ENVIRONMENTAL HEALTH PROJECT

WASH Reprint: Field Report No. 418

Technological and Environmental Health Aspects of Wastewater Reuse for Irrigation in Egypt and Israel: *Final Project Evaluation*

Richard Huntington
James Crook

November 1993

Prepared for
ENVIRONMENTAL HEALTH DIVISION
OFFICE OF HEALTH AND NUTRITION

Center for Population, Health and Nutrition
Bureau for Global Programs, Field Support and Research
U.S. Agency for International Development

USAID

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Environmental Health Project
Contract No. HRN-5994-C-00-3036-00, Project No. 936-5994
is sponsored by the Bureau for Global Programs, Field Support and Research
Office of Health and Nutrition
U.S. Agency for International Development
Washington, DC 20523

WASH and EHP

With the launching of the United Nations International Drinking Water Supply and Sanitation Decade in 1979, the United States Agency for International Development (USAID) decided to augment and streamline its technical assistance capability in water and sanitation and, in 1980, funded the Water and Sanitation for Health Project (WASH). The funding mechanism was a multiyear, multimillion-dollar contract, secured through competitive bidding. The first WASH contract was awarded to a consortium of organizations headed by Camp Dresser & McKee International Inc. (CDM), an international consulting firm specializing in environmental engineering services. Through two other bid proceedings, CDM continued as the prime contractor through 1994.

Working under the direction of USAID's Bureau for Global Programs, Field Support and Research, Office of Health and Nutrition, the WASH Project provided technical assistance to USAID missions and bureaus, other U.S. agencies (such as the Peace Corps), host governments, and nongovernmental organizations. WASH technical assistance was multidisciplinary, drawing on experts in environmental health, training, finance, epidemiology, anthropology, institutional development, engineering, community organization, environmental management, pollution control, and other specialties.

At the end of December 1994, the WASH Project closed its doors. Work formerly carried out by WASH is now subsumed within the broader Environmental Health Project (EHP), inaugurated in April 1994. The new project provides technical assistance to address a wide range of health problems brought about by environmental pollution and the negative effects of development. These are not restricted to the water-and-sanitation-related diseases of concern to WASH but include tropical diseases, respiratory diseases caused and aggravated by ambient and indoor air pollution, and a range of worsening health problems attributable to industrial and chemical wastes and pesticide residues.

WASH reports and publications continue to be available through the Environmental Health Project. Direct all requests to the Environmental Health Project, 1611 North Kent Street, Suite 300, Arlington, Virginia 22209-2111, U.S.A. Telephone (703) 247-8730. Facsimile (703) 243-9004. Internet EHP@ACCESS.DIGEX.COM.

WASH Field Report No. 418

TECHNOLOGICAL AND ENVIRONMENTAL HEALTH ASPECTS OF WASTEWATER REUSE FOR IRRIGATION IN EGYPT AND ISRAEL:

FINAL PROJECT EVALUATION

Prepared for the U.S. Agency for International Development,
Near East Bureau,
under WASH Task No. 473

by

Richard Huntington
and
James Crook

November 1993

Water and Sanitation for Health Project
Contract No. 5973-Z-00-8081-00, Project No. 936-5973
is sponsored by the Office of Health, Bureau for Research and Development
U.S. Agency for International Development
Washington, DC 20523

RELATED WASH REPORTS

Guidelines for Improving Wastewater and Solid Waste Management. WASH Technical Report No. 88. August 1993. Prepared by Richard N. Andrews, William B. Lord, Laurence J. O'Toole, and L. Fernando Requena, with assistance from E. Brantly, P. Roark, and F. Rosensweig.

Guidelines for Water Reuse. WASH Technical Report No. 81. September 1992. Prepared by James Crook, David K. Ammerman, and Daniel Okun.

Central American Regional Workshop on Wastewater Management: San Salvador, El Salvador, July 12-16, 1993. WASH Field Report No. 419. August 1993. Prepared by Armando F. Balloffet and Alan Hurwitz.

Andean Regional Workshop on Alternative Approaches to Wastewater: Santiago, Chile; September 28-October 2, 1992. WASH Field Report No. 394. March 1993. Prepared by J. Ellis Turner and Alan Hurwitz.

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ABOUT THE AUTHORS

Richard Huntington, Vice President and senior social scientist with the International Science and Technology Institute, Inc. (ISTI), has over 20 years' experience in developing countries as a project manager, research coordinator, consultant, and university professor. In Egypt, he served as ISTI's Chief of Party for the Neighborhood Urban Services Evaluation Project (1983-86), as field research coordinator for WASH's assessment of A.I.D.'s $125 million village water supply program (1987-88), and as an evaluator of the social and political aspects of the Regional Cooperation Project on Vector-Borne Diseases (1985). Huntington led A.I.D.'s first broad evaluation of the PVO support program in the West Bank and Gaza in 1984. He was director of a major two-year study of institutional development of PVOs in 18 countries. In Sudan, Huntington served as Harvard's Field Research Coordinator for an A.I.D-funded rural development project. At the American University in Cairo (1981-84), Dr. Huntington directed rural studies of the social organization of irrigation, the introduction of a new agricultural processing technology, and village craft production and marketing. Dr. Huntington has served on the faculties of Harvard University (1974-81), Princeton University (1984), the American University in Cairo (1981-84), and the University of Khartoum (1979-80). He is author of three books, including *Irrigation and Society in Rural Egypt*, and numerous articles. He has a Ph.D. in anthropology from Duke University.

James Crook is an environmental engineer with Camp Dresser & McKee Inc., Cambridge, Massachusetts, and has firm-wide responsibility for technical coordination and guidance of water reclamation and reuse activities. He was previously employed by the California Department of Health Service, where he developed that state's water reclamation criteria. Dr. Crook was the principal author of water reuse guidelines prepared for the U.S. Environmental Protectional Agency and U.S. Agency for International Development and has provided technical guidance and assistance on numerous reuse projects in the United States. His international experience includes water reclamation and reuse projects in Brazil, Canada, Chile, and Morocco. Dr. Crook has a B.S. degree in Civil Engineering from the University of Massachusetts and M.S. and Ph.D. degrees in environmental engineering from the University of Cincinnati.

ACRONYMS

A.I.D.	U.S. Agency for International Development (Washington)
ASRT	Academy of Scientific Research and Technology
BOD	biochemical oxygen demand
COD	chemical oxygen demand
MERC	Middle East Regional Cooperation
NIOF	National Institute of Oceanography and Fisheries
SES	Suez Experimental Station
TDS	total dissolved solids
TSS	total suspended solids
USAID	U.S. Agency for International Development (overseas missions)
WASH	Water and Sanitation for Health (Project)
WHO	World Health Organization
WSP	wastewater stabilization pond

EXECUTIVE SUMMARY

Shortly after the signing of the Camp David Accords, Congress established the Middle East Regional Cooperation (MERC) Program to fund research projects involving Egyptian, Israeli, and American institutions and scientists working together on problems of common interest and importance to Egypt and Israel.

This final evaluation of the Technological and Environmental Health Aspects of Wastewater for Irrigation Project was carried out in Israel and Egypt from July 5 to 20, 1993. Under this project, Egyptian and Israeli scientists have been working together carrying out research and demonstrations on the safe and effective reuse of sewage water that has been treated to meet World Health Organization (WHO) standards in "low technology" stabilization pond systems. Research and demonstrations involve arid land reclamation and irrigation, fish rearing, monitoring and analysis of health aspects and water quality, and experiments to improve further the stabilization pond technology. Participants meet periodically in Egypt and Israel to plan and evaluate their research and demonstration activities.

The project grantee is the University of Michigan. The participating agency in Egypt is the National Institute of Oceanography and Fisheries which has put together a group of researchers from leading universities and the Ministry of Agriculture. The participating institution in Israel is Hebrew University.

The subject of the project activities — appropriate technology for wastewater treatment and reuse for aquaculture and agriculture in arid lands — remains extremely relevant and important throughout the region. The ultimate scarcity of water resources and issues regarding water quality have moved up on the Egyptian policy and development agenda in recent years. For the region, the allocation of water resources has become a major issue in the negotiations of the peace process between Israel, its neighbors, and the Palestinians. Water resources are central to regional peace and to Egyptian economic development.

The Wastewater Reuse Project carries out the classic activities envisioned for the MERC Program. It has fostered reciprocal visits between Israeli and Egyptian researchers, joint participation in workshops and seminars, training activities, and joint research and publication. Members of a core group of senior researchers have developed strong professional and personal bonds and continue to be the prominent participants. Under the present project, two subsequent generations of Israeli and Egyptian researchers are now involved in the research.

Much high-quality scientific, analytical, and technical work has been carried out by Egyptians and Israelis under the auspices of the Wastewater Reuse Project. This high-quality scientific and technical work adds credibility to the importance and utility of regional cooperation. The overall political context, however, still inhibits cooperation between Egypt and Israel, and it is still an act of courage for an Egyptian researcher to be visibly involved. It is disappointing that of the over 40 Egyptian participants, only six have visited Israel.

The Suez Experimental Station, completed under the predecessor project and continued and improved under the present grant, is well designed, well operated and maintained, and a sustainable asset for the Egyptian government's National Institute for Oceanography and Fisheries. As expected, the trials at the Suez Experimental Station (with the caveats noted in the next paragraph) demonstrate that fish and crops can safely and efficiently be reared and grown using wastewater treated to WHO standards.

Despite good research and successful operation of the Suez Experimental Station, important and crucial issues and problems remain inadequately understood. These are the following:

- The extreme salinity of the influent, and the much greater salinity of the effluent from the stabilization ponds at Suez has presented a range of practical problems for the agronomic trials and leaves a number of open questions regarding many aspects of the pond operation and reuse of the wastewater.
- Helminths are still present in the maturation pond of the treatment system and in the fish-raising pond at levels that equal or exceed WHO guidelines. Concentrations of helminths in the latter may be elevated due to the activities of fish and pond operators that disturb sediments. Concentrations may be lower than they would be if the wastewater were less saline, and it is not clear whether greater retention time would reduce helminth concentrations.
- Viral analyses of the treated wastewater have not yet been performed, despite the fact that Egyptian scientists received extensive training in this area at Hebrew University. Such analyses will be necessary to assure that the wastewater is acceptable for high-level uses, e.g., agriculture and aquaculture.
- Researchers do not know the actual retention time of wastewater, as dye tests have not been done. Considerable seepage could significantly lengthen the retention time of the effluent, or thermal stratification could shorten the time (as is the case in Israeli ponds), or both.
- Problems with thermal stratification in Israeli ponds have not been solved by Israeli researchers. There may be implications for Egyptian attempts to replicate the Suez technology.
- The performance of the Suez pond system is better than predicted (regarding coliforms). It is important to understand why this is so in order to replicate the technology.

The project is behind schedule on most planned activities that relate to the process of dissemination and wider application of the technologies of stabilization ponds and agricultural and aquacultural reuse of wastewater treated to WHO standards. Chief among these remaining activities are:

- Workshops (national and local for Suez) regarding the opportunities and necessary safeguards for the wider use of these technologies to benefit Egypt. These workshops are not intended simply to present the results of the Suez research for automatic adoption elsewhere, but to use the Suez experience as a basis for broader discussion of the potential for stabilization pond and reuse technologies.

- Economic and sociological analyses regarding costs and benefits, changing social and cultural attitudes, and investment opportunities and risks with different wastewater reuse applications.
- Operational manuals for pond operation, safety precautions, monitoring techniques, fish rearing practices, and agricultural applications. Final guidelines would be premature.
- The publication rate from the Egyptian participants is very low. In addition to possible research papers, there is a need for more general articles and brochures (in Arabic) regarding the potential for wastewater reuse and summarizing the Suez experiments.

Some of these activities are quite rightly saved for the project's end. Others, such as at least one workshop, more publications, and social and economic analysis, should have begun sooner.

Overall, the Wastewater Reuse Project has its important successes and near successes, but it is the only site in Egypt that is systematically examining the public health aspects of a technology whose wider application in Egypt and the Near East is extremely important.

Chapter 1

INTRODUCTION AND BACKGROUND

1.1 Middle East Regional Cooperation Program (MERC)

Shortly after the signing of the Camp David Accords, Congress established the Middle East Regional Cooperation Program to fund trinational research projects involving Egyptian, Israeli, and American institutions and scientists working together on problems of common interest and importance to Egypt and Israel. Since 1981, ten such projects have been funded for a total of almost $60 million. Typically, the projects focus on common research and development issues in the areas of arid lands agriculture, marine technology and environment, or public health and epidemiology.

Not surprisingly, the MERC Program combines the objectives of foreign policy, science, and economic development into a demanding and sometimes uneasy triumvirate. Good science can be compromised (or enhanced) by close involvement with difficult political policy considerations. Many development practitioners are more comfortable practicing their craft at least one step removed from the political considerations just as there are diplomats who would prefer not to sully their programs with drip irrigation and sewage treatment activities. Furthermore, the performance of the MERC program is constrained by the very constraints of the overall political situation it was created to help ameliorate. Since Camp David, progress has been slow for the Middle East peace process, with periods of backward and forward momentum. Clearly, the overall climate and relations between Israel and Egypt have not thawed as the optimists hoped during the dozen years since Camp David. Egyptian participants in the cooperative program may have an easier time at present than during the early years (or during some difficult periods since); however, vulnerability remains and it is still an act of some courage for an Egyptian researcher to actively engage in MERC activities.

