REUSE OF WASTEWATER AT THE SAN JUAN DE MIRA STABILIZATION PONDS: PUBLIC HEALTH, ENVIRONMENTAL, AND SOCIOECONOMIC IMPLICATIONS[1]

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Sewage wastewater reuse, common in many arid and semiarid parts of the Americas, offers potential economic benefits but poses significant health risks. This article reviews extensive field studies designed to determine how well waste stabilization ponds operating under the desert conditions of coastal Peru can reduce the associated health hazards.

Introduction

The large-scale reuse of untreated domestic sewage for irrigation is commonplace in many arid and semiarid zones of Latin America, as a result of increasing population pressures, water shortages, and protein shortfalls. Twenty per cent of the land is arid or semiarid, having only 5% of the water resources of the Region; but this land supports 60% of the population (367 million people in 1983—*1*). Hence, rivers that adequately served the inhabitants' water supply, waste disposal, and irrigation requirements in earlier times cannot meet these needs today. This suggests the suitability of some form of land disposal and the increased importance of reuse.

However, this practice may pose some health risk for farm workers and for the general population consuming agricultural produce from sewage reuse sites. High rates of enteritis, other diarrheal diseases, typhoid, and hepatitis occur in the populations that generate the sewage, and the environmental survival of the pathogenic organisms associated with these diseases is favored by the prevailing tropical conditions. It is therefore essential that any sewage reuse project have at least the minimal effective sanitary control measures needed to mitigate potential public health risks.

Some examples of reuse in Latin America are as follows:

- In Chile the "Zanjon de la Aguada" irrigation canal receives 80% of Santiago's domestic and industrial sewage and is used together with the polluted waters of the lower Maipo River to irrigate some 16,000 hectares of land near the city. Of this, an area of 6,200 hectares irrigated with six cubic meters per second of raw sewage supplies the city with horticultural products There are problems with *Salmonella*, *E. coli*, *Shigella*, Hepatitis A, *Entamoeba histolytica*, *Giardia lamblia*, and other pathogens. *Salmonella* antibodies have been detected in 57% of the population and typhoid antibodies in 30% *(2)*.
- Irrigation District No. 3 near Mexico City comprises 41,500 hectares irrigated with raw or mixed sewage. Other irrigation districts near the city also use raw sewage. Tests to detect fecal coliforms in the irrigation water have indicated an average concentration of 10^8 MPN/100ml.[3] It has been shown that edible crops for raw con-

[1]Reprinted, with minor changes, from the text by the author in American Water Works Association Research Foundation, *Proceedings of the Water Reuse Symposium III, August 26-31, 1984*, "Future of Water Reuse," Denver, Colorado, 1985. This article will also be published in Spanish in the *Boletín de la Oficina Sanitaria Panamericana*.

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[3]MPN = Most probable number

In: Bulletin of the Pan American Health Organization; vol. 19, no. 2 (1985) p. 142-164

sumption from these reuse sites were contaminated with fecal coliforms on the order of 3,000 MPN *E. coli*/10g *(3)*.

• Along the Peruvian desert coast 33 reuse projects have been identified (Table 1), many using waste stabilization pond effluents. However, there are some uncontrolled reuse sites in and around Lima that irrigate a total of 2,800 hectares with two cubic meters per second of raw domestic and industrial sewage. Peruvian authorities are currently planning the reuse of two and a half cubic meters per second of *treated* sewage to irrigate 4,000 hectares of desert land to the south of Lima *(4)*.

These and other experiences throughout the Third World clearly show that reuse is a reality and that economic demand often creates spontaneous indiscriminate reuse. The responsible public health authorities must anticipate these

Table 1. Sewage reuse sites in Peru.

Location	Flow (liters per second)	Area (hectares)	Treatment provided
1) Ayacucho	60	–	Imhoff tanks + facultative ponds
2) Tacna	150	200	Aerated ponds + facultative ponds
3) Piura	110	–	Ponds
4) Ica	270	300	Facultative ponds
5) Nazca	20	–	Facultative ponds
6) Huaral	50	–	Facultative ponds
7) Puente Piedra	37	–	Aerated ponds[a]
8) Monsefu	15	–	Ponds
9) Viru	5	–	Facultative ponds
10) Chocope	6	–	Aerated ponds
11) Moquegua	30	–	Facultative ponds
12) Lurin	–	–	Imhoff tank
13) Olmos	–	–	Imhoff tank
14) San Pedro de Lajas	–	–	Imhoff tank
15) Chiquian	–	–	Imhoff tank
16) Buenos Aires	–	–	Facultative ponds
17) Arequipa	1,160	–	Percolating filters
18) Ventanilla	–	195	Facultative ponds
19) Cañete	–	–	Raw for vegetables
20) Sullana	–	–	Facultative ponds
21) Paita	–	–	Facultative ponds
22) Cajamarca	–	–	Facultative ponds
23) Chincha	–	–	Facultative ponds
24) Chepen	–	–	Facultative ponds
25) Huanta	–	–	Percolating filters
26) Juliaca	–	–	Facultative ponds
27) Lambayeque	–	–	Facultative ponds
28) Parcona	–	75	Facultative ponds
29) Lima:			
a) San Juan	200	1,600	Raw for silviculture
b) San Juan	160	220	Facultative ponds
c) Villa el Salvador	1,000	–	Raw for vegetables
d) Callao, Collector No. 6	1,000	1,000	Raw for vegetables[a]
e) San Martín de Porres, Collector Comas	940	1,750	Raw for vegetables[a]
f) San Miguel, Collector Palomino	10	40	Raw for vegetables

Sources: F. Yánez et al. *(4)* and J. M. Zapater *(14)*.
[a]Receives industrial wastes.

economic pressures and plan for and implement adequate sanitary control measures. In addition to the risk of microbial contamination by bacteria, viruses, and parasites, there are potential problems of chemical contamination of edible crops, livestock, dairy products, and fish through the bioaccumulation of trace metals and toxic organic substances. Clearly, then, there is a pressing need for field research aimed at evaluating sanitary control strategies relating to reuse.

The San Juan Reuse Project

The San Juan de Miraflores sewage reuse project, which is located on the southern edge of Lima, began in 1961 with the construction of 21 experimental waste stabilization ponds occupying 20 hectares of desert land. The ponds entered into operation in 1964, and the treated effluents have since been used for agriculture, silviculture, and park irrigation. Aquaculture experiments have also been carried out in advanced-level polishing ponds. These uses are summarized in Table 2.

Table 2. Reuse at the San Juan experimental site.

SILVICULTURE:

- Creation of greenbelts
- Irrigation of recreational parks
- Recovery of sanitary landfill site

AGRICULTURE

- Irrigation of horticultural produce (squatters)
  - vegetables, fruit trees
- Irrigation of forage crops (squatters)
  - alfalfa
- Irrigation of animal feed crops grown for zoological park
  - papaya, banana, corn
- Irrigation used for commercial flower-raising
  - roses

AQUACULTURE:

- Fish/prawn
  - *Tilapia*
  - giant malaysian shrimp
- Aquatic plants for poultry feed
  - duckweed

Since 1977 the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS), in cooperation with Peruvian health authorities, has undertaken extensive field and laboratory studies of the quality of the treated effluents and pathogen survival characteristics. The aim of this research has been to evaluate the health risks of reuse and to demonstrate the effectiveness of waste stabilization ponds as sanitary control facilities employed prior to reuse.

