Pan American Health Organization

PAHO/ACMR 17/20
Original: Spanish

SEVENTEENTH MEETING OF THE
PAHO ADVISORY COMMITTEE ON MEDICAL RESEARCH

Lima, Peru
2-6 May 1978

RESEARCH IN TREATMENT OF WASTE WATERS

RESEARCH IN WASTEWATER TREATMENT

Dr. Fabián Yánez
Adviser in Wastewater Treatment
Pan American Center for Sanitary Engineering
and Environmental Sciences (CEPIS)
Pan American Health Organization (PAHO)

SUMMARY

The present paper introduces a discussion on the importance and main areas of research in the field of wastewater treatment, which are considered desirable to promote. A description of the research project "Evaluation of the San Juan Stabilization Ponds" and other research projects conducted in the countries on this field for which CEPIS has provided advisory services is presented.

I. INTRODUCTION

The complexity of the wastewater treatment field cannot be overemphasized. Among the factors which make wastewater treatment and disposal operations difficult are the following:

- The complex composition of liquid wastes, whose adequate characterization may only be made through the analysis of many of their components.

- The variability of wastes, both from the standpoint of concentration and flows, which compels to develop complicated measuring and sampling programs for characterization.

Both factors are in turn affected by other two variables that further complicate the problem with time; these are:

- As cities grow and industry is incorporated or expanded, conditions vary with time having a continuous unsteady state.

- Lastly, the quality requirements in the receiving bodies become increasingly more stringent. These requirements are in relation with quality parameters specific to several water uses (often competitive). A listing shows that the number of these quality parameters surpasses one hundred; with groups of them affecting these uses in one way or other. (1)

On the other hand, the construction of wastewater treatment and disposal systems requires investment of considerable magnitude, and in order to put low-cost solutions to the reach of a great number of developing countries it is necessary to use appropriate technologies. This term, which seems to become generalized, is used in the present paper to imply "the correct use of autochthonous (or simple) technology or the adaptation of non-autochthonous technology to satisfy local conditions, making maximum use of available resources in both cases to reach a low-cost solution." (2)(3)

The role of experimentation in connection with the complexity of problems in this field can be appreciated in the preceding discussion and to emphasize the need of research in relation with the development of appropriate technology, the following Schumacher's quote is presented: (4)

> "Certainly, experience indicates that to reach the limit of knowledge necessary for the development of appropriate technology, it is often needed a higher level of creativity than that required in developed countries for research and development. First it is necessary to review the principles and then to recognize limitations existing in poverty conditions and that are absent in affluent conditions. Many cases can be presented where the way to reach the cheap and simple solutions demands the strategy of using the more sophisticated procedures of thought and calculation and these can only be successfully found with the help of the best and more recent research instruments."

II. RESEARCH AREAS WHICH DESERVE ATTENTION

A discussion on "Research Needs" is out of the scope of this paper; they were outlined in a CEPIS report (5) to the previous meeting of this Committee, where it was recommended that "in general PAHO should give high priority to research on environmental health, in balance with other priorities of the Organization." (6)

The following discussion intends to describe the research working areas which are considered important for promotion, maintaining as reference frame the objectives and working policy of CEPIS. It is emphasized that these areas do not represent priorities and it is recognized that under the above-mentioned definition, most areas of research are under the concept of "Appropriate Technology". In addition, it is convenient to indicate that one area does not exclude the others as most research projects include several areas. A summary of these is given on table 1.

Regarding the development of the four general research areas, it is suggested the promotion, at the field level, of the first two, that is: research for design and operation of waste treatment plants and specific projects of appropriate technology. Country institutions working in these two areas should receive all the possible assistance. The third area of methodological research may be performed by country institutions in connection with local aspects and by CEPIS in connection with Regional aspects. Regarding the fourth area of standardization of experimental procedures it is suggested that CEPIS take the lidership.

There are also other working areas related with the development of infrastructure for research. These demand multidisciplinary action and are shared by many of the CEPIS fields of specialization, for this reason are left out of the scope of this paper.

