EPA RESEARCH ON LAND TREATMENT

by

Richard E. Thomas and Curtis C. Harlin, Jr.
Water Quality Control Branch
Robert S. Kerr Environmental Research Laboratory
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

Prepared for
U.S. Environmental Protection Agency
Technology Transfer Program

ABSTRACT

The Water Quality Control Branch of the Robert S. Kerr Environmental Research Laboratory has been assigned EPA responsibility for conduct of in-house and extramural research on land application of municipal effluents and the use of effluents in aquaculture projects. We have integrated our research covering these approaches because the shift from land application through wetland systems to aquaculture is a gradual transition and all approaches rely on closely integrated scientific principles. Although the specific topic of this seminar focuses on land application, we should remember that combined land application and aquaculture systems have potential for certain needs.

The major focus of our land application research effort is the development of a technical data base which will establish the capabilities of land application approaches for management of wastewaters. Although the concept of applying wastewaters to the land has been with us for centuries, the needs of today and the future pose new questions about the suitability of the concept for proposed widespread and greatly varied uses. The objective of this presentation will be to acquaint participants with both the short-term and long-term plans for accomplishing the research needed to bolster existing information for implementing land-based wastewater management systems.

Our research plan has been developed around the thesis that the many differing approaches for applying wastewater to the land can be categorized into three groupings. These groupings are identified as cropland irrigation, infiltration-percolation, and overland flow. This presentation will summarize information about completed, ongoing, and planned research of the Water Quality Control Branch.

This summary of completed and ongoing projects will highlight major research findings which pertain to consideration of practical implementation of land-based systems now. Emphasis will be placed on research data which points to factors of prime interest for site selection and system design when considering land application as a wastewater management alternative. Research conducted by several EPA divisions and other sources will be used to supplement that conducted under the guidance of the Water Quality Control Branch at the Robert S. Kerr Environmental Research Laboratory.

The coverage of research planned for initiation in FY-1975 and in future years will address major issues which need further resolution. Emphasis will be placed on detailing a projected timetable for the accumulation of reliable data to clarify these major areas needing further resolution. The elaboration of the long-term research timetable will include detail on the type of interim data which will be available as well as the projected long-term goals.

SECTION I

INTRODUCTION

The Water Quality Control Branch (WQCB) of the Robert S. Kerr Environmental Research Laboratory (RSKERL) has been assigned Environmental Protection Agency (EPA) responsibility for research to utilize agriculture, silviculture, or aquaculture projects for management of municipal wastewaters. The major focus of this integrated research program is the development of a reliable data base which establishes the capability of these approaches with respect to National goals for wastewater management. The transition from strictly land application through wetland systems to strictly aquaculture systems is a gradual change and all of these systems are influenced by similar scientific principles. For this reason, this discussion of land application will cover some concepts which some people would consider as aquaculture approaches.

Historically, the involvement of the WQCB in research on land application of municipal wastewaters predates the formation of EPA by many years. Projects supported by predecessor agencies, including the Federal Water Quality Administration, the Federal Water Pollution Control Administration, and the U.S. Public Health Service, are an integral part of technical data base being developed by the WQCB. The results of these projects conducted under the auspices of predecessor agencies provide much of the current data base and serve as the principal guides for the direction of short-term and long-term research goals.

Short-term needs are designated as those associated with improvements scheduled for adoption within five years, while the long-term needs are

designated as those associated with the 1983 and 1985 goals of the Water Pollution Control Act of 1972. Short-term plans place emphasis on expanding our quantitative data base through investigation of current operations involving crop irrigation and infiltration systems. Complementary research is being conducted to develop innovative approaches for achieving secondary treatment or more advanced levels of treatment. One such approach is overland-flow treatment of raw comminuted wastewater to achieve low cost and advanced treatment without production of sludge. Long-term plans provide more flexibility for evaluation of integrated systems directed to the attainment of management concepts to achieve greater reuse of wastewaters. Plans for obtaining this goal incorporate more laboratory studies and field development studies directed to modifying existing practices, combining process units to achieve better reuse of wastewater constituents, and exploring new ideas for incorporating wastewater reuse into the production of food and fiber products. One example of such an integrated system is the combining of overland flow, high-rate infiltration, and a fish rearing pond in sequence to produce a clear, stable effluent low in nutrients and bacteriologically acceptable for discharge without further disinfection.

