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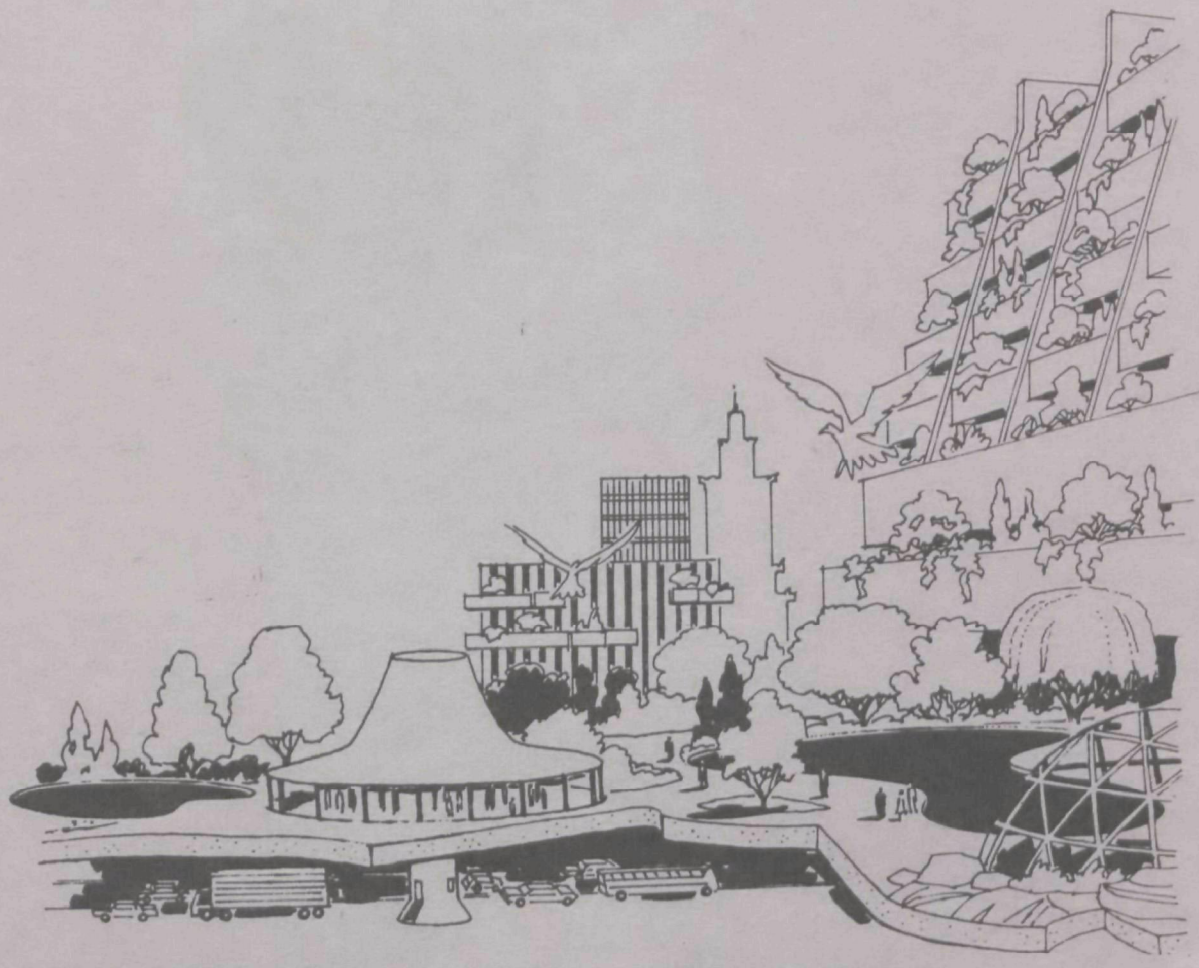
SOIL SYSTEMS FOR MUNICIPAL EFFLUENTS---A WORKSHOP AND SELECTED REFERENCES



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SOIL SYSTEMS FOR MUNICIPAL EFFLUENTS--
A WORKSHOP AND SELECTED REFERENCES

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ABSTRACT

An investigation of the use of Soil Systems for recycling treated municipal waste effluents was conducted. The scope of the project included: the preparation of a user manual entitled Applying Treated Municipal Wastewater to the Land: Current Technology and an annotated bibliography of selected references in subject area.

A state of the art investigation was made of the design, operation and control of irrigation and infiltration-percolation types of soil systems. The summarized results from this investigation were used by workshop participants selected from state, municipal, and federal agencies who were involved in soil system activities as a starting point in writing the manual. The workshop culminated in the preparation of a draft of the manual. The bibliography contains selections which portrayed or influenced the present state of art in the subject field.

This report was submitted in fulfillment of Grant No. 16080 GWF under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

KEY WORDS: TREATED MUNICIPAL WASTEWATER, SOIL SYSTEMS, IRRIGATION, INFILTRATION-PERCOLATION, USER MANUAL.

CONTENTS

TABLES

SECTION I

CONCLUSIONS

1. Soil Systems have the potential for removing additional pollutants from treated municipal wastes and deserve consideration when expanding or furthering the waste treatment processes in municipalities.

2. Each soil system must be designed subject to the constraints imposed by the proposed site, the planned hydraulic load, and the contaminate level of the effluent to be applied.

3. The operating and control parameters in soil systems utilized for irrigation have been established through previous field practice and research.

4. A letter of inquiry sent out by the project staff revealed that the agencies of responsibility in the 32 states and 1 territory which replied had no specific state or municipal regulations in force pertaining to the use and operation of soil systems per se.

5. Technological transfers and policy alternatives on environmental problems can be determined by small, informal work groups composed of individuals involved in research, operation, and control activities in the problem area.

6. The techniques utilized in this project are applicable for certain research activities. Such functions as state of the art determinations, synthesizing research findings into a new system or process configuration, summarizing research findings on a particular topic, and aiding technology transfers between research specialists and the practitioners in a discipline are amenable to this approach.

7. Students and other non-experts can be trained in information search techniques and in the terminology of a scientific specialty. Senior scientists can utilize this talent pool and eliminate a portion of their time normally spent in making an exhaustive information search of the topic of research interest. Once trained in search procedures, a search group can be given minimal instruction in the terminology of a new discipline and redirected on a new research topic.

SECTION II

RECOMMENDATIONS

Based upon the findings and conclusions of this investigation, it is recommended that:

1. Research be centered to determine the optimal application rates of treated municipal waste, schedules of effluent application, and operational parameter of infiltration-percolation systems in the various climatological and physiographic regions of the United States.

2. Further investigation be instigated to determine the final disposition of metals and organics of industrial origin which are constituents of municipal wastes.

3. Additional techniques be developed for maintaining high infiltration rates through the surfaces of infiltration-percolation systems.

4. Infiltration-percolation systems be examined for application as an alternate to returning wastewater effluents directly to the area's drainage network in situations where no treatment or primary treatment is presently utilized.

5. The non-profit sector be utilized to effect dialogues through workshops and conferences between specialists in the private sector and government in proposing and structuring new institutional arrangements for environmental management and control.

SECTION III

INTRODUCTION

This has been an investigation to determine the status of soil systems as a means of providing additional polishing to treated municipal wastewaters. The central purpose of this effort was to evaluate the literature and information presently available and from this to structure a design and operation manual for reference and general use by practitioners in the field.

The interest in this method of wastewater renovation stems from the factors of increased nationwide demand for water and the unequal distribution of water supplies over the country. Variations in the types, properties, and occurrences of wastes, geographic areas, urban layout, climatic elements, economic resources and water needs have necessitated that a variety of approaches be provided for treating and reclaiming wastewaters. Soil systems offer decision makers another option which can be added to the list of treatment techniques for local adoption when a municipality or sewage district must expand or replace its treatment facilities.

Although not specifically used for the function of water reclamation, application of wastewater to the soil is one technique which has been in use for centuries. Irrigation with raw sewage and with wastewater treatment plant effluent has been a common practice in many countries of the world. The water itself and the nutrients it contains have been valued as agricultural resources. In the United States however, the public health aspects early precluded the use of raw sewage for irrigation. Water contaminated by human wastes was recognized as a transmission medium for communicable diseases and infections. The practice of applying treated wastewater to the soil, however, has been found to be an effective means of reducing suspended particles, nutrients, and biological organisms from the waste stream with little or no health risk. This technique of treatment through soil systems is applicable for renovating water either in water deficient or in humid areas. Soil systems are used for irrigation in water deficient areas to distribute and apply treated wastewater to different types of agricultural crops and for various types of landscaping. Infiltration-percolation type soil systems in humid or arid areas utilize the soil to obtain advanced treatment of wastewater effluents from secondary treatment processes in order that it may be cycled for reuse.

This report deals with the technique by which the project goals were accomplished and contains as an addendum a bibliography of the design manual. The design manual prepared under the provisions of the grant exists as a separate document from this report, and as such will not be discussed other than in Section I and Section II of this report.

The project objective and its methodology were formulated on the premises of establishing a means of facilitating technology transfer and of reducing the time frame in which pertinent research findings can be identified and

affixed in a strategy of practical application. The procedure that evolved was effective in reaching the project goals. The original project workplan was envisioned as follows.

A review of literature was to be made of published material and unpublished material on soil systems in the areas of health, technological characteristics, and current regulations, laws, and policies. The review findings were to be evaluated by the project staff and the most pertinent sources abstracted. The abstracts were to be sent to a selected group of experts whose work or research experience were in the area of soil systems. Comments on the abstracts evoked from the experts were to be the basis for a workshop agenda. At the workshop the experts would meet and write the draft copy of the design manual. This copy would then be corrected by the project staff and sent to the participants of the workshop for final approval before the manuscript was submitted to the contracting agency.

This procedure was modified somewhat during the project period. The methodology used does have merit and can be used in the survey, delineation, and evaluation of problems in the environmental area.

SECTION IV

PROJECT ACTIVITIES

The project activities will be discussed briefly for the purpose of describing a technique which worked well in this particular instance where research findings in a particular area were reviewed and the review results were used to synthesize a user document in a specific interest area.

Information Search

The first phase of the project was the search for information. Means were formulated to locate both published and unpublished information. The unpublished information was presumed to reside with state agencies who might happen to be involved with wastewater. Abstract and periodical indexes would be used to locate the published documents.

Unpublished Material

A letter of inquiry was used to inquire about unpublished material. A form letter was sent to all the state departments of health, state water resource boards, and state pollution control agencies to ask for policy statements and design guidelines currently controlling the use of soil systems in that particular state. Many of the replies received expressed an interest in the study results but had little information to offer in the area of soil systems. Many of the recipients of the inquiry letters were uncertain as to the definition of the term soil systems. A second letter was not sent since it was determined that little would be gained by pursuing that topic further with those agencies.

The answers from the states produced little in the area of rules and regulations. Replies were received from 31 states and 1 territory by specific state agencies which would be directly responsible for administering regulations or cognizant of any established rules and regulations pertaining to the use of treated municipal effluents in soil systems. None of the states which replied had specific regulations in force pertaining to the use and operations of soil systems per se. Two states at the time of the survey in early 1971 were actively engaged in activities which would lead to specific regulatory policies. The Ground Water Section of the Department of Environmental Resources for Pennsylvania had written a "Spray Irrigation Manual" designed to help municipalities and consultants in locating and designing sites for spray irrigating municipal wastes. This publication was being reviewed at the time of the inquiry. The manual was to stress that all wastes which could contain pathogens must be disinfected before being sprayed. The Pollution Control Agency for the state of Minnesota was preparing design criteria recommended for irrigation and seepage basin waste disposal systems.

The replies mentioning the use of treated effluents in irrigation systems showed little change in the position of the states from that expressed in an earlier survey conducted by Coerver (22) when he ascertained the status of state health regulations pertaining to the use of sewage effluents for irrigation. Several systems utilizing treated effluents were reported in operation in Colorado whereas no information on this state was available in the earlier report. Wisconsin reported the use of a ridge and furrow system. Missouri indicated in early 1971 that no irrigation systems were in operation but one was proposed.

Answers from several of the states indicated to the investigators that current regulations or policies might be used to judge the merits of proposed infiltration-percolation systems. The Air and Water Pollution Control Department of Florida reports, "There are no specific regulations other than our evaluation of specific projects and their merits under our permit system". Nevada's Division of Health reports, ". . . the only regulations controlling soil systems are those which prohibit the contamination of ground water". Wisconsin's Department of Natural Resources relates that "Each proposal is judged on its own merits".

The replies received from the states included some in-house documents on research activities which proved of value to the study. The dearth of information pertaining to specific rules or policies gave the project staff an indication that guidelines were needed to help establish policy in this area.

Literature

The preparation for the literature search started with the training of undergraduate students in library search procedures. Since the students were from disciplines other than the study area, a familiarization program in which the terminology and practices utilized in the subject area was presented. Four hours out of the twenty hours in the training program were used in subject familiarization. Typical articles with the key terminology underlined were given as reading assignments to the students. Check sheets designed for evaluating the articles were given to the students to familiarize them with the project interest areas. The final hour of the familiarization phase was a slide presentation showing soil systems presently in use.

Twelve hours of the program were devoted to demonstration and practice exercises in the organization of libraries, the use of card catalogs, periodical indexes, abstract sources, and in techniques of library research. The last four hours were spent in practical work searching abstracts in the water resource area. In this period, the students had a chance to get their questions answered on the boundaries of the search area and the techniques to be used. The students were each assigned to a particular periodical index or abstract source to examine. A check sheet like the one used during the training phase and an author coded index card were completed for each article which exhibited any relationship to soil systems in the areas of health, operational characteristics, or regulatory

measures. After completing the review of the assigned source material another was assigned for examination.