In evaluating a MERC project, it is important to keep in mind the unusually close interconnection between policy, science, and development, on one hand, and to place the project activities within the context of the changing overall Middle East situation, on the other hand. The evaluation of a MERC project needs to consider the merits of the scientific research performed, the quality and sustainability of the institutional, professional, and personal relationships established between the two countries, and the practical applications of the research or technical demonstration activity toward solving practical development problems that may improve the quality of life for significant populations.

1.2 Technological and Environmental Health Aspects of Wastewater for Irrigation Project

This project aims to demonstrate the technical, environmental health, and socioeconomic feasibility of wastewater recycling and reuse for agricultural purposes in the region. The present Wastewater Reuse Project builds on the work of an earlier MERC activity conducted under the Project for Cooperative Marine Technology in the Middle East. Under that previous subproject, the Suez Experimental Station (SES) was designed and constructed, providing two types of stabilization pond wastewater treatment systems, and fish rearing experiments in the treated wastewater were designed and implemented. The present project continues the investigation of improved design for stabilization pond treatment systems and wastewater reuse for aquaculture. Additionally, the new project carries out an important demonstration of the reuse of wastewater for reclaiming arid lands and for growing commercially valuable agricultural products. This evaluation focuses on the current project; however, the degree of carry-over and continuity with the earlier project makes it difficult to separate the accomplishments of the one from the other. Also, to the extent that the current project stresses the integration of aquacultural and agricultural reuse of wastewater makes it unwise to separate too rigidly the one from the other.

The project lead grantee is the University of Michigan, Department of Environmental and Industrial Health, School of Public Health. The participating agency in Egypt is the National Institute of Oceanography and Fisheries, which has put together a group of researchers from Ain Shams University, the Ministry of Agriculture's Land Reclamation Institute and Desert Research Institute. The participating institution in Israel is Hebrew University, Division of Environmental Sciences.

The Wastewater Reuse Project is the smallest of all MERC projects, with a total budget of slightly over $1 million to support activities at multiple institutions in three countries for three years (1990-1993). A recent amendment to the grant provides for an additional year with no increase in funding. Despite its modest budget, the project has relatively high visibility among MERC Projects. Perhaps because it provides something concrete to observe in a fixed location not far from Cairo, the Suez Experimental Station is almost invariably visited by ambassadors, dignitaries, and international teams of experts on water and environmental issues.

1.3 Purpose of the Evaluation

This report constitutes the final evaluation of the Wastewater Reuse Project. According to the evaluation scope of work (see attachment A), the evaluation has two stated purposes and one implied purpose.

- Review project activities and outputs in order to determine the extent to which the project has met its grant objectives.

- Consider whether the research findings of this project (taken with those of similar trials in Egypt, Israel, and other Middle Eastern countries) warrant a larger pilot test program in an expanded and varied set of locations in Egypt.
- As the project has just been granted a one-year no cost extension, an implied purpose of this evaluation is to consider the extent to which the proposed final year activities are appropriate, and to make recommendations for the 1993-1994 workplan modifications.

1.4 Evaluation Methodology and Schedule

Washington

The evaluators met at the offices of the Water and Sanitation for Health (WASH) Project in Arlington, Virginia, for a two day formal team planning meeting. At these meetings, the evaluators collected and reviewed project documentation and research reports. The principal investigator presented a detailed history and background on the project during a set of meetings on the first day. On the second day, the evaluators finalized the evaluation schedule, completed logistical arrangements, and prepared a preliminary report outline. An extended briefing was held at A.I.D. (NE/DR) with the project officer, senior technical specialists, and others with considerable knowledge of the history of the MERC Program. Also present was the director of the Winrock team now responsible for management and technical support to the MERC Program.

Israel

The evaluators arrived in Jerusalem on July 5, 1993. In Israel, the evaluators and four senior Egyptians attended presentations on the project research findings carried out by the Israeli participants, examined the pilot treatment "ponds" funded under the project, and visited three Israeli wastewater treatment plants (Jerusalem, Dan Region, and Naan Kibbutz) that exemplify wastewater reuse and stabilization pond technology in that country. The evaluators also met with senior officers of Hebrew University. The evaluation team leader spoke with the U.S. Embassy official in Tel Aviv responsible for the MERC Program in Israel.

Egypt

The evaluators arrived in Egypt on July 11. The team visited the Suez Experimental Station and NIOF research laboratories in Suez, reviewing the stabilization pond technology and aquaculture and irrigation experiments. While in Suez, the team met with the Deputy Governor and representatives of the Suez City Council in order to ascertain the degree of local support for the project activities.

In Cairo, the senior project researchers from Ain Shams and Cairo Universities made formal presentations of their research findings on agricultural and aquacultural applications and were available for questions and discussion. The evaluators also met with senior officials of the Academy of Scientific Research and Technology (ASRT) and the Cairo Wastewater Organization.

USAID/Cairo representatives briefed the evaluators on the agency's past and future programs in the area of wastewater treatment and wastewater reuse. The evaluators also met with the officer of the U.S. Embassy responsible for overseeing the MERC program in Egypt. The evaluators also met with senior Egyptian researchers of the Social Research Center of the American University in Cairo who are familiar with the village level social issues regarding water, sanitation, irrigation, and public health.

The evaluators visited three additional field sites in the vicinity of Cairo: a large wastewater treatment plant south of Helwan, a private farm using treated wastewater for irrigation in the desert near El Saf, and a sewered village with a small treatment plant in the delta region.

The evaluators departed Egypt on July 20, 1993.

Chapter 2

SUSTAINABLE EGYPTIAN-ISRAELI COOPERATION

2.1 Core Group of Cooperating Researchers

The Wastewater Reuse Project has strengthened the ties among a relatively small group of Israeli and Egyptian researchers that first came together under the Marine Technology subproject activity. This group consists of approximately 10 Israelis and Egyptians who periodically visit each other's countries, remain in contact by telephone and fax, and meet at professional meetings and conferences. It is a diverse group formed early in the previous project through the efforts of the Egyptian-American principal investigator at the University of Michigan.

There are American critics of the MERC program who stress that the projects tend to involve the "same faces" today as in the early years a decade ago. However, these American critics may underestimate the importance in the Middle East of life-long professional and personal relationships. The fact that the same senior researchers continue over the years to deepen their ties to one another is important. When a small group of senior Egyptian and Israeli scientists can sit together in a restaurant in Israel (as the evaluators witnessed) and reminisce about the early days of their cooperation as long as eight and ten years ago, one is <u>beginning</u> to develop significant professional and personal networks in the Middle East. Real trust and mutual respect gain considerable weight and value only with the passing of some years. In this regard, it is important to note that this same group is now exploring further work together regarding the Gulf of Aqaba, work that may for the first time take MERC into truly cooperative research involving Israel and neighbors in addition to Egypt.

Previous evaluations and criteria for MERC projects stress that cooperation is most effective when it is among researchers of equal stature. In this regard, there is a certain imbalance within the Wastewater Reuse Project. On the Israeli side, the principal investigator is an internationally known expert at an eminent university, whereas the senior Egyptians on the project are distinguished leaders of prestigious Egyptian government research agencies but are less well known in international scientific circles. The senior Israeli researchers are well aware of developments in their field both within their small country and elsewhere, especially in the U.S. The Egyptians tend to be more restricted in their knowledge of similar projects and developments in Egypt, perhaps as a function of the more compartmentalized Egyptian research bureaucracy. Similarly, they are less aware of developments in their field outside Egypt than are their Israeli partners.

This potential problem is mitigated to a large extent under the Wastewater Reuse Project by two factors. One is the fact that the University of Michigan principal investigator is an American of Egyptian origin, thus balancing out the fact that the Israeli principal investigator is an Israeli of American origin. The other mitigating factor is the involvement of Israelis of

Palestinian and Iraqi origin who speak Arabic as a native language, and of younger Egyptians who have been recently trained in the U.S.

As a result, and by project design, the Israelis do most of the ground-breaking research, and the Egyptians contribute the implementation and monitoring skills, including first-rate applied microbiological and agronomic studies.

2.2 Widening Network of Researchers and Participating Institutions

Within each country, and especially in Egypt, the network of researchers involved in MERC has expanded during the past three years. The current round of research on the Wastewater Reuse Project is being carried out and in many instances largely directed by a new generation of researchers in both countries. Although the same names may appear on the MERC Project Proposal face sheets, new faces are found in the laboratories.

In Egypt, over 40 researchers, faculty members, and graduate students have been involved in this cooperative project with Israel and the U.S. Of special importance is the strong involvement and leadership from relatively young researchers at Egypt's most prestigious universities and departments thereof. Additionally, three Egyptian graduate students have earned their degrees based on research done under the Wastewater Reuse Project. Similarly, in Israel, younger researchers carry out research components of the project as post-doctoral fellows and doctoral candidates. Three generations of Egyptian and Israeli researchers participate in MERC through this project.

MERC guidelines stress that cooperation, although strongly person to person, should, to the extent possible, involve prestigious institutions from the participating countries. The Academy for Scientific Research and Technology has long been providing in Egypt the prestigious leadership for the Wastewater Reuse activities. Under the present grant, the additional participation of a large number of researchers from several universities (Ain Shams, Cairo, Zagazig) is an important development, involving approvals by university administrators (often understandably cautious regarding activities that might invite student unrest) and of officials of the Ministry of Education. In Israel, Hebrew University has developed a strong and committed program of support for cooperative research as a result of this and other MERC projects.

2.3 Cooperation Activities

During the past three years, there have been a total of six workshops or coordination meetings held at Cairo, Suez, or Jerusalem involving both Egyptian and Israeli personnel. Additionally, two Egyptian researchers received extensive training in modern laboratory techniques and equipment at Hebrew University in Jerusalem, and one Arabic-speaking Israeli researcher provided significant training on research and monitoring techniques to six Egyptian researchers at the Suez station. Perhaps the most important cooperation activity was the original joint effort in designing and operationalizing the Suez Experimental Station with its two stabilization pond systems. The project's output in terms of joint publications is disappointing compared to some other MERC projects. However, it is important that in many respects this Wastewater Reuse Project is more of a demonstration of known technologies than a primary research activity. The Egyptian components, in particular, do not lend themselves readily to international peer-review journal publication. Dissemination of project results in Egypt is more important than sharing the results with an international audience.

Regarding travel between the two countries, it remains a relatively rare and special event. The evaluators were in Israel simultaneously with four senior Egyptians, whose presence was the cause for two television programs (one on the Arabic news broadcast and one in English as part of a special investigation of water issues). The day when visits to Israel by Egyptian research delegations do not command some media attention has sadly yet to arrive. On the other side, although Israeli visitors are more warmly and easily welcomed now than in the past, recent terrorist activities have made security precautions for visiting Israeli delegations complex. Aspects of MERC cooperative activities are still running against the grain in Egypt, despite increasing support from government authorities.

2.4 Sustainability of Cooperation

The core group of cooperating researchers has proven its continued interest in developing new and wider cooperation activities (see Table 1) for funding under MERC auspices. The evaluators see little evidence, however, that Egyptian and Israeli colleagues are likely to be applying jointly to other funding resources for jointly developed research grants. Each group is certainly building appropriately upon the base created by the Wastewater Reuse Project.

The Israeli participants are building on the experience to position themselves to contribute to solving the water resource issues that are becoming a central part of the next stage of the Middle East peace negotiations involving the Palestinians and Jordanians in particular. It would not be unexpected if during the next few years, the Egyptians and Egyptian-American participants on the Wastewater Reuse Project have a role to play in this important technical/diplomatic issue.

The Egyptian side is correctly turning its attention toward wider pilot demonstrations and implementation of reuse technology at home to solve pressing environmental and economic problems for an expanding population. If, down the road, the wide implementation of reuse technology in Egypt were to involve additional participation of Israeli individuals, public institutions, or private companies, it would be appropriate and beneficial, provided that the overall diplomatic and political situation improves.

