United States
Environmental Protection
Agency

Robert S. Kerr Environmental
Research Laboratory
Ada OK 74820

Research and Development

EPA-600/S2-81-151 Sept. 1981

EPA

Project Summary

Soil Filtration of Sewage Effluent of a Rural Area

B. R. Sabey, K. A. Barbarick, and N. A. Evans

The effects of sprinkler-irrigated municipal sewage effluent and of surface tile drainage on a mountain meadow were investigated in the summers of 1977 and 1978. The treatments consisted of combinations of irrigations with effluent or ditch water at the rate of 7.5 centimeters/week (cm/week) and of drainage tiles or natural drainage. Before application, the effluent contained significantly higher levels of some water quality parameters than the ditch water.

The drainage tiles were effective in lowering the groundwater elevations for about 85% and 10% of the season in 1977 and 1978, respectively. Higher plant concentrations of sodium (Na) and manganese (Mn) in 1977 and plant yields and Mn concentration in 1978 were found in the plants harvested from the plots that were irrigated with sewage effluent. The influence of the effluent on groundwater quality and soil characteristics did not pose serious health or environmental problems.

Another study to determine the feasibility of adding sewage effluent to mountain meadow land during winter was initiated in 1977 at Hayden, Colorado, near the summer effluent application site. The latter study was motivated by the possibility of decreasing construction costs of sewage treatment facilities.

It was determined that 7.5 cm/week of effluent could be added to the plots under an ice or snow cover if the soil profile was not frozen prior to ice and snow cover formation in the late fall and early winter. The size of ridge and furrow configuration did not influence any of the biological and chemical parameters measured in the study. The winter soil filtration system was effective in decreasing the concentrations of some chemical constituents including ammonium (NH_4^+) and potassium (K^+), as well as decreasing biochemical oxygen demand (BOD), chemical oxygen demand (COD), and indicator organisms. The decrease in indicator organism numbers was not as great the second year of the study as it was the first.

In general, the effluent distribution system worked reasonably well even in the winter as long as rapid drainage of the pipes was provided at the conclusion of the application period of each day. The feasibility of adding effluent to the land has been demonstrated when weather conditions provided adequate snow covers prior to freezing of the soil profile.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project which is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Summer Study

The waste products that society produces will require disposal or recycling techniques which minimize contamination of the environment. Among these waste products are sewage sludges and effluents. Every municipality, regardless of size must treat and dispose of, or utilize, its sewage in some manner. Current alternatives range from secondary treatment involving anaerobic digestion, trickling filtration, aerobic digestion, lagooning, polishing ponds, or combinations thereof. Land application is being considered in many areas as a possible final treatment for effluent before it reaches a stream. For large cities, the more elaborate treatments may be more practical for handling the large volume of sewage; however, for small treatment plants in rural areas, the possibility of soil filtration as part of the treatment process could be more practical. Bouwer (1968)[1] claimed that the quality improvement obtained by soil percolation is probably comparable to that obtained by coagulation, sedimentation, carbon adsorption, and disinfection.

[1]Bouwer, H. 1968. Returning wastes to the land, a new role for agriculture. J. Soil & Water Cons. 23:164-168

Many studies have been conducted utilizing land treatment for disposal or recycling of municipal and industrial effluents. The study conducted at Hayden, Colorado was unique in two ways. First, it was conducted at high altitudes of the Rocky Mountain region. Secondly, it involved application of wastewater to mountain meadow type of vegetation (see Table 1).

The effectiveness of land treatment depends on the quality and application rate of the sewage effluent and the soil characteristics. Consequently, the objectives of this research were:

1. To determine if the soil could effectively remove the problematic substances from primary treated municipal effluent before the filtrate entered streams, lakes, or groundwater. The major concerns were:
   a. Nitrogen (N) compounds such as nitrates (NO_3), ammonium (NH_4), and organic-N.
   b. Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn)
   c. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
   d. Fecal and total coliform and fecal streptococcus.
2. To follow the changes in soil properties created by sprinkler irrigation with sewage effluent.
3. To investigate the benefits of providing drainage in a "soil filtration" system.
4. To determine if the yields and quality of hay produced by a mountain meadow irrigated with sewage effluent differed from those obtained from irrigation with typical irrigation water.
5. To determine the length of season during which sprinkler irrigation was feasible on mountain meadows at the altitude and latitude of Hayden.