It had originally been planned for teams of searchers to go to the larger universities in the state and collect articles pertinent to the search area. In utilizing the resources at the Robert S. Kerr Water Research Center Library and those at the East Central State College Library it became apparent that the local resources would suffice in identifying articles pertaining to soil systems. As the search continued, the compilation of author cards showed that considerable cross-referencing had taken place by searching the different sources. The use of the check sheet was abandoned as the searchers attained the skill of determining whether an article or the article abstract contained sufficient material in the search area. The author coded cards became the basis for the evaluation phase of the identified literature.

Review of Literature Search Findings

A survey of the author cards obtained in the literature review was used to identify the publications which summarized soil system project activities and key articles which best described or summarized the work of the scientist-author. Copies of these articles or abstracts of the articles were then obtained. The usefulness of the article was determined through a critical reading made by one of the trained student helpers. The project staff then reviewed the selected articles for information applicable to the project goals.

Modifications in the original workplan were made after this review. Rather than abstracting the pertinent articles and sending them to the workshop participants for review, a decision was made that the project staff would summarize the research findings and prepare a preliminary draft of the design manual based upon the information review. The draft would then be sent to the participants for their review and comments prior to the workshop.

This procedure was followed and the draft was prepared with two major sub-sections. The sections were designated "Guidelines for Design and Operation" and "Health and Regulatory Aspects of Soil Systems." The health and regulatory aspects of soil systems were combined into one section since the two topics were found to be mutually dependent during the review phase of the information search. The workshop plans were also adjusted to reflect this dualism.

The draft was sent to the participants and their comments on the manual were sought prior to their arrival at the workshop. A revised copy of the original manual manuscript with the draft copy statement and the comments provoked from the individual participants were prepared for distribution to the participants upon arrival at East Central for their review prior to the first workshop session. The pre-conference responses from the consultants were satisfactory with 8 of the 12 responding. Last minute changes in personnel who were able to act as conference

participants negated the time interval for prior study of the manuscript and comment before arrival at the workshop.

Conduct of the Workshop

The workshop was held from May 3, 1971 to May 6, 1971 at East Central State College in Ada, Oklahoma. The participants and the agenda of the workshop are shown on Tables 1 and 2.

The group sessions were chaired by Environmental Protection Agency representatives. Mr. Kenneth Dotson chaired the sessions of the Design and Operation Section. Mr. R. E. Thomas, the project officer for the grant, was the chairman for the sessions of the Health and Regulation Section.

The discussions and activities varied within each group. The Design and Operation Section used the draft copy as a starting point for their activities and expanded the coverage of the manuscript topics. The Health and Regulation Section in their discussion found that it was necessary to consider both the design and the operation of soil systems in conjunction with the determination of the health aspects and the regulatory measures required for public health safety. This group examined the complete draft and made modifications also in the D. and O. portion. The group decided that comments on the health and regulatory measures were needed at the points where the design and operation topics were discussed rather than in a separate section. Secretaries with each group compiled the modifications in the draft and prepared a revised copy which reflected the group's activities.

At the first session in which the full group met, copies of each group's revisions were passed out. The conferees spent this session editing their group comments and reading the comments from the other group.

In the last two sessions of the workshop, the participants spent their efforts in joining the two manuscripts into one. The notes, comments and guidelines given in the last sessions were used by Mr. Thomas, the EPA project officer, to put together a post workshop draft of the manual.

The workshop conferees were given a short questionnaire to answer about the conduct of the project activities. The questionnaires and a summary of the replies obtained from the participants are included in Appendix B.

Post Workshop Phase

The post conference draft was assembled by the project officer. In this draft, the design, operation, health, and regulatory aspects of the manual were edited to reflect the attitude of the Environmental Protection Agency toward soil system activities. The comments received on this draft were acted upon and the user manual was assembled. This was submitted to the granter for final approval.

TABLE 1

WORKSHOP PARTICIPANTS

Name	Agency	Address
Herman Bouwer Chief Hydraulic Engineer	U. S. Water Conservation Lab USDA, ARS	4331 East Broadway Phoenix, Arizona 85040
W. R. Dinges Health Program Specialist	Division of Wastewater Technology and Surveillance	Texas State Dept. of Public Health Austin, Texas 78701
G. Kenneth Dotson Soil Scientist	EPAWQO	Robert A. Taft Water Research Lab Cincinnati, Ohio
F. D. Dryden Deputy Asst. Chief Engineer	County Sanitation District Los Angeles County	2020 Beverly Blvd. Los Angeles, Calif. 90057
Stuart Dunlop Professor of Microbiology	University of Colorado Medical Center	Denver, Colorado
Alvin L. Franks	Division of Water Quality State Water Resources Control Board	1416 9th Street Sacramento, Calif. 95814
Clark Harvey Professor of Agronomy	Department of Agronomy	Texas Technological College Lubbock, Texas 79406
Thomas D. Hinesly Soil Ecologist	Department of Agronomy	University of Illinois Urbana, Illinois 61801
William Jopling	Bureau of Sanitary Engineering Department of Public Health	2151 Berkeley Way Berkeley, Calif. 94704
L. T. Kardos Environmental Scientist	Pennsylvania State University	108 Research Building 3 University Park, Pa.
Donald Pierce	Division of Engineering Michigan Dept. of Public Health	3500 N. Logan Lansing, Michigan 48914
James E. Santarone	Wastewater Section Florida Division of Health	P. O. Box 210 Jacksonville, Florida 32201
Richard E. Thomas Research Soil Scientist	EPAWQO	Robt. S. Kerr Water Research Center Ada, Oklahoma 74820
T. C. Tucker, Prof.	University of Arizona	Tucson, Arizona 85721

TABLE 2

WORKSHOP AGENDA

Date	Time	Activity
May 3, 1971	6:30 p.m.	Informal mixer and dinner, compliments of Ada Chamber of Commerce
May 4, 1971	8:30-9:00 a.m.	Charge to participants
	9:00-10:15	1st session-Individual group discussion
	10:15-10:30	Coffee Break
	10:30-12:00	2nd session-Individual group discussion
	12:00-1:00 p.m.	Lunch
	1:00-3:00	3rd session - Individual group discussion
	3:00-3:15	Coffee Break
	3:15-5:00	4th session-Individual group discussion
May 5, 1971	8:30-10:00 a.m.	5th session - Individual group discussion
	10:00-10:15	Coffee Break
	10:30-12:00	6th session - Summary of individual group discussion
	12:00-3:30 p.m.	Lunch and tour of Robert S. Kerr Water Research Center
	3:30-5:00	7th session - First full group discussion
	6:30	Dinner and entertainment
May 6, 1971	8:30-10:15 a.m.	8th session - Full group discussion
	10:15-10:30	Coffee Break
	10:30-12:00	9th session - Full group concluding comments
	12:00	Closing Luncheon

The documents utilized in the preparation of the pre-conference draft were abstracted or the document abstract was collected and compiled into an annotated bibliography. This bibliography and an accompaning author index comprise Appendix A of this report.

SECTION V

ACKNOWLEDGMENTS

East Central State College wishes to thank Mr. R. E. Thomas, EPA Project officer, and Miss Lorene Fuller, librarian at the Robert S. Kerr Water Research Center, for their services and cooperation in achieving the project goals.

Acknowledgment is made to faculty, staff and students of East Central as follows:

Dr. B. J. Tillman	Grant Director
Mrs. Phyllis Johnson	Typist

SECTION VI

APPENDICES

APPENDIX A

AN ANNOTATED BIBLIOGRAPHY OF SELECTED REFERENCES USED IN THE PREPARATION OF THE USER MANUAL AND AUTHOR INDEX

1. ANONYMOUS. 1953. Comments on Sewage Irrigation. Sew. & Indus. Wastes 25:2:233-234.
A survey of the opinions of users of sewage for irrigation. Four farm owners from around the San Antonio, Texas area give statements on the effect of sewage on their crops or pastures.

2. ANONYMOUS. 1956. Continued Study of Waste Water Reclamation and Utilization. A report by the State Water Pollution Control Board, Sacramento, California Pub. No. 15.
Expansion of waste water reclamation facilities by the steel and other industries, the scheduling of numerous, important conferences on the re-use of waste waters, and the planning of new waste water reclamation projects all indicate the increasing, nation-wide interest being given to the reutilization of waste waters.
While public health problems have not arisen at any of the many golf courses now using a sewage effluent for irrigation, reasonable uniform procedures need to be developed.
A cooperative study has shown the reclamation of liquid sludge by land disposal to be practicable. A cooperative study has also shown the reclamation of a normal, domestic sewage by means of a primary lagoon system will provide an effluent amenable to the irrigation of grasses and shrubs. It is recommended that the study of waste water reclamation and utilization be continued.

3. ANONYMOUS. 1957. Study of Waste Water Reclamation and Utilization. 3rd Report of the State Water Pollution Control Board, Sacramento, California Pub. No. 18.
Studies show that waste water constitutes an increasing portion of the nation's water supply. The Talbert Valley reclamation operation shows that it is possible for a group of private farmers to organize, finance and construct a reclamation system to utilize a sewage effluent for economical irrigation of field crops. The several golf course studies showed that the problems peculiar to irrigation with reclaimed water such as odors, corrosion, chlorination for coliform control and soil salinity can be controlled by careful planning. The studies also showed where ground water recharge through injection wells is possible. Health hazards are discussed as well as the San Diego liquid sludge disposal operations and the Mojave waste water reclamation operation.

4. ANONYMOUS. 1963. Treated Sewage Irrigates Crops. Engr. News-Record 171 (Part 2):45-46 (Oct.3).
Pennsylvania State University conducts a spray-irrigation program to test the effect of treated domestic sewage on forest plantings and adjacent croplands. The experiments seek to show how plant nutrients in waste water can be conserved and best put to use in a community. The program workers expect to learn how much acreage should be irrigated, best rates of application, and the equipment needed. Part of the effluent is sprayed on fields planted to rye, wheat, corn, and alfalfa. That diverted to forested areas is sprayed on tree tops from elevated nozzles. The experimenters expect to learn its effect on crops and timber as well as its effect on game and fish.

5. ANONYMOUS. 1965. Microbiological Content of Domestic Waste Waters Used for Recreational Purposes. A report by the State Water Quality Control Board, State of California Pub. No. 32.
A water reclamation project involving secondary treatment of domestic sewage followed by storage, filtration and disinfection was studied over a period of 30 months. Virus studies were carried on for two years in the laboratory of the San Diego Department of Public Health. Bacteriological, physical and chemical data were gathered from 30 months of analysis of samples taken from eight points in the treatment and recovery system with some variations as described in the report.

6. ANONYMOUS. 1966. Warwick B. C. Improve effluent with spray irrigation equipment. Survr munic. City Engr 127:3862:41-42.
An illustrated description is given of spray irrigation equipment installed at Warwick sewage works in May, 1966 as the initial stage of alleviating overloaded conditions. After primary sedimentation, effluent is pumped through standard farm irrigation equipment over an area of 7.2 acres of grassland (which is divided into 2 plots, each of which is allowed a 14-day rest period) before drainage to the river Avon.

7. ANONYMOUS. 1966. Wastewater Reclamation at Whittier Narrows. A report by the State Water Quality Control Board, State of California Pub. No. 33.
The general objective of this investigation was to determine the effects of intermittent percolation through soil of highly treated activated-sludge effluent on the quality of ground water in the Whittier Narrows area. The project was designed to study the fate of significant mineral, organic, and biological constituents of renovated wastewater and the phenomena associated with their removal or transformation. The investigations were divided into three major categories. (1) A total of 25 wells in the vicinity of Whittier Narrows were monitored with respect to water quality at various elevations by means of a selective-depth pumping unit. (2) Test spreading basins were constructed and operated to study the phenomena associated with intermittent vertical percolation through the upper few feet of soil. (3) Laboratory soil columns were utilized to compare the degradation of the new linear alkylate sulfonates (LAS) with the conventional alkyl benzene sulfonates (ABS).

8. ANONYMOUS. 1967. Warwick B. C. Extend spray irrigation scheme for effluent improvement. Survr munic. City Engr 129:3905:26-27.
A description, illustrated by plan and photograph, is given of extensions and modifications to the original spray irrigation system for disposal of effluent at Warwick sewage works; these include the construction of a lagoon which receives humus-tank effluent, and from which the original irrigation area is now sprayed, and the use of an additional 10-acre plot (divided into 2 equal plots to allow a rest period for each) onto which storm sewage from the storm tank is sprayed.

9. ANONYMOUS. 1967. Water Reclamation and Reuse. Journ. WPCF. 39:5:734-741.
Literature review of a symposium on Water Conservation by Reuse, by the American Institute of Chemical Engineers at its 59th Annual Meeting. Gives location and purpose of a large variety of systems and states

general information on the type of system, efficiency, cost, and health aspects.

10. ANONYMOUS. 1968. Reclamation of Waste Water. A report by the Los Angeles Dept. of Water and Power, City of Los Angeles, California. This report covers irrigation in the Sepulpa Flood Control Basin. Costs are included. Irrigation and recreation in Griffith Park is discussed as well as discussions of three sources of reclaimed water for the Park. A wastewater treatment plant is proposed to be constructed jointly by Los Angeles and Glendale.

11. AMIROV, R. O., SALIMOV, D. A. 1967. Sanitary-Helminthological Evaluation of Sewage Farms Under Climatic Conditions of the Apsheron Peninsula. Hygiene and Sanitation 32:4-6:437-439.
Biological characteristics of sewage from Baku are given. High per cent of viable helminth eggs is found in the municipal sewage (54.4). Sewage is treated by Imhoff process. The treated sewage is used for irrigation because of poor sandy soil and lack of rainfall. It was found irrigation by flooding contaminated vegetables. There were no viable eggs found after two months in the soil. Investigations show sewage can be successfully used to irrigate eastern part of the Apsheron Peninsula. Recommends irrigation on thermal processed food only and only by farrow irrigation. Climatic information given.