Site Description

The San Juan stabilization ponds were originally designed as two-cell facultative ponds with average depths of 1.3 to 1.5 meters. The 21 ponds are arranged in two batteries—an upper battery of 10 ponds and a lower battery of 11 ponds. They are built over porous, alluvial, sandy subsoils. Average rainfall in the area is less than 15 mm per year. Average daily temperatures range from 15°C in the winter months to 23°C in the summer months.

The San Juan complex receives sewage from three lower-class Lima neighborhoods—San Juan de Miraflores, Pamplona Baja, and Ciudad de Dios—with a sewered population of some 108,500 (59%) out of a total population of about 193,000. The average sewage flow is 360 liters per second. The treated effluents are used to irrigate some 280 hectares of forests and parks and 220 hectares of farmland, with another 1,300 hectares being planned for greenbelts with low irrigation requirements (see Table 2). Most of the farmland on the perimeter of the experimental site itself has been occupied and operated since 1964 by squatter families.

The Research Program

Since these experimental ponds began operating in 1964, they have provided valuable design information to Peruvian engineers—as may be seen by the number of pond installations that have subsequently been built and utilized for reuse (see Table 1). Since 1977 CEPIS and a number of other international agencies and Peruvian research institutions have cooperated in developing a comprehensive reuse research program at San Juan, with the aim of evaluating the experiences there and further extending those experiences to other parts of Peru and the Americas.

The research program includes three projects that have already been concluded, three that are underway, and three that have been proposed and are currently under negotiation with different funding agencies. Each of these projects has focused on a particular aspect of treatment and reuse. They are as follows:

Concluded projects:

1977-1979—an engineering evaluation of pond performance and design criteria.

1980-1982—an evaluation of the sanitary risks of treated effluent reuse for agriculture, emphasizing bacteriologic concerns.

1983-1984—an evaluation of aquaculture using treated pond effluents.

Projects underway:

1984-1986—an evaluation of potential groundwater contamination due to infiltration from ponds and irrigation sites.

1984-1985—a study of the sanitary aspects of duckweed production in treatment ponds and use of such duckweed as poultry feed.

1984-1985—a feasibility study of the San Bartolo reuse scheme to irrigate 4,000 hectares of desert land using two and a half cubic meters per second of Lima sewage.

Proposed projects:

1985-1986—an epidemiologic and socioeconomic evaluation of sewage reuse.

1985-1986—an evaluation of the toxicologic risks of sewage reuse.

1985-1986—an evaluation of the virologic risks of sewage reuse.

The remainder of this article will concentrate on the description and findings of the concluded research efforts, for which CEPIS was primarily responsible. However, some preliminary discussion of the other ongoing and proposed projects will also be presented.

Phase I: Engineering Appraisal

The first phase of the San Juan research program began in 1977 with an engineering appraisal of the waste stabilization ponds. The main purpose of the study was to evaluate a series of stabilization ponds working under a variety of loading conditions in a tropical environment, in order to develop local design criteria. The study was performed by CEPIS with the financial support of the International Development Research Center (IDRC) of Canada, and with the participation of the National Agrarian University (UNA) of Peru.

Eight ponds were chosen for inclusion in the study. Since they had been in operation for over 10 years already, the ponds were drained and dried and the sludge was removed. This provided an opportunity to observe sludge characteristics and buildup, including the influence of inlet structure design. New inlet and outlet structures were built that incorporated rectangular or triangular weirs for flow measurement, along with a Parshall (venturi) flume to measure total raw sewage flow and dividing chambers to control inflows to the ponds. The ponds were sequenced as shown in Figure 1, in four two-cell series of primary and secondary lagoons. As the ponds were refilled, infiltration data were collected and all the hydraulic structures were calibrated. The dividing chambers were set to achieve average loading rates of 400, 600, 800, and 1,000 kg per hectare-day to primary ponds P1, P2, P3, and P4, respectively (see Figure 1).

The data collection program lasted for six months. Field measurements included continuous hydraulic recording of the raw sewage flow and daily observation of inlet and outlet flows; monthly infiltration studies; daily temperature measurements of raw sewage and of all pond effluents; and daily Secchi depth (water transparency) measurements in all ponds. Daily meteorologic information was obtained—including wind speed and direction, ambient temperature, evaporation, solar radiation, and hours of sunshine. Qualitative observations of pond appearance, color, odor, scum, and floating matter were also recorded daily. Two series of continuous twenty-four-hour tests were performed in the secondary ponds to obtain vertical profiles of diurnal dissolved oxygen and temperature along with alkalinity and pH data.

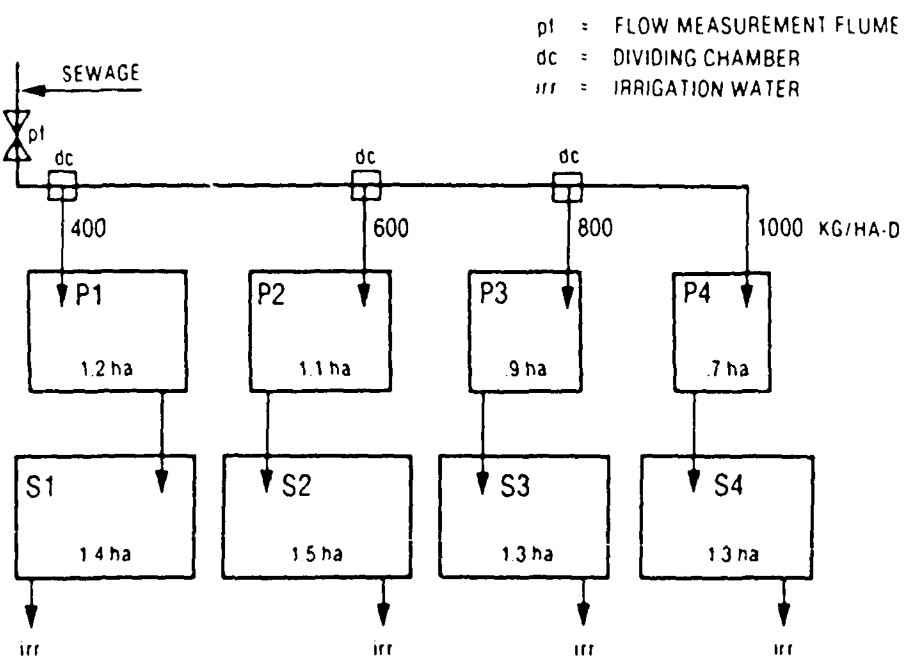
The sampling and analysis program was performed in CEPIS' laboratory according to standard methods with detailed laboratory manuals prepared for chemical and microbiologic procedures *(5, 6)*. Hourly samples of raw sewage were taken by means of a low-cost automatic sampler developed at CEPIS. Weekly grab samples were obtained from all ponds near the outlet structures. Laboratory determinations included total and dissolved five-day biological oxygen demand (BOD_5) and chemical oxygen demand (COD); suspended solids and residue (total, volatile, and fixed); alkalinity; calcium; hardness; pH; potassium; sodium; conductivity; chlorides; sulfates; ammonia nitrogen; organic nitrogen; nitrite and nitrate nitrogen; and total phosphate and orthophosphate. Microbiologic determinations included identification and counting of algae; identification and counting of pathogenic protozoa and helminths; enumeration of total and fecal coliforms by most probable number (MPN) techniques; and the isolation of *Salmonella* with complete biochemical and serotype identification (the latter performed at the Peruvian National Reference Laboratory for Enterobacteria).