Table 1

AREAS OF RESEARCH IN WASTEWATER TREATMENT

A. Research design and operation of treatment plants

1. Experimental procedures for process design
   a. Wastewater characterization *
   b. Development of constants for mathematical models *
2. Wastewater treatability
   a. Laboratory studies
      - Physical-chemical treatability
      - Biological treatability
   b. Pilot plant scale
3. Treatment process performance evaluation
   a. Operative-corrective aspects *
   b. Criteria for plant expansion and/or upgrading of capacity *

B. Specific projects of appropriate technology

1. New conceptions and arrangements of processes
2. Minimization and recovery
   a. Energy saving and recovery
   b. Wastes minimization and by-products recovery
   c. Reuse of wastewater and sludge
      - Recovery of arid lands *
      - Industrial reuse
      - Fish culture *

C. Methodological research

1. Mathematical models for treatment process and plants
2. Cost as a tool for evaluation of technology

D. Standardization of experimental procedures *

*Areas covered in the San Juan Stabilization Pond Research Project

III. ONGOING RESEARCH PROJECTS

A. Evaluation of the San Juan Stabilization Ponds, Lima

This project is being conducted by CEPIS with the support of the International Development Research Centre (IDRC) and the collaboration of the Peruvian Ministry of Health as the national counterpart. It covers several working areas, as indicated in table 1.

The climate of the Peruvian coast, affected by the Pacific current, presents the characteristics of scarce rainfall and narrow temperature variation, making of this zone a semi-arid desert. Lack of water is evident at present and, accordingly, it may be foretold that it will be impossible to satisfy demand for this element. The Lima Metropolitan area has undergone a swift expansion, made only possible by the urbanization of old farming areas. This makes possible to predict that the problem of agricultural supply of products will worsen in the future, and be further aggravated by the scarcity of water. Because of these circumstances, the Peruvian authorities have taken into account the necessity of considering wastewater as a water resource indicating that, for the water basin that provides water to Lima, reuse of treated wastewaters is a "definite necessity." (7)

This situation illustrates the importance of this project to establish criteria for arid land recovery for agricultural use. As the stabilization ponds are a low-cost and high-efficiency treatment method in the destruction of pathogens, these research activities fully justify the following objectives:

- To evaluate the performance of the San Juan ponds in a variety of operating conditions.

- To study the public health implications of the reuse of stabilization pond effluent in agriculture, through the determination of the survival of pathogenic organisms.

- To study, with the developed data, the feasibility of treating the wastewaters from the southern interceptor of Lima and the economical impact of agriculture and fish culture with stabilization pond effluent.

This is a two-stage activity project. In the first stage the national counterpart will carry out the modifications in the lagoons site, such as the installation of meters and flow distributors, and pond bottom recovery. During this period it has been planned the acquisition of equipment and the conduction of a literature review on experimental procedures of research with ponds, irrigation and aquaculture.

During the second stage an evaluation will be made of eight ponds that operate two in series and two parallel groups with loads of 400, 600, 800 and 1,000 kg BOD/ha/day, as indicated in figure 1.

The parameters to be measured are related to water quality criteria for agriculture, fish culture, pond ecology, processes control and public health reasons. A list of these parameters is given in table 2.

The experimental procedures for sampling, preservation and analyses are specific for each determination and have been chosen in accordance with the standard methods (8), and the existing limitations for each case. These data are summarized in table 3. Considering the time demanded by the different analyses and their associated field activities, an initial sampling program has been selected, this is indicated in table 4. Figure 2 shows the procedure for the determination of Salmonella and Shigella.

From the data collected, criteria may be developed to satisfy the objectives of the study under the following aspects:

- Variation of loads removed of the different components, in terms of applied loads.

- Destruction of pathogen organisms (protozoan/helminth) in function of the operating conditions of primary ponds.

- Development of data on the kinetics of reduction of organic matter and coliforms.

- Study of the influence of wind as a mixing agent to prevent thermal stratification.

- Predominance of macrospecies.

- Study of infiltration self-control.

- Study of sludge accumulation and drying.

- Determination of critical climatic conditions in design.

B. <u>Other research in the Region</u>

In the field of wastewater treatment CEPIS has provided advisory services in several research projects that are carried out in some countries.

Collaboration has been offered to SENDOS and to the University of Chile in the implementation of a working program in the Melipilla Experimental Wastewater Treatment Plant.