12. ASKEW, J. B., BOTT, R. F., LEACH, R. E., ENGLAND, B. L. 1965. Microbiology of Reclaimed Water from Sewage for Recreational Use. Amer. Journ. of Public Health 55:2:453-462.
As part of a continuing research program at the Santee Sewage treatment plant, intensive bacteriologic and virologic tests have been performed on specimens from seven sampling points. Bacteriologic determinations indicate that it is possible to create a lake from reclaimed water that has coliform counts within the limits allowed for conventional origin. Virological tests completed to date on samples of raw sewage, primary settling effluent, and activated sludge effluent have been 100% positive, yielding 13 distinctive viruses. The per cent of samples positive after approximately 30 days detention in an oxidation pond dropped to 25, and the recreational lake samples have been consistently negative for virus.

13. BACHMANN, G. 1954. The sewage utilization plant at Memmingen. Wasserw.-Wass. Techn. 4:191; Zbl. Bakt., I, Ref., 1955, Vol 157:344.
The author describes the sewage works of Memmingen where sewage, after sedimentation for 1½ hours, is used as artificial rain. The yield of hay on watered land has been increased by 52 per cent.

14. BEHNKE, J. J., HASKELL, E. E., JR. 1968. Ground Water Nitrate Distributions Beneath Fresno, California. Jour. AWWA 60:4:477-480.
The occurrence and distribution of nitrates in ground water is a complex problem dependent upon many variables. Nitrate concentration maps are useful in ground water studies to indicate areas receiving unusual nitrate concentrations. Nitrate may not be an effective ground

water tracer in all cases, because its concentration in the water table changes markedly with horizontal distance. Areas receiving nitrate concentrations from organic sources should also have high chloride concentrations. Therefore, a comparison of the chloride and nitrate concentrations in the ground water may offer some insight into the effects of bacterial action on nitrate concentrations. Nitrate concentrations in the uppermost 10 feet of the ground water body were approximately one-third higher than in deeper waters - below 10 feet the nitrate concentration was essentially uniform with depth.

15. BENDIXON, T. W., HILL, R. D., SCHWARTZ, W. A., ROBECK, G. G. 1968. Ridge and Furrow Liquid Waste Disposal in a Northern Latitude. Jour. Sanitary Div. - ASCE 94:SA1:147-157.
The operation and performance of a municipal ridge and furrow liquid waste disposal system in use since 1959 was monitored for a year and a half. One hundred and fifty thousand gallons a day of trickling filter effluent are disposed into the soil via four 1-acre basins. A heavy stand of grass left unharvested over the winter apparently contributes to successful operation. The changes in infiltration rates and quality of the infiltrate with season and under various loading and operating conditions are examined, as are companion field and indoor lysimeter studies comparing various design and operational factors that may influence infiltration protection of ground water.

16. BLUMEL, F. 1965. Methods of treating agricultural land--a good method for the treatment and application of sewage. Wass. Abwass., 1965, 35-45.
Existing methods for use of sewage in agriculture and plans for its use in modern farming and soil improvement are discussed, and the author reviews the application of sewage on land without preliminary treatment, after mechanical treatment, and after biological treatment, and compares these methods with those used abroad. Special reference is made to the use of sewage effluents and trade waste waters for irrigation.

17. BOUWER, H. 1970. Ground Water Recharge Design for Renovating Waste Water. Jour. Sani. Engrg. Div. - ASCE 96:SA1:59-74.
Ground water recharge through surface spreading can be an effective and economical method for further treatment or renovation of conventionally treated sewage effluent, cannery wastes, or other low-quality water. The process could also be used in cases where keeping the waste water out of surface waters is the main consideration. Infiltration of the waste water can be accomplished with recharge basins, ridge-and-furrow systems, or sprinklers. Most of the quality improvement takes place as the fluid percolates through the first few feet of soil, but it is considered desirable to allow the water to travel laterally as ground water for several hundred feet or more before it is collected as reclaimed water by drains or wells. The design of a system of recharge areas with infiltration facilities and of wells or other facilities to collect the reclaimed water must be based on: (1) Keeping the water table beneath the recharge area at sufficient depth to maintain high infiltration rates, sufficient aerobic percolation, and rapid drainage of the soil profile during dryup; (2) allowing sufficient time and distance of underground travel of the reclaimed water; and (3) minimizing spread of the reclaimed

water into the aquifer outside the recharge system if contamination is to be avoided. A procedure is presented to predict water-table positions for a system of parallel, rectangular recharge areas, with wells located midway between the areas. This enables the evaluation of the most favorable layout of recharge areas and wells with the desired water table response and travel times. Procedures for obtaining the necessary information on the hydraulic conductivity conditions of the aquifer for recharge systems are presented. Using an analog technique, the horizontal and vertical hydraulic conductivity of an aquifer can be determined from the recharge rate and the water level response in two observation wells of different depths. From the hydraulic conductivity data thus obtained, an effective transmissibility coefficient of the aquifer for recharge can be computed for use in the analysis of a multiple-basin, multiple-well recharge and renovation system. The procedures are illustrated with an evaluation of the hydraulic properties of the aquifer for an experimental recharge system in the Salt River bed west of Phoenix, Arizona, and with a calculation of watertable positions and travel times for a system consisting of two parallel recharge strips with wells midway in between.

18. BOUWER, H. 1968. Returning Wastes to the Land, A New Role for Agriculture. Jour. Soil and Water Cons. 23:5:286-290.
There is an everpresent need for reclamation and reuse of wastewater. Land disposal is one way to use these wastes. Not only does the soil benefit from the fertilizer value of the sewage effluent but the water goes through a drastic quality improvement through soil percolation before it reaches the ground water. Recharge basin management is discussed along with the economics of land disposal. Three methods of reducing the nitrate content from the soil are studied. A description of the Flushing Meadows Project is given as an example of waste water reclamation.

19. BOUWER, H. 1970. Water Quality Aspects of Intermittent Systems Using Secondary Sewage Effluent. Paper given at the Artificial Groundwater Recharge Conference Univ. of Reading, England. 21-24 Sept., 1970.
Results from an experimental project on reclaiming water from secondary sewage effluent by ground water recharge with infiltration basins in the dry Salt River bed near Phoenix, Arizona, have shown that the infiltration rate in grass-covered basins is 25 per cent higher and in a gravel-covered basin 50 per cent lower, than in a bare soil basin. Alternating 2-week inundation periods with 10-day dry-up periods (17 days in winter) yields an annual infiltration rate of about 100m (330 ft.). The hydrogeological conditions of the Salt River bed, i.e. about 0.9m (3 ft.) of fine, loamy sand underlayed by sand and gravel layers to great depth and a ground-water table at about 3m (10 ft.) depth, are very favorable for high-rate waste water reclamation by groundwater recharge.

20. CHASE, WILLIAM J. 1960. Spray Disposal of Domestic Wastes. Pub. Works 91:137-141 (May). PHE ABST. 40:S:107.
Emphasizes the need for proper disposal methods in relation to spray irrigation of pasture and wooded areas with domestic wastes. Requirements are given in regard to pretreatment, allowable volumes according to conditions, spray-nozzle arrangement, prevention of harm to foliage,

and other details of application. Deep silty soil is preferable. Clay subsoil may lead to bad effects from adsorption of sodium through ion-exchange.

21. CHISTOVICH, G. N., ADEL'SON, L. I., IVANOVA, S. P., IL'IN, V. V., KIBORT, R. V., LYABINA, L. M., MOGUCHII, A. M., NECHAEVA, E. A., PADERINA, E. M. SMIRNOVA, A. M., SHANDURIN, S. V., YAKOVLEVA, G. S. 1965. Experience of Comprehensive Sanitary and Microbiological Evaluation of Sewage Irrigation Fields in the Suburbs of Leningrad. Hygiene and Sanitation 30:10-12:129-131.
A total of 17 samples of sewage and 27 samples of drainage water, 131 samples of soils and 21 series of samples of vegetables, principally cabbage was used in this experiment. A total of analyses was 1774. Besides cabbage, cauliflower and potatoes were also used.
This article dealt with the following three areas:
(1) The degree of efficiency of sewage purification in the SIF (sewage irrigation fields.)
(2) The degree of contamination of the soil in SIF and whether it undergoes spontaneous decontamination fast enough.
(3) The possibility of using those vegetables grown in SIF.

22. COERVER, J. F. 1969. Health Regulations Concerning Sewerage Effluent for Irrigation. Presented at a symposium held July 30, 1968 in Ruston, La. Louisiana Polytechnic Institute Alumni Foundation.
Regulations on the use of municipal sewage effluent for irrigation vary from state to state. The use of untreated sewage for irrigation is generally prohibited. States approve the use of treated sewage for irrigation except in those more hazardous situations involving vegetables eaten raw, public access lawns, and dairy pastures, although some states recognize that sewage can be reclaimed by extensive treatment to satisfactorily reduce hazards.

23. CRAWFORD, A. B., FRANK, A. H. 1940. Effect on Animal Health of Feeding Sewage. Civil Engrg. 10:8:495-496.
The U. S. Department of Agriculture's Beltsville Research Center conducted a study in which sewage effluent was fed to swine and cattle to see if disease would be carried in the stock. Raw sewage, treatment plant effluent, and sludge were mixed with bran and fed to the stock regularly. The water of the test animals was also saturated with the effluent. It was concluded that virulent bacteria are not present in sufficient concentration in the incoming sewage of the test sewage plant to cause disease in susceptable animals.

24. CROSBY, J. W., JOHNSTONE, D. L., DRAKE, C. H., AND FENTON, R. L. 1968. Migration of pollutants in a glacial outwash environment. Wat. Resour. Res., 4, 1095-1114.
Soil samples were taken from test holes to determine the movement of polluting chemicals and bacteria in the alluvial soil of the Spokane river valley, Wash., caused by soil disposal of septic-tank effluent from a nursing home. It was found that bacteria were normally removed after passage through 20 ft of soil; that moisture fronts moved further,

laterally and vertically, in the winter; and that chlorides and nitrates moved at rates comparable to those of the dispersing effluents. Detailed observations of moisture distribution were supplemented by observations using sand models, and it was demonstrated that dry conditions at depth were caused by lateral dispersion by capillarity.

25. DAVIS, G. E., STAFFORD, J. F. 1966. Tucson Wastewater Reclamation Project. First Annual Report, Tucson Wastewater Reclamation Project, June 1965-June, 1966. Tucson Wastewater Reclam. Proj. Rep., July 1966. Water and Sewers Dept., Tucson; Univ. of Arizona, Tucson.
A summary of the first year of the Tucson Wastewater Reclamation Project. The primary purpose of the project is to demonstrate the chemical, microbiological, and virological safety and aesthetic acceptability of including wastewater, which has been renovated by use of a soil system, as a dependable and substantial portion of the future water supply for metropolitan Tucson.

26. DAY, A. D., DICKSON, A. D., TUCKER, T. C. 1963. Effects of City Sewage Effluent on Grain Yield and Grain Malt Quality of Fall-Sown, Irrigated Barley-Agronomy Jour. 55:317-318.
Experiments were conducted over a 2 year period to compare the grain yield, grain quality, and malt quality of 2 malting barley varieties (Atlas 54 and Hannchen) irrigated with sewage effluent with the yield and quality of the same 2 barleys irrigated with well water and fertilized with different amounts of commercial fertilizer. The sewage effluent came from the Tucson, Arizona sewage plant after the standard activated sludge treatment. It contained approximately 65 lbs. of Nitrogen, 21.8 lbs. of Phosphorous (50 lbs. P_2O5), and 26.6 lbs. of Potassium (32 lbs. K_2O) per acre-foot. About 3 acre-feet of effluent per acre was applied four times. Well water in the area contained about 10 lb. of N., 0.2 lb. of P (0.5 lb. of P_2O5), and 11.6 lb. of K (14 lb. of K_2O) per acre-foot.
The results of various tests showed that kernel weights and kernel size were reduced on plots irrigated with sewage effluent. Nitrogen was increased by sewage effluent. Although the sewage effluent plots produced a higher total yield of malt extract percentage from both varieties, the high nitrogen in the sewage effluent tended to reduce barley and malt quality.

27. DAY, A. D. AND TUCKER, T. C. 1959. Production of Small Grains Pasture Forage Using Sewage Effluent as a Source of Irrigation Water and Plant Nutrients. Agronomy Journal 51:569-572.
Winter pasture forage yields of 11.14 tons per acre were obtained from barley irrigated with sewage effluent with no additional fertilizer. Similarly, wheat and oats production was 263 percent and 249 percent higher, respectively, than for check plots that received only pump water. Barley was more sensitive to the detrimental effects of sewage effluent than were wheat and oats.

28. DAY, A. D., TUCKER, T. C. 1959. Production of Small Grains Pasture Forage Using Sewage Effluent as a Source of Irrigation Water and Plant Nutrients. Agronomy Journal 51:569-572.

Eight experiments were conducted over a two-year period (1957-58) at Cortaro, Arizona, to compare the pasture forage production of small grains (barley, wheat, oats) irrigated with sewage effluent with the pasture forage obtained when small grains were irrigated with regular irrigation water and fertilized with different amounts of commercial fertilizer. These grains irrigated with sewage produced up to 263% more forage compared to that of pump water.

29. DINGES, W. R. 1969. Review of Literature on Irrigation of Human Food Crops with Waters Containing Various Amounts of Domestic Wastewaters. Unpublished material by Div. of Wastewater Technology and Surveillance, Texas State Dept. of Health.
Definitive epidemiological information about the transmission of diseases by consumption of foods irrigated with contaminated water is, essentially, non-existent. A search of the literature did not reveal studies made on irrigation of food crops with treated and disinfected sewage treatment plant effluents. Most investigators were of the opinion that disease-causing organisms, with the possible exception of Ascaris lumbercoides (eggs) and tubercule bacteria (spores), die rapidly (2-30 days) under field conditions. The efforts at establishment of realistic sanitary standards for irrigation waters by public health authorities have suffered due to a paucity of reliable information.