The detailed analysis and interpretation of these data have been reported elsewhere by Yánez et al. and Yánez *(4, 7, 8)*. Only the major findings are highlighted in this paper.

Biological Oxygen Demand (BOD_5) Loads and Removal

During the study period, BOD_5 loads on the primary ponds ranged from 200 to 1,200 kg per hectare-day. It was found that the overall average removal efficiencies for the primary and secondary ponds were 80.6% and 76.5%, respectively *(4)*. These efficiencies were relatively

Figure 1. Arrangement of the San Juan stabilization ponds during Phase I, the engineering evaluation phase. The loading rates for the four two-pond series were 400, 600, 800, and 1,000 kilograms BOD_5 per hectare-day (kg/ha-d).



constant over the full range of applied loads. This was corroborated by comparison with research results reported for other tropical countries *(4)*. Yánez *(8)* concludes that significantly higher aerial loading rates can be used for design purposes in tropical climates than those conventionally adopted in temperate zones.

An analysis of the correlation between aerial BOD_5 loads versus the ratio of influent to effluent ammonia nitrogen showed that at 20°C the ammonia fraction remained less than one for loading rates up to 357.4 kg BOD_5 per hectare-day. Since in a biological reactor ammonia nitrogen usually increases only through anaerobic processes, the indicated load represents the upper limit between facultative ponds and predominantly anaerobic ponds. Adjusting for the water temperature, Yánez *(8)* recommends the use of the following design equation for facultative ponds:

$$La = 357.4 \times 1.085^{(T-20)} \qquad [1]$$

where La is the maximum applied BOD_5 load in kg per hectare-day and T is the water temperature in °C. Higher loadings (and thus smaller areas) are obtained using this relationship in tropical climates as compared with conventional design relationships based on ambient air temperatures, since in tropical climates water temperature remains higher than the average air temperature.

Parasite Removal

Although the primary ponds removed the great majority of intestinal parasites, it was found that under coastal Peruvian conditions primary ponds are not enough for complete removal of pathogenic protozoa and helminths. It was shown that helminths were completely removed by two ponds in series with a total minimum retention time of 5.5 days. However, a few protozoan organisms were found in secondary pond effluents of the more highly loaded series. For complete removal of protozoa, at least two ponds in series were needed with a total minimum detention time of 36 days. Yánez et al. *(4)* attributed the appearance of parasites in secondary effluents to resuspension due to temperature inversions, and suggested that removal could be improved using baffled pond effluent weirs for the retention of floatables or scum. Further research was recommended.

Fecal Coliform Removal

In all but the most highly loaded (P4-S4) series, there was an apparent reduction of two log cycles in *E. coli*, from 10^8 MPN/100ml in raw sewage to 10^6 MPN/100ml in secondary effluents. However, the data were too scattered to permit definite conclusions, and so further research was recommended on coliform survival characteristics *(4)*.

Salmonella *Survival*

Regarding *Salmonella* survival, the information collected included the isolation of nine serotypes and positive isolation in 20 out of 20 tests of pond effluents. Contrary to expectations, two stabilization ponds in series with a total detention time of 36 days were not enough to completely destroy *Salmonella* species. Additionally, the serotypes isolated (principally Paratyphi B, Derby, and Newport) were prevalent in the area of Lima and were found to have developed resistance to antibiotics. This could pose a problem, since it implies that pathogenic *Salmonella* serotypes have acquired genetic R-factor resistance and may be more difficult to destroy in the water environment. Also, there is a possibility that this resistance can be transferred from *Salmonella* to other pathogenic bacteria in ponds via R-factor plasmids. This, along with the increased reuse of domestic sewage in the urban fringe areas of Lima, could represent a public health problem of increasing magnitude. More detailed studies were recommended, including enumeration of *Salmonella*, in order to fully evaluate the *Salmonella* destruction potential of stabilization ponds *(4)*.

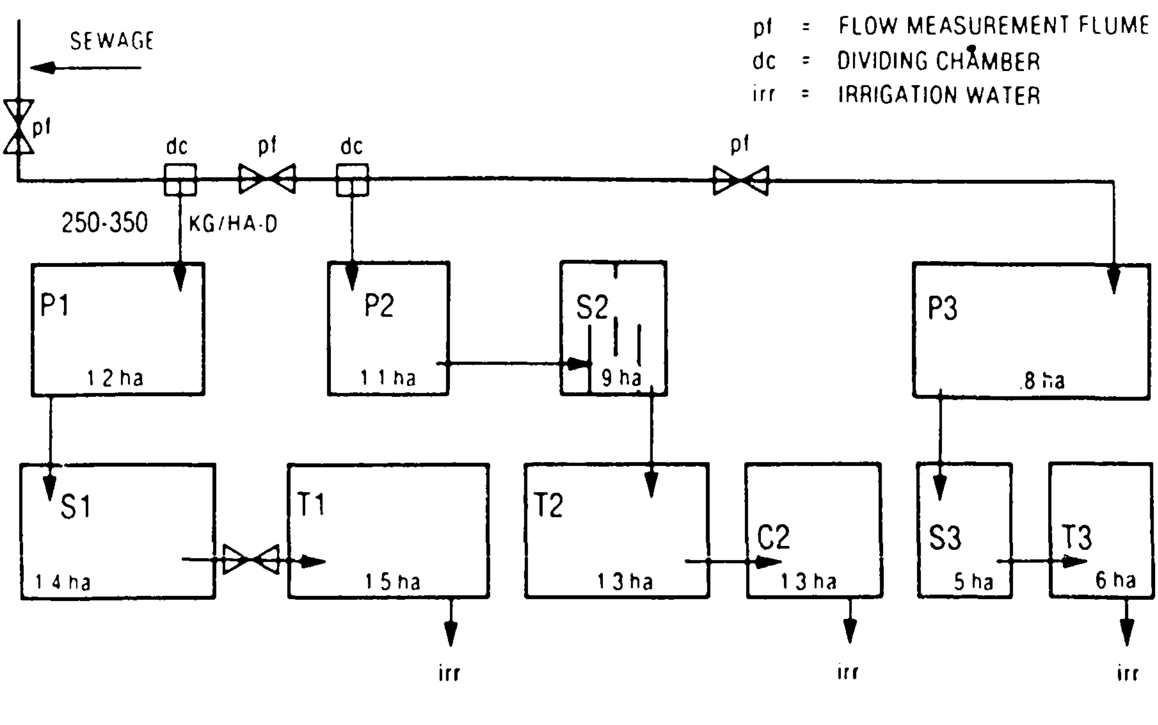
Phase II: Pathogen Survival Studies

The main purpose of the second phase of research at San Juan was to investigate the reduction of pathogenic organisms achieved through a series of waste stabilization ponds, with the objective of developing practical information for the design of ponds under tropical conditions and for the large-scale agricultural reuse of treated effluents. The project was conceived and executed at the request of the Peruvian Ministry of Health, and was financed by that Ministry and the Inter-American Development Bank (IADB).