Table 1

Cooperation Activities

Workshops and Coordination Meetings:		
August 1990	Workshop	Suez
December 1990	Workshop and Meetings	Cairo and Suez
July 1991	Steering Committee	Jerusalem
January 1992	Training of Two Egyptian Researchers	Jerusalem
February 1992	Steering Committee	Cairo
June 1992	Training by Israeli Researcher	Cairo and Suez
June 1992	Workshop on Agriculture (No Israelis present)	Cairo
June 1992	Steering Committee	Cairo and Jerusalem
July 1993	Workshop and Meetings	Jerusalem

Travel:

Number of Egyptians to visit Israel: 6 (Eisawy, Badawi, Shaaban, Hassan, Naguib, El-Ibiary)

Number of Israelis to visit Egypt: 4 (Shuval, Fattal, Nasser, Cohen)

Participation of Researchers:

Faculty and researchers at Hebrew University: 10

Egyptian researchers: 40

Ain shams University, Faculty of Agriculture: 7

Cairo University, Faculty of Veterinary Medicine: 3

University of Alexandria, Faculty of Veterinary Medicine: 1

Zagazig University: 2

National Institute for Oceanography and Fisheries: 12

National Desert Research Institute: 2

From other Government Agencies and Laboratories: 13

Graduate Student Research:

Egyptian M.Sc. and Ph.D. theses based on project research: 3

Israeli M.Sc. and Ph.D. theses based on project research: 2

American Ph.D. theses based on project research: 1

Papers and Publications:

Joint scientific papers and publications: 3

Number of Egyptians on joint papers with Israelis: 1

Number of Israelis on joint papers with Egyptians: 3

Total number of papers and publications based on project research: 20

2.5 Institutionalization of Project Activities in Egypt

The establishment of the Suez Experimental Station is a major accomplishment of the two successive Wastewater Reuse projects. This research site is now a permanent part of the facilities of the National Institute of Oceanography and Fisheries, supported by the NIOF regional station and laboratories in Suez. It will continue to operate under Government of Egypt funding following the completion of this project. Interest in Egypt in wastewater reuse has increased dramatically during the past few years, and it can be expected that the Suez facility will be utilized for research, demonstration, and training as reuse implementation projects come on line for Egyptian cities and villages. The Government of Egypt has a strong stake in the Suez station, having funded a significant part of the construction costs.

Equally important in the institutionalization of the wastewater reuse project results, and of the Suez station in particular, is the history of strong support from the Governors (present and past) of Suez and of the City Council. Representatives of the governorate and municipality stressed that they have sadly witnessed in recent years the biological death of the Suez Bay and the consequent loss of tourism assets as a result of contamination. The governorate and city officials are convinced that wastewater reuse holds the key to the creation of a protective green belt around this desert city, and to the creation of other urban parks and green areas to make the city more livable and attractive.

Much needs to be done during the final year of the Wastewater Reuse Project to assure that the monitoring techniques and demonstration aspects developed at the Suez station have the appropriate impact on infrastructure planning in Egypt. The network of researchers from the various universities and institutes is a fragile one that may not survive the end of the project if steps are not taken to provide some institutional framework. Also, much needs to be done in Egypt to increase awareness of the possibilities (and dangers and limitations) of wastewater reuse among the agencies most directly involved in such development (the Ministry of Housing and the National Organization for Potable Water and Sanitary Drainage, as two key examples).

Neither the NIOF nor the Academy for Scientific Research and Technology is an implementation agency concerned with wastewater, although the ASRT is taking a lead in developing and coordinating the development of key aspects of water resources policies, including reuse.

Chapter 3

TECHNICAL ASSESSMENT OF PROJECT ACTIVITIES

This project is, as mentioned earlier, a follow-on from a subproject of the MERC Marine Technology Project, which examined the potential of using treated wastewater in fish rearing ponds. The wastewater stabilization pond (WSP) system at Suez, including the fish rearing ponds, was constructed prior to implementation of this project, which was funded to develop innovative low-cost technologies for the treatment and reuse of domestic wastewater for fish production and irrigation. The present project was conceived to include three interdependent areas of research:

- Treatment of domestic wastewater to a level determined to be "safe" for aquacultural and agricultural applications;
- Reuse of the treated water for fish production; and
- Reuse of the effluent from the fish ponds for land reclamation and crop irrigation.

The stabilization pond system was selected because of its low cost (except for the purchase of land), simplicity and ease of operation, and treatment effectiveness in warm climates similar to that of the Middle East. Two different types of pond systems were selected for study at Suez—one comprising anaerobic, facultative, and maturation ponds (System A) and one composed of a series of plankton ponds (System B). Both systems have been in operation for over two years and have been monitored extensively for many parameters, including physical properties, organic loading, inorganics, nutrients, heavy metals, pathogens (except for viruses), and plankton chlorophyll.

In addition to the studies conducted on the WSP systems at Suez, research was conducted in Israel to evaluate the effectiveness of single cell stabilization ponds, principally directed toward microorganism removal and improvement in pond retention time. The effect of different baffle configurations on the retention time—and hence, effluent water quality—was also evaluated in existing Israeli single cell ponds. Related research in Israel has included detection and enumeration of viruses in wastewater and pond system effluents, evaluation of die-off rates for E. coli and different types of viruses in wastewater and groundwater, and the effectiveness of photochemical disinfection. A small WSP pilot plant has been constructed at the Ein Karem, Jerusalem Wastewater Treatment Plant to further study and evaluate pond systems. This pilot will include research directed at water quality, disinfection, and improvement of retention time via baffle systems.

The System A pond system at Suez includes two fish ponds and two depuration ponds used during aquaculture experiments. In a continuation of previous experiments at the site, the viability of using WSP effluent in fish rearing ponds was evaluated. Studies included evaluation of water quality in the fish ponds, fish production capability, fish quality, and health aspects associated with fish consumption. One study compared the quality of fish grown in the Suez ponds to those grown in the polluted lake that is the source of much of Egypt's commercially available fresh water fish.

Recent experiments at Suez have focused on the use of the treated wastewater for agricultural irrigation. High salinity in both the wastewater and soil have presented difficult problems which have been largely overcome by selecting salt-tolerant crops and by pre-washing the soil to remove the salt prior to planting. Sewage sludge has also been used as a soil conditioner to increase the nutrient content of the soil. The agricultural research, which is still in progress, includes irrigation of crops in fields adjacent to the Suez Experimental Station, the establishment of a wind-break of trees around the perimeter of the site, and the production of food crops and ornamental plants in greenhouses—both in the ground and in pots using different types of water mixtures.

In this section, we review each of the technical activities and experiments undertaken as part of the project. The candor with which we note shortcomings should not detract from our overall assessment of the project's success.

3.1 Assessment of Treatment System at the Suez Experimental Station (SES)

3.1.1 Design

The Suez Experimental Station's Water Reuse System (see Figure 1), located 15 km west of the City of Suez, occupies an area of about 13 ha. The treatment facilities have been constructed on 5 ha, with the rest of the area reserved for agricultural applications. The SES has been operating since June of 1988, where about 400 m^3/d of raw sewage is diverted from the City Sewage Treatment Plant for treatment using two separate types of waste stabilization ponds. Based on a wastewater contribution of 100 liters/capita/day, the facility (using both pond systems) could serve a population of 4,000. The raw sewage input is predominantly of domestic origin, with an insignificant industrial contribution. The two different WSP systems are termed System A (also called the American System) and System B (also called the French System).

System A is a battery of 5 ponds, originally constructed with support from USAID. The current treatment system consists of the following:

- Two 7 m x 7 m anaerobic ponds, 3.5 m in depth. Only one pond is in service at any one time, i.e., one pond is operated for about 9 months, then the other pond is used during draining and sludge removal from the previously used pond. The side walls of these ponds—and the other ponds in the system—are concrete-lined for stability; however, the bottoms of all the ponds are unlined. The theoretical retention time in each of these ponds is about 1 day based on an influent flow of 125 m^3/d.

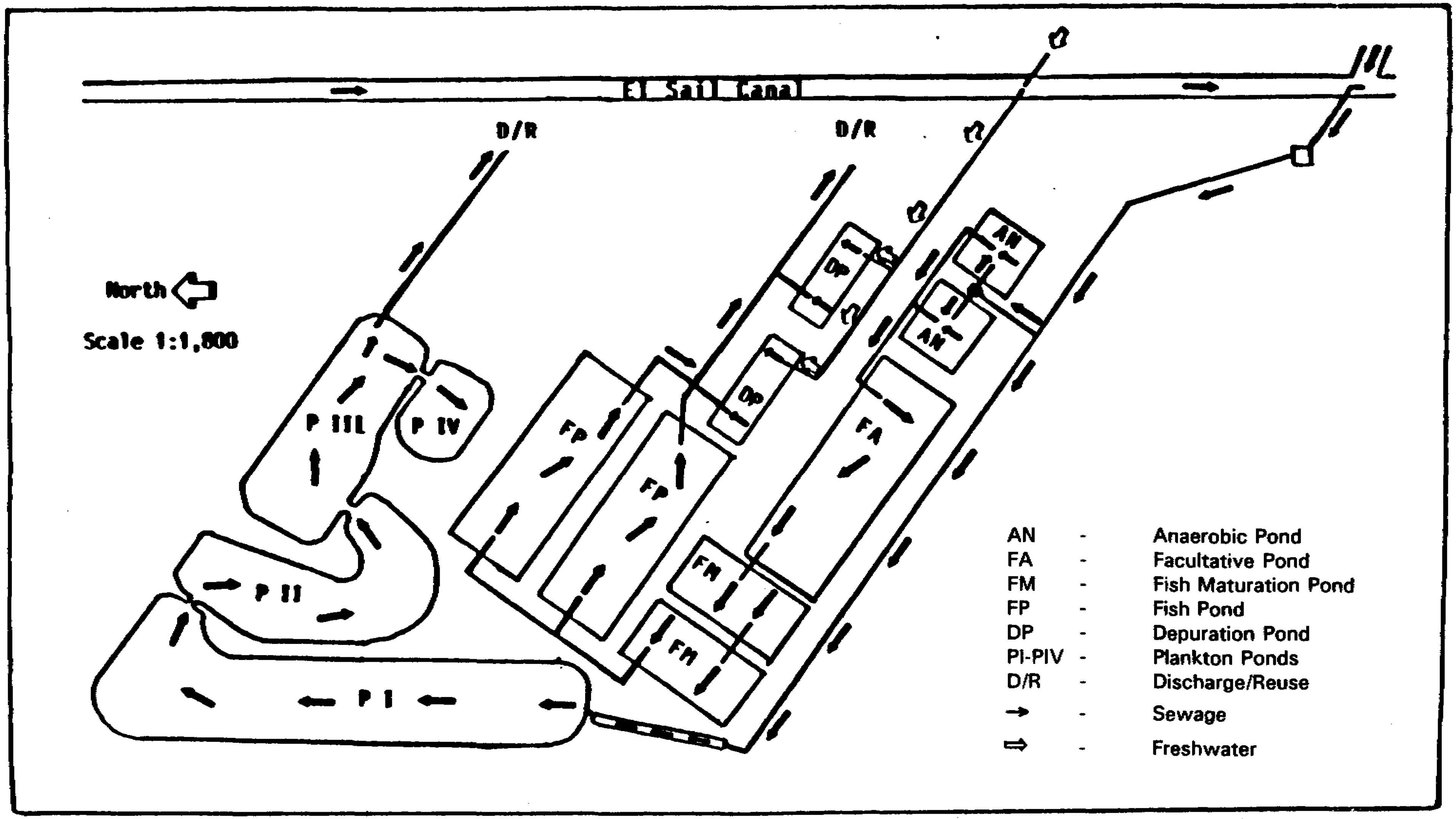


Figure 1

Suez Experimental Station—Water Reuse System

- One facultative pond 75 m long, 20 m wide, and 1.5 m deep. The theoretical retention time in the pond is about 15 days. Project reports indicate the retention time to be 10 days.
- Two maturation ponds operated in series. Each pond is 30 m long, 9 m wide, and 1.5 m deep. The theoretical retention time in each pond is about 3 days. Project reports indicate the retention time in each maturation pond to be 5 days.
- Two fish rearing ponds operated in parallel. Each pond is 70 m long, 20 m wide, and 1.5 m deep. The theoretical retention time in each pond is 26 days.
- Two fish depuration ponds (not part of the wastewater treatment system). Fish are transferred to these ponds, which contain fresh water, for clearing contaminants from the reared fish.

This system receives 125 m^3/d of raw sewage from the City of Suez from the El-Sail Canal. The total theoretical retention time (based on influent flow) in the anaerobic, facultative, and maturation ponds is about 22 days, which is 1 day longer than that given in the project reports. It is estimated by the project proponents that about 25 m^3 of water is lost through evaporation and seepage, such that approximately 50 m^3/d enters each of the fish rearing ponds. Most of the research associated with this project has been directed at System A. The design of System A is principally based on design criteria provided in The World Bank's Technical Paper number 7 (Arthur, 1983), which was developed for stabilization pond systems in warm climates of developing countries.

System B was designed and constructed with support from NIOF, without expenditure of USAID funds from this project. This treatment system receives 275 m^3/d of raw sewage and consists of three shallow ponds operated in series. These three ponds have nonsymmetrical shapes with surface areas of 3950 m^2, 2000 m^2, and 1950 m^2, and water depths of 1.4 m, 1.2 m, and 1.1 m, respectively. This system has a calculated residence time of about 36 days at the stated flow of 275 m^3/d. This differs substantially from the reported design retention time of 21 days. A fourth pond, with a surface area of approximately 400 m^2 and a depth of 1 m, is provided for aquaculture research.

Both of these pond systems were designed to meet the WHO guidelines for unrestricted agricultural use of reclaimed water, i.e., $\leq$1,000 fecal coliform organisms/100 mL and $\leq$1 nematode egg/L.

3.1.2 Operation and Maintenance

The simplicity of these pond systems renders them relatively easy to operate and maintain. The treatment plant facilities appeared to be well-constructed and free of excessive vegetation (weeds, etc. near the water's edge), clean, and operated as designed. However, due to a lack of available sewage caused by construction of a new sewage treatment facility in the City of Suez, System B was not receiving any raw sewage and the water in the ponds was becoming stagnant and heavily laden with algae. There are plans to modify the raw sewage intake to increase the total flow to SES to the design flow of 400 m^3/d.