Winter Study

Application of sewage effluent to mountain meadows during the summer growing season appeared to be much more feasible than during the winter months where soils were more likely to freeze to a considerable depth and prohibit infiltration and permeability. If the soil surface and profile could be protected by the insulation of an ice sheet and/or a layer of snow as illustrated by Figure 1, it would be possible to apply effluent by furrow irrigation under the snow and ice and still use the soil as a filtration system. This would allow a municipality to decrease the winter storage capacity and thus make land application more cost effective.

Although there have been many studies on the effectiveness of land application of sewage effluent in the eastern, central, and southern parts of the United States, few have been made in the intermountain west. Only one study on winter application of effluent at higher altitudes was reported in the literature. That study involved the winter application of effluent from the sewage treatment plant of a cheese processing factory in Wyoming (Armstrong et al., 1978[2]). No study was found on the soil filtration treatment of municipal sewage effluent during the winter season.

[2]Armstrong, D.L., J. Barrelli, and R.D. Burman. 1978. Land application of wastewater for treatment and disposal. The Thayne, Wyoming Experience. Proceedings Rocky Mountain Region Meeting, Amer. Soc. Agr. Eng., Denver, Colorado. February 10.

The objectives of the winter study were as follows:

1. To determine if it were possible to keep the soil profile unfrozen during the winter by forming a sheet of ice covered by snow over a ridge and furrow formed surface.
2. To determine if an effluent application rate of 7.5 cm/week could be maintained throughout the winter season.
3. To determine if the size of the ridges and furrows influenced the ease or difficulty of effluent application under the snow and ice.
4. To determine to what degree the soil filtration system of effluent treatment would decrease the content of several chemical and biological constituents of the effluent.

Table 1. *Vegetation Species Found in the Mountain Meadow Used for Land Treatment of Polishing Pond Effluent of Hayden, Colorado*

Common Name	*Scientific Name*
Red clover	*Trifolium pratense L.*
Orchard grass	*Dactylis glomerata L.*
Timothy	*Phleum pratense L.*
Bluegrass	*Poa pratensis L.*
	Poa compressa L.
Dandelions	*Taraxcum offinciale L.*
White clover	*Trifolium repense L.*
Sweetclover	*Melilotus officinalis L.*
Alfalfa	*Medicago sativa L.*
Red fescue	*Festuca rubra L.*
Sedge-type grasses	*Carex spp. (Dill.) L.*
Western wheatgrass	*Agropyron smithii L.*

Conclusions

The field study was used to compare the effects of irrigation of the mountain meadow with sewage effluent (SE) vs. ditch water (DW) pumped from a nearby stream and the presence of natural drainage vs. drainage tiles. The meadow was irrigated for about 20 and 22 weeks in the summers of 1977 and 1978, respectively. The drainage tiles were

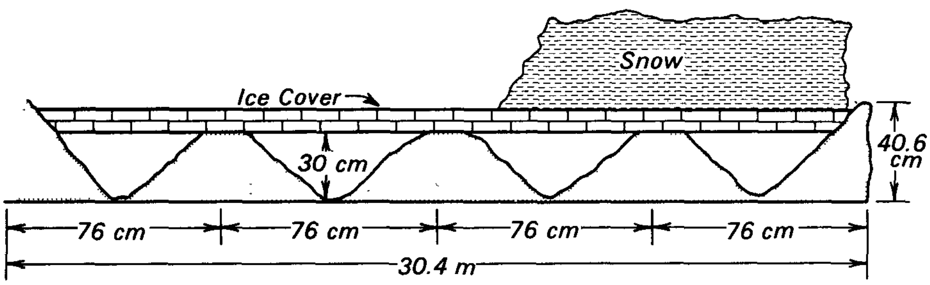

Figure 1. *Cross section plot A.*

effective in lowering the groundwater for about 85% of the application season in 1977; however, the groundwater elevations were lowered only about 10% of the season in 1978.

Only the NO_3-N levels in the irrigation sources (prior to application) varied with sampling date in 1977. All other chemical and biological parameters did not significantly change between summer samplings. The SE contained significantly higher concentrations of most of the chemical and biological constituents than the DW used for irrigation. Data illustrated that the chloride concentrations in the soil solution, groundwater and tiles in 1978 were increased by the application of SE. Many of the parameters in the soil water samples from the plots fluctuated with the time of sampling.

Data reported in the project report illustrated that in 1977 some of the plant characteristics were significantly affected by the major treatment factors. A higher level of grasses was found in the treatments with drainage tiles. The type of drainage influenced some plant quality parameters because of the difference in the characteristics of grasses and legumes and their ability to absorb various nutrients and trace metals. Sewage effluent caused increases in the total uptake of some of the plant nutrients and trace metals. The addition of SE increased plant concentrations of Na and Mn. Significantly higher levels of Na and Mn in the effluent as compared to the DW probably caused these increases.