Within this, collaboration has been given in the following projects:

- Reuse of wastewater for irrigation and algae growth

- Treatment of wastewater by oxidation ditches

- Development of the Melipilla Experimental Wastewater Treatment Center (CEXAS)

- Start-up of the Melipilla Experimental Wastewater Treatment Plant

From the above-mentioned projects, the latter has deserved particular attention as the objectives are of immediate application through the development of design criteria for several wastewater and sludge treatment processes. Advice was also given in the following research projects that were developed by engineering students in their last year at the university, with the help of a guide professor:

- Cost of wastewater treatment plants for small communities

- Research on the present state of plants in Chile

- Pond operation and maintenance

- Trickling filter distributors

- Simplified design of coarse racks

- Sludge treatment

In Argentina, collaboration is given to the Instituto Nacional de Ciencia y Técnica Hídricas (INCYTH) in the implementation of an experimental field that will count with a pilot plant and with a mobile unit to perform treatability studies.

Other research activities have been carried out in Brazil, at the Centro de Ciencia e Tecnologia of the Federal University of Paraíba (CCT/UFPB) with an experimental wastewater plant. Collaboration has been given in these studies, particularly in the standardization of experimental procedures, in the stabilization pond research project.

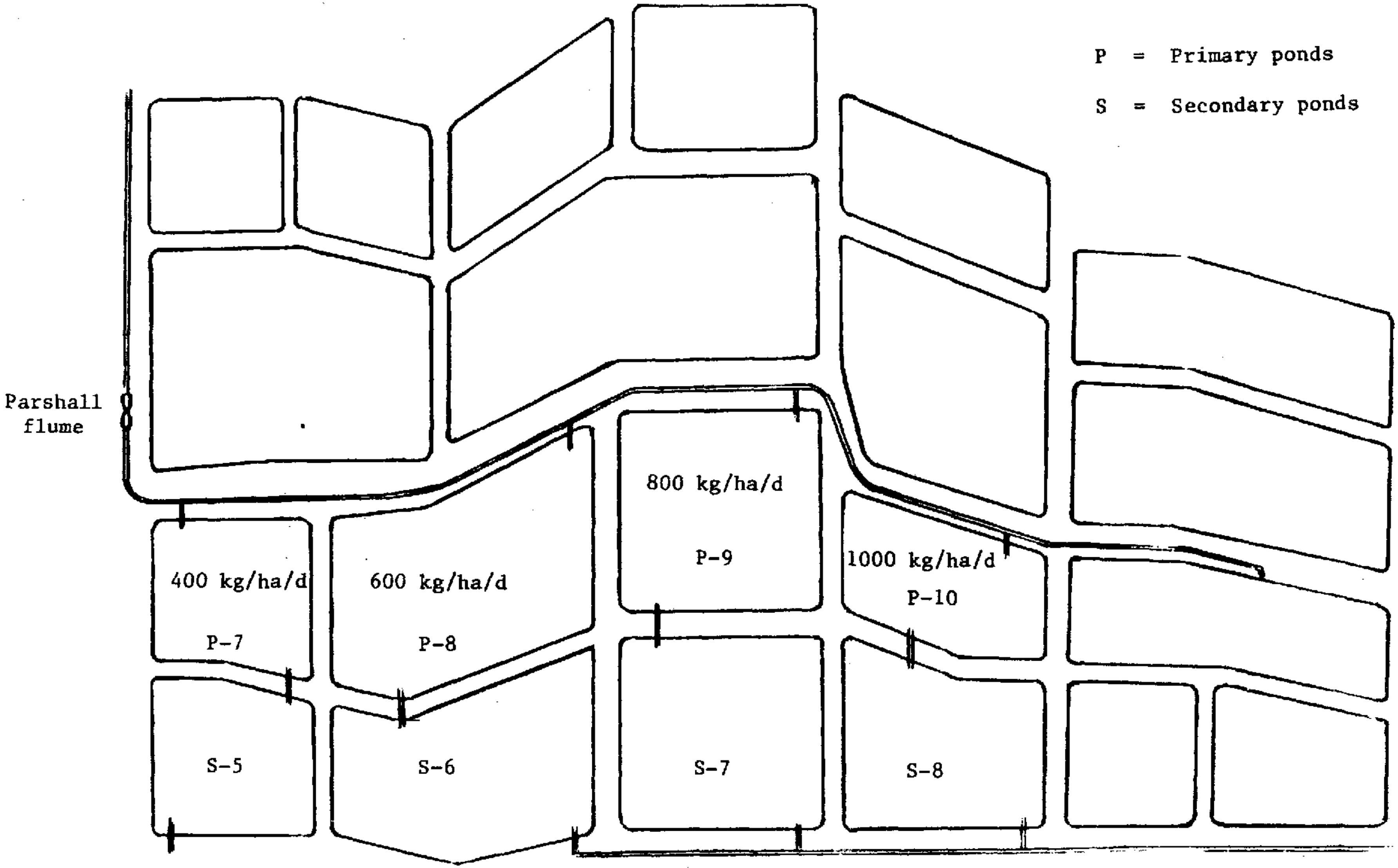

Figure 1

SAN JUAN POND COMPLEX

Table 2

SELECTED PARAMETERS AND THEIR RELATION WITH QUALITY CRITERIA

Parameter	Units	Public Health	Process Control	Pond Ecology	Reuse		
					Agriculture	Fish Culture	
I. NON BIOLOGICAL							
A. Meteorological							
1. Wind velocity	km/h	+	+	-			(a)
2. Wind direction	degrees	+	+				(a)
3. Air temperature	°C		-	-		-	(a)