Workers at the treatment facility wear protective clothing when collecting wastewater samples. All scientists, engineers, and laborers reportedly received medical examinations prior to working at the experimental station.

3.1.3 Water Quality

The composition of the influent raw sewage to SES is typical to that of other Egyptian cities with the exception of salinity and hardness. Due to apparent high rates of saline water intrusion into the sewerage system, the total dissolved solids and hardness are in excess of 5,000 mg/L and 1,000 mg/L, respectively. Fecal coliform levels range from 10^4/100 mL to 10^6/100 mL, while BOD, TSS, and COD average 280 mg/L, 400 mg/L, and 510 mg/L, respectively. The nitrogen and phosphorus levels in the raw sewage are similar to those in raw sewage from Ishmalia and Pt. Said and average 40 mg/L and 9 mg/L, respectively. Heavy metals, alkalinity, and oil/grease are present in concentrations similar to those in the raw sewage from the other two cities (University of Michigan, 1991).

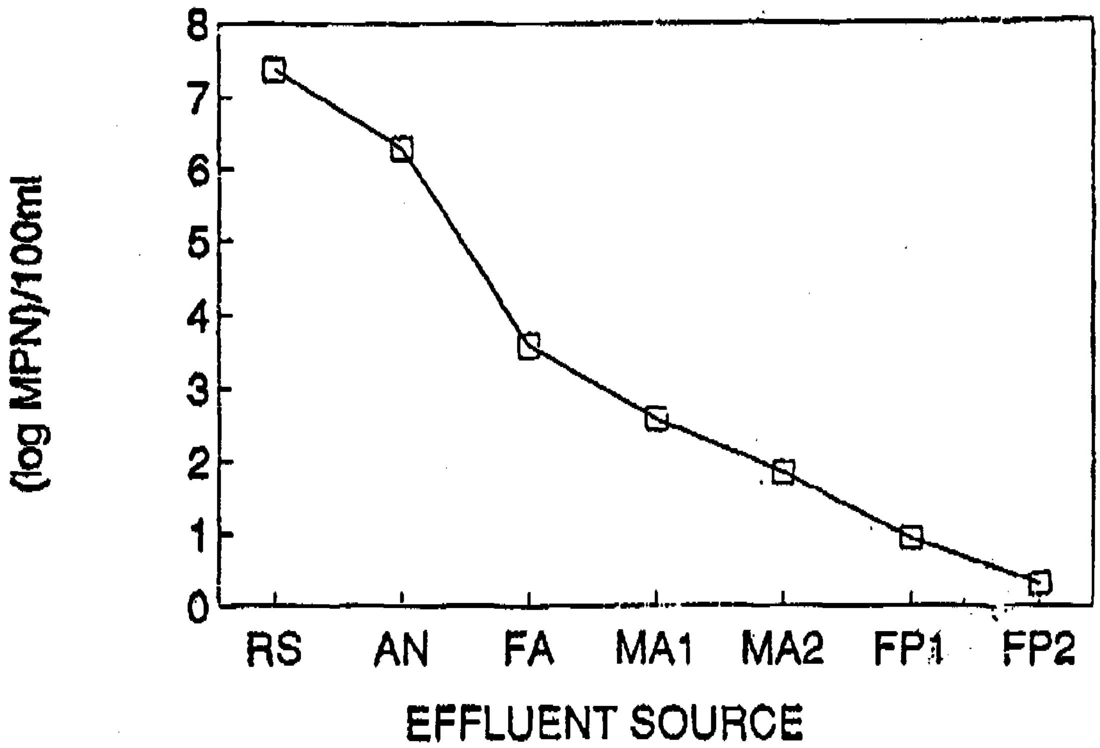
Water quality analyses over the course of the study indicate wide fluctuations for several constituents monitored. For example, in calendar year 1992 the BOD was 99-386 mg/L at the end of the second maturation pond and 20-245 mg/L in the fish ponds for System A, while the BOD in the effluent from System B was 89-380 mg/L. Similarly, during the same time period, COD was 20-53 mg/L at the end of the second maturation pond and 16-64 mg/L in the fish ponds for System A, while the COD in the effluent from System B was 20-67 mg/L. Data indicate that the BOD and COD concentrations were generally at the low end of the ranges presented above.

With a few exceptions, constituent levels for inorganics and heavy metals in the wastewater were determined to be at acceptable levels for crop irrigation. Boron concentrations ranged from 0.5 to 1.6 mg/L in System A ponds and ranged from 0.7-1.8 in System B ponds. These boron levels may adversely affect certain sensitive crops. The cadmium concentration ranged from 0.005 to 0.01 mg/L in System A ponds, indicating that cadmium levels are close to the recommended acceptable limit for agricultural waters.

The salinity of the wastewater increased in each succeeding pond for both systems. For System A, the salinity was greater than 9,000 mg/L at the end of the second maturation pond and greater than 12,000 mg/L in the fish ponds. The salinity was over 8,000 mg/L at the end of the last pond of System B. The increases in salinity were most likely due to evaporation and dissolution of salts from the soil underlying the ponds.

Fecal streptococci, total coliforms, and fecal coliforms were each consistently less than 100/100 mL in effluent from the second maturation pond and the fish ponds in System A. Helminth ova and cysts were found in the maturation ponds in concentrations up to 4-8/L and in the fish rearing ponds in concentrations up to 2-4/L. The helminth concentrations exceed WHO guidelines for wastewater used for agriculture and aquaculture.

The Suez pond systems, especially System A, are highly effective in consistently producing wastewater to a very high bacteriological standard. Figures 2, 3, and 4, derived from project research reports, indicate the levels of reduction for total coliforms, fecal coliforms, and bacteria. Viral analyses have not yet been conducted on the raw sewage or wastewater at various stages of treatment.



RS: Samples of sewage before entering anaerobic oxidative pond

AN: Samples taken from outlet of anaerobic oxidative pond.

FA: Samples taken from outlet of facultative pond.

MA_1: Sample taken from outlet of maturation pond number one.

MA_2: Sample taken from outlet of maturation pond number two.

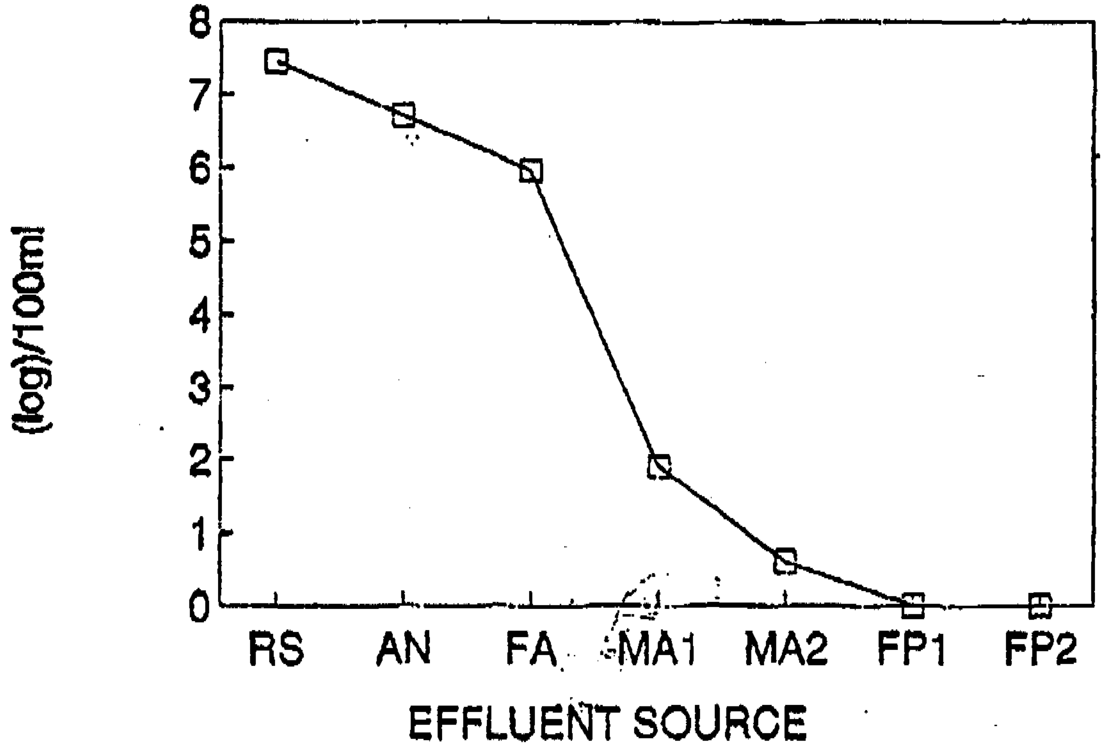
FP_1: Sample taken from the beginning of fish pond.

FP_2: Sample taken from the end of fish pond.

Figure 2

Average Total Coliform Count

(log Most Probable Number)/100 mL



RS: Samples of sewage before entering anaerobic oxidative pond (AN).

AN: Samples taken from outlet of anaerobic oxidative pond (AN).

FA: Samples taken from outlet of facultative pond.

MA_1: Sample taken from outlet of maturation pond number one.

MA_2: Sample taken from outlet of maturation pond number two.

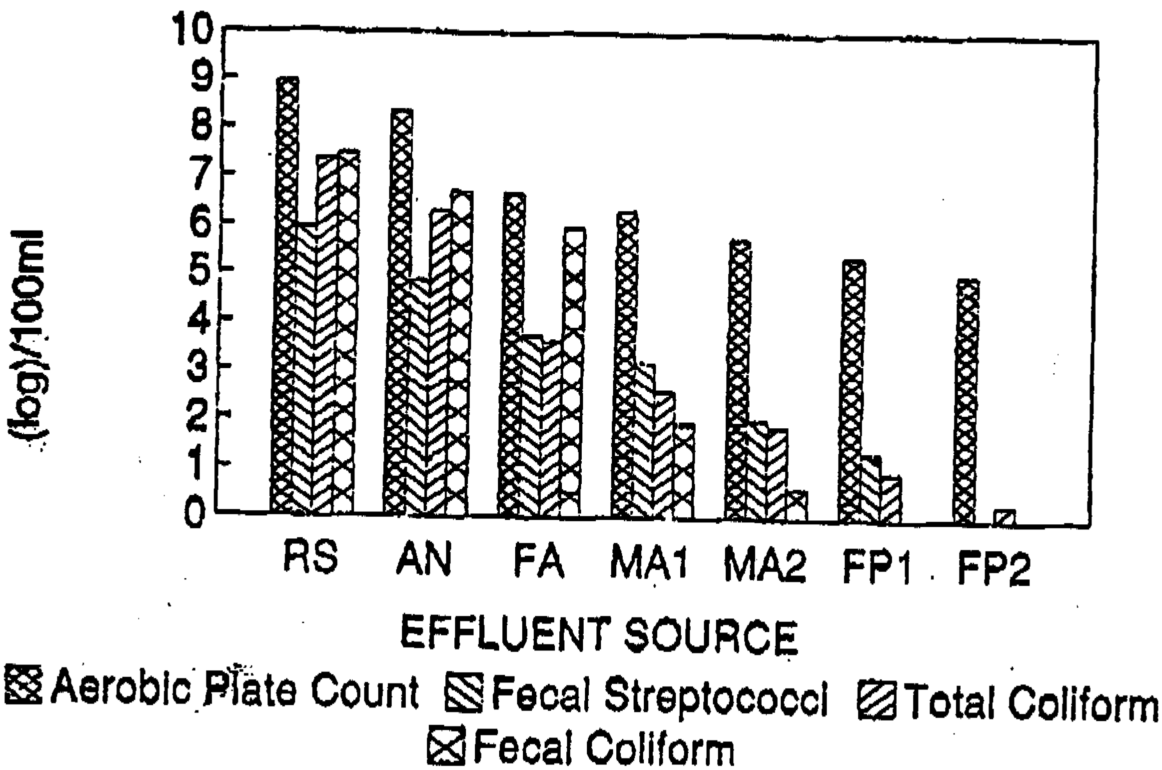
FP_1: Sample taken from the beginning of fish pond.

FP_2: Sample taken from the end of fish pond.

Figure 3

Fecal Coliform Count—January 1993

(log)/100 mL



RS: Samples of sewage before entering anaerobic oxidative pond

AN: Samples taken from outlet of anaerobic oxidative pond.

FA: Samples taken from outlet of facultative pond.

MA_1: Sample taken from outlet of maturation pond number one.

MA_2: Sample taken from outlet of maturation pond number two.

FP_1: Sample taken from the beginning of fish pond.

FP_2: Sample taken from the end of fish pond.