The major treatment factors did not affect the plant distributions measured in 1978. Two plant harvests were made in the summer of 1978, and the time of harvest had a highly significant effect on a number of plant concentrations and/or total uptake values. Proper management of mountain meadows can result in two cuttings with the second harvest providing lower yields than the first cutting. Data presented in the project report showed that the application of sewage effluent resulted in increases in yield and the higher yields resulted in higher amounts of total uptake of some nutrients and metals. Because of the higher Mn levels in the effluent, the addition of sewage effluent resulted in increases in plant Mn concentration. The application of ditch water caused increases in the plant Fe concentrations. The reasons for this effect of the ditch water on the Fe concentrations may have been due to the higher Fe levels in the ditch water.

Time of sampling as indicated by data in the project report influenced the levels of the exchangeable cations, total metals, and available micronutrients in the soil samples. The decrease in exchangeable Mg was attributed to the higher levels of Ca as compared to Mg in the irrigation sources. The addition of irrigation water could have accounted for the changes in exchangeable cations. For total metals and micronutrients, changes between samplings could not be totally attributed to additions from the irrigation waters or losses from plant uptake. Consequently, the reason for the changes in these soil properties were not known. The type of drainage was found to influence some of the soil chemical properties for samples from different depths. Since the effect of type of drainage was not consistently reflected in the plant data, the soil differences were not considered important. The application of sewage effluent produced increases in surface soil samples in the exchangeable Na, bicarbonate (HCO_3), extractable inorganic PO_4, and exchangeable K. The higher levels of Na, P, and K in the sewage effluent as compared to the ditch water probably caused the increases in the surface soils.

Results from the field study indicated that the application of sewage effluent at the rate of 7.5 cm/week for two irrigation seasons posed no serious health or environmental problems. Also, drainage tiles did lower the groundwater levels for about 85% and 10% of the application season in 1977 and 1978, respectively. Leaching of problematic substances into the groundwater or change in the soil properties was found to be of little practical concern. Changes in the level of various N species in the soil were probably the result of using intermittent rather than flood irrigation. Irrigation with effluent resulted in higher plant yields and total uptake of various plant nutrients than were found with irrigation with the ditch water. Therefore, application of the effluent resulted in beneficial effects to the hay crop in 1977 and 1978.

It was possible during the two winter seasons of this study, to add 7.5 cm/week of effluent due to the early snow cover that fell on the plots keeping the soil profile from freezing and thus allowing infiltration into the soil to occur below the snow layer. The time of snowfall is weather-dependent and varies from year to year. During years when snow falls and accumulates later, an ice sheet on the ridges and furrows could be developed by the use of a plastic sheet, spread on top of the ridges, upon which water would be finely sprayed on the plastic during freezing conditions. A thick sheet of ice could result that would insulate the soil against freezing until later snowfall would cover the ice and provide more insulation.

Although there were no apparent chemical or biological differences in the parameters measured, due to the two sizes of ridges and furrows, both were generally effective in improving the quality of water before movement into the river. The soil filtration system used in this study for treatment of Hayden, Colorado municipal sewage effluent was effective with the exception of one questionable area. There were relatively high concentrations of some of the indicator organisms that appeared in the soil water at the lower sampling depths during the second year of the study. This aspect should be pursued for further verification.

Recommendations

Although this study has given some useful and definitive information, the application of municipal sewage effluent from mountain communities (higher altitudes) to mountain meadows should be investigated under different soil conditions. Other soils may respond differently than those used in this study.

Additionally, a study using an effluent of lesser quality than that of this investigation should be used on mountain meadows under near similar conditions to this study. The effluent used on these plots did not stress the system with the possible exception of the indicator organisms. Further investigations on indicator organism accumulation and movement should be made.

The next step would be summer and winter application of effluent to field scale areas using the methods of this study. It appears that under the proper weather conditions (especially temperature and timely snowfall) as existed at this site during 1977-1978 and 1978-1979, the system could be used successfully.

B. R. Sabey, K. A. Barbarick, and N. A. Evans are with the Department of Agronomy and Water Resources Research Institute, Colorado State University, Fort Collins, CO 80523.

***Lowell E. Leach** is the EPA Project Officer (see below).*

The complete report, entitled "Soil Filtration of Sewage Effluent of a Rural Area," (Order No. PB 81-238 073; Cost: $11.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Robert S. Kerr Environmental Research Laboratory
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

☆ U S GOVERNMENT PRINTING OFFICE, 1981 — 757-012/7328

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300