These EPA efforts are coordinated with the efforts of other Federal agencies through participation in interagency committee work and through joint support of projects. Extramural projects funded through contracts, grants, or interagency agreements play a major role in the improvement and expansion of the data base for planning and designing land application systems. Our principal purpose at this seminar is to highlight research activities which may influence design and management of land application systems which you, as system planners or system designers, will be considering in the near future.

SECTION II

ONGOING RESEARCH

First, let us address some completed or ongoing studies in detail to assess plans for filling the gaps in the technological data base. Detailed discussion of the results of completed or ongoing studies will be directed to clarification of technical judgments regarding the present technical data base. Discussion of future plans will provide insight into the types of additional short-term information being sought and an estimate of when various bits of information will become available.

COMPLETED AND ONGOING STUDIES

This discussion will address crop irrigation, infiltration-percolation, and overland-flow projects separately. An additional category of basic research applicable to more than one category will close the section.

Crop Irrigation

Cropland irrigation with municipal effluents is a well-established practice in the southwestern United States. Many facilities have practiced effluent irrigation for more than 30 years at the same site. Utilization of the practice has grown steadily since the first operations were initiated in the late 1800's and some 300 facilities are active at present. In spite of this number of active facilities, there is an obvious lack of quantitative data to delineate the balance between the beneficial and adverse influences on the local environment. Our laboratory has completed or is actively involved in ten field projects addressing various aspects of crop irrigation practices.

One group of projects places emphasis on locating and evaluating currently available quantitative information on application rates, crop responses, soil changes, and groundwater quality changes. To date, this approach has been very useful in defining management techniques for general use in the Southwest, as well as furnishing a base for other geographic locations. A recently completed survey of existing facilities[1] and an assessment of current technology[2] summarize the accomplishments.

A second group of projects is designed to demonstrate crop irrigation approaches in geographic areas where historical information is scarce. The long-term project at Pennsylvania State University[3] is an example of a project of specific regional significance. The ten years of data collection at this site shows that crop irrigation can benefit crop production in a cool, humid climate with little effect on the local groundwater body. Other ongoing demonstration projects of specific interest include the Muskegon Wastewater Management System; a smaller study at Belding, Michigan; a study at Falmouth, Massachusetts; and a study at Tallahassee, Florida. Some of these projects will be covered in detail by other speakers so comments on individual projects will be brief. The Muskegon project is designed to demonstrate seasonal irrigation in conjunction with off-season storage of all treated wastewater, as well as complete recovery of the renovated wastewater for surface discharge. This total containment system represents a very advanced concept of crop irrigation for wastewater management. The 1975 season will be the first for collection of full season data for all system components. Data collected over the next several years will be an important addition to the current data base. The study at Belding, Michigan utilizes an oxidation pond effluent (a 5-cell pond system) in a summer irrigation program for forages, sod, and ornamentals, and in a winter irrigation program for forages. This study is providing additional data on winter operations, responses of sod and ornamentals, and water quality influences resulting from non-containment operations. The site has sandy soils over a shallow water table which promotes lateral movement through interflow with discharge to a surface stream. The Falmouth, Massachusetts study is designed to demonstrate

several management techniques on sandy soils with recharge of the groundwater in a sand aquifer at a depth of about ten meters. The Tallahassee, Florida study has a similar objective for a project site with radically differing climatic conditions. Interpretative data from these projects will become available within a year or two.

Infiltration-Percolation

Infiltration-percolation is a well established practice at many small municipal facilities throughout the United States. Design and operation of these systems have emphasized disposal of a treatment plant effluent, and it is only within the last decade that an effort has been made to determine the treatment which can be achieved by adjusting the management of a system. Our laboratory has been or is actively involved in nine field studies addressing the evaluation and demonstration of management options which enhance the treatment achieved by infiltration-percolation systems.