30. DREWRY, W. A., ELIASSEN, R. 1968. Virus Movement in Groundwater. Jour. WPCF 40:257-271.
Virus retention by soils is studied. The adsorption of virus by soils is greatly affected by the pH of the water-soil system. At lower pH values it was found that adsorption was faster. Virus adsorption by some soils can be greatly enhanced by increasing the cation concentration of the liquid phase of a soil water system. It was concluded that virus movement through soils under saturated conditions should present no great health hazard with respect to underground water supplies.

31. DUNLOP, S.G., TWEDT, R. M., WANG, W. L. 1952. Quantitative Estimation of Salmonella in Irrigation Water. Sewage and Industrial Wastes 24:1015-1020.
A quantitative method has been developed for the estimation of Salmonella in sewage-contaminated irrigation water. Of 11 samples of irrigation water, 8 were positive for Salmonella. The median value for all 11 samples of vegetables irrigated with this water was positive for those organisms.
Ratios of 255,000 coliforms and 4,800 enterococci to one Salmonella were computed from the median values obtained from the water samples. In comparing coliform and enteroccus counts from vegetables subjected to washing and blending, no consistent trend was shown in favor of either method.
Tables included are as follows:
Table I.--Quantitative Determinations of Salmonella in Irrigation Water (Forest and International Centrifuged Sediments Inoculated into Modified Tetrathionate Broth, 3 Tubes Each of 1.0, 0.1, and 0.01 Ml.)

Table II.--Quantitative Determinations of Salmonella in Irrigation Water (Forest Centrifuged Sediments Inoculated into Modified Tetrathionate Broth, 3 Tubes Each of 1.0, 0.1, and 0.01 Ml.)
Table III.--Summary of Most Probable Numbers of Coliform Organisms and Enterococci in Irrigation Water, Samples 397-417 (MPN Counts in Thousands per 100 Ml.)
Table IV.--Comparison of Coliform and Entercocci Counts on Vegetables Using Direct Washing and Blending.

32. DUNLOP. S. G., WANG, W. L. 1961. Studies on the Use of Sewage Effluent for Irrigation of Truck Crops. Jour. Milk Food Tech. 24:2:44-47.
Salmonella, Ascaris ova and Endamoeba cysts were recovered from more than 50 per cent of irrigation water samples contaminated with raw sewage or primary-treated, chlorinated effluents. Only one of 97 samples of vegetables yielded Salmonella, but Ascaris ova were recovered twice from 34 of the vegetable samples, the latter only when raw sewage was being discharged into the stream. Although this work is not yet completed, it would appear that, under the conditions studied, the use of partially treated, chlorinated sewage effluents diluted in streams does not significantly contaminate the vegetables furrow-irrigated with this water. On the other hand, the presence of pathogenic organisms in most of the water samples represents a potential public health hazard to the farmers and communities using the water.

33. DYE, E. O. 1958. Crop Irrigation with Sewage Effluent. Sewage and Indus. Wastes 30:6:825-828.
A series of analyses were conducted, exdending over a 2 year period, covering the chemical consideration in the application of sewage effluent from the activated sludge treatment plant at Tucson, Arizona to soil and plants. The total soluble salts of the effluent are within the range of ordinary tap water. The HCO_3 increase at the field is reflected in the pH change (7.4 to 7.9) and is influenced by algal growths; however, this rise is only temporary. The slight rise in Na content suggests increased detergents use which may in turn explain the P_2O_5 rise. The total nitrogen increase is explained by microbial nitrogen fixation. This method with only a few adaptations makes agricultural use of usually wasted water with no hazards to operators or others possible.

34. DYE, E. O. 1968. Wastewater Reclamation Project. Water Sewage Works 115:4:139-144.
The city of Tucson is interested in waste water reclamation, with approval by health authorities. The second year of the Tucson Wastewater Reclamation Project embodied a program of intensive sampling and analysis of applied activated sludge effluent, intrafilter aliquots representing progressive stages of renovation, and the end products. Two phases of application were completed and critically reviewed leading to the beginning of a third. Costs were discussed.

35. EASTMAN, P. W. JR. 1967. Municipal Wastewater Reuse for Irrigation. Jour. Irr. and Drainage Div. - ASCE. 93:IR3:25-31. Jour. WPCF 40:6:969-974.
The demand for reuse of wastewater is discussed with a projection of water needs to the year 2000. States using sewage applied to land with estimated population served are described. California and Texas are

two states used as examples for sewage irrigation. Health aspects of sewage irrigation are studied in detail with references to other countries.

36. EHLERS, V. M., ROBERTS, F. C., JR., REINKE, E. A. 1934. Experiences with Sewage Farming in Southwest United States. Amer. Jour. Pub. Health 25:119-127, 1935. Sewage Wks. Jour. 7:320-322.
This article discusses the sewage disposal (using land systems) problems and advantages in three states: Texas, Arizona, and California. The article discusses the cost of the systems, the length of operation, the type of crops which were grown, and the revenue from them. Suggestions were given by Texas engineers. All data necessary was given for the state of Arizona including rainfall, temperature, population, average sewage flow, average type of sewage, etc. Ways of dispelling odors were discussed. Health aspects, danger of polluting groundwater, previous treatment and crop yields were discussed to a great extent. A great deal was said about California's health laws (as to what crops could be legally irrigated with sewage water and the type of sewage that could be used) and their effect on the number of land systems used.

37. FISH, H. 1966. Some investigations of tertiary methods of treatment. Instn publ. Hlth Engrs J. 65:33-47.
Tertiary treatment of sewage-works effluents in Essex by irrigation on grass plots, slow sand filtration, microstraining, and lagooning has been studied over a period of 12 months and the improvements achieved performance for removal of BOD and suspended solids, and for nominal oxygen balance of the effluent but some of the results obtained by lagooning were superior. All 4 processes produced similar results when treating humus-tank effluent conforming to the Royal Commission standard. The costs of the processes are compared and their merits are considered in relation to requirements of river authorities, sewerage authorities, and public health protection.
In reply to a question raised in discussion, the author stated that these processes caused only slight reduction in the concentration of anionic detergents.

38. FLEMING, R. R. 1963. Water Reuse by Design. The American City 78:106-108.
The author reviews the reuse of sewage effluents as practiced in the United States. Large quantities are reclaimed for both industrial and agricultural reuse. Other reuse includes groundwater recharge to prevent salt water intrusion. Over 200 municipal plants in Texas supply effluent for irrigation. Several Arizona and New Mexico cities water golf courses and parks with sewage effluent. Other examples of reuse are cited.

39. FOSTER, H. B., JR., JOPLING, W. F. 1969. Rationale of Standards for Use of Reclaimed Water. Jour. Sani. Engrg. Div. - ASCE 95:SA3:503-514.
Committees developed workable standards for safely utilizing reclaimed wastewater in California. Applications such as irrigation of crops and parks, and recreational empoundments were developed. In the development of the standards, the major controversy centered around four basic subjects.
(1) Sampling and analysis requirements for adequate disinfection.
(2) Specification of proper practices in the production and use of reclaimed waste water.
(3) Use of descriptive terms versus specific quality parameters in definitions.
(4) Quality requirements for specific uses.

40. FOSTER, H. B., JR., WARD, P. C., PRUCHA, A. A. 1965. The Removal of Nutrients by Spraying Effluent on a Saturated Hillside--Lake Tahoe, California. Paper presented before ASCE, Sanitary Division, Pennsylvania State University, August, 1965.
Sewage effluent was sprayed on an 80-acre hillside, sparsely forrested with pine. During the first study period, Oct.-Nov. 1963, over 90% of the total phosphate, over 56% of the total nitrogen, and over 65% of the ABS were removed from the hillside. The following spring, April 1964, removal efficiencies were found to be lower. At this time, the hillside was thoroughly saturated with the melt from ice and snow banks. The hillside was covered with heavy snow during the early months of 1965. Masses of ice had built up around the spray nozzles. Removal efficiencies were lower than at any previous times. Phosphate, total nitrogen, and ABS removals were 27%, 26%, and 32% respectively. During all periods of study the fecal coliform and enterococcus densities were greatly reduced by the passage over the hillside spray area.

41. FRANKEL, R. J. 1967. Economics of Artificial Recharge for Municipal Water Supply. Resources for the Future, Inc., Washington, D. C. Artificial Recharge and Management of Aquifers, Symposium of Haifa (March 19-26, 1967), International Association of Scientific Hydrology, Publication No. 72, p. 289-301, 1967.
A research project was undertaken to determine whether or not waste reclamation could be economically competitive with other water sources for municipal water supply. Numerous advanced waste treatment systems and recycle schemes were evaluated. Waste-water renovation through groundwater recharge proved to be the most feasible solution to reclamation of the effluent of any type treatment plant today. Further study has evaluated the chemical and physical limitations of artificial recharge using municipal wastes; the economic trade-offs between additional treatment prior to recharge and greater land utilization and the break-even point for land values as a function of economics of

scale. Finally the economics of a particular case study in the arid West of the United States is discussed as well as proposed scheme for converting the nation's capital, Washington, D. C., in the humid East from using solely surface water supplies to using artificial recharge of undeveloped aquifers for future expansion of water supplies.

42. GREENBERG, A. E., THOMAS, A. F. 1954. Sewage Effluent Reclamation for Industrial and Agricultural Use. Sewage and Industrial Wastes 26:761-770. Chem. Abs. 49:col 7161D, 1955.
Planned reclamation is designed to produce a usable water from sewage. Such reclaimed waters may be used by industry or agriculture "directly" or "indirectly." The latter involves replenishing groundwater basins from which industrial, agricultural, or domestic supplies are drawn. Experiments performed by the University of California's Sanitary Engineering Research Laboratory are discussed, and the conclusions are summarized.

43. GRIGOR'EVA, L. V., GONCHARUK, E. I. 1966. Elimination of Viruses from Sewage in Experimental Underground Filtration. Hygiene & Sanitation 31:10-12:158-163.
Laboratory models of underground filtration beds and filtering wells have been constructed to investigate the danger of bacterial contamination of sewage. Two Coxsackie strains, A5 and A14, and E. Coli No. 163 were used to test the sewage.
The sewage load was 301/24 hrs per 1 running meter for underground filtration beds and 1801/24 hr per 1 m^2 for the filtering wells. The application of sewage continued for 42 days.
The results showed that the purification from viruses and bacteria was more satisfactory in the case of the underground filtration beds than in the case of filtering wells. After application in the period of maturation, Coxsackie A viruses and E. Coli were more frequently detected in the concentrated filtrate but only until the 20th day. The underground filtration let through 0.002 to 0.042% of the initial bacteriophage while the filtering well let through 0.007 to 0.109%.

44 GRIGOR'EVA, L. V., GORODETSKII, T. G., OMEL'YANETS, T. G., BOGDANENKO, L. A., 1965. Survival of Bacteria and Viruses on Vegetable Crops Irrigated with Infected Water. Hygiene and Sanitation 30:10-12:357-361.
Investigates the survival of the pathogenic bacteria of the coli group, Coxsackie viruses of Group A, Escherichia coli, and bacteriophages on the leaves and fruits of plants irrigated with infected water. The plants were grown in a laboratory condition but with natural simulation. At different stages of vegetation period the plants were sprinkled with sewage water with a low coli titer (10-8 -- 10-15) or with water which was additionally contaminated with coli bacteriophage. Survival times of enteroviruses and pathogenic bacteria of E. Coli family is compared. The survival time depends on several factors, such as the species of plants, the conditions and length of the vegetation period, the past of the plants investigated (whether leaves or fruit), the species and strain of the microorganism and its initial concentration. Three

vegetables species were investigated and their conditions for the survival of bacteria and viruses were discussed. The least favorable conditions for the survival of bacteria and viruses were offered by cabbage leaves and the most favorable by tomato leaves.

45. GUYMON, B. E. 1957. Sewage Salinity Prevents Use of Effluents for Golf Course Irrigation. Wastes Engrg. 28:80-83. P.H.E. Abst. 37:S:69.
The salinity of the treated sewage of the city of Coronado, California was found to be too high to permit its use for irrigating a proposed 18-hole public golf course on land bordering San Diego Bay. The annual cost of irrigating the tract with the municipal supply was estimated to be $26,000. The author presents salinity data for both the public water supply and the sewage, covering a typical 24-hour day. A method of separating the merging flows of two main outfall sewers, one high in salinity and the other acceptable, is illustrated and briefly explained.

46. HAJEK, B. F. 1969. Chemical Interactions of Wastewater in a Soil Environment. Jour. WPCF 41:1775-1786.
The effects of wastewater disposal to soil will be scrutinized increasingly to predict the assimilative capacity of soil. One phase of wastewater disposal to soil, that of chemically contaminated wastewater, has been discussed to acquaint environmental engineers and scientists with experimental methods presently available for making such a prediction. These methods are wastewater chemical characterization, and chemical interactions of soil-waste systems.

47. HARMSEN, H. 1957. Irrigation and utilization of sewage residues. Stadtehygiene 8:25-27.
In view of the objections raised, especially from the hygienic point of view, to the provisions of DIN 19 650, issued in 1956 and dealing with irrigation and the use of sewage, the author surveys work done and legal enactments on the hygienic problems of use of sewage on land.

48. HARVEY, C. AND CANTRELL, R. 1965. Use of Sewage Effluent for Production of Agricultural Crops. Texas Water Development Board, Austin, Report 9 December 1965.
The report summarizes the results of a 1965 Texas survey on agricultural use of sewage effluent. Discussed are the suitability and cost of effluent for crop production as well as crops and acreage irrigated. The authors state that "crop irrigation with effluent can contribute to the economy of the area and solve satisfactorily the sewage disposal problem."