For this study the ponds were resequenced, as shown in Figure 2, so that they formed two three-cell series (P1-S1-T1 and P3-S3-T3) and a four-cell series (P2-S2-T2-C2). This configuration allowed for pathogen survival studies with longer hydraulic detention times. Also, in accordance with the recommendations emerging from the previous phase, all pond effluent weirs were baffled to reduce the potential for parasite transport via floating matter. Additional flow measurement (Palmer-Bowlus type) flumes were incorporated. In pond S2, three baffles were installed to convert the pond from a mixed reactor to a plug-flow reactor. When the modified ponds were completely filled, all hydraulic measurement flumes and weirs were calibrated. Aerial BOD loading rates were maintained between 250 and 350 kg per hectare-day during this phase.

Because the true hydraulic detention times of the ponds appeared in phase I to be considerably shorter than the theoretical detention times, the complete mixing assumption required checking. An intensive program of hourly temperature pro-

Figure 2. Arrangement of the San Juan stabilization ponds during Phase II, the sanitary evaluation (pathogen survival) phase.



file measurements was undertaken to characterize the stratification characteristics of the ponds. Also, 16 dye tracer studies were carried out to determine the hydraulic characteristics of all the ponds, particularly their dispersion constants.

To determine bacteria dieoff rates, three types of tests were conducted. These were done (1) in full-scale stagnant ponds with no influent or effluent; (2) in plastic bags immersed in ponds and filled with 100 liters of pond water; and (3) in pond S2, which was of the plug-flow type. Initially, parallel tests were conducted in the stagnant ponds and plastic bags. However, because the sampling procedure for stagnant ponds was too cumbersome and the dieoff results for both tests gave exactly the same results, the first type of test was abandoned in favor of the second. A total of 31 dieoff tests were performed, 12 in the primary ponds, 13 in the secondary ponds, five in the tertiary ponds, and one in the quaternary pond.

Other field measurements made were similar to those made in phase I, with additional continuous hydraulic recorders being installed at the new flume locations.

The sampling and analysis program was considerably reduced so as to concentrate primarily on total and soluble BOD (one, three, five, and seven day), COD, ammonia nitrogen, and total and suspended solids. Microbiologic determinations included the identification and relative counting of parasites, total and fecal coliform enumeration using MPN procedures, and *Salmonella* enumeration using MPN techniques together with biochemical and serotype identification methods *(6)*. Data were collected biweekly over a period covering 17 months.

Detailed data analysis and assessment reports have already been presented. A description of pond temperature dynamics has been provided by Burgers *(9)*. Lloyd *(10)* has analyzed the bacteria dieoff data. And an overall report of tracer studies, dispersion and stratification characteristics, BOD removal performance, and pathogen survival has been provided by Yánez *(7)*. The main points of their findings are summarized here.

Temperature and Thermal Stratification

The following relationship was developed for Peruvian coastal conditions from water and ambient air temperature records *(9)*:

$$T = 8.49 + 0.82Ta \qquad [2]$$

$$Tm = 4.64 + 0.91Ta \qquad [3]$$

where T and Tm are the average and maximum water temperatures and Ta is the average air temperature, in °C. Equation [2] is of great importance locally, as it allows the use of equation [1] for design purposes. Equation [3] applies to stratified conditions. Daytime thermal stratification occurred when solar radiation exceeded 160 calories per square centimeter per day and there were at least six hours of direct sunshine. For stratification events, the thermocline set up between 30 and 60 cm.

Hydraulic Performance

Tracer studies verified a high degree of short-circuiting in the ponds during stratification, which facilitated the rapid transport of viable pathogens through them. The tracer studies also provided data for the calculation of the true detention periods and of the dispersion factors of the ponds. On the basis of these results, Yánez *(7)* recommended the design of rectangular ponds with a dispersion factor of 0.6 and with maximum distance between the inlet and outlet.

Fecal Coliform Removal

The reduction of *E. coli* in three-cell pond systems with a ten-day true hydraulic detention time was found to be 99.98% and 99.96% in summer and winter, respectively *(10)*. Based on 31 mortality rate tests in primary through quaternary ponds, the average dieoff rate for *E. coli* was found to be 0.84 per day *(7)*. More rapid dieoff was achieved in the secondary and tertiary ponds, as compared to the primary ponds, probably due to the higher pH and oxygen levels, scarcer nutrients, and greater likelihood of predator and antagonistic organisms being present. For design purposes under coastal Peruvian conditions, the following equation is proposed:

$$Kb = 0.84 \times 1.07^{(T-20)} \quad [4]$$

where Kb is the net bacterial mortality (per day) and T is the water temperature in °C *(7)*.

Compared with other treatment processes, stabilization ponds in series are much more efficient at removing fecal coliforms. By adding additional pond cells or increasing polishing pond volumes to obtain detention periods on the order of 20 days, it should be feasible to obtain *E. coli* levels below 1,000 MPN/100ml.

Salmonella *Survival*

With respect to *Salmonella*, reductions of 99.8% were obtained in three-cell systems. Raw sewage concentrations of 2,400 MPN/100ml were reduced to 4.5 MPN/100ml in tertiary effluents *(10)*. In a series of comparative mortality tests, *Salmonella* dieoff rates were found to be very similar to rates for *E. coli (7)*. This suggests that *E. coli* is an appropriate indicator organism for *Salmonella* in waste stabilization pond systems. Increasing the detention time to 20 days, which would bring *E. coli* counts down to acceptable levels, would also further reduce *Salmonella*.

Parasite Removal

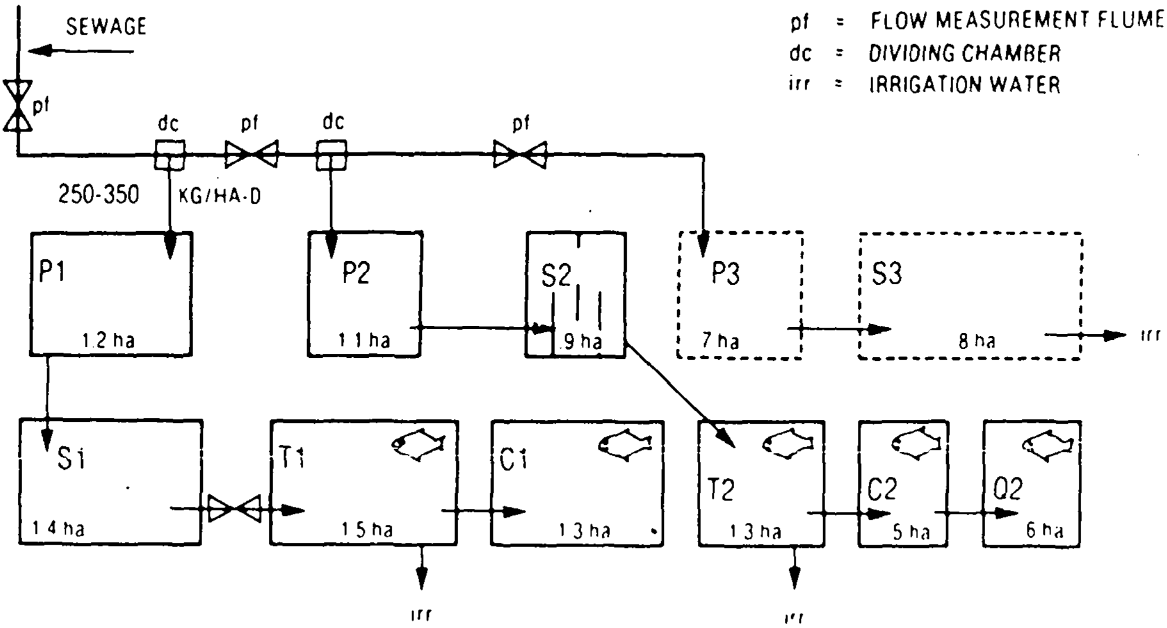
During this phase, with the use of baffled effluent weirs in the primary ponds, no pathogenic protozoa or helminths could be detected in secondary pond effluents. For complete removal, it appears that pond systems which produce four log reductions in *E. coli* through a twenty-day retention period will certainly remove parasitic ova as well. Therefore, although the mechanisms of removal are completely different, fecal coliform indicators may be used with confidence to assess the health risks from parasites, and monitoring of the latter may be dispensed with *(10)*.