Previously completed studies include four research studies in water-short southwestern states and two research studies in water-rich north central states. The studies in the southwest were conducted at Whittier Narrows, California,[4] Santee, California,[5] Phoenix, Arizona,[6] and Hemet, California.[7] The studies in the north central area were in Detroit Lakes, Minnesota,[8] and Westby, Wisconsin.[9] The study at Whittier Narrows, California was conducted to study the effectiveness of the infiltration-approach for direct recharge of a potable groundwater supply with secondary effluent.[4] The results of this study showed that spreading periods of about 9 hours followed by drying periods of about 15 hours produced a clear and highly oxidized water acceptable for recharge at this site. This method of operation resulted in conversion of almost all applied nitrogen to nitrate and produced nitrate concentrations of 20 to 30 mg/l in the renovated water. Since these concentrations exceeded the 10 mg/l limit for drinking water, it was recommended that dilution with low nitrate water would be necessary before repumping for use as a water supply. The concurrent study at Santee, California

evaluated the use of infiltration-percolation to make municipal effluent suitable to fill and maintain the water level in recreational lakes.[5] Locating the infiltration-percolation basins in the alluvium of a shallow stream channel provided substantial lateral movement underground after about 3 meters of vertical percolation. In addition to excellent removal of solids, oxygen-demanding substances, pathogens, and phosphorus, total nitrogen in the renovated water was reduced to 1.5 mg/l (from 25 mg/l applied to spreading basins) after about 500 meters of lateral underground travel. Emphasis was placed on evaluating this nitrogen removal at the Phoenix, Arizona study using a similar mode of operation.[6] Results of the Phoenix study showed that the frequency of application has a major influence on nitrogen removal. Spreading and drying periods of a few days or less promoted nitrification and resulted in less than 10% total nitrogen removal, whereas spreading and drying periods of 10 to 20 days resulted in apparent denitrification and up to 80% nitrogen removal. In the third year of study it was shown that this degree of removal was a combination of adsorption and denitrification. This study also highlighted the importance of underground residence time and/or distance of travel for achieving phosphorus removal at the high loadings used for the infiltration-percolation approach.

Another important factor related to local hydrological conditions was graphically demonstrated by the study at Hemet, California.[7] An unusually wet winter season at this location caused the local water table to rise up to the bottom of the spreading basins. The resultant reduction in hydraulic acceptance rate and deterioration of treatment efficiency made it necessary to quickly develop an alternate method for handling their effluent.

Although the two north central area studies represent radically differing climatic conditions, overall performance was quite similar to that observed in the southwest. The Detroit Lakes, Minnesota project entailed a four-year experiment using 20-hour spraying periods followed by 4-hour drying periods to apply about 30 meters per year of effluent on a sandy soil.[8] Our definitions place this system in the infiltration-percolation

category even though it used sprinkler application and is referred to as a spray irrigation system. It is significant that the use of short spreading and drying cycles in this climate produced nitrogen and phosphorus interactions comparable to those for studies in the southwest. Nitrogen was converted to nitrate which appeared in the groundwater (at a concentration comparable to that in a municipal effluent) while 70% of the phosphorus was removed after no more than 7 meters of travel distance through the soil. The other study in this climate was a one-year evaluation of the performance of an existing ridge and furrow basin facility.[9] The system was located on a silt loam soil and a loading of about 15 meters per year was obtained with wetting periods of two weeks followed by drying periods of two weeks. As was the case for the study in Arizona, the long spreading period resulted in about 70% removal of total nitrogen without affecting the removal capacity for other measured parameters.

The first of several studies to make comprehensive evaluations of existing infiltration-percolation facilities has just been initiated at Lake George, New York. Results of previous studies at this site[10] show that the 35-year-old infiltration system at this site has good potential for further collection of quantitative data. Several studies of this type will be implemented to expand the scope of quantitative data to include parameters of current interest. Completed and ongoing research on the infiltration-percolation approach to land spreading of municipal effluents are encouraging for future use on a much larger scale. Technological data are already available to design and operate systems for a limited number of situations, but of more importance is the apparent utility of the approach under widely differing climatic conditions. We are optimistic that further research efforts can establish well-defined design criteria and management techniques for use throughout the United States.