49. HEUKELEKIAN, H. 1957. Utilization of Sewage for Crop Irrigation in Israel. Sewage and Industrial Wastes 29:8:868-874. Chem. Abs. 51:col 17050B, 1957.
The low annual rainfall in the agricultural areas of Israel and its lack of sufficient water supplies makes irrigation with sewage effluents feasible. The problems involved are: (1) construction and collection systems for the wastes, (2) transmission of the sewage to agricultural areas, (3) adequate treatment of wastes prior to irrigation, (4) development of suitable farming areas and practices for the utili-

zation. The land is irrigated about once in 10 to 15 days receiving ½ inch during 220 days. At this rate irrespective of the method of application there is no problem with odors or flies unless the sewage had developed septicity prior to its arrival at the irrigation site. There are 2 alternatives as to previous treatment of the sewage: (1) secondary treatment for unrestricted crop irrigation or (2) primary treatment for irrigation of crops not eaten raw by human beings such as beets, cotton, pasture and hay, vegetables eaten only after cooking, fruit trees, nursery plants, and ornamental plants and flowers. The primary treatment with restricted use may be the most preferred. Methods of primary treatment suitable for irrigation are: (1) screening or comminution, (2) plain sedimentation tanks, (3) Imhoff tanks, (4) septic tanks, and (5) earth basin tanks. The type of treatment used will depend on the size of the plant, the cost of construction, and the ease of operation. Plots irrigated with sewage show an accumulation of chlorides; however, these are leached out during the rainy season. The sewage also adds 2.5 to 3 kg. of Nitrogen, 1.0 kg. of phosphorus, and 1.3 to 1.6 kg. of potassium per capita per year.

50. HILL, R. D., BENDIXON, T. W., ROBECK, G. G. 1964. Status of Land Treatment for Liquid Waste - Functional Design. Presented at Water Pollution Control Federation, Bal Harbour, Florida, October 1, 1964.
The distribution of liquid waste-land disposal systems by type of waste, application technique, and geographic location has been presented. The over 2,000 reported installations spread over many states with vastly different climatic conditions have been used for the disposal of different wastes, and have had great diversity in the waste application techniques used.
A review of the literature revealed that the median application rates at seepage ponds, ridge and furrow, and spray systems were 1.5, 0.74, and 0.22 inches per day respectively. Sand soils were used almost exclusively at seepage pond installations, while soils with poorer infiltration and percolation rates were usually used at ridge and furrow, and spray sites. Cover vegetation reported in the literature is described and its use at soil systems reviewed.

51. HOLLER, K. 1952. Fifteen Years of the Uthleben Sewage Cooperative. Wasserwirtschaft-Wassertechnik 2:397.
Progress and effect of 15 years of sewage farming and technical installations are described. Of about 613 hectares (1,515 acres) 440 hectares received spray irrigation and 173 hectares received trench irrigation. The present maximum sewage flow is about 4,800 cu. m. per day (1.27 m.g.d.) The raw sewage flows through a grit removal unit and thence into a 5,000 cu. m. equalizing lagoon functioning at the same time as a settling basin. This is drained once a year for sludge removal. About 50 per cent of the wet sludge is used directly with cattle manure on the fields. The other 50 per cent is dried on beds and composted with garbage. The sewage is pumped to the land through movable pipes. The importance of proper timing of irrigation is emphasized and illustrated for grains (oats, wheat), beets, rape seed, and pastures. Comparisons of crop yields with non-irrigated surrounding areas are given.

52. HYDE, C. G. 1950. Sewage Reclamation at Melbourne, Australia. Sew. and Indus. Wastes 22:8:1013-1015.
Geological, climatic, and population statistics at Melbourne, Australia are given. A description of the sewage farm facilities is included. These facilities handle an average load of 58 m.g.d. Grass filtration is used and cattle are raised or fattened on the plots.

53. JANERT, H. 1954. The suitability of different methods of application for the utilization of sewage. Wasserw.-WassTechn. 4:231; Zbl. Bakt. I Ref., 1955, 157:343.
The author recommends sub-soil irrigation as the best method for agricultural utilization of sewage. Costs for surface and sub-soil irrigation are about the same; artificial rain costs more than twice as much. The hygienic advantages of sub-soil irrigation are discussed in detail.

54. JEY, B. N., AGADZHANOV, R. A., ALLAKHVERDYANTS, S. A., DASHKOVA, E. M. MAIOROVA, L. A., SHTOK, E. SH. 1960. The Results of Sanitary and Hygienic Investigations of Ashkhabad Sewage Farms. Gigiena i Sanitariya No. 12, 18-20.
The results of sanitary and hygienic investigations performed at the Ashkhabad sewage farms have shown that the irrigation of farm fields with sewage from Ashkhabad city produces heavy contamination of the soil. The processes of mineralization and natural soil purification, taking place during the interval of 3 to 6 days in between the watering periods cannot cope with all the amount of organic waste introduced into the soil.
The vegetables grown on sewage farms and, especially, those in contact with the surface of the irrigated soil, are contaminated with Esch. coli and eggs of helminths.
In contrast to other parts of the USSR, in these regions, the eggs of helminths are found in water, soil and on vegetables only during autumn and spring months.

55. KARDOS, L. T. 1967. Waste Water Renovation by the Land--A Living Filter. Agriculture and the Quality of Our Environment, American Association for the Advancement of Science, Pub. No. 85, 1967, Washington, D. C., pp. 241-250.
The 4 year Penn State Project was designed to reclaim waste water by the land using a "living filter" system. The soil ranged in surface texture from silt loam to silty clay loam, with slopes averaging 4%. Each irrigation area was 240 ft. wide and 800 ft. long, and the crops were grown in a strip arrangement in a rotation sequence. The rate of application of effluent in 1963 was 0.64 in/hr, and 0, 1, and 2 in/wk. was applied. In 1964 and 1965 the rate was 0.25 in/hr. The fertilizer equivalent of the waste water at the 2 in/wk level was equal to that of 2000 lbs of 7-12-11 fertilizer/acre in 1963, 2000 lbs of 14-15-14 fertilizer in 1964, and 2000 lbs of 5-10-5 fertilizer in 1965. The crops were harvested and subsamples were analyzed for nitrogen, phosphorous, potassium, calcium, magnesium, etc. Soil water samples were taken by means of suction lysimeters. Since the beginning of the project the area has been under severe drought conditions; however, hay

yields were increased 139%, corn silage 39%, corn grain 78%, and oats grain 70%. The phosphorous and potassium concentrations in the alfalfa were 63 and 35% higher in the effluent-treated plots than the control plots, while at the same time the quantities removed were 300 and 224% higher. At the 1 in/wk level corn silage removed 200% total N, 39% P, and 62% K. The microbes also degrade the complex organic molecules. After three years of operation water samples showed that the renovation capacity of the soil profile was still excellent. The growing crop prevents the break through of excessively large amounts of Nitrate Nitrogen. The "living filter" also recharges the water table by about 80% of the effluent applied to the land.

56. KIKER, J. E., JR. 1955. Reclamation of Water from Sewage. Preliminary Draft of a paper presented March 15, 1955 at the 8th Florida and Public Health Engineering Conference, University of Florida, Gainsville. Gives the need for water reclamation and reuse. Examples stated are the Bethlehem Steel Company at Sparrows Point, Maryland who has spent in excess of $2 million for the development of a water supply with the treated effluent of the Back River Sewage Treatment Works of Baltimore City and the University of Florida which irrigates its lawns with effluent from its treatment plant. The University has found the effluent valuable for irrigation in the production of flowers and in growing shrubbery and turf for campus beautification. Other uses, potentialities, and benefits of water reuse are discussed along with planning and operation recommendations.

57. KREUZ, A. 1955. Hygienic evaluation of the agricultural utilization of sewage. Gesundheitsing. 76:206-211.
The author discusses, with references to the literature, the hygienic problems arising from the agricultural utilization of sewage, giving accounts of the amount of agricultural use in the U.S.A., Gt. Britain, the Soviet Union, and Germany, and dealing with dangers to health, the effect of treatment on pathogenic organisms and worm eggs, and precautions necessary in the use of sewage and sludge. The fertilizing and humus-forming effects of sewage and sludge and the effect of treatment on the fertilizing constituents are also considered.

58. KRONE, R. B., MCGAUHEY, P. H., GOTAAS, H. B. 1957. Direct Recharge of Ground Water with Sewage Effluents. Jour. San. Engrg. Div. - ASCE 83:SA4: Paper 1335 25pp.
The results of an investigation found that secondary sewage effluents could be successfully injected underground through an experimental recharge well at a rate equal to about ½ the safe yield of the well, and that the well could be redeveloped to restore its original characteristics after clogging by injecting chlorine. An injection rate of 8.4 gal/min/ft of aquifer was found to be practical. Gravel packing of the recharge well was found to be necessary.
No particular danger to public health as a result of travel of bacterial pollution with ground water was found. Coliform concentrations of 2.4×10^6/100 ml. at a distance of 100 ft. from the recharge well in the direction of normal movement from the well and 63 ft. for other directions. No coliforms appeared at greater distances. Neither

increased concentrations of organisms nor greater injection rates produced greater distances of bacterial travel in the aquifer. It was also concluded the mineral quality of recharged water may be expected to undergo little improvement as it moves through an aquifer; however, the normal ions in sewage, other than industrial sewage, are not pollutants in the usual sense of the word.

59. KUDRYAVTSEVA, B. M. 1968. Influence of Lyubertsy Filtration Beds upon Sub-surface Waters. Hygiene and Sanitation 33:1-3:271-274.
The Lyubertsy filtration beds are in an area where artesian waters are extensively used for water supply. The beds are situated on a plain. The geological structure of the area shows that the ground waters occur in Quaternary sands at a depth of about 1 m. The artesian waters occur in Upper, Middle, and Lower Carboniferous fissured limestones. The principal confining layer is formed by Upper Jurasic clays.
The sewage received by the filtration beds has the usual composition of household-fecal sewage. Twenty-six bore holes were drilled for studies of ground waters around the filtration beds. Ground waters from bore holes near the beds had a high concentration of ammonia (4 mg/1), chlorides (85 mg/1), sulfates (105 mg/1) and dry residue (500 mg/1), as against 0.5 mg/1 ammonia, 15 mg/1 chlorides, 40 mg/1 sulfates, and 180 mg/1 dry residue in the water of a control bore hole. The coli index of the ground waters decreases from 500 at a distance of 5 m from the filter to 5 at a distance of 125 m, their progress over this distance taking approximately 300 days. Over the same period, the concentration of ammonia nitrogen decreased from 4 to 0.5 mg/1, oxidizability from 10 to 5 mg/1, etc. The concentration of chlorides in the flow of ground water increased with increasing distance, from 85 to 127 mg/1, their concentration in the sewage being at the level of 50-60 mg/1 during the last two years.

60. KUO, T. 1965. The utilization of city sewage in China. Vattenhygien 21:84-87.
The author discusses the increasing utilization of municipal sewage for irrigation and fish culture in China. The sewage undergoes preliminary treatment to conform with the standards of public health and to ensure that the contents are suitable for farming and fish culture. Over a number of years there has been a remarkable increase in the production of wheat, rice, and kelp. The need is stressed for further research into the effects of infiltration of the sewage into the ground water, and the measures needed to protect soil and crops from extraneous contamination and to prevent the spread of contagious diseases.

61. KUTEPOV, L. E. 1968. (Purification of effluent water by soils) Pochvovedenie No. 11, 57-69.
A review with 55 references. Fields irrigated with effluent can be used as independent purification systems or can be combined with artificial biological purification systems.

62. LEHMAN, G. S. 1968. Soil and grass filtration of domestic sewage effluent for the removal of trace elements. Thesis, University of Arizona. 129 pp.; Diss. Abstr. 1969, 29:B:3578.
Studies were carried out on the removal of trace elements from sewage-works effluents by filtration through soil and grass, using different cycles of application. The best results were obtained with application for one day, followed by 3 dry days; this provided the necessary aerobic environment for removal of trace metals, nitrification of reduced nitrogen compounds, and removal of coliform organisms, while the short flooding period provided the anaerobic conditions necessary for removal of nitrate by denitrification.

63. MCGAUHEY, P. H., KRONE, R. B. 1967. Soil Mantle as a Wastewater Treatment System: Final Report. Sanitary Engineering Research Laboratory, College of Engineering & School of Public Health, Univ. of California, Berkeley. SERL Report No. 67-11.
The problem of treating sewage effluent through soil systems is defined with concepts and rationale discussed. The problem of clogging of the soil and quality changes in the soil systems is observed and reported. Existing systems are described and requirements for engineered soil systems are suggested.

64. MCGAUHEY, P. H., KRONE, R. B., WENNEBERGER, J. H. 1966. Soil Mantle as a Wastewater Treatment System: Review of Literature. Sanitary Engineering Research Laboratory, College of Engineering and School of Public Health, University of California, Berkeley. SERL Report No. 66-7.
Article reviews the literature on sewage treatment through soil systems. Topics discussed are the problems of soil systems, infiltration and percolation, clogging of the soils, quality changes in soil systems, and engineered systems. 289 references.

65. MARTIN, B. 1951. Sewage Reclamation at Golden Gate Park. Sew. and Indus. Wastes 23:3:319-320. P.H.E. Abstract 31:S:36.
Sewage plant at San Francisco's Golden Gate Park is described. Detention time in the primary sedimentation tank is about 2 hrs. In the aeration tanks the detention period is approximately 8 hrs. The effluent after treatment with chlorine meets drinking water standards. Until 1947 the plant effluent was used solely for maintaining the level of various lakes in the park. After July of that year the effluent was pumped directly into the irrigation system and Stow Lake. Costs are evaluated.

66. MERRELL, J. C., JR., JOPLING, W. F., BOTT, R. F., KATKO, A., PINTLER, H. E. 1967. The Santee Recreation Project Santee, California - Final Report. U. S. Dept of the Interior, Fed. Water Poll. Control Administration. Wat. Poll. Contr. Res. Ser. Pub. No. WP-20-7.
This report presents the results of a study of the Santee, California lakes. The Santee Lakes were deliberately planned the community's reclaimed sewage effluent. The seven-agency cooperative study evaluated the fate of virus, total and fecal foliform, and fecal streptococci as waste water passed through conventional secondary treatment processes, the sand filtration, and the recreational lakes. It was found that the additional treatment provided by intermittent sand filtration met most

of the requirements for recreational use of the terminal ponds. No health hazards have been demonstrated by the viral or other findings and this fact had considerable impact in the promotion of public acceptance of the use of the recreational facilities.