Phase III: Aquaculture Appraisal

As part of a larger project to evaluate the production of fish *(Tilapia nilotica)* and prawns *(Macrobrachium rosenbergii)* in the San Juan polishing ponds receiving treated effluents, CEPIS carried out a water-quality monitoring program. The overall project objectives were: (1) to determine the efficiency of the experimental wastewater-aquaculture system for controlling environmental conditions in the ponds, in order to foster good fish growth; (2) to demonstrate the economic viability of the sewage-aquaculture system; and (3) to evaluate any public health problems that might be associated with human consumption of the fish and prawns. Fish stocking, survival, and production studies were carried out by the National Agrarian University (UNA). Fish microbiology and parasitology work was done by the Institute for High-Altitude Veterinary Research (IVITA). The project was funded by the United Nations Development Program (UNDP), the World Bank, and the German Agency for Technical Cooperation (GTZ).

Because of somewhat stringent water-quality requirements, fish experiments were planned only for advanced polishing ponds receiving at least treated effluents from secondary ponds. Therefore, the ponds were resequenced as shown in Figure 3 to create a four-cell series and a five-cell series. The quaternary ponds (C1 and C2) and the quintenary pond (Q2) were designed as shallow (1m) batch ponds that received only sufficient makeup water to compensate for infiltration and evaporation losses. All other ponds were continuous-flow ponds. Aerial BOD_5 loading rates were set between 250 and 350 kg per hectare-day. Fish were stocked at different

Figure 3. Arrangement of the San Juan stabilization ponds during Phase III, the aquaculture appraisal phase.



intervals in ponds T1, C1, T2, C2, and Q2, while prawns were only experimented with in ponds C2 and Q2.

The water-quality monitoring program lasted 12 months. Routine twice-daily sampling was established for the fish ponds (at 10 a.m. and 2:30 p.m.) for temperature and dissolved oxygen at 20, 40, and 60 cm, and for pH and total ammonia. This also permitted the routine calculation of the un-ionized ammonia fraction, which is toxic to fish. In addition, temperature and dissolved oxygen profiles were recorded every two hours for periods of three to five days in the fish ponds on a rotational basis, along with diurnal pH measurements. The remainder of the field observation program was similar to that employed in the previous phases.

Laboratory measurements included analysis of weekly raw sewage samples and samples from all the fish ponds for BOD_5, COD, ammonia nitrogen, organic nitrogen, orthophosphate phosphorus, detergents, and alkalinity. In addition, total and fecal coliform, parasite, and primary productivity determinations were made monthly. During the last months of the program, standard plate count and *Salmonella* determinations were done in pond water and sediment samples, and fecal coliforms and parasites were analyzed in sediments.

The aquaculture experimental program has only recently been concluded, and much of the data is still to be worked up. Therefore, only the preliminary findings of the water-quality monitoring program will be discussed here.

Environmental Conditions in the Fish Ponds

Fish survival and growth can be adversely affected by sustained low dissolved oxygen concentrations or high levels of un-ionized ammonia or detergents. Monitoring and control of these variables is essential for successful fishculture production. The data summarized in Tables 3a and 3b *(11)* show that on the average acceptable values were attained at San Juan in the batch-operated polishing ponds (C1, C2, and Q2). Only marginal water quality was obtained in the tertiary treatment ponds. In the case of dissolved oxygen and un-ionized ammonia, conditions were controlled in large part by the photosynthetic cycle.

Dissolved oxygen concentrations in the afternoon usually reached supersaturated levels due to the high algal biomass present in the advanced stabilization ponds. At night, the dissolved oxygen often dropped to very low levels because of biomass respiration, but early morning recovery was rapid. At the loading rates used, low levels of dissolved oxygen should not be a problem for fish. The prawns, however, may have

Table 3a. Environmental conditions in the San Juan stabilization ponds used for aquaculture apal. The figures shown are averages obtained via daily samples taken from May 1983 through April 1984.

Time	Water sample from designated pond (see Figure 3)	Dissolved oxygen (mg/l) at indicated depth: 20 cm	40 cm	60 cm	Temperature (°C) at indicated depth: 20 cm	40 cm	60 cm	pH (units)	Total ammonia (mg/l)	Un-ionized ammonia (mg/l)
	T1	2.7	2.0	1.6	22.5	22.5	22.5	7.8	11.3	0.6
	C1	4.6	3.6	3.1	23.6	23.6	23.6	8.2	2.5	0.3
Morning	T2	4.2	2.6	1.8	24.3	24.3	24.2	8.1	8.5	0.7
	C2	5.3	4.3	3.7	23.4	23.4	23.3	8.6	1.9	0.3
	Q2	4.2	3.0	2.3	23.8	23.8	23.7	8.5	1.4	0.2
	T1	7.6	5.8	4.0	24.1	23.9	23.6	8.1	11.3	1.0
	C1	11.5	9.3	7.0	25.6	25.5	25.1	8.7	2.4	0.8
Afternoon	T2	15.4	12.4	5.5	27.3	27.1	25.5	8.5	8.1	1.3
	C2	13.4	11.0	7.3	25.2	24.9	24.5	9.0	1.8	0.6
	Q2	12.8	9.6	5.8	26.0	25.7	25.0	9.0	1.4	0.5

Table 3b. Environmental conditions in the San Juan stabilization ponds used for aquaculture appraisal. The figures shown are averages obtained via weekly samples taken from May 1983 through April 1984.

Raw sewage or water sample from designated pond (see Figure 3)	Concentration (mg/l) of: BOD_5	Ammonia nitrogen	Organic nitrogen	Nitrate nitrogen	MBAS detergents	Alkalinity
Sewage	155.7	31.4	18.1	0.25	1.38	270.5
P1	12.6	23.5	12.1	-	1.62	215.5
S1	11.7	16.6	12.0	-	1.46	196.9
T1	20.9	10.7	9.8	-	1.12	189.8
C1	16.5	2.6	10.7	-	0.94	141.0
P2	10.6	19.8	14.4	0.05	1.55	241.4
S2	10.4	16.8	9.8	0.08	1.78	185.6
T2	18.7	8.8	9.0	0.32	1.13	135.9
C2	7.8	2.5	10.5	0.51	0.85	116.6
Q2	6.8	1.6	10.8	0.15	0.98	121.2

been stressed by persistently low benthic dissolved oxygen concentrations.

It is recommended that total ammonia nitrogen levels be maintained below 2 mg per liter to avoid fish toxicity effects. In the case of San Juan, this was not possible in the tertiary ponds, where the average concentrations ranged from eight to 12 mg per liter. At these levels, the UNA investigators reported apparent stressing and stunted fish growth relative to that found in the advanced polishing ponds (J. Moscoso and H. Nava, personal communication). The levels in the latter ponds were maintained at satisfactory concentrations by their batch-flow style of operation, which significantly reduced the ammonia loadings to the ponds. Short-term toxicity problems may arise in ponds on sunny days when photosynthetic activity of algae often drives the water pH above 10. Under these conditions, almost all of the ammonia is in the un-ionized form.

