineering, p. 14-17.

Boyle Engineering Corporation. 1977. "Large Array of Wastewater Land Treatment Alternatives", U.S. Army Corps of Engineers Phoenix Urban Study.

Boyle Engineering Corporation. 1976a. "Preliminary Assessment of the Potential Land Application Sites", U.S. Army Corps of Engineers Phoenix Urban Study.

Boyle Engineering Corporation. 1976b. "Potential Reuse Options for Municipal Wastewater Effluent and Residual Solids", U.S. Army Corps of Engineers Phoenix Urban Study.

Bryan, E. H. 1975. "Management of Municipal Wastewater Treatment Residuals", Proceedings of the 1975 National Conference on Municipal Sludge Management and Disposal.

Burbank, N. C. 1975. "Mililani Town Wastewater Reclamation and Recycling Project", Journal of the American Water Works Assoc., p 67, 487.

Dugan, G. L., et al. 1975. "Land Disposal of Wastewater in Hawaii", Journal Water Pollution Control Fed., 47, 2067.

Gilbert, R. G., et al, 1976. "Wastewater Renovation and Reuse: Virus Removal by Soil Filtration", Science, 192(4243):1004-1005.

Goff, James D. 1977 . "Municipal Wastewater Reuse Priorities for Metropolitan Phoenix", American Society of Civil Engineers, Reprint No. 2943.

Goff, James D., and Horsefield, Dave, 1976. "Wastewater Resources in North Central Texas", Journal of the American Water Works Association.

Goff, James D. and Ewing, Ronald E. 1978. "Modeling for Land Application of Wastewater", Modeling, Identification and Control in Environmental Systems, Proceedings of the IFIP Working Conference on Modeling and Simulation of Land, Air and Water Resources Systems, North-Holland Publishing Company, Amsterdam.

Kocerba, B. A. 1973. "Land Application of Wastewater at Colorado Springs", APWA International Congress and Equipment Show, Denver, CO.

Lance, J. C. 1975. "Fate of Nitrogen in Sewage Effluent Applied to Soil", Journal Irrigation and Drain Div., Proc. American Society Civil Engr., p 101, 131.

Love, G. J., et al. 1975. "Potential Health Impacts of Sludge Disposal on Land", Proceedings of the 1975 National Conference on Municipal Sludge Management and Disposal.

McNabb, J. F., and Dunlap, W. J. 1975. "Subsurface Biological Activity in Relation to Groundwater Pollution", Groundwater, p 13, 33.

Pound, C. E., and Crites, R. W. 1973. "Wastewater Treatment and Reuse by Land Application", Vol II, U.S. Environmental Protection Agency, Technologh Transfer Series, Report EPA 660/2-73-006B.

Pound, C. E., and Crites, R. W. 1975. "Design Seminar for Land Treatment of Municipal Wastewater Effluents: Design Factors, Part I", U.S. Environmental Protection Agency, Technology Transfer Program.

Ragone, S. E., et al. 1975. "Mobilization of Iron in Water in the Magothy Aquifer During Long Term Recharge with Tertiary Treated Sewage, Bay Park, N.Y.", Journal of Research of the U.S.G.S., p 3, 93.

Sorber, C. A. 1974. "Public Health Aspects of Land Application of Wastewater Effluents", Land Application of Wastewater, Newark, Delaware.

Sullivan, R. H., et al. 1973. "Survey of Facilities Using Land Application Wastewater" U.S. Environment Protection Agency, Office of Water Program Operations, Report

EPA-430/9-73-006.

Uiga, A. 1976. "Let's Consider Land Treatment - Not Land Disposal", Civil Engineering, ASCE, 46(3):60-62.

Wolman, Abel. 1977. "Public Health Aspects of Land Utilization of Wastewater Effluents and Sludges", Journal Water Pollution Control Federation, p 2211-2218.