67. MERZ, R. C. 1955. A Survey of Direct Utilization of Waste Waters. Calif. State Water Poll. Control Bd. Sacramento, Pub. No. 12, 80 pages.
A comprehensive survey of current practices in the use of waste water by industry, by agriculture, for recreation, and for groundwater recharge. The study permitted the following conclusions with regard to the agricultural use of waste water: (a) Sewage effluent has been shown to be a satisfactory irrigation water, where chemical concentrations permit and where health regulations pertaining to type of crop are met; (b) Sewage effluent has been shown to be an adequate medium for leaching alkali soils, or improvement of barren soils; (c) Reclamation by land irrigation is a means of protecting the quality of surface waters; (d) Irrigation provides secondary treatment and disposal of wastes in an economical manner and may provide the municipality with a substantial monetary return; and (e) An ideal use of oxidized sewage effluent is for irrigation of parks and golf courses and as a supply for decorative lakes. Conclusions pertaining to other uses are also given. Numerous examples of reuse are cited, and pertinent abstracts from the literature are included. The bibliography contains 227 entries.

68. MERZ, R. C. 1959. Waste Water Reclamation for Golf Course Irrigation. Jour. San. Eng. Div., Amer Soc. Civ. Engr. 85:SA6, 1, 79-85.
Three years' experience at municipal and military golf courses shows that reclaimed wastewater can be properly used for irrigation purposes. Value is derived from the fertilizing constituents. Difficulties may arise in certain soils due to increased sodium content of the water. Chlorination will prevent odor nuisance as well as the spread of B. coli through wind action.

69. MULLER, G. 1957. Infection of vegetables by application of domestic sewage as artificial rain. Stadtehygiene 8:30-32.
The author describes experiments in which plots of land, on which carrots, cabbages, potatoes, and gooseberry bushes were growing, were watered with settled sewage. The soil, vegetables, and fruits were tested for thepresence of Bact. coli and Salmonella at intervals up to 40 days after application of sewage. The amounts of sewage used were small but Salmonella were detected in the soil and on the potato tubers after 40 days, on carrots after 10 days and on cabbage leaves and gooseberries after 5 days.

70. MULLER, W. 1955. Irrigation with sewage in Australia. Wass. u. Boden 7:12; Zbl. Bakt. I, Ref., 1956, 159:503.
The author gives an account of the conditions in which sewage is used for irrigation in Australia. Only settled and biologically treated sewage may be used. Surface irrigation is preferred. The amounts vary from 350 to 7500 mm a year. Land for arable and pasture use and for fruit growing is irrigated.

71. OAKLEY, H. R., CRIPPS, T. 1969. British Practice in the Tertiary Treatment of Wastewater. Jour. WPCF 41:1:36-50.
Studies effluent standards in Great Britain. Some legal aspects are discussed. Five methods of tertiary treatment given are: pebble bed clarifiers, land irrigation, microstraining, slow and rapid sand filtration, and effluent lagoons. In the section on land irrigation the author states that it is generally recognized that use of land for treatment of anything other than secondary tank effluent by irrigation is wasteful in a country where land is at a premium. Even irrigation with secondary effluent is suitable only for smaller works where this method can serve a particularly useful function in smoothing the inevitable variations in effluent quality. Properly managed land irrigation areas can produce effluents of consistently high quality. Land irrigation is not well suited to large works or to sites in urban areas or areas of high agricultural value.

72. ONGERTH, H. J. AND HARMON, J. A. 1959. Sanitary Engineering Appraisal of Waste Water Reuse. Jour. Amer. Water Wks. Assn. 51:647-658.
This article briefly summarizes the historical development of waste water reclamation and describes ways in which waste water may be utilized. The engineering, public health, economic, legal, and aesthetic problems encountered in waste water reclamation are discussed.

73. ORLOB, G. T., BUTLER, R. G. 1956. Use of Soil Lysimeters in Waste Water Reclamation Studies. Jour. San. Engrg. Div. - ASCE 82:SA3:1002.
Article concerned with infiltration rates, soil particle size (with respect to infiltration rates), soil particle size distribution and effects of clogging on infiltration rates in experiments near Lodi, California. 14 figures and 4 tables.

74. PAGE, H. G., WAYMAN, C. H. 1966. Removal of ABS and other Sewage Components by Infiltration through Soils. Groundwater 4:1:10-17.
The nature and extent of movement of ABS and other sewage components through natural soils were studied in the laboratory and in the field north of Denver, Colorado. Small amounts of ABS and bacteria pass through soils and reach the zone of saturation, where they move laterally down-gradient several thousand feet.
In laboratory studies Denver Sewage - plant effluent was filtered through packed columns of 8 types of soils. ABS was not significantly removed by most of the soils; however, muck, greensand marl, and residual basalt soil initially removed up to 94 per cent of the ABS. Bacterial clogging occurred quickly in the fine soils but only in modest amounts in the course sand, even after three months of flow.
Field studies included analysis of river and irrigation water contaminated from sewage-plant effluent, and well water from selected sites down-gradient between unlined irrigation ditches and the river. Concentrations of ABS and bacteria were significantly reduced during infiltration of irrigation ditch water to the water table. Dissolved solids showed practically no change between the ditches and the wells.

75. PARIZEK, R. R., KARDOS, L. T., SOPPER, W. E., MYERS, E. A., DAVIS, D. E., FARRELL, M. A., NESBITT, J. B. 1967. Waste Water Renovation and Conservation. Pennsylvania State University Studies No. 23, The Pennsylvania State University, University Park, Pennsylvania.
The application of treated effluent to croplands and forrested areas was initiated in 1962 to develop a means of spraying effluent on land throughout the year, to determine the degree of renovation of effluent, to explore the possibility of conservation of water and to measure the effect on soils, crops, trees, and wildlife. The geology, soils, and hydrology of proposed irrigation sites were investigated to ensure safe disposal of effluent by spray irrigation and to avoid excessive runoff, ponding, and water logging of mantle and the type of underlying rocks. The effluent, primarily derived from domestic sewage, comes from the State College sewage facility which has two parallel, 2-stage treatment plants each with a capacity of 2 million gallons a day. Renovation (per cent reduction in concentration of constituents) was demonstrated on crop and forrested areas at all application rates. Sixty to eighty per cent of the water applied to the research areas found its way to the ground water reservoir. The yields of various crops were compared for areas receiving zero, one, or two inches per week of effluent. Renovation of sewage effluent was measured in the forest and found to be comparable to that in the crop areas. Estimates of numbers and kinds of mammals and mosquitoes and of birds and their blood parasites have been obtained from 1962-64. Thus far, no differences have been detected.

76. PARKHURST, J. D. 1965. Progress in Waste Water Re-Use in Southern California. Jour. Irr. & Drainage Div. - ASCE 91:IR1:79-91.
The author emphasizes the extensive planning behind Los Angeles County's current water reuse operation. Waste water reclamation falls into two categories: (1) that which is incidental to water pollution control in inland areas; and (2) planned reclamation for the production and reuse of reclaimed water. The latter would be for the purpose of meeting a particular water resource need as in Los Angeles County. Factors and conditions which justify water reclamation facilities are discussed. The plan developed in southern California should stimulate interest in planning for reuse in other communities that are concerned about their future water resources. The author states, "The question is not whether there will be water reuse, but when, where, and how well it will be implemented."

77. PARNESS, W. H. 1968. Golf Course and Airport Irrigate with Sewage Effluent. Amer. City 83:5:90-92.
Discusses the financial aspects of irrigation with sewage effluent. The city of Livermore, California used this water to create 4 artificial lakes in the golf course; to irrigate the area near the runways which is leased for agriculture adding to the airport's income; to use for fire protection at the airport and golf course. The golf course became self-supporting in 1968. It operated on a budget of $155,600, but income was expected to be $163,000. The airport brought in a net profit that exceeded $7,000 in the first half of the fiscal year 1967-1968.

The high quality effluent from their sewage treatment plant is chlorinated and piped to the golf course lakes and irrigation systems. With its high nitrate content the effluent fosters turf and crop growth. About 35% of golf course maintenance centers around water so this plant comprises a major asset.
In 1967 the city financed a $1.1 million plant expansion with the aid of a $360,000 grant plus their sewer connection fees. This converted the old trickling-filter process into an activated-sludge system and doubled its capacity from 2.5 m.g.d. to 5 m.g.d. The plant removes 96% of the BOD and 96% of the suspended solids. Financial aspects were also discussed.

78. PAULSMEIER, F. 1955. Experiences in the agricultural utilization of sewage. Desinfekt. u. Gesundheitswes 47:118; Zbl. Bakt., I, Ref., 1956, 159:495.
From experience with the irrigation fields of Berlin, the author discusses the agricultural and economic advantages of agricultural use of sewage. He gives figures for the amounts of nutrient substances in the sewage of Germany and deals with arguments raised against agricultural utilization.

79. PENNYPACKER, S. P., SOPPER, W.E., KARDOS, L. T. 1967. Renovation of Wastewater Effluent by Irrigation of Forrest Land. Jour. WPFC 39:2:285-296.
Methods and complete descriptions of apparatus used for sewage treatment through forest soil are given. Study areas are described fully giving plant species on each section. Application rates are given in both British and metric units. Three tables and six figures give composition of effluent before and after percolation, and concentration of materials at different depths.

80. PETER, I. Y. 1958. Sewage Effluent into Sand Dunes. Water and Sew. Wks. 105:493.
The effluent of a number of simple primary treatment sewage plants near Tel-Aviv is pumped and distributed by sprinklers onto unused sand dunes, after submitting the land to a minimum of regrading. Up to now 225 dunams (4 dunams-1 acre) have been cultivated for two years. The rate of application is 8-10 cu. m. per day per dunam for 200-250 rainless days. The crops grown are cattle fodder. Within the first irrigation cycle the sandy soil was turned into good humus and the shifting dunes were stabilized. An experimental percolation area has been set aside and it has been established that the permissible rate of application is 80-100 cu. m. per dunam per day, or about 10 times the desirable rate used for agricultural purposes. This rate of application has helped raise the ground water table by several decimeters.

81. POPP, L. 1967. Bacteriological and virological investigations on the utilization of sewage in agriculture in areas of Lower Saxony. Schr Reihe Kuratorium Kulturbauw. No. 16, 43-80.
Detailed laboratory and field experiments have been carried out to assess the effects of agricultural utilization of sewage in areas of Lower Saxony. Different processes of irrigation, application as artificial rain on plants and soil, and the effect of treatment by subsoil

irrigation and of drainage water from sludge-storage tanks on receiving waters were investigated in connexion with hygienic aspects and with special reference to the viability of pathogenic bacteria.

82. REINKE, E. A. 1951. California Regulates Use of Sewage for Crop Irrigation. Wastes Engr. 22:364,376.
The State Department of Public Health has adopted regulations governing use of sewage for crop irrigation. They prohibit use of raw sewage on growing crops; provide that partially disinfected effluents shall not be used to water growing vegetables, garden truck, berries, or low-growing fruits such that fruit is in contact with the ground; but may be used on nursery stock, cotton, and such field crops as hay, grain, rice, alfalfa, sugar beets, fodder corn, cowbeets, and fodder carrots. Well-oxidized, nonputrescible and reliably disinfected or filtered effluents, which meet the bacterial standards established for drinking waters, may be used without restriction.
The degree of sewage pollution of irrigation waters varies with the source of supply.

83. ROBECK, G. G., COHEN, J. M., SAYERS, W. T., AND WOODWARD, R. L. 1963. Degradation of ABS and Other Organics in Unsaturated Soils. Jour. WPCF 35:1225-1236.
Soil lysimeter studies showed the alkyl benzene sulfonate (ABS) in a septic tank effluent can be degraded from 5 to 35 mg/1 to less than 0.5 mg/1 if applied properly to certain unsaturated soils. Under intermittent loading on a daily basis aerobic organisms survived. Most sandy soils handled at least 0.5 to 1.0 foot per day of waste. Organisms usually found in sewage and soil were able to degrade ABS, 2, 4, 5-T, 2, 4-D, and o-cresol if time were allowed to adjust and handle new organics in the waste. Coliform organisms, odor, turbidity, and COD were greatly reduced and nitrification took place when the ABS was degraded below 0.5 mg/1.

84. ROBECK, G. G., BENDIXEN, T. W., SCHWARTZ, W. A., AND WOODWARD, R. L. 1964. Factors Influencing the Design and Operation of Soil Systems for Waste Treatment. Jour. WPCF 36:971-983.
Soil lysimeter studies with septic tank effluent indicate that soil systems can degrade the new synthetic organics as well as the usual COD components. It appears that groundwater can be protected when wastes are properly applied to the soil. Several important design and operational features are listed which will help effect a 90 to 95 per cent reduction of ABS and other COD components in a septic tank effluent and also protect the groundwater from microbial forms.

85. ROBECK, G. G. 1968. Microbial Problems in Ground Water Ground Water 7:3:33-35.
Research work has indicated that non fecal coliform can develop or increase at a considerable depth within a sewage recharge system. This seems to point to the need of a more specific indicator of fecal organisms, and the need for the removal of waste that might be food and nutrients for the organisms before waste water percolates down more than 1 or 2 ft. Using fecal coliform as a test for the safety of well

water may well be more meaningful than the old test as well as being easier to run. The cost and hazards of making studies concerning enteric virus limit work to small scale tests where cracks, weathering, sunlight, etc. can only be simulated. Using round water rates of a few feet per day, no significant difference in the movement of a 30 micro-milicron virus and a 1 micron coliform was detected, and under the right conditions the coliform multiplied and penetrated deeper than the smaller virus. The amount of virus removed by 2 ft. of sand varies with the flow rate, but in almost every case the virus was removed amazingly well. It was also found that organisms native to domestic sewage can act as a seed for developing a population in the soil to degrade detergents and other organic materials. Oxidizing ammonia to nitrates is for some a cause of concern. There are several possibilities to solve the denitrification problem: 1. organisms can be developed in a waste treatment column of activated carbon or sand that will create denitrification. 2. the nitrates could be removed when the water is withdrawn from the ground by clinoptilolite, a natural zeolite that will selectively remove ammonia-nitrogen from waste water. The problems still need further investigations and tests before they will be practical to put into use.