Hard detergents are used in Peru, but the levels in raw sewage are not high. In all of the fish ponds, detergent concentrations were around 1 mg per liter of methylblue activated substance (MBAS).

In summary, it was found that suitable environmental conditions for fish production could be maintained in advanced polishing ponds under Peruvian conditions.

Fecal Coliform Removal

Considering that *E. coli* was shown to be a good indicator organism for *Salmonella* and parasites, monitoring was continued during the third phase. The results are shown in Figures 4 and 5 *(11)*. The tendencies observed in previous phases were confirmed, in that *E. coli* concentrations were reduced to 1,000 MPN/100ml through four ponds, and down to 100 MPN/100ml through five ponds. Again, no parasites survived the secondary ponds. Thus, waste stabilization ponds with adequate retention periods can produce irrigation water meeting common guidelines for unrestricted use *(12)*.

No other conventional sewage treatment process, except perhaps for disinfection, can match the ability of stabilization ponds to remove pathogens. Ponds thus offer a good appropriate technology option for tropical Third World countries. In combination with reuse, they can constitute an effective sanitary control measure.

Figure 4. Total coliform and fecal coliform counts (obtained using MPN techniques) in raw sewage and in water samples from ponds P1, S1, T1, and C1 (see Figure 3).

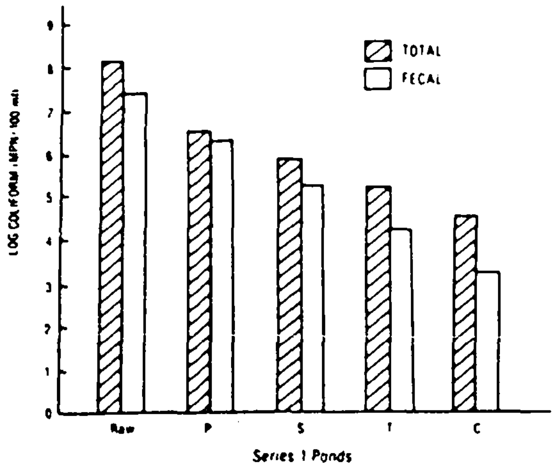
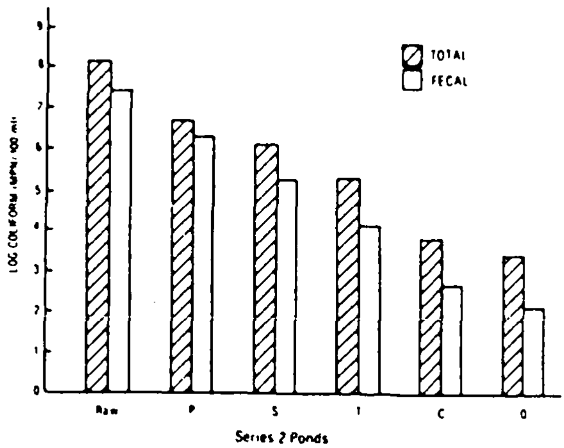


Figure 5. Total coliform and fecal coliform counts (obtained using MPN techniques) in raw sewage and in water samples from ponds P2, S2, T2, C2, and Q2 (see Figure 3).



Epidemiologic and Socioeconomic Factors

A number of preliminary studies have been conducted to identify the key epidemiologic and socioeconomic variables that should require further investigation at San Juan. The following is a brief description of the most important factors involved:

A socioeconomic survey was carried out on the population in direct contact with the San Juan experimental project by Matos Mar *(13)*. This included, first, the site-worker population consisting of eight government workers and their families. The workers were responsible for the operation and maintenance of the site and of the ponds themselves, and for silviculture activities (principally growing eucalyptus forests and recreational parks) and experimental farming (raising animal food crops for the zoological park). Then there were 16 farm families that had settled on the perimeters of the site itself, occupying 36.5 hectares, and that irrigated with treated effluents. These families, known locally as the *precarios*, were squatters who invaded the site during the 1960s and managed to remain despite a constant threat of eviction. The site authorities exercised little or no control over their use of the water, nor over their cultivation or marketing of food or animal forage crops. Immediately adjacent to the experimental site, two other groups (totaling 51 families) settled more recently on 171 hectares of desert land. Both of these groups take water from raw sewage canals that are meant to irrigate nearby greenbelt areas. In all, it has been estimated that 388 people are directly involved in sewage reuse activities.

These three local populations use the San Juan effluents, raw or treated, principally for agriculture. Most obtain water for drinking and domestic use from vendors who bring it in tanker trucks. Local water application rates for farm irrigation in the desert climate reach about one liter per second per hectare; the water is applied by flood irrigation every five to seven days. Crops are grown year-around. Typical total productivity is in excess of 500 tons per year for the 16 squatter families at San Juan. The crops grown include alfalfa and other forage products, fruit from trees, and horticultural produce (corn, potatoes, onions, tomatoes, squash, beans, celery, and lettuce). All of the farm families, without exception, raise farm animals such as pigs, cows, goats, chickens, and ducks.

Food crops are consumed directly, sold to neighboring populations, or sold in truckloads by the growers to intermediaries who in turn market them in the nearby slum communities—including the principal markets of San Juan de Miraflores and Villa María del Triunfo *(13, 14)*.

Epidemiologic data were collected by Campos *(15)* from the populations in the districts producing the sewage and from those consuming the produce from the reuse site. These data show that the most prevalent infectious diseases in the area are acute diarrheal diseases (principal agents are rotaviruses, enterotoxigenic and enteropathogenic *E. coli, Campylobacter, Salmonella,* and *Shigella*); typhoid and paratyphoid fever; viral hepatitis; poliomyelitis; and diseases involving intestinal parasites such as *Entamoeba histolytica* and *Giardia lamblia*. The mortality and morbidity associated with these diseases in Lima are high. For example, in 1978 acute diarrheal diseases caused 10.3 infant deaths per thousand live births and were the leading cause of death among children less than five years of age in Peru *(16)*. Mortality from typhoid and paratyphoid fever in Peru in 1980 was 1.74 deaths per thousand among the total population, the highest in Latin America. 1980 morbidity and mortality data on selected (often waterborne) enteric diseases in Lima are shown in Table 4.

Data collected by Lucas *(17)* on intestinal parasites near San Juan indicate that the rate of infection by *Ascaris lumbricoides* was 31.1% among a group of 61 subjects from families living and working at the San Juan pond site, while the rate in a group of 139 students from a local school one kilometer from the site was only 5.8%. Although the experimental design of the study does not permit hypothesis testing, these results indicate that a detailed study should be conducted of *A. lumbricoides* transmission around the reuse site.

Table 4. 1980 illnesses and deaths from selected enteric diseases in Lima among the general population and among those less than five years old. (The total Lima population was approximately 4,447,000 and the population under five was approximately 513,800 in 1980.)

Disease(s)	Reported deaths among: The whole population	Reported deaths among: The population 0-5 years old	Reported cases among: The whole population	Reported cases among: The population 0-5 years old
Acute diarrheal diseases	1,686	1,355	35,852	26,431
Typhoid fever	154	39	8,142	1,097
Hepatitis	50	9	2,574	1,156
Poliomyelitis	15	12	121	117

Source: M. Campos *(14)*.