Figure 4

Bacteriological Loads of Water Samples

(log)/100 mL

3.2 Assessment of Existing Israel Pond Systems

The efficiency of typical small, single-celled stabilization ponds in Israel was also investigated under the MERC activity. The two sites selected were at the Sha'alabim and Netiv Halamed Hays (LH) kibbutzim. The Sha'alabim pond receives sewage from a population of 850-1,300 (depending on time of year), is 1 m deep with a surface area of 1,250 m^2, and has a theoretical retention time of 4.8-7.5 days. The stabilization is preceded by two anaerobic sedimentation ponds. The Netiv (LH) pond receives sewage from a population of 430 and an equivalent amount of wastewater from a dairy operation, is 1 m deep with a surface area of 1,650 m^2, and has a theoretical retention time of 6.4 days.

These two ponds were ineffective in removing microorganisms from the wastewater. E. coli and enterococci levels were reduced by approximately 1 log (90 %) in each of the pond systems, while F+ coliphage removal averaged 1.34 logs (95%) and 1.84 logs (99%) in the Sha'alabim and Netiv LH ponds, respectively. The dissolved oxygen levels in both effluents were erratic and often lower than in the raw sewage. Chlorella was the predominant algal species found in the effluent samples and ranged from 2.0×10^3 to 5.2×10^5 cells/mL at Netiv (LH) and 6.5×10^3 to 1.9×10^6 cells/mL at Sha'alabim.

Subsequent studies of the Kibbutz Sha'alabim pond verified the poor removals of indicator organisms and viruses. Only about 1 log (90%) of fecal coliforms, enterococci, and F+ bacteriophages were removed by the pond. Enteroviruses were detected in 23% and 31% of the influent and effluent samples collected in the summer months, respectively. 20 out of 55 (36%) of the picked plaques were found to be poliovirus. In another study, 19 of 63 effluent samples from the Sha'alabim pond were found to be positive for enteroviruses.

The poor performance of these two ponds is apparently typical of the problem at many of the approximately 200 such single cell treatment ponds that dot rural Israel. One of the objectives of the research under MERC is to improve the understanding of how the performance of such ponds can be improved.

3.2.2 Effect of Hydraulic Flow Patterns on Pathogen Removal

The pond in Kibbutz Sha'alabim was selected to study the effect of baffles on hydraulic flow patterns in single celled ponds. It was hoped that placing a simple maze of barriers (baffles) in various patterns would re-direct the flow pattern and improve the pond's performance. This pond is 50 m long, 30 m wide, and has an average water depth of 1 m. Using Rhodamine Water Tracer (RWT), it was found that the actual retention time in the pond was much less than the theoretical retention time. Approximately 5% of the effluent short-circuited the system and was discharged after a residence time of only 16 hours. Thus, three different baffle configurations were installed in the pond. The first configuration was a single baffle across the middle of the pond. The second configuration was a baffle across the middle of the pond and a second baffle mid-way between the first baffle and the discharge end of the pond to provide a serpentine flow pattern. The third configuration was four baffles equally spaced across the pond.

The baffle systems were ineffective in reducing hydraulic residence times in the ponds and did not improve microorganism removals. In addition, 6 of 17 effluent samples were positive for enteric viruses, with concentrations of up to 16 plaque-forming units per milliliter (pfu/mL). It was hypothesized that thermal stratification in the pond caused the colder wastewater to short-circuit the system. It was further postulated that the lack of improvement in microbiological reduction was associated with bottom flow and minimal exposure to high levels of bacteriocidal factors such as light, pH, dissolved oxygen, and high temperature found in the epilimnion. Future plans call for trying a set of baffles that explicitly block the bottom, forcing the flow to go under and over structures in order to break up the thermal stratification.

3.2.3 Survival of E. coli and Viruses in Wastewater and Groundwater

Laboratory experiments were conducted to determine the survival of indicator organisms (E. coli and F^+ bacteriophages) and pathogenic viruses (poliovirus 1 and hepatitis A) in wastewater and groundwater after 30 days and 90 days at various temperatures. This study demonstrated that the die-off of E. coli was different from that of the pathogenic viruses, i.e., greater than the viruses in groundwater at low temperatures and in primary effluent at high temperatures. The die-off of F^+ bacteriophages was similar or lower than those of E. coli, Hepatitis A virus, and poliovirus under all test conditions. Based on this study, it was concluded that F+ bacteriophages are a more reliable indicator of the presence of pathogenic viruses in water than the widely used E. coli.

3.2.4 Disinfection by Solar Energy

Using sunlight and photosensitizers (dyes) is a new approach to wastewater disinfection. The sensitizers absorb solar radiation in the visible region (400-700 nm) and transfer the absorbed energy to the substrate, which results in its protodegradation. The purpose of this research, conducted at the Hebrew University, is to investigate sensitized photooxidation as a means of reducing the retention time necessary in pond systems to remove or inactivate pathogenic microorganisms. Some of the advantages of this method of disinfection are that it uses solar energy, requires only a relatively short contact time to be effective (based on preliminary research), is effective in turbid water, may only require a low sensitizer concentration, can work under artificial light, and has not been shown to form toxic byproducts. Disadvantages are that the technique has been shown to be most effective at pH 8.5-8.8 (thus requiring pH adjustment of the water), the sensitizer used in the research—methylene blue (MB)—is much more expensive than chlorine, and MB imparts a color to the water. It should be noted that MB is biodegradable in the environment.

The experiment to date has been laboratory-scale and has only investigated the disinfection of coliform bacteria. A great deal more research has yet to be undertaken to verify the effectiveness and utility of this process. For example, the effectiveness of sensitized photooxidation as a means of destroying pathogenic bacteria, enteric viruses, and parasites has not yet been investigated. Further, use of this method requires electrical power and chemical feed facilities, thus adding a level of sophistication not likely to be amenable to implementation at many small rural sites where WSPs are desirable.

3.2.5 Hebrew University Stabilization Pilot Plant

The pilot plant consists of a 100-liter operational reservoir and a series of 6 fiberglass tanks. The first tank is 1 m x 3 m x 1 m and operates as a facultative pond, while the other five, each with dimensions of 1 m x 1 m x 1 m, serve as maturation ponds. Wastewater is pumped from the Ein Karem, Jerusalem Wastewater Treatment Plant primary sedimentation basins into the operational reservoir, from which it flows to subsequent tanks by gravity. Sampling taps are located at the entrance and exit of each tank. Several problems were encountered during startup of the pilot plant, including clogging and an inability to establish constant flow conditions. These problems have been corrected, but no evaluations have yet been made using the pilot plant.

Because experiments have not yet been conducted using the pilot plant, it is not known if this small facility will accurately mimic full-scale pond systems. Side wall effects, temperature differences, etc. will have to be carefully evaluated to determine the usefulness of the pilot plant.

3.3 Aquaculture Experiments at Suez

Two types of fish species were investigated at SES during the aquaculture experiments, Mugil and Talipia spp., in addition to an initial experiment in which approximately 2000 recently hatched *Oreochromis niloticus* fry were stocked in the fish rearing pond to monitor growth rates. The one-year experiment with *O. niloticus* indicated (by extrapolation) that more than 4 tons/hectare/year of the fish could be produced for a combined sex culture.

Talipia and Mugil spp. fingerlings introduced into the wastewater fish ponds were examined before entering the fish rearing ponds and after various time periods, i.e., 1 day, 1 month, 2 months, and 3 months. Bacterial counts on the surface of fish, which were high upon introduction into the ponds, dropped markedly after one and two months of culturing and exhibited little change in succeeding months.

The bacterial counts were higher in the fish pond water than on the surface of the fish. E. coli were isolated from the surface of about 10% of the fish, but were not found in muscle tissue. *Staphylococcus aureus,* salmonella, and shigella organisms were not isolated from either species of fish. *A. hydrophila,* which can be pathogenic under certain conditions, was isolated from the surface of both species, but was not found in muscle tissue of either species. No helminth ova or cysts transmissible to man were detected in the fish.

A comparative study demonstrated that fish from Lake Manzalah, which receives large quantities of untreated waste, contained a great deal more disease organisms and malformations than fish grown in the SES ponds. During this study, total coliform counts averaged 1.85/100 mL in the effluent from the second maturation pond and 1.69-1.85/100 mL in the fish ponds, while fecal streptococcus averaged 1.98/100 mL in the effluent from the second maturation pond and 1.33/100 mL in one of the fish ponds. Helminth studies found several parasites, including free-living nematode worms, *Ascaris lumbricoid* ova, *taenia spp.* eggs, and Giardia and Entamoeba cysts in fish pond samples. The helminth concentration was highest during the summer months, and was reported to be 2-4 ova/L. Some helminth eggs were found in internal organs of fish grown at SES.

WHO guidelines (World Health Organization, 1989) recommend that fish pond water contain ≤1,000 fecal coliforms/100 mL and no viable trematode eggs. The helminth standard is particularly important in the Middle East, where schistosomiasis is endemic. The WHO guidelines also state that pathogens may accumulate in the digestive tract and intraperitoneal fluid of fish. The aquaculture experiment at SES did not examine pathogen levels in the intraperitoneal fluid of the fish.

Based on the above studies, it is not apparent that fish grown in the fish ponds at SES are safe for human consumption. Although the fish were demonstrated to contain less disease organisms than fish grown in Lake Manzalah, some of the fish grown in the fish ponds were observed to contain helminth ova, as did the wastewater in the fish ponds.

3.4 Agriculture Experiments at Suez

3.4.1 Soil Evaluation

Soil analyzed in the agricultural plots at SES was found to contain layers of crystallized soluble salts. The TDS of the soil ranged from 21,000 to 57,000 mg/L, indicating a highly saline soil. Analyses for other constituents, including heavy metals and calcium carbonate, indicated acceptable soil conditions (except for salinity). Salt was leached from the soil by repeated applications of treated wastewater prior to using the land for agricultural purposes. The washing of saline soil is a common land reclamation technique in Egypt.

3.4.2 Irrigation Practices and Analytical Results

Due to the high salinity of the wastewater, plants were selected that tolerate high salinity. Also, the wastewater was diluted with tap water prior to irrigation, e.g., wastewater to tap water ratios of 1:2 and 1:6. The soil was conditioned by adding sewage sludge to increase the nutrient levels of the soil. All field plots were irrigated by surface methods (ridge and furrow). In addition to the irrigation plots, a number of experiments were conducted in greenhouses, using drip irrigation for tomato cultivation and surface irrigation of trees and ornamental plants in pots having imported soil.

Crops evaluated during this study included barley, maize, broad bean, rape seed, sugar beets, chamomile, tomatoes, cotton, and ornamental plants. As might be expected from experience elsewhere, the nutrient value of the wastewater resulted in higher crop yields and faster growing plants than did irrigation with tap water or tap water with salts added. It should be noted that all of the agricultural investigations are not yet complete and more complete results will be forthcoming.

Analyses of barley, rape seed, and beans indicated that heavy metals did not accumulate to unacceptable levels in these crops. Although it is stated in the project overview, dated June 22, 1993, that monitoring of the soil and plants for human pathogens and parasites has revealed no undesirable health concerns, data to support (or refute) this statement was not found in any of the project reports reviewed as part of this evaluation.

While the agricultural results are not surprising, they could be misleading if taken out of context. Because the high salinity of the wastewater required the wastewater to be diluted with tap water prior to application as irrigation water, constituents in the wastewater other than TDS were also diluted to levels uncharacteristic of stabilization pond effluent. Hence, while the agricultural experiments verify the utility of crop irrigation with water similar to that used at Suez, i.e., diluted high salinity wastewater, the experiments conducted to date do not fully demonstrate the health or agronomic effects of irrigation with wastewater.

Chapter 4

POTENTIAL FOR STABILIZATION POND AND REUSE TECHNOLOGIES IN EGYPT

Wastewater stabilization pond and reuse technologies such as demonstrated at Suez offer tremendous potential in many Egyptian locations, especially those in desert areas or along the borders of the delta and valley where the elevation of the desert is not too high above the populated area. Even in agricultural areas where land is at a premium, and expensive, there may be situations where the WSP technology is more cost effective in the long run than more technologically complex mechanical treatment systems.

Municipal and domestic wastes are a major and growing problem for overall water quality and public health in Egypt. In densely populated, low lying agricultural villages, almost thirty million people are unserved by sewage systems. Until recently, the use of leaching pits and direct discharge into drains was an adequate response. With the increasing population and rising water table due to intensified agricultural irrigation and increased supplies of piped potable water, many villages are now facing the necessity of investing in expensive sewage collection and treatment facilities. Recent and current investment in urban wastewater treatment systems provides adequate service to the residents of the major cities. At least some of the new systems provide secondary treatment and even disinfection and their effluents, therefore, are potentially suitable for reuse. These high technology systems, however, require sophisticated operations and maintenance procedures. When operations and maintenance are insufficient, effluents may not be safe for certain reuse applications. Discharge of inadequately treated effluents to agricultural drains (to be mixed with fresh water and reused for irrigation downstream) and to the Mediterranean does present growing environmental problems in Egypt today.

Egypt, with USAID's encouragement, turned away from its 1970s emphasis on developing desert areas in order to focus its agricultural development efforts on improving production on the prime lands under Nile irrigation. However, as the amount of prime land decreases (due to expansion of residential construction) and the population increases, the necessity for arid land development is reviving.