86. ROHDE, G. 1962. The Effects of Trace Elements on the Exhaustion of Sewage-Irrigated Land. Jour. Inst. Sew. Purif. Pt. 6, 581-585. Water Poll. Abst. 36:421 (2063).
At the Berlin sewage farm, some of the soil has recently shown signs of exhaustion, and crop yields have fallen. Samples of exhausted soil and soil on which healthy plants were growing were examined, particularly for trace elements. The results were compared with analyses of similar samples from a sewage farm in Paris where signs of exhaustion had also been observed. The soil at the Berlin farm is sandy and acid, while that at the Paris farm is rich in lime. The results of the analyses are tabulated and discussed. It appears that the main cause of exhaustion at both Berlin and Paris is the presence of high concentrations of copper and zinc.

87. ROMANENKO, N. A. 1969. Hygenic Requirements for Irrigation with Sewage Outside the USSR. Hygiene and Sanitation 34:10-12:275-278.
Reviews the practices, policies, regulations, and health standards that have evolved out of the practice of using soil systems for disposal and purification of sewage, sludge, and effluent.

88. RUDOLFS, W., FALK, L. L., RAGOTZKIE, R. A. 1951. Contamination of Vegetables Grown in Polluted Soil: I. Bacterial Contamination. Sew. & Ind. Wastes 23:3:253-268.
Studies the removal of bacteria and decontamination of vegetables irrigated with sewage. Methods discussed include storage, washing with water, detergent solutions, decontamination formulations, and germicidal rinses. Methods of harvesting the fruit are discussed. Research was done on tomatoes which had been irrigated with sewage and records were kept. For each tomato the following information was recorded: (a) the plant on which it grew, (b) its height from the ground, (c) its state of ripeness, (d) the presence of cracks or crevices in and about the stem and blossom ends, (e) the shading of the fruit by leaves and

other fruit. Climatological data were given. Those tomatoes (even those grown on soil which had received previous but not current sewage treatment and those which had received none at all) that had normal stem ends instead of those which were cracked and split showed lower average contamination. Little evidence could be found of a relationship of the coliform concentration to the height of the fruit above the ground and the splashing of the soil upon the fruit during rain. Complete exposure of tomatoes to the sun resulted in lower coliform concentrations on the surfaces of normal tomatoes.

89. RUDOLFS, W., FALK, L. L., RAGOTZKIE, R. A. 1951. Contamination of Vegetables Grown in Polluted Soil: VI. Application of Results. Sew. & Ind. Wastes 23:8:992-1000.
Studies have been made with tomatoes, lettuce, spinach, and carrots grown in soil receiving sewage irrigation and artificially contaminated with E. Coli, Salmonella, Shigella, E. Histoytica, Ascaris eggs, and feces. Preparation for assays included the maceration of whole vegetables in a Waring Blender because no successful way to wash the organisms from the vegetables has been found. The coliform group of bacteria was used to test the sanitization of the vegetables. It was found that even vegetables grown in the absence of sewage pollution contained numbers of coliform organisms; therefore, it was determined that vegetables receiving surface irrigation with sewage, but not containing a higher number of coliform than normal vegetables are safe to eat. Overhead irrigation was found to be safe also, if the spraying is discontinued at least one month before harvesting. It was found that strains of Salmonella and Shigella do not survive on vegetables more than one week. The resistance of cysts of E. Histolytica depends on the amount of moisture present, but under field conditions they usually survive only three days. To reduce the danger of transmitting amoebic dysentery, the last application containing these cysts should be one week before harvest. Ascaris eggs were recovered in reduced numbers from the vegetables one month after application, but they had all degenerated. The danger of transmission of Ascaris is greatly reduced if fecal matter fertilization is stopped one month before harvest. It has also been found that the only reliable method of decontamination of bacterial, amoebic, and helminthic organisms after the vegetables have been harvested is pasteurization.

90. SCHULZE, K. L. 1966. Biological Recovery of Wastewater. Jour. WPCF 38:12:1944-58.
The need for better quality in renovated wastewater has prompted the development of tertiary or advanced treatment methods. After biological tertiary treatment it is considered a good approach to use the effluent for irrigational purposes. The many tons of Nitrogen and phosphorous contained in the effluents would be a valuable asset in the production of crops and timber as well as serving to replenish the ground water table. It is preferrable to use tertiary effluents instead of primary or secondary to cut down on problems of putriscible matter and odors. Even with tertiary treated effluents there may be problems such as accumulation of sodium and chloride in the soil. There would also be the difficulty and expense of storage of the effluent

during the winter months. However, in considering the problems and inadequacies of todays treatments, it is imperative to reorient our thinking and to develop new approaches to the problem.

91. SCHWARTZ, W. A. BENDIXON, T. W. 1970. Soil Systems for Liquid Waste Treatment and Disposal: Environmental Factors. Jour. WPCF 42:4:624-630.
Evaluates quantitatively selected aspects of unsaturated depth of media, climate, and vegetation, and their effects on the operation of soil systems. The quantitative approach was intended to permit comparison between various environmental situations and thus contribute to the establishment of guidelines for site selection as an integral part of soil system design.
The studies were performed at the Robert A. Taft Water Research Center, Cincinnati, and outdoors at the Loveland, Ohio, waste water treatment plant. Ground water depth studies were made under room temperature conditions, using 6 in. (15 cm) diameter lysimeters; the studies concerned with climatic effects and vegetation used 3 ft (0.9m.) diameter units in the natural environment. The units were put into the ground, flush with the ground surface, with graded gravel bases and appropriate underdrains to collect effluent samples (composited daily). All units were dosed intermittently once each day. Results were given.
Biological treatment and hydraulic longevity and effects made on them by the different seasons and by vegetation were discussed. Plant assimilation of nitrogen and phosphate were also discussed.

92. SEGAL, A. 1950. Sewage Reclamation at Fresno, California. Sewage and Ind. Wastes 22:1011-1012.
The city of Fresno owns and operates a municipal farm, 1292 acres in area, where the treated sewage effluent is used for the irrigation of crops. In addition to 600 acres of grassland, the water is used to irrigate such forage crops as alfalfa, sudan grass, and kaffir corn. A herd of over 600 fine Hereford cattle are maintained on the farm. For the fiscal year ending June 30, 1949, the city realized an operating profit of $9,346.
In 1921, the city owned only 812 acres, and disposal of sewage effluent created a serious problem with a high water table only about 2 ft. below the surface. Law suits were filed by adjacent landowners for waterlogging and flooding adjacent lands. To correct this situation some of the land was lagooned, and 9 wells were installed from 200 to 300 ft. deep with no perforation of the casing less than 100 ft. from the surface. The wells were successful in lowering the water table. Water from the wells was diverted to the Fresno Irrigation District for use in its system. Increased irrigation agriculture and installation of many wells in the area have helped to improve the groundwater level and facilitate the percolation of plant effluent into the underground basin.

93. SEPP, E. 1970. Nitrogen Cycle in Ground Water. Bureau of Sanitary Engineering, State of California Department of Public Health
The sources of nitrogen compounds in soil and ground water are numerous and diverse. The compounds undergo complex transformations caused by environmental factors. Atmospheric precipitation adds from 0.7 to 14 pounds of nitrogen per acre to the soil annually. Nitrogen

fixing organisms in the soil may add from a few pounds to 200 pounds per acre of nitrogen per year. Depending on circumstance, either agricultural practice or land disposal of sewage may be the major contributor of nitrogen to groundwater. Ammonia and ammonium ion are held close to soil surface by adsorption and cation-exchange reactions. Nitrate and nitrite ions, however, move freely with the percolating water. Experiments showed how nitrogen may be removed from the soil by cropping, leaching, erosion, or volatilization. At present, not enough is known to establish design criteria for controlling nitrate reduction in the aquifer.

94. SEPP, E. 1965. Survey of Sewage Disposal by Hillside Sprays. Bureau of Sanitary Engineering, State of California Department of Public Health. Sewage disposal by hillside spraying was studied at 30 treatment plants. Fourteen of these plants have secondary treatment and the remaining have only septic tanks or Imhoff tanks. Only 10 plants have chlorination. Design and operation of the sprinkling systems were studied giving types of nozzles and pipelines used and causes and effects of nozzle clogging. Application rates operation data and appearance of the spray sites is described. Results of bacteriological and chemical tests, travel of airborne bacteria, and odor and insect problems are discussed. It is recommended that hillside spraying be used only for summer loads. The use of hillside spraying is to be discouraged for year round operation.

95. SEPP, E. 1971. The Use of Sewage for Irrigation--A Literature Review. Bureau of Sanitary Engineering, Dept. Pub. Hlth., State of California. After reviewing literature from many areas in the U.S., Europe, and the Mid-east, it was concluded that the consumption of raw vegetables irrigated with sewage has given rise to outbreaks of typhoid fever and worm infection. Crops grown in fields may be contaminated directly by sewage and polluted water, or indirectly through contact with polluted soil. Pathogenic bacteria, amoeba cysts, and helminth eggs cannot penetrate the surfaces of healthy, unbroken vegetables. Survival times of the various organisms are reported. Studies indicate that the coliform bacteria count on grass and clover leaves drops to the natural level 14 days after sewage application. Bacteriological standards for irrigating crops with sewage have been established in some of the western states of the U.S. and in Europe. Wide variation in the requirements, however, exist.

96. SOPPER, W. E. 1968. Renovation of Municipal Sewage Effluent for Ground-water Recharge through Forrest Irrigation. Paper No. 571 Internat. Conf. on Wat. for Peace, Wash. D. C. 1967. Jour. WPCF 40:6:969-974.
Centre County, Pennsylvania has a problem of water supply shortage and pollution of existing supply by dumping treated sewage into the stream. A study project was set up to attempt to solve these problems.

Effluent treated by primary settling, standard and high rate trickling filters, modified activated-sludge process, final settling, and chlorination was used to irrigate stands of white spruce, red pine, and a 60 yr. old natural mixed oak stand. The effluent was applied at a rate of 0.25 in/hr at 1 to 2 in/wk except 1 plot which received 4 in/wk. The effluent was renovated effectively and the ground water level was increased.

97. SOPPER, W. E. 1968. Waste Water Renovation for Reuse: Key to Optimum Use of Water Resources. Water Research Pergamon Press 2:471-480.
In order to meet the increasing demand for sewage purification, treated municipal waste water was applied to forrested areas at various rates of application to determine the feasibility of land disposal of such effluents and to determine to what extent effluents could be renovated by the biosystem and recharged to the ground-water reservoir. It was found that satisfactory renovation of waste water was achieved when the effluent was applied at rates of 1, 2, and 4 in. per week in forested areas during the period April-November. Approximately 90 per cent of the water, applied at 2 in. per week during this period was recharged to the groundwater reservoir. Results of this study appear to indicate that municipal waste water can be satisfactorily renovated for groundwater recharge through irrigation of forrested areas under controlled conditions.

98. STEFFEN, A. J. 1964. Control of Water Pollution by Wastewater Utilization: The Role of the WPCF. Wat. & Sew Wks. 111:384-385.
The Water Pollution Control Federation has stressed the great importance of wastewater reuse in its Statement of Policy, Point No. 9: "That Wastewater represents an increasing fraction of the nation's total water resource and is of such value that it might well be reclaimed for beneficial reuse through the restoration of an appropriate degree of quality." The concern of the WPCF is evidenced by the many papers and discussions on this subject that are presented at Association and Federation publications and by the various medals and awards presented for research in this field.

99. STENBURG, R. L., CONVERY, J. J., SWANSON, C. L. 1968. New Approaches to Wastewater Treatment. Jour. Sani. Engrg. Div. - ASCE 94:SA6:1121-1136.
Pilot plant and full-scale plant research and development studies of conventional process modifications and tertiary processes will serve to develop design data and provide more accurate and reliable cost-quality relationships for many individual and combined treatment processes. Basic research and laboratory-scale studies of other approaches to wastewater treatment are also being conducted. As new processes are developed, they will be evaluated in pilot plant and full-scale facilities.
Waste characteristics vary widely with locations and each waste stream must be considered individually in selecting unit processes.
Costs of tertiary treatment will be high by present standards.
Greatly increased expenditures will be required to eliminate pollution of our lakes and streams. Water reuse by industry and for nonpotable

purposes will be necessary to reduce the financial burden. Potable water reuse by mixing with fresh water supplies is considered to be a distinct possibility in the future.

100. STONE, R., CONRAD, E. T. 1970. Automatic Water and Waste Treatment Plants in Operation. Civil Engrg - ASCE 40:5:37-40. Selected Water Res. Abs. 3:24:34.
Description of an automatic waste treatment plant which reuses purified waste water for recreational purposes with a portion of the effluent being used for hillside irrigation. The effluent for irrigation is not recharged into the recreational system.

101. THOMAS, R. E., BENDIXON, T. W. 1969. Degradation of Wastewater Organics in Soil. Jour. WPCF 41:5:808-813. Wat. Poll. Abs. 42:10:461.
The results of Lysimeter studies show that soil microorganisms can digest much of the organic carbon contained in primary and secondary wastewater effluents. About 80% of the organic carbon from septic tank effluent was digested under a variety of conditions. Large variations in temperature, the loading rate, and the duration of dosing had no effect on the percentage of the organic carbon which was degraded. Organic carbon application rates up to 31 tons/yr/acre. A loading rate of 3.7 tpms/yr/acre resulted in a net reduction in the organic carbon content of a silt-loam soil. CO_2 equivalent to about 60% of the degraded organic carbon was released at the soil surface in one experiment. Sludge loadings equivalent to 30 tons/yr/acre of organic carbon can be applied to sandy soils for extended periods without resulting in a detrimental accumulation of organic residues in the soil. Based on typical values for the composition of sludge,this would be equal to 100 tons/yr/acre of dried digested sludge solids. Proper management of liquid and organic carbon loads can result in long-term continuous, operation with only minor changes in the organic carbon content of the soil. Future studies are planned to evaluate the interaction between loading factors and the alteration of the physical and chemical properties of the soil.