This example and the above data indicate a need to be especially cautious, so as to keep the reuse process from creating an additional link in the chain of transmission of enteric diseases. An epidemiologic evaluation of the role of reuse in the transmission of the predominant pathogens, and the establishment of an adequately supervised sanitary code are therefore essential conditions for continued and expanded reuse on the Peruvian desert coast.

The economic benefits for developing countries resulting from safe, controlled reuse projects are many: the recovery of arid lands for agriculture; the creation of employment and settlement opportunities; increases in food production that can help resolve protein deficits and improve nutrition; the potential for increased recreational opportunities and amenities through the creation of parks and greenbelts; and the development of a viable alternative to other forms of sewage disposal and their corresponding pollution and public health problems. The San Juan example shows that Lima can consider reuse as a technically and economically feasible alternative to its current practice of ocean disposal. In the near future, Lima will have to make costly decisions about expanding its sewerage infrastructure. Lima can spend tens of millions of dollars building ocean outfalls to protect its recreational beaches and fishing areas, or it can invest those same resources in a large-scale reuse scheme that can produce the above benefits. And, indeed, the very potential of benefits suggests that reuse may generate additional resources that can help finance the required treatment ponds.

The public health "risks" of reuse must be viewed in the same light. Only 43% of the urban population in Latin America is connected to sewer systems, and of the wastewaters collected, over 90% are discharged directly without treatment of any kind *(18)*. In the slum communities that everywhere surround the urban centers, this situation is especially pronounced, and so excreta disposal is a priority sanitation and health problem. Localized solutions that involve low-cost sewer systems, waste stabilization ponds, and reuse may provide better sanitation for millions of urban poor. Also, the fact that indiscriminate reuse takes place anyway out of economic necessity, as illustrated at the beginning of this paper, highlights the need for well-organized reuse projects with adequate sanitary controls. That is, greater public health risk may lie in not considering reuse and failing to plan for it intelligently.

Future Research Requirements

Thus far, the San Juan research program has shown that under tropical conditions waste stabilization ponds in series can provide an efficient and effective means of treating domestic sewage and removing pathogenic bacteria and parasites. The effluents meet common guidelines for unrestricted irrigation. Also, the ponds can be designed and operated so as to maintain environmental conditions suitable for fish production. Suitable design criteria have been presented.

Since groundwater constitutes a major source of domestic water supply for Lima and the entire Peruvian coastal area, potential groundwater contamination problems due to infiltration from treatment ponds and reuse sites must be evaluated. Such research is currently being performed by the local water supply authorities with the support of the British Geological Survey, The British Overseas Development Agency, and CEPIS.

In order to extract the maximum benefit from sewage reuse, additional resource recovery and recycling opportunities must be identified and evaluated. A project recently started involves the production of duckweed *(Lemnaceae)* in the ponds and its use as a poultry feed. An evaluation of the sanitary implications is included. This research is being done by investigators from UNA, the Nutrition Research Institute in Lima, and Johns Hopkins University, with funding from the United States Agency for International Development.

Many important public health questions remain. As already mentioned, more needs to be known about the epidemiology of sewage reuse. Since classic epidemiologic techniques would be difficult to apply, because of the small sample size and expense, a more straightforward study has been proposed *(19)* to evaluate the health and nutritional status and socioeconomic standing of the reuse workers and their families. One aim is to identify the many direct and indirect health benefits from reuse.

Although much is now known about the behavior of pathogenic bacteria and parasites in the ponds, no work has been carried out on viruses. Even in the developed countries, this is a research area that has been greatly neglected until recently. With the emergence of new techniques for more easily identifying and enumerating pathogenic viruses associated with sewage, the author believes that these methods must be transferred to the developing countries as quickly as possible, and that field research must be initiated. A project to evaluate the virologic implications of reuse at San Juan has been submitted for funding.

Finally, there is a need to take a closer look at the question of the bioaccumulation of toxic substances in the treatment and reuse ecosystem. This has not been considered a serious problem at the San Juan complex, since the sewage is mainly of domestic origin. However, the large-scale reuse of Lima wastewaters with a strong industrial component is another matter. A proposal has also been put forth to conduct a screening study of the most sensitive biological components of the reuse ecosystem for evidence of trace metals and organic toxic substances that are known to be used in the area.

Technology Transfer

The long-term goal of CEPIS is to apply the information obtained through these research efforts for the development and transfer of appropriate technology that will benefit the countries of the Region. To accomplish this, the Center seeks to fully integrate research with training and information exchange activities, and to establish working links between institutes in other countries conducting similar studies.

In the area of training, over the past four years CEPIS has presented an annual international postgraduate short course on waste stabilization pond design and operation for Latin American sanitary engineers. An extensive amount of didactic material has been produced and distributed as part of the course. Also, environmental engineers, scientists, and technicians from the Region have had the opportunity for in-service training on research methods as part of the San Juan program. In all, 44 professionals and students have received such training in CEPIS for periods ranging from a few weeks to 16 months. Six graduate theses have resulted from student participation in the project in coordination with national universities.

On the technical information side, in addition to the production of research reports, articles, theses, and didactic materials, several important manuals have been published in Spanish. These include a manual on experimental methods for evaluating stabilization ponds *(20)*; a monograph of the design of waste stabilization ponds under tropical conditions *(8)*; a manual on chemical procedures for the analysis of water and wastewater *(5)*; and a manual on microbiologic procedures for the analysis of water and wastewater *(6)*. To facilitate the exchange of information, CEPIS also coordinates the Pan American Network for Information and Documentation on Water and Sanitation (REPIDISCA). The network collects, analyzes, and reports on national literature in Spanish and Portuguese that deals with appropriate technology; and CEPIS publishes a quarterly abstract journal of the regional document data base and makes document copy services available to other investigators *(21)*.

There is a growing interest within the Region in expanding research on low-cost treatment options and sewage reuse. In response to this, CEPIS/PAHO plans for the coming year to build up a research network with the aim of stimulating such investigations in national institutions across the Region and encouraging the exchange of results and findings between research engineers and scientists. The participation of leading institutions in developed countries will also be sought when appropriate, so as to encourage the transfer of information about their experiences in this field.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the many institutions that have participated in and funded the San Juan research program, as mentioned in the body of this article. Special recognition is due Dr. Fabián Yánez, who initiated the research program at San Juan and directed the first two phases. The dedication and hard work of the entire CEPIS research team is also greatly appreciated. The opinions expressed are solely those of the author, however, and are not necessarily those of CEPIS or PAHO.

SUMMARY

The reuse of sewage wastewater for irrigation is commonplace in many arid and semiarid zones of Latin America. The practice involves significant health problems, however, and so it is essential that any reuse project employ at least the minimal effective sanitary control measures needed to mitigate potential public health risks. To help assess the ability of waste stabilization ponds to provide such control under desert conditions prevailing along the Peruvian coast, the Pan American Center for Sanitary Engineering and Environmental Sciences has been conducting extensive field and laboratory studies at waste stabilization ponds of the San Juan de Miraflores sewage reuse project on the southern outskirts of Lima. This article provides a descriptive overview of those studies.

The first phase of the work, begun in 1977, evaluated the effects obtained with four sets of two ponds in series receiving average organic waste loads of 400, 600, 800, and 1,000 kilograms of BOD per hectare-day. Among other things, the results indicated that while BOD removals were consistently high, not all pathogenic protozoa were removed by two ponds in series with a minimum detention time of 5.5 days, that 36 days of detention time were not enough to destroy all *Salmonella* species, and that certain *Salmonella* serotypes isolated demonstrated resistance to antibiotics.