Overland Flow

Overland-flow treatment of municipal wastewaters is a newly developing technology in the United States. Our laboratory has completed an 18-month study to assess the technical feasibility of treating raw sewage by overland flow.[11] The positive results of this study, as well as a just

completed 15-month extension of the study to explore alum addition for improving phosphorus removal have led to two new studies. One of these is a field evaluation to study overland flow for a 380 m^3 daily flow (0.1 mgd) at a small rural city. The second is a test to compare treatment efficiency and area requirements for primary and secondary effluents as opposed to direct treatment of raw sewage. These efforts are the initial steps in a broader effort which will be required to establish a sound data base for implementation of overland flow as a ready alternative to other established wastewater management approaches.

Basic Research

In addition to studies addressing specific land application approaches, our laboratory is conducting or has supported several studies on fundamental processes which are involved in the functioning of land application systems. Studies have been focused on special aspects of phosphorus retention in soils, denitrification, biodegradation of organics, and climatology.

Phosphorus retention in soil has been studied from the specific aspect of predicting long-term phosphorus removals by measurement of specified soil properties. Enfield[12] has reported an initial prediction model based on laboratory work with 26 mineral soils. Completed and ongoing denitrification studies are addressing the relation of oxygen status in an attempt to delineate management approaches for achieving and maintaining 90% nitrogen removal by denitrification. Continuing studies on biodegradation of organics have addressed the use of ATP (adenosine triphosphate) as a tool to measure bioactivity and the use of small-scale laboratory apparatus to assess the relative biodegradability of wastewaters from different sources. The study of climatology has been directed to assessing methodology to use readily available weather data for determining winter storage needs. These basic studies have applicability to all three land application approaches and provide a better basis for establishing field projects to develop or demonstrate specific features of improved

technology. Details on these projects shall not be given because the primary focus of this seminar is on information which can be used now rather than what may happen as a result of present research activities.

SECTION III

FUTURE RESEARCH

Future plans for research on land application approaches adhere to our categorization of land application into three specific types of systems. As indicated, short-term plans call for utilization of studies on existing systems and selected demonstration projects to gain as much improvement in the data base as is possible in a short time. These short-term plans address the 1977 and to some degree the 1983 milestone dates of PL 92-500. The long-term plans call for directing more attention to the study of innovative combinations of land application alone or with other process units to achieve a very high degree of contaminant control. These long-term plans address the 1985 goal of non-polluting discharge, as well as the intermediate 1983 goal of best practicable waste treatment technology.

SHORT-TERM PLANS

Projected Branch support over the next two to three years will provide a diversified program which will make important gains in all four of the major research areas. Emphasis will be placed on filling technology gaps for the crop irrigation and infiltration-percolation approaches which are being implemented as alternative wastewater management systems at the present time. Development of overland-flow technology will be aimed at assisting small rural communities needing a simple and economical secondary process. Basic research will continue with little change in goals or emphasis.

A major fraction of short-term support will be allocated to collection of quantitative data at about ten existing crop irrigation systems and ten existing infiltration-percolation systems. These one- to two-year

studies should be completed by the end of FY-1977 and the results of the studies will be distributed as technical information bulletins shortly thereafter. The short-term plans also call for initiation of several demonstration projects in anticipation of a need to demonstrate improved management techniques for the crop irrigation and infiltration-percolation systems. Efforts will be made to select project sites in geographic locales where governmental units and the public are interested in the potential of land application but do not have ready access to observe an ongoing facility. These short-term efforts on the crop irrigation and infiltration approaches will emphasize the collection of quantitative data to delineate the capabilities of existing design technology. Major efforts to develop new design technology will be considered as a long-term objective.

The short-term plans for overland-flow studies address the development of new technology. Short-term objectives for overland-flow studies will emphasize two areas of development. One of these will be the development of overland flow as a unit process for treatment of raw municipal wastewaters on a year-round basis in warm climates. Overland flow will offer many rural communities a much needed method for meeting or exceeding the present definition of secondary treatment at a cost comparable to that of primary treatment. The second objective will be the development of overland flow as a seasonal operation for upgrading existing pond systems which cannot meet present criteria for secondary treatment. The prospects for developing a timely data base for these two objectives are good and there is an obvious need for the intended results.

Basic research will continue in the areas already under study, as well as being expanded to include work on heavy metals. Short-term goals include positive identification of denitrification as the mechanism for nitrogen removal by overland flow; establishment of a method for predicting soil removal of phosphorus; a routine methodology for predicting winter storage needs from weather station data; and development of the ATP procedure for measuring bioactivity in soils. Completion of work in other areas will fall under long-term plans.