102. TODD, DAVID K. 1965. Economics of Groundwater Recharge. ASCE Proc., 91:HY4:249-270.
Many variables are involved in determining the cost and economic advantage to be gained from artificial recharge of ground water aquifers. Information upon which to base such estimates is scarce. The size, purpose, and method of recharge are significant factors, as are land and water costs. Data from several recharge operations are presented in an attempt to arrive at a logical basis for estimating these costs.

103. TRAVIS, P. W. 1960. Organizing a Sewage Effluent Utilization Project. Pub. Works 91:119-120.
Following successful trial projects by the Orange County Farm Bureau and other agencies to test the feasibility of using domestic sewage effluent for crop irrigation, an agreement was drawn up between the Sanitation Districts and about 30 land owners setting forth the rules governing the use of domestic sewage effluent from the district's lines for irrigation. The Talbert Water District was formed and, soon after a bond issue was passed, an industrial waste permit was acquired, and

the constructional and operational plans were approved by the Health Department. The agreement concerning use of the effluent restricted its use to irrigation of alfalfa, sugar beets, dried beans, and dried peppers and it also set forth requirements to insure that sanitary and healthful conditions were maintained at all times. The effluent is made available by 3 pumps that supply the 40,000 ft. irrigation system at a capital cost of about $100 per acre. Two problems have developed: corrosion by sulfides and the odor. The latter has been solved by dripping Alamask into the water. Over all the farmers seem satisfied and the project has proven to be worthwhile.

104. TRIEBEL, W. 1966. Experiences with the disposal of sewage sludge in agriculture. Korresp. Abwass. No. 10, 11-16.
In a detailed report on the activities of the Niersverband, which is responsible for the protection of German waters in the 1348-km^2 catchment area between the Rhine and the Maas, special reference is made to the disposal and utilization of sewage sludge in agriculture. Details are also given of the sewage-treatment facilities at the group sewage works of the Niersverband. The increased use of sewage sludge in agriculture is illustrated in tables, which show that since 1960 the group sewage works have supplied on average 820 farms, resulting in increased yields of truck crops, especially beet, and pastures. Studies showed also that wet sludge, deposited on grassland, had lasting effects in reducing and thus regulating the soil evaporation. Special reference is made to the advantageous sorption capacity of digested sludge which greatly improves dry soil, contrary to dried sludge which, owing to irreversible hydrophobia (caused by the drying process) has adverse effects on the sorptive soil structure. Compared with artificial fertilizers the use of sludge in agriculture presents more work; this however is compensated by the valuable properties in the humus, restoring the exploited soil. Existing parasites and micro-organisms are destroyed by pasteurization plants which have recently been installed, operating at a temperature of 65°C and for a period of 15 min., to comply with health regulations.

105. VAISMAN, YA. I. 1963. The Spread of Bacterial Contamination in Underground Water. Hygiene and Sanitation 29:4:21-26, 1964.
From the data from the literature review at the first of the article it is concluded that the existing data are extremely controversial with respect to the quantitative characteristics of the main limiting factor which should be made the basis of calculations for determining the boundaries of the second belt of the safety zone for underground water supply sources. This precipitated a study of bacterial spread in underground water. It was concluded that the colon bacillus can go a distance of over 850 meters in the ground current in medium-grain sand with cross-layers of gravel and pebble deposits, and that 400 days should be necessary for complete self-purification of the ground flow from bacterial contamination.

106. WERLY, E. F. 1958. The Use of Sprinkler Irrigation Systems for Waste Disposal. Irrig. Engrg. & Maintenance 8:1:21-27.
Discussion of the problems, requirements, and considerations given for the development of an efficient and economic sprinkler system for waste disposal.

107. WHEATLAND, A. B. AND BORNE, B. J. 1960. Modifications of polluted waters resulting from percolation in soil. (Water Pollution Research Lab., Stevenage, Engl.). CEBEDEAU No. 49, 225-34.
Tests conducted with a sewage effluent and water from the river Trent indicate that the percolation of these liquids through the soil removes NH^3 by cationic exchange. The removal of NH^3 depends on the nitrification of the NH^3 already absorbed. At normal temps. during most of the year, most of the NH^3 is removed is an intermittent system of distribution (e.g. by 12 hr. cycles) is employed. It is important not to distribute water contg. more NH^3 than the superficial bed can adsorb and to allow sufficient time between distributions for the penetration of atm. 0 and for the adsorbed NH^3 to be oxidized. In practice the rate of percolation will be detd. both by the surface and by the perimeter of the area of aspersion, and the rate per unit of surface will vary inversely with the perimeter. Concns. of Cu, Ni, Cr, Mn, Zn, and Pb in the percolate were much lower than in the water distributed. The proportion of bacteria removed varied between 81% and 96.5% within the test area considered.

108. WHETSTONE, G. A. 1965. Reuse of Effluent in the Future with an Annotated Bibliography. Texas Water Development Board, Austin, Report 8, December 1965. (187pp.)
An excellent comprehensive review of the literature dealing with reuse of effluent for purposes of irrigation, recreation, industry, ground water recharge, and potable water supply. There is a total of 663 abstracts dating from 1892 through 1965. The literature reviewed is broad in scope, covering historical development, current status, and unresolved issues in the reuse of effluents. The abstracts are indexed by authors and subject, and are presented in chronological order.

109. WILLIAMS, R. E., EIER, D. D., WALLACE, A. T. 1969. Feasibility of Reuse of Treated Wastewater for Irrigation, Fertilization and Ground-Water Recharge in Idaho. Idaho Bureau of Mines and Geology, Moscow, Idaho.
It has been demonstrated that under appropriate hydrogeologic conditions wastewater renovated by a porous medium can be expected to meet U. S. Public Health Service drinking water standards. Appropriate hydrogeologic conditions include the presence of an unconsolidated porous medium (such as sand) through which the wastewater can move an appreciable distance (which will vary with geologic conditions) before entering a water supply; the absence of surficial, jointed rocks through which the wastewater might move without appreciable adsorption of dissolved solids by the porous medium; and a water table depth of at least five feet. Hydrogeologic conditions less than optimal will result in less than optimal renovation of the wastewater, in which case care must be taken during application if water supply sources are located near the disposal area. Only rarely will a given hydrogeologic environment not renovate wastewater to the equivalent of secondary (biological) treatment. In many cases renovation of wastewater by vegetation and the geologic column can be substituted for tertiary treatment. Terrestrial disposal has also been used in lieu of secondary treatment.

110. WILSON, C. W., BECKETT, F. E., (ed.) 1968. Municipal Sewage Effluent for Irrigation. Agricultural Engineering Dept. Louisiana Polytechnic Institute, Ruston, La.
Papers given at a symposium held at Louisiana Polytechnic Institute July 30, 1968. Areas covered were Problems and Opportunities; Soil Response to Sewage Effluent Irrigation; Crop Response to Sewage Effluent;Salt Build-up from Sewage Effluent Irrigation; Agricultural Application of Digested Sewage Sludge, Practical Irrigation with Sewage Effluent; Groundwater Recharge with Treated Municipal Effluent; The Movement of Disease Producing Organisms Through Soils; Survival of Pathogens and Related Disease Hazards; Health Regulations Concerning Sewage Effluent for Irrigation; A Technical and Economic Feasibility Study of the Use of Municipal Sewage Effluent for Irrigation; Eutrophication.

111. WILSON, L. G., LEHMAN, G. S. 1967. Reclaiming Sewage Effluent Prog. Agric. In Ariz. 19:4:22-24. College of Agriculture, Univ. of Arizona, Tucson.
Data on preliminary studies, conducted cooperatively by the Water Resources Research Center, and the Sanitary District No. 1 of Pima County is presented. The main purpose of these studies was to determine the effectiveness and durability of grass filters during tertiary treatment of sewage effluent under Arizona conditions. Auxiliary studies were made to determine intake rate and depth of penetration of percolating effluent to provide data for future soil filtration studies.

AUTHOR INDEX

(Figures refer to bibliography entry)

APPENDIX B

RESULTS OF THE QUESTIONNAIRE SURVEY GIVEN TO THE WORKSHOP PARTICIPANTS

Question 1 - Is this an adequate technique for technology transfer?

Participant answers:

"Yes, for this type of data and at this level of data collection."
"It worked well here."
"Surprisingly effective in this instance. My first experience with it."
"Yes."
"Excellent."
"I feel our session was effective in this area; with varied backgrounds and orientation it was often necessary to define terms for adequate communication."
"Yes, I feel this was good way to transfer ideas and technology."
"Excellent."
"It is an additional technique - and certainly serves a purpose - adequate for intended purpose."
"Yes - in addition to workshop subject also."
"Yes, but with not more than 5 individuals for each area and not less than three and with greater selectivity of individuals."
"No, but it will help point uninformed people in the right direction. Its a good way to transfer generalities from one field to another."
"Yes, very good."

Question 2 - What changes would you have made in the pre-workshop phases of the project?

Participant answers:

"I was not involved at the early stages but could have made more of a contribution if I had had more time."
"Earlier distribution of draft. Circulation of a revised draft."
"Need more instruction on what is needed from the consultant - nature, extent and depth of review and comment. How much supplementary material desired, etc."
"Present procedure worked pretty good."
"Would like to have had abstracts of current literature (if pertinent) I do not see the journals on this subject regularly. Have to ask for interlibrary loan on selected articles."
"Earlier mailing or first class mailing of draft; more detail explanations re what was desired in way of treatment of first draft."
"It may have been better if the first draft and second draft with comments could have been submitted prior to the actual meeting. As each of the persons amending have available other persons in their home area which could have been used, for input information. This would have given the two groups more time together."
"It may have been worthwhile to assign each participant a specific topic or topics for which he would have been responsible for reviewing the literature, abstracting pertinent information, and served as discussion leader for his assigned pact."
"Possibly one more exchange of material."
"None."

"A longer lead time for the outside participants and a stronger nucleus of competency in the fields involved in preparation of the initial draft."
"Allow more time for participants to review and comment. I think participants should be asked for a list of topics that should be included prior to seeing the first draft."
"Perhaps it would be advantageous to provide, along with the initial draft, an outline of the points being made (very brief). Then ask the participant to add any other points he thought should be included and maybe ask him to identify the most important ones for each section. Commenting on a write-up is easy but it tends to lock one into the form & subjects which are given."

Question 3 - What changes in the following should have been made?
(a) Physical facilities

Participant Answers:

"No change."
"Facilities were very adequate."
"Excellent."
"Excellent."
"None. They were excellent."
"Quite adequate."
"Good."
"None, Excellent."
"Very nice."
"More than adequate."
"They were very adequate - provision of secretaries an excellent feature."
"No complaints at all. Everything was extremely well-managed. The redrafting is always a problem & I believe the girls did very well."

Question 3 - What changes in the following should have been made?
(b) Conduct of the sessions

Participant answers:

"Good."
"Really great - with the capable and resourceful moderator we had. Might not always work out this well."
"Sometimes discussions get side tracked, less time could have been spent on editorial matters."
"Good. I was lost at first, not quite sure of my mission. I thought the first mailing was all introduction."
"Very good - perhaps more structure would increase output in limited time, however, some secondary benefits could be lost."
"Good."
"None. The size of groups were about ideal. Dividing into two sections was a good idea, because too much time would have been spent in too much discussion if the groups had been larger."
"Have the two groups better coordinated"
"Fine."

"More liaison between the two groups to prevent the unnecessary overlapping activity which occurred."
"Good. Stayed on subject - I don't think split groups should go over the same parts in detail. They should work on separate parts, then combine."
"I think a maximum of 4 people can bounce ideas around faster with not too much loss in content. (If you get the right 4). The two sections may have been a cause of some loss of time. Again, the number of people required it. Maybe if the subject had been different with clearer separations? Perhaps if the groups had been made up of half health and half operation people and each had taken one system. (Maybe not) Perhaps there should have been just fewer participants. Some good progress was made on Wed. a.m., when different pieces were assigned to individuals to come up with a write-up."

Question 3 - What changes in the following should have been made?
(c) Length of the workshop

Participant answers:

"Good."
"It was about the right length. Gracious hospitality was appreciated."
"Fine."
"About right."
"Just about right, perhaps one day longer"
"About right."
"OK."
"The length of the workshop was sufficient. However, I believe that no one would have objected to evening sessions if it would have resulted in a more complete manual. You are to be commended for the dinner arrangements on the first evening. It served as the "ice-breaker" needed to put everyone at ease for the first work session."
"Lengthen it - or have more work done prior to the workshop."
"Fine."
"For this particular project a total of 6 half-day sessions would have been desirable."
"About all one can afford to spend as a group. Someone has to take the time to finish it. Good luck."
"I think it was just about right."

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6 Title

Soil Systems For Municipal Effluents - A Workshop and Selected References

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27 Abstract

An investigation of the use of Soil Systems for recycling treated municipal waste effluents was conducted. The scope of the project included: the preparation of a user manual entitled Applying Treated Municipal Wastewater to the Land: Current Technology and an annotated bibliography of selected references in subject area.

A state of the art investigation was made of the design, operation and control of irrigation and infiltration-percolation types of soil systems. The summarized results from this investigation were used by workshop participants selected from state, municipal, and federal agencies who were involved in soil system activities as a starting point in writing the manual. The workshop ;culminated in the preparation of a draft of the manual. The bibliography contains selections which portrayed or influenced the present state of art in the subject field.

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