The second phase of the work, using two sets of three ponds in series and one set of four ponds in series, focused primarily on pathogen survival. Over-

all, the data tended to confirm that stabilization ponds in series remove fecal coliforms more efficiently than most other treatment processes. They also indicated that detention periods on the order of 20 days should make it feasible to obtain *E. coli* levels below 1,000 MPN per 100 ml. In addition, the results suggested that pond systems which produce a ten-thousand-fold reduction in fecal coliforms will remove virtually all pathogenic protozoa and helminth eggs as well. In tropical climates maximum detention time can be achieved by appropriate design of rectangular ponds.

The third phase of the study, which used one set of four ponds in series and one set of five, dealt with production of fish *(Tilapia nilotica)* and prawns *(Macrobrachium rosenbergii)* in ponds beyond the secondary maturation ponds. Preliminary results of this work have indicated that adequate environmental conditions for raising fish could be maintained in advanced "polishing" ponds such as these, but prawn production could be affected by low dissolved oxygen and high ammonia conditions.

At the same time, epidemiologic data from Lima indicate that acute diarrheal diseases and parasite infections are prevalent in the population of the study area. This situation indicates a need for special caution—so as to keep the sewage reuse process from creating an additional avenue for transmission of enteric diseases. However, the potential economic benefits of reuse are considerable; and the fact that indiscriminate reuse takes place anyway in many places suggests that the greatest public health risk may be incurred by not considering reuse and failing to plan for it intelligently.

REFERENCES

(1) Economic Commission for Latin America. Water Management and Environment in Latin America. In: *Water Development Supply and Management, (Volume 12)*. Pergamon Press, Oxford, 1979.

(2) Court Moock, L., H. Baeza-Sommers, and R. Gómez Diaz. Intensification of water use from the Maipo River, Chile. In: United Nations, Economic Commission for Latin America. *Water Management and Environment in Latin America*. Pergamon Press, Oxford, 1979, pp. 259-272.

(3) Dirección General de Usos de Agua. Reuso del agua en la agricultura. Secretaría de Recursos Hidráulicos, Mexico City, 1974.

(4) Yánez, F., R. Rojas, M. L. Castro, and C. Mayo. Evaluation of the San Juan Stabilization Ponds: Final Research Report of the First Phase. Pan American Center for Sanitary Engineering and Environmental Sciences, Lima, 1980.

(5) Esparza, M. L. Procedimientos simplificados de análisis químicos de aguas residuales. Technical Document Series, No. 10. Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente, Lima, 1983.

(6) Mayo, C. Procedimientos simplificados de análisis microbiológicos de aguas residuales. Technical Document Series, No. 12. Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente, Lima, 1984.

(7) Yánez, F. Indicator and Pathogen Organisms Die-away in Ponds under Tropical Conditions. Paper presented at the 56th Annual Conference of the Water Pollution Control Federation, Atlanta, 2-6 October 1983.

(8) Yánez, F. Avances en el tratamiento de aguas residuales por lagunas de estabilización. Technical Document Series, No. 7. Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente, Lima, 1982.

(9) Burgers, L. Temperature behavior in stabilization ponds under tropical conditions. Pan American Center for Sanitary Engineering and Environmental Sciences, Lima, 1982.

(10) Lloyd, B. J. Lagoon Treatment of Sewage and the Health Risks Associated with the Survival of Enteric Pathogens, with Particular Attention to Coastal Peru. University of Surrey, United Kingdom, 1982.

(11) Bartone, C. R., M. L. Esparza, C. Mayo, O. Rojas, and T. Vitko. Monitoring and Maintenance of Treated Water Quality in the San Juan Lagoons Supporting Aquaculture: Final Report of Phases I-II. Pan American Center for Sanitary Engineering and Environmental Sciences, Lima, 1984.

(12) World Health Organization. ***Reuse of Effluents: Methods of Wastewater Treatment and Health Standards***. WHO Technical Report Series, No. 517. Geneva, 1973.

(13) Matos Mar, J. Informe sobre la situación socio-económica de las familias que utilizan las aguas de las lagunas de San Juan de Miraflores. Instituto de Estudios Peruanos, Lima, 1984.

(14) Zapater, J. M. Reuso de aguas residuales para riego en la zona de Lima Metropolitana. Universidad Nacional Agraria, La Molina, 1983.

(15) Campos, M. Cuadro epidemiológico de las enfermedades infecciosas relacionadas a la disposición de excretas en Lima Metropolitana. Instituto de Medicina Tropical "Alexander von Humbolt," Lima, 1984.

(16) Pan American Health Organization. ***Health***

Conditions in the Americas, 1977-1980. PAHO Scientific Publication No. 427. Washington, D.C., 1982.

(17) Lucas, C. Prevalencia de parásitos humanos entéricos en la zona de San Juan. Thesis. Universidad de Lima, 1980.

(18) Bartone, C. R., and H. J. Salas. Developing alternative approaches to urban wastewater disposal in Latin America and the Caribbean. *Bull Of Sanit Panam* 18(4):323-336, 1984.

(19) Bartone, C. R., B. Cvjetanovic, and T. Schorr. A Protocol for the Epidemiological and Socioeconomic Investigations of Health Impacts from the Use of Treated Effluents for Irrigation in San Juan de Miraflores. Pan American Center for Sanitary Engineering and Environmental Sciences, Lima, 1984.

(20) Yánez, F. Manual de métodos experimentales: Evaluación de lagunas de estabilización. Technical Series, No. 24. Pan American Health Organization/Pan American Center for Sanitary Engineering and Environmental Sciences, Lima, 1982.

(21) Bartone, C. R. Planning regional document-delivery services for the Water Decade: The Latin American and Caribbean Region. *UNESCO Journal of Information Sciences* 4(4):253-262, 1982.

ROTARY INTERNATIONAL PROMOTES IMMUNIZATION ACTIVITIES

The Rotary Foundation, an international nonprofit corporation, has provided over a million dollars in grant funds since 1979 to support Latin American Health Ministries' expanded programs on immunization, in coordination with PAHO and other agencies.

In 1982, the Board of Directors of Rotary International (a worldwide association of Rotary clubs) set a goal to collaborate in the immunization of all the world's children against polio by 2005, the hundredth anniversary of Rotary, and since then work directed toward this goal has been carried out in 19 Latin American, African, Asian, and Western Pacific countries. Rotary International has, to date, awarded a total of US$7.6 million in grants for that purpose.

Providing expert advice for polio immunization is but one element of Rotary's Polio 2005 campaign. The organization has also pledged to raise US$120 million to fund experts, vaccines, and equipment.

Up to now, Rotary International has supported the following countries in carrying out EPI work, in coordination with PAHO:

Country	Rotary grant (US$)	Country	Rotary grant (US$)
Belize	51,200	Haiti	196,000
Bolivia	104,000	Honduras	207,000
Costa Rica	50,000	Panama	537,000
El Salvador	247,000	St. Lucia	66,000
Guatemala	374,000		

Persons and institutions interested in this work may obtain further information by writing to The Rotary Foundation, 3-H, 1600 Ridge Ave., Evanston, Illinois 60201, U.S.A.

Source: Pan American Health Organization, *EPI Newsletter* 7(2):2-3, 1985.