LONG-TERM PLANS

Projected Branch support from FY-1977 through FY-1981 should support a program which will culminate in the distribution of additional technical bulletins on crop irrigation, infiltration-percolation, and overland flow to supplement EPA Technical Bulletin EPA-430/9-75-001. These technical bulletins will detail improved procedures for planning a land-based wastewater management system, selecting the process train best suited to the site, designing the system, and operating the system. These technical bulletins will be complemented by a series of research reports providing reliable technical data which substantiate the recommendations contained in the bulletins. Much of the data in the research reports will have come from demonstration projects which will still be in operation as permanent facilities. Establishment of demonstration projects at sites where operations will continue for several decades is a key objective in long-term plans. The value of these sites for visual inspection and periodic collection of quantitative data is an essential building block for establishing a reliable data base which can be extended beyond the immediate needs for revamping our wastewater management methodology.

SECTION IV

REFERENCES

1. Sullivan, Richard H., Morris M. Cohn, and Samuel S. Baxter. Survey of Facilities Using Land Application of Wastewater. Environmental Protection Agency, Washington, D.C. Report No. EPA-430/9-73-006. July 1973. 377 pp.

2. Pound, Charles E., and Ronald W. Crites. Wastewater Treatment and Reuse by Land Application--Vol. II. Environmental Protection Agency, Washington, D.C. Report No. EPA-660/2-73-006b. August 1973. 249 pp.

3. Kardos, Louis T., William E. Sopper, Earl A. Myers, Richard R. Parizek, and John B. Nesbitt. Renovation of Secondary Effluent for Reuse as a Water Resource. Environmental Protection Agency, Washington, D.C. Report No. EPA-660/2-74-016. February 1974. 495 pp.

4. McMichael, Francis Clay, and Jack Edward McKee. Wastewater Reclamation at Whittier Narrows. The Resources Agency, State Water Quality Control Board, Sacramento, California. Publication No. 33. 1966. 100 pp.

5. Merrell, John C., Jr., Albert Katko, and Herbert E. Pintler. The Santee Recreation Project, Santee, California (Summary Report). Public Health Service Publication No. 99-WP-27. December 1965. 69 pp.

6. Bouwer, Herman, R. C. Rice, E. D. Escarcega, and M. S. Riggs. Renovating Secondary Sewage by Ground Water Recharge with

Infiltration Basins. Environmental Protection Agency, Washington, D.C. Report No. 16060 DRV 03/72. March 1972. 102 pp.

7. Eastern Municipal Water District. Study of Reutilization of Wastewater Recycled Through Ground Water. Environmental Protection Agency, Washington, D.C. Water Pollut. Contr. Research Report Series No. 16060DDZ07/71. Vol. 1. July 1971.

8. Larson, Winston C. Spray Irrigation for the Removal of Nutrients in Sewage Treatment Plant Effluent as Practiced at Detroit Lakes, Minnesota. In: Algae and Metropolitan Wastes, Transactions of the 1960 Seminar. U.S. Dept. of Health, Education and Welfare. pp. 125-129.

9. Bendixen, Thomas W., et al. Ridge and Furrow Liquid Waste Disposal in a Northern Latitude. J. Sanit. Eng. Div., Proc. Am. Soc. Civil Eng. 94(SA1): 147-157. February 1968.

10. Aulenbach, Donald B., James J. Ferris, Nicholas L. Clesceri, and T. James Tofflemire. Thirty-five Years of Use of a Natural Sand Bed for Polishing a Secondary Treated Effluent. (Presented at Rural Environmental Engineering Conference. University of Vermont. September 27, 1973.) 46 pp.

11. Thomas, R. E., K. Jackson, and L. Penrod. Feasibility of Overland Flow for Treatment of Raw Domestic Wastewater. Environmental Protection Agency, Corvallis, Oregon. Report No. EPA-660/2-74-087. December 1974. 30 pp.

12. Enfield, C. G., and D. C. Shew. Comparison of Two Predictive Non-Equilibrium One-Dimensional Models for Phosphorus Sorption and Movement Through Homogeneous Soils. J. Environ. Quality. Vol. 4, No. 1. January-March 1975.