Responsible Egyptian authorities now express great interest in wastewater reuse for land reclamation and have made significant recent investments toward that end. WSP technologies offer promise because they are easier and less expensive to operate and maintain than high technology systems; WSP systems are, therefore, more likely to produce effluents of consistently acceptable quality for reuse. However, it seems that the low technology and relatively low costs of WSP technology have not attracted the interest of the authorities relying on donor funding for such infrastructure. USAID, on the other hand, has recently provided leadership in exploring WSP technology but has done little other than the MERC activity to pursue the reuse of wastewater on a larger scale. Recent USAID-funded wastewater project designs call for delivering the treated effluent into the sea (Alexandria, Suez) or into agricultural canals. The work carried out at Suez under the MERC Wastewater Reuse Project provides an important demonstration, and full operational data to contribute to the development of wider applications of the WSP, aquaculture, and agricultural reuse technologies.

4.1 Other Stabilization Pond Experience in Egypt

Although the literature of the MERC Wastewater Reuse Project gives the impression that it is the sole such project in Egypt, the situation has evolved considerably since the construction of the Suez Experimental Station. With support from USAID, a number of WSP systems have been constructed or expanded. There are now at least nine such USAID-funded systems on line or about to come on line. Others are also reported to exist. Among the USAID-funded ponds, there are four in the New Valley oasis area far to the west of the Nile Valley, three in South Sinai (remaining from the days of Israeli occupation and recently upgraded and expanded with USAID support), and two in Damietta governorate in the far north of the delta. Other WSP systems are on the drawing boards for places such as Rosetta. The functioning WSP systems serve populations ranging from 5,000 to 20,000, and most of them discharge their effluents to drains or to the sea.

4.2 Experience with Wastewater Reuse for Agriculture in Egypt

Direct wastewater reuse for agriculture is also developing rapidly in Egypt. The effluent of at least one of the Sinai systems, however, is used to irrigate a range of agricultural crops (Raslan, 1993). Operational data on the pond systems in Egypt were not available at the time this report was written. One of the major new sewage treatment stations for Cairo (outside of Helwan) is designed to deliver 250 m^3/d of treated wastewater to be used for irrigation along a 40 km long concrete-lined canal delivering the water to the desert on the southwest side of the Nile. Similarly, another treatment station (Gabil Al Asfar) has been using its effluent for irrigation for over half a century. New stations to replace and supplement Gabil Al Asfar are designed to allow for irrigation reuse, according to the Director General of the Cairo Wastewater Organization.

The evaluators visited the Helwan site as well as a commercial farm using its effluent for irrigation. All along the effluent canal, "squatters" were pumping water into desert plots and growing crops to be sold in the markets. Even the formal commercial farms were growing a range of crops with little regard for what might be appropriate precautions or appropriate types of crops for rearing on wastewater. Some crops are being irrigated by spray systems; others, such as melons, lay directly on the soil absorbing wastewater of uncertain quality. The treatment plant is designed so that during times of excessive flow, the excess will by-pass the treatment plant and discharge directly into the effluent canal. By design, the quality of the wastewater will at times not be suitable for reuse in irrigation. Although one applauds the extension of wastewater reuse into the desert from the Helwan treatment plant, it is clear the monitoring procedures, design criteria, and reuse guidelines need to be developed, disseminated, and to some extent, checked and enforced.

4.3 Similar Wastewater Treatment and Reuse Technologies Elsewhere in the Middle East

There are several examples of wastewater treatment by stabilization pond system pond systems in the Middle East; however, most are not designed to achieve the World Health Organization (WHO) recommended microbiological guidelines for agricultural use of the water for food crops. The WHO guidelines recommend that reclaimed water used to irrigate food crops likely to be eaten raw should contain not more than 1,000 fecal coliforms/100 mL and not more than 1 intestinal nematode egg/l (World Health Organization, 1989). The WHO guidelines further recommend that a more stringent standard, i.e., 200 fecal coliforms/100 mL, is appropriate for reclaimed water used to irrigate public lawns where the public may come into direct contact with the irrigated area.

4.3.1 Wastewater Stabilization Pond in Jordan

One of the largest stabilization pond systems in the region is at Amman, Jordan. The As-Samra waste stabilization pond system treats a major portion of the wastewater generated by the people, commercial establishments, and industries in Amman. The ponds also treat wastewater from Zarqa, Ruscifa, and Hashimiya. The pond system consists of three trains. Each train includes two anaerobic, four facultative, and four maturation ponds operated in series. The total water surface area is approximately 190 ha. In 1991, the hydraulic load averaged about 100,000 m^3/d, which was well in excess of the design flow of 68,000 m^3/d (Camp Dresser & McKee International, 1993). Not unexpectedly, the effluent from the overloaded system often does not meet design standards for BOD and fecal coliforms. In 1992, for example, the effluent BOD averaged 126 mg/l and the number of fecal coliforms ranged from 200 to 100,000 per 100 milliliters.

4.3.2 Wastewater Reuse for Agriculture in Israel

As mentioned earlier, there are about 200 wastewater pond systems in Israel, most of which are small, single-celled ponds providing a very limited degree of treatment.

Two systems, however, illustrate successful pond systems as well as successful examples of the reuse of treated domestic sewage for agricultural irrigation. These systems are the Naan Kibbutz and the Dan Region Sewage Treatment and Reclamation Project.

The influent to the Naan Kibbutz ponds is nearly raw wastewater from the overloaded oxidation ponds of a nearby town. The system consists of two oxidation ponds operated in parallel, followed by an 11-hectare (ha), 10-m deep lined reservoir with a capacity of 700,000 cubic meters (m^3) having a minimum retention time of 3 months (Shuval *et al.*, 1986). The pond system reduces BOD from approximately 400 mg/L to 60 mg/L, fecal coliform levels from 10^7-10^9/100 mL to 10^2-10^4/100 mL. The retention time in the oxidation ponds was sharply reduced in April 1993, resulting in a BOD level of 167 mg/L in the reservoir effluent. The effluent from the ponds is filtered to remove algae and zooplankton prior to use as irrigation water for cotton and flowers.

The Dan Region project provides wastewater for soil-aquifer treatment via groundwater recharge. A portion of the flow receives pond treatment prior to pumping to the recharge area, while the rest of the flow receives treatment via the activated sludge process prior to being pumped to the recharge area. The pond system, which has been in operation since the 1970's, treats approximately 20 x 10^6 m^3 per year through recirculated oxidation ponds followed by maturation ponds. In 1991, the average concentration of suspended solids was reduced from 412 mg/L in the raw sewage to 153 mg/L in the pond system effluent, BOD from 403 mg/L to 68 mg/L, and COD from 854 mg/L to 285 mg/L (Kanarek *et al.*, 1991). In addition, the concentrations of trace elements in the pond effluent was below recommended limits for irrigation. The Dan Region Project treats the sewage of the city of Tel Aviv and delivers it to the Negev Desert, where it is used for irrigation.

4.3.3 Wastewater Reuse for Aquaculture

The literature contains little information regarding the use of wastewater for aquaculture purposes in the Middle East, although fish-rearing is known to occur in sewage-contaminated waters in the region. It has been reported that 50-100 ha of fish ponds in Israel receive sewage, usually from small rural communities (Edwards, 1985). Typical fish species include common carp, Chinese Carp, mullet, and tilapia. The fish are depurated in clean pond water for several weeks to remove residual objectionable odors and pathogens. Yields may be as high as 5,000 kg/ha/yr. A review of the literature by Edwards (1992) indicates that there are several kibbutzim in Israel that use sewage to enrich their fish ponds. It is important to note that aquaculture with sewage is not officially sanctioned in Israel. In Egypt, it is reported that some private fish farmers use sewage water and water from drains that include sewage water to provide a nutrient medium for raising fish. The Suez aquaculture system, however, differs from these instances in that it uses wastewater that is treated to high standards and closely monitored.

4.4 Scale and Location Requirements for Future Applications

These two Israeli systems combined with the Suez Experimental Station provide three excellent models for a range of situations and scales of operation.

- The largest is the Dan Region system in Israel, which processes almost all of the sewage from Tel Aviv to very high standards, using complex treatment systems. The treated sewage is stored in the ground through a groundwater recharge system, and then is delivered to the desert in the south of Israel during the season of peak agricultural demand at a cost lower than the cost of delivering fresh water from other available sources. The system thus minimizes the discharge of treated wastewater to the sea, conserves increasingly scarce "fresh" water resources for consumption by a growing population, and enables the continued profitable operation of the agricultural economy of Israel's arid lands.

- The Naan Kibbutz system is a smaller local system that takes the sewage from nearby towns, processes it inexpensively in a WSP, and uses the effluent to produce commercially valuable but nonedible crops, i.e., cotton and flowers.

- The Suez system offers a model for extremely arid regions having highly saline wastewaters, whereby the wastewater of a sizable city may be inexpensively treated to relatively high standards. The Suez system could be modified to further investigate improved treatment efficiency by using one of the fish ponds as an additional maturation pond.

These examples, and those from Jordan, indicate that these technologies can be implemented to serve communities of various sizes in a range of types of location, from major cities to "secondary cities" to rural communities. Furthermore, the stabilization ponds reported to have been recently constructed or expanded under USAID funding suggest additional types of locations and community sizes.

The evaluators found an extreme case in a recently sewered delta village where land is scarce and expensive. The village has a population of approximately 10,000 and has a USAID-funded experimental "Aqualife" treatment system that has yet to function properly. It is discharging nearly raw sewage into an agricultural drain. Interestingly, plans were found that had been drawn up by the BVS Project in 1985 for a WSP system for this village. A quick calculation of the cost of land in this village suggests that the more extensive WSP model might have proven equally cost effective even here in the heart of the delta. There is a natural reluctance to utilize scarce agricultural land for wastewater treatment, although the land is also used for buildings, chicken coops, and other purposes. A combined wastewater treatment and fish farm operation is worth serious consideration, if not in the heart of the delta like this village, at least along its edges.

Two factors impede a fuller presentation of future options for pilot WSP and reuse systems at this point.

- First, and most important, is the lack of economic analysis under the MERC Wastewater Reuse Project. Egypt is moving in the direction of cost recovery and "market pricing" for water resources. It is critical that the project be able to calculate its unit price for treated wastewater and compare it to the accepted costs for producing competing water resources for land reclamation and arid land irrigation, for instance.

- Second, as there are clearly more stabilization ponds and wastewater reuse activities than are indicated by project materials or by the evaluation scope of work, a separate task would be required to visit, document, analyze, and draw conclusions from over a dozen sites throughout Egypt, stretching from the Oases in the southwestern desert to the resorts at the tip of the Sinai Peninsula. It is important to recognize the significance of this recent experience, and to pull it together as part of future project design activities for wastewater treatment components of an infrastructure project.

Chapter 5

PROJECT MANAGEMENT

Overall, the Wastewater Reuse Project has been well managed from the standpoint of keeping disparate groups of researchers on board and moving forward despite some difficult periods (such as the Gulf War). The principal investigator has, in the view of the participants, fairly balanced the competing interests and sometimes contradictory tendencies of the American, Israeli, and Egyptian participating institutions. This perceived sense of fairness is a critical factor for a successful MERC cooperation project.

Activities both in Israel and Egypt are behind schedule, which has necessitated the one year extension at no additional cost. A number of key activities, such as the social and economic analyses (originally planned to be partially funded by the World Bank), studies of possible low technology helminth removal approaches, and all workshop/dissemination activities are among the undone project tasks. These activities are on the agenda for completion during this final year.

The process of semi-annual reports and workplan development has been relaxed compared to the usual A.I.D. expectations, and not up to the level specified in the grant agreement. There were periods of up to a year during which no reports were presented to A.I.D., and recent reports provide little in the way of workplans for the coming period. Closer monitoring from A.I.D. might have provided more stimulus to improve both the frequency and content of these reports, and might have sharpened project performance somewhat. Even now, there is not a sufficiently detailed workplan and schedule for the final year's activities.

Given the relatively small size of the grant, all of the institutions involved have made significant uncompensated contributions to the project. The University of Michigan, for instance, is covering most of the costs of the socio-economic study being carried out by one of its Ph.D. candidates. In meeting with officials in Egypt and Israel, the evaluators found strong evidence of support for the project on the part of the senior administrations of the participating institutions in Egypt and Israel.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The project is incomplete, and will need to carry out a number of important activities during its one-year extension in order to fulfill its promise.

6.1.1 Relevance of Project

The subject of the project activities—appropriate technology for wastewater treatment and reuse for aquaculture and agriculture in arid lands—remains extremely relevant and important throughout the region. The ultimate scarcity of water resources and issues regarding water quality have moved up on the Egyptian policy and development agenda in recent years. For the region, the allocation of water resources has become a major issue in the negotiations of the peace process between Israel, its neighbors, and the Palestinians. Water resources are central to regional peace and to Egyptian economic development. Whatever shortcomings there may be in the site and technical activities of this small research project, it is the only project in Egypt that is systematically investigating the environmental health aspects of stabilization ponds and reuse technologies, and the only research project investigating the simultaneous reuse of wastewater for aquacultural and agricultural activities.

6.1.2 Meeting MERC Cooperation Objectives

The Wastewater Reuse Project carries out the classic activities envisioned for the MERC Program. It has fostered reciprocal visits between Israeli and Egyptian researchers, joint participation in workshops and seminars, training activities, and joint research and publication. Members of a core group of senior researchers have developed strong professional and personal bonds and continue to be the prominent participants. Under the present project, two subsequent generations of Israeli and Egyptian researchers are now involved in the research. The overall political context still inhibits cooperation between Egypt and Israel, and it is still an act of courage for an Egyptian researcher to be visibly involved. It is disappointing that of the over 40 Egyptian participants, only six have visited Israel.

6.1.3 Quality of Scientific and Technical Accomplishments

The project presents a highly checkered record of scientific and technical work. Much high quality scientific, analytical, and technical work has been carried out by Egyptians and Israelis under the auspices of the Wastewater Reuse Project. This high quality scientific and technical work adds credibility to the importance and utility of regional cooperation. However, there are also significant deficiencies in the scientific and technical work. These include: a lack of virus sampling by the Egyptians at the Suez Experimental Station; sporadic water quality sampling, i.e., the frequency of monitoring was variable over the course of the project; and data presentation is scattered over several of the project reports and all of the data collected are not summarized or tabulated in any one report. The actual sampling frequency of various water quality parameters is not stated in the reports reviewed as part of this evaluation, and could not be determined from the information provided.

6.1.4 Experimental Station

The Suez Experimental Station, completed under the predecessor project, and continued and improved under the present grant, is well designed, well operated and maintained, and a potentially sustainable asset for the Egyptian government's National Institute for Oceanography and Fisheries. However, the highly saline water and soil greatly limit its utility as a demonstration facility at this time. If the salinity problem is resolved and the other technical recommendations in this report are accomplished, the utility of the experiment station will be significantly enhanced.

6.1.5 Aquacultural and Agricultural Reuse of Wastewater

The high salinity concentration of the wastewater limits the usefulness of some of the data obtained. The need to dilute the pond effluent (because of the salinity) prior to agricultural irrigation reduces the concentration of all the chemical constituents in the irrigation water, and thus results in irrigation with water not representative of typical stabilization pond effluent. Given the highly saline solution, there was little else to be done. However, this study cannot be used as a sole basis for guideline development, and will need to be replicated or otherwise verified and improved upon at other locations using wastewater having a lower TDS concentration.

The high salinity of influent wastewater is probably due to the infiltration of saline groundwater into the sewerage system of the City of Suez and may be reduced as a result of renovations to the system that are presently underway. Although reducing the salinity of influent and effluent wastewater will clearly improve the usefulness of the experiment station, the project has demonstrated that the undiluted, highly saline effluent can be used for raising trees and some crops. Furthermore, experience gained in this project in conditioning saline soils and selecting salt-tolerant crops is valuable with regard to reclaiming desert lands in this region.

The trials at the Suez Experimental Station (with the caveats noted in the next section) demonstrate that fish and crops can be successfully reared and grown using wastewater. However, although the pond system is well-designed and operated, the wastewater does not yet consistently meet WHO standards for helminths for the intended agricultural and aquacultural uses.

6.1.6 Remaining Scientific and Technical Issues

Despite good research and successful operation of the Suez Experimental Station, important and crucial issues and problems remain inadequately understood. These are the following:

- The extreme salinity of the influent, and the much greater salinity of the effluent from the stabilization ponds at Suez has presented a range of practical problems for the agronomic trials and leaves a number of open questions regarding many aspects of the pond operation and reuse of the wastewater.
- Helminths are still present in the maturation pond of the treatment system and in the fish-raising pond at levels that equal or exceed WHO guidelines. Concentrations of helminths in the latter may be elevated due to the activities of fish and pond operators that disturb sediments. Concentrations may be lower than they would be if the wastewater were less saline. And, it is not clear whether greater retention time would reduce helminth concentrations.
- Viral analyses of the treated wastewater have not yet been performed, despite the fact that Egyptian scientists received extensive training in this area at Hebrew University. Such analyses will be necessary to assure that the wastewater is acceptable for high level uses, e.g., agriculture and aquaculture.
- Researchers do not know the actual retention time of wastewater, as dye tests have not been done. Considerable seepage could significantly lengthen the retention time of the effluent, or thermal stratification could shorten the time (as is the case in Israeli ponds), or both.
- Problems with thermal stratification in Israeli ponds have not been solved by Israeli researchers. There may be implications for Egyptian attempts to replicate the Suez technology.
- The performance of the Suez pond system is better than predicted (regarding coliforms). It is important to understand why this is so in order to replicate the technology.

6.1.7 Dissemination, Technology Transfer, and Implementation in Egypt

The project is behind schedule on most planned activities that relate to the process of dissemination and wider application of the technologies of stabilization ponds and agricultural and aquacultural reuse of wastewater treated to WHO standards. Chief among these remaining activities and products are:

- Workshops (national and local for Suez) regarding the opportunities and necessary safeguards for the wider use of these technologies to benefit Egypt. These workshops are not intended simply to present the results of the Suez research for automatic adoption elsewhere, but to use the Suez experience as a basis for broader discussion of the potential for stabilization pond and reuse technologies.

- Economic and sociological analyses regarding costs and benefits, changing social and cultural attitudes, and investment opportunities and risks with different wastewater reuse applications.

- Operational manuals for pond operation, safety precautions, monitoring techniques, fish rearing practices, and agricultural applications. Final guidelines would be premature.

- The publication rate from the Egyptian participants is very low. In addition to possible research papers, there is a need for more general articles and brochures (in Arabic) regarding the potential for wastewater reuse and summarizing the Suez experiments.

Some of these activities are quite rightly saved for the project's end. Others, such as at least one workshop, more publications, and the social and economic analyses, should have begun sooner.

6.2 Recommendations

6.2.1 Recommendations for Priority Activities for Final Year of Project

There are very limited financial resources for the project, and a limited time frame before the project's end. The following activities must take place if the project is to achieve its purpose of testing and disseminating the results of these technologies.

- Complete economic and social analyses of wastewater reuse for agriculture and aquaculture. The range of potentially appropriate locations for wider application of these technologies depends directly on cost factors, on one hand, and market opportunities on the other. The MERC Wastewater Reuse Project will not contribute significantly to the wider implementation of these technologies until it can provide detailed information on required investments and rates of return on these investments.

- Plan and hold a national workshop in Egypt regarding the potentials and constraints of wastewater reuse for agriculture and aquaculture. This activity is an essential part of the process of moving from research and demonstration toward wider implementation of pilot projects of this technology in Egypt. The fact that the Suez Experimental Station is not an unqualified success does not mean that its experiences and research results should not be shared or that wastewater reuse should not be considered for wider implementation. The issues of salinity, continued presence of helminths, possible short-circuiting, and others are central to the wider application of the technology in many arid locales in Egypt.
- Plan and hold a smaller local workshop in Suez, bringing together governorate, municipal, and industry persons to discuss the realistic opportunities for expanding the reuse of wastewater from the new municipal treatment plant.
- Concentrate scientific research and technical work on understanding and addressing the problem of the helminths in the water. To this end they could extend the retention time of the Suez pond system to try to improve settling out of helminths. This could be done by using one of the fish ponds as a third maturation pond. Researchers might also examine the possible effects of high salinity on helminth retention, and the effects of the fish (and the seining operations) on stirring up helminths.
- Complete the planned tests of different baffle systems in the pilot plant in Israel to attempt to alleviate the short-circuiting problems associated with single-celled ponds.
- Perform the planned dye study of the WSP system at Suez to determine the actual retention time in the ponds.

6.2.2 Other Technical Recommendations for the Suez Experimental Station

The following activities should be considered as appropriate and even necessary for the Suez Experimental Station in order to deepen and complete the knowledge of the performance of the WSP at that location.

- Perform virus testing on the wastewater in the WSPs at Suez.
- Further agricultural studies should examine whether helminths are present in the soil (and thus could be a health hazard to farm workers) or on crops that come in contact with the wastewater (and thus could be a health hazard to consumers of the crops or meat from animals that eat fodder crops).
- Investigate the existing WSPs in Egypt to see if any could be used to verify or duplicate the results obtained at Suez.

- Compare the quality of fish from the aquaculture experiment at Suez to fish raised in fresh water—not polluted water—to determine if they are of equal quality, i.e., free of microbiological or chemical contaminants.

6.2.3 Recommendations to USAID/Egypt on Future Implementation of WSP and Wastewater Reuse Technologies

USAID/Egypt should include further pilot wastewater treatment and reuse projects in selected sites as part of its new secondary cities program as well as for other infrastructural projects for villages and new settlements. Judging simply from the range of examples visited by the evaluators in Israel and Egypt, there is not one simple niche or scale for such technologies, but a relatively broad range of technical and economic possibilities. The experience of the Suez Experimental Station, once recommended activities are completed, will provide a partial basis for planning pilot projects in other sites. Equally important, the Suez station could serve as a training center for operation and monitoring techniques.

As part of the project design process, USAID should carry out a short comparative review of Egypt's recent experiences with various appropriate technology for wastewater treatment and reuse activities. Suez appears to be the most completely studied system, but more information could be gathered regarding others, which would deepen the understanding and contribute to site selection for pilot systems. Especially because of the high salinity at Suez, USAID needs to combine the data from the Suez experience with that of other examples before embarking on a wider pilot program. Such a comparative study would do much to indicate the extent to which the salinity problem affects the results at Suez.

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UNIVERSITY THESES RESULTING FROM PROJECT

Bacterial Studies on Fishes Cultured in Wastewater. By: Ayman Ibrahim Shaaban. Cairo University, Faculty of Veterinary Medicine, Department of Food Hygiene. (Completed Ph.D. Thesis)

Studies on Yeast as Fish Pathogen. By: AAdel Abdel-Aleam Mahdy. Zagazig University Department of Fish Disease. (Completed)

Bacteriological Studies on Fishes Cultured in Treated Wastewater From Zoonotic Point of View. By: Jehan El-Moghazi, Department of Zoonosis, Faculty of Veterinary Medicine, Cairo University. (M.VSc. In Progress)

Appendix A

SCOPE OF WORK

EGYPT/ISRAEL: Evaluation of MERC Wastewater Reuse for Irrigation Project

Background

A project entitled "Technical and Environmental Health Aspects of Wastewater Reuse for Irrigation" is one of several projects funded by AID under the Middle East Regional Cooperation (MERC) Program. The purposes of the MERC Program are to promote cooperation between Israel and Arab countries of the Middle East, and conduct research and other development activities that will improve the well-being of the people. Achievement of these purposes is expected to promote peace in the region.

The Wastewater Reuse Project began in August 1990 with the acceptance of a grant from AID by the University of Michigan (UM) to accomplish a program of research in concert with the National Institute of Oceanography and Fisheries (NIOF) in Egypt, and the Hebrew University of Jerusalem (HU). Much of the research in Egypt is done at the Suez Experimental Station (SES) and the city of Suez is actively involved in the project. Much of the field research in Israel is done at kibbutz Sha'alabim and Netiv LH. The UM is responsible for administering the grant, including making sub-grants to its partner institutions in the Middle East to accomplish project purposes.

The purposes of the project are to promote mutual exchange of technology and knowledge, foster cooperation among the participating scientists, and develop guidelines for the safe reuse of wastewater for irrigation. Emphasis is to be placed on low-cost sustainable technologies applicable to the region and to similar arid lands. World Health Organization (WHO) standards are to be applied in developing treatment system design criteria and evaluating results.

The project has three main components:

Laboratory and Pilot Plant Studies

This includes:

a) The development of a predictive model of bacterial inactivation in a stabilization pond system;

b) The evaluation of several helminth removal technologies;

c) Effectiveness of various treatment systems in removal of enteric viruses and protection from viral contamination by drip and other irrigation techniques;

d) Soil characterization, soil conditioning, and assessment of various agricultural practices, and;

e) Identification, monitoring, and removal of chemical pollutants from raw and treated wastewater, and the development of predictive models for estimation of accumulation in soil and plants

Field Applications

This includes studies of various chemical, microbial, agricultural crop, and irrigation system parameters to determine guidelines for the safe use of wastewater for irrigation at the Suez experiment station.

Training

This includes on-the-job courses in wastewater treatment for irrigation, and research methods and techniques; workshops; study tours; and an international conference. Training manuals, conference proceedings and other publications produced by the collaborating scientists are to aid dissemination of information in Egypt and Israel.

Wastewater reuse refers to the reuse of treated wastewater effluent is such uses as aquaculture and irrigation. In this "direct reuse" the quality of the wastewater can be monitored and deleterious health impacts avoided. Wastewater reuse programs are particularly beneficial where water is currently discharged into the sea without being reused. Under the Wastewater Reuse Project, research has been carried out both in Israel and Egypt to determine the potential for wastewater reuse in several applications.

The project has helped develop a wastewater treatment research facility, where two types of stabilization ponds are being tested. An effluent monitoring program has been active for two years. Research findings indicate the effluent is suitable for aquaculture and agriculture, but planned agronomic trials using the effluent have been curtailed due to the high salinity of the available soils.

The estimated completion date for the project is 19 May 1993. AID is currently considering a one-year extension of the project at no additional cost.

<u>Objectives</u>

AID's Near East Bureau has asked WASH to provide a team to evaluate the Wastewater Reuse Project to determine whether or not it has achieved its stated objectives. The evaluation is also to determine whether the research done in this project, considered with the findings of other wastewater treatment and reuse programs in Egypt, Israel and those in similar environments in other countries, has produced sufficient knowledge of the treatment of village sewage and the safe direct reuse of the effluent to warrant a pilot test program in a few Egyptian villages.

The envisioned pilot test would be the next logical phase, where available physical and biological knowledge would be applied in a real-world laboratory of a few villages. This pilot test would include the development of baseline data on relevant variables, systematic introduction of changes in the handling of village sewage and use of the effluent, and scientific observation of the social, economic, biological, and physical effects of those changes in the communities. The pilot tests would be designed to provide the social and economic information needed for decisions on widespread adoption of the village sewage treatment technologies, if warranted.

Additionally, since one of the Congressional mandates of this program is to foster cooperation between Egypt and Israel, specific attention is to be given to describing how this objective has been met. The evaluation will include a summary of past and present examples of cooperation under the project, as well as the expected degree of post-project cooperation.

Methodology

The following evaluation components should be considered and addressed in the final report produced by the team. The discussion of each component should be concise, yet should identify important factors affecting implementation, and place them in the context of achieving project purposes. Recommendations should be based upon specific information or examples, and should be directed towards increasing project performance or success.

There are three main areas of concern:

Management

Assess the adequacy and effectiveness of the various elements of project management and project design. The following should be addressed:

- Does the US institution adequately back-up the research efforts in Israel and Egypt in such topics as flow of funds, report submissions, research monitoring, equipment purchasing, technology transfer, convening meetings, and communications with all parties, including AID?
- Are technical and financial reports timely and complete?
- Are workshops and progress reviews held regularly?
- Do funds flow to PIs (Principal Investigators) when needed?
- Has USAID Mission involvement been appropriate?

Cooperation

Determine the amount of present and sustainable cooperation generated by the project by noting the following:

- Number of institutions and scientists of both countries involved in the project
- Has travel between the two countries become easier? Are visits becoming more numerous?
- Number of co-authored publications and presentations at international meetings
- Evidence of data, analysis, and insight exchanged

Technical Questions of Project Progress

Determine the extent to which the project has completed the technical objectives outlined when it began, to include the following:

- Compile a listing of research conducted and technology generated
- Describe other accomplishments, such as training, infrastructure development, and technology transfer
- Examine and comment on the workplan for 1993-94. Does the staff have the required background to implement the workplan?
- Comment on the need for the agronomic research that could not be done because of the high salinity of the soil

As indicated in the "Objectives," the report should also analyze the availability of proven technology for sewage treatment and wastewater reuse. The analysis should provide information for a decision on whether or not it is advisable to move ahead with planning a pilot project on wastewater treatment and reuse for agriculture and/or aquaculture in a few villages in Egypt. The content of the analysis will depend upon the team's findings in Egypt and Israel, but the following issues may be among those that should be addressed:

A) Discuss the results of the research done in the project, and experience in other projects in the Middle East, that argue for and against moving into a pilot test in a few villages. Indicative questions should include:

   1) What definitive knowledge of treatment of sewage and direct reuse of the effluent has been developed in this research and in other tests and experiences in the Middle East?

   2) What are the characteristics of the intake sewage at the Suez site, and in what important ways would intakes at various other sites be expected to vary? Which treatments have given consistent results? Which effluent characteristics are important for agriculture; for aquaculture? Which treatments have consistently produced usable effluent with the briefest retention? What are the tradeoffs among treatments, retention times, and safety of effluent?

   3) If a pilot test program seems warranted, what factors should govern selection of test villages?

B) Discuss scale issues, including village populations, amounts of sewage produced, physical requirements for collection and transport, and spatial requirements for treatment by various usable low-cost techniques.

C) Discuss anticipated social issues, including effects of disruption of present sewage handling techniques, effects on community health, odor tolerance, acceptance of improved sewage handling techniques, and of products from effluent-produced crops and fish.

D) What factors should be considered in an analysis to determine whether or not to proceed with a pilot reuse project (i.e., costs and benefits, sustainability, financing, public health issues, etc). Recommend specific studies which could be conducted over the remaining life of the project which could better define these factors.

The evaluation team should follow the format and guidelines established by USAID in the supplement to Chapter 12, AID Handbook 3, entitled "AID Program Design and Evaluation Methodology Report No. 7." The team should utilize the following data collection and interview methods:

1) Review the relevant project papers and contracts, progress reports, and previous evaluation reports.

2) Conduct interviews and discussions with members of the program's steering committee, project principal investigators (PIs), and scientists involved in the project, and examine their activity records, data analysis, and conclusions.

3) Meet with other relevant officials including USAID staff to determine project issues involved in a wastewater reuse pilot project.

Tasks

Days 1-4

1) Read background materials prior to travelling to Washington.

2) Travel to Washington and participate in a two or three day Team Planning Meeting (TPM). Briefings are anticipated from AID/W personnel, Winrock International, and Dr. K.H. Mancy of the University of Michigan.

3) At the end of the TPM, a workplan and report outline should be developed.

Days 5-15

1) Travel to Cairo and visit with Dr. Ahmad Eisway, Dr. A.F. Abdel Latif, Dr. Hussein K. Badawi, and Dr. Ahmad El-Ibiary of the National Institute of Oceanography and Fisheries (NIOF).

2) Visit Fred Guymont, Alvin Newman, and other personnel at the USAID/Cairo Mission. Become familiar with USAID and other projects relevant to the reuse of wastewater in Egypt.

3) Visit with Drs. Ehab Beibars, Fahmy El-Gammal, A.M. Ibrahim, Mohyi AlSaeed Eissa, Mohammed Ibrahim El-Samrah, Mohammed Sherif, Ezzat Awad and other staff doing research on wastewater reuse at the Suez experiment station.

4) Visit other sites TBD in the Cairo area to see traditional and new sewage treatment facilities.

Days 16-24

1) Travel by air to Tel Aviv and by road to Jerusalem.

2) Visit with Prof. H.I. Shuval, Dr. B. Fattal, Dr. Abid Nasser, and study sites in the Jerusalem area.

3) Visit with Mr. David Mulenex of the US Embassy.

4) Visit other sites in Israel TBD to review sewage treatment technology for wastewater reuse.

5) Submit a draft report of conclusions and recommendations to appropriate AID/Embassy officials, and conduct a debriefing.

Days 25-31

1) Travel back home and complete work on the draft of the report.

2) Submit the draft report to the AID/W Near East Bureau for review and comments, and conduct a debriefing.

3) Respond to comments and prepare a Final Draft of the report.

4) Return home.

<u>Personnel and Level of Effort</u>

The team should be composed of two members:

Environmental Engineer

This individual should have extensive experience in research on the treatment of urban community wastewater for reuse in agriculture and similar applications. Experience in research on monitoring toxins, pathogens, dissolved salts and solids, and other factors affecting effluent quality in wastewater treatment systems; and in the design or testing of economic and effective systems, is essential. A comprehensive knowledge of current technologies for treatment and reuse of domestic wastewater in desert environments, particularly in the Middle East, is required.

Development Sociologist/Anthropologist

This individual should have a thorough understanding of the development process, of AID's global and regional objectives, and of AID's special concerns in evaluating its work and in conceptualizing new development projects. Experience in evaluating AID development and research projects and in leading AID evaluation teams is required. An understanding of public health issues, the technical aspects of agriculture, aquaculture, irrigation water management and wastewater treatment is desirable.

Both team members should have a minimum of ten years of experience related to environmental health or development, and should have excellent writing skills. Prior development work in Egypt or Israel is also desirable. It is anticipated that approximately 28 person days of effort will be necessary to carry out this activity.

End Product

The report will be written jointly by the evaluation team under the coordination of the designated team leader, who will be responsible for taking the lead in debriefing AID/W, AID/Embassy (Egypt and Israel), and appropriate Egyptian/Israeli government officials.

The report should follow the guidelines established in the "Supplement of Chapter 12 of AID Handbook 3." The report will also be turned into a WASH Field Report.

The report should consist of the following items:

- A short (3 - 5 pages) Executive Summary that includes major findings, conclusions, and recommendations

- A main body that includes background material, a description of major activities, findings, conclusions, and recommendations. This main body--exclusive of the Executive Summary and Annexes--should not exceed 30 single-spaced pages.

- Any Annexes that may support the conclusions and recommendations. This should include an analysis of the state of knowledge of treatment of wastewater for reuse as irrigation water for agriculture and/or aquaculture in village Egypt.

Schedule (Tentative)

Background Prep	July 5-6, 1993
TPM	July 7-9, 1993
Travel to Egypt	July 10-11, 1993
Field Work (Egypt)	July 12-20, 1993
Travel to Israel	July 20 or 21, 1993
Field Work (Israel)	July 21-27, 1993
Return to US	July 28-29, 1993
Report Writing	July 29-August 2, 1993
Travel to DC/Debriefing	August 3, 1993
Report Finalization	August 4-5, 1993
Return Home	August 5 or 6, 1993

Appendix B

LIST OF PERSONS CONTACTED

Israel

Hillel I. Shuval, Lunenfeld-Kunin Professor of Environmental Health, Director of the Environmental Health Laboratory, Division of Environmental Sciences, The Hebrew University of Jerusalem

Badri Fattal, Division of Environmental Sciences, The Hebrew University of Jerusalem

Abid Nasser, Division of Environmental Sciences, The Hebrew University of Jerusalem

Shabtay Dover, Director, Authority for Research and Development, The Hebrew University of Jerusalem

Elinor Slater, Coordinator, US-Sponsored Research Programs, Authority for Research and Development, The Hebrew University of Jerusalem

Adam Kanarek, Director Dan Region Sewage Disposal and Reclamation Plant, Mekorot Water Co. Ltd.

Egypt

Ahmad Eisawy, Director Emeritus, National Institute of Oceanography and Fisheries, Co-Principal Investigator

Abu El-Futuh Abdel Latif, Former President of the National Academy of Scientific Research and Technology

Hussein Kamel Badawi, President of the National Institute of Oceanography and Fisheries

Ahmed I. El-Ibyary, Under Secretary of State, Academy of Scientific Research & Technology

Kharyria Naguib, National Research Centre

M.I.M. Boeikaa, National Institute of Oceanography and Fisheries

Mohamed M. Shereif, Environmental Toxicologist, Faculty of Agriculture, Ain Shams University, Team Leader of the Irrigation and Agriculture Applications Group

Mohey El-Said Easa, Professor of Fish Pathology, Faculty of Veterinary Medicine, Cairo University

Mahmoud Ismail Abd-el-Rahman, Desert Research Center

Mohamed Silem Ali, Associate Professor of Soil Fertility and Plant Nutrition, Desert Research Center

Adel Ibrahim Tanios, Lecturer of Microbiology, Animal Health Research Institute

A.M. Eissa, Faculty of Agriculture, Ain Shams University

General Fayez Hashem, Deputy Governor, Suez

General Salah Magahed, Secretary General, Suez

Ahmad Hilal, President of City Council, Suez

Wael El-Qadour, City Council Member, Suez

Yahia Awad, Director of Information Center, Suez

Alvin P. Newman, Chief, Office of Engineering, Agency for International Development, Cairo

Mamdouh Raslan, Sanitary Engineer, Office of Urban Administration and Development, Agency for International Development, Cairo

Thomas H. Moore, Economic Section, American Embassy, Cairo

Samiha El Katsha, Social Research Center, American University in Cairo

Soheir Mehanna, Social Research Center, American University in Cairo

Ossama Ashmawy, General Manager, Consulting Engineering Bureau (Formerly the Director of the Cairo Wastewater Organization)

Washington, D.C.

Henderson Patrick, Project Officer, Middle East Regional Cooperation Program, Near East Bureau, Agency for International Development

Bert W. Porter, Near East Bureau, Agency for International Development

Herb Blank, Near East Bureau, Agency for International Development

Floyd Williams, Project Coordinator, Middle East Regional Cooperation Program

Appendix C

MERC SUMMARY DATA SHEET

Wastewater Reuse for Irrigation

Grant Agreement Signed (effective date of grant): July 1, 1990
Proposal Date: March 1989
LOP funding $1,075,000
Current Obligation: $1,074,800
PIO/T: 398-0158- (most recent)
Estimated Completion Date: FY 93 May 19, 1994
Reports:

Annual—includes items in semiannual report, status of project, project results, financial report and budget analysis.
Semiannual—includes progress; visits, etc.; accomplishments vs. goals; problems.
Quarterly—none required.
Quarterly Financial Report—per standard provisions
Special Reports—as requested by A.I.D.
Final Report—90 days after completion date

Evaluations:

Evaluation Plan—due four months after signing agreement, second plan due four months after signing Amendment No. 3.
External—none required

Goal:

To determine the effectiveness and optimum technology of various single and/or combined wastewater treatment and management systems in preparing effluent to meet the World Health Organization Health criteria for wastewater irrigation.

Involved Institutions, Contacts:

A. University of Michigan

Prof. Khalil H. Mancy, Project Director

B. Academy of Scientific Research and Technology, Egypt

Ahmad Essawy, ASRT

C. Hebrew University, Israel

Hillel Shuval, Hebrew University