4. Evaporation	mm		+		+		(a)
5. Solar radiation	h/day	+	-	+		-	(a)
B. Hydraulic							
1. Average flow	l/sec		+	-	+	-	
2. Maximum hourly flow	l/sec		+		+	-	
3. Maximum daily flow	l/sec		+		+	-	
4. Minimum water balance	mm		+	-	+	+	
5. Level fluctuation	m		+	-			
6. Pond depth	m		+				
C. Physical facts							
1. Sludge depth	m	-	+	-			
2. Liquid temperature	°C		+	-		-	
3. Temperature profile	°C		+	+	-	+	
4. Oil and grease	mg/l	-	-	-	+	+	
5. Solids							
a. Total	mg/l		-				
b. Suspended	mg/l	-	+	+	-	+	
c. Dissolved	mg/l		-	+	-	-	
d. Settleable	mg/l/h		+				
6. Light penetration	m		-	+		+	
7. Pond appearance/color	qualitative	-	+	-		+	

Table 2 (continuation)

Parameter	Unit	Public Health	Process Control	Pond Ecology	Reuse	
					Agriculture	Fish Culture
8. Odor	qualitative	+	+	+	-	+
9. Scum and floating matter	qualitative	-	+	+	-	+
10. Vegetation in dam	qualitative	+	+	+	-	-
D. <u>Physical-chemical factors</u>						
1. Conductivity	μs/cm^2				+	
2. pH			+	+		+
E. <u>Chemical factors</u>						
1. Dissolved oxygen	mg/1	-	+	+		+
2. Chemical oxygen demand	mg/1		+		-	-
3. Carbonated system components						
a. Alkalinity						
- Carbonates	mg/1	+	+			
- Bicarbonates	mg/1		+			
- Hydroxides	mg/1	+	-			
4. Calcium	mg/1			-		
5. Magnesium	mg/1			-		
6. Total hardness	mg/1			-		
7. Chlorides	mg/1			-	+	+
8. Sulfates	mg/1				+	
9. Nutrients						
a. Total nitrogen	mg/1			+	+	
- Organic	mg/1			+	+	
- Ammonia	mg/1		+	+		-
- Nitrites	mg/1				+	+
- Nitrates	mg/1	+	+		+	
b. Total phosphorus	mg/1		-	+	+	
- Orthophosphate	mg/1			+		+
10. Trace elements						
a. Sodium	mg/1			+	+	

Table 2 (continuation)

Parameter	Units	Public Health	Process Control	Pond Ecology	Reuse	
					Agriculture	Fish Culture
F. [illegible]chemical factors						
[illegible] [illegible]chemical oxygen demand	mg/1		+			-
[illegible]						
A. [illegible]cal						
1. [illegible]forms	MPN/100 ml	+	+			-
2. [illegible]orms	MPN/100 ml	+	+			-
3. [illegible]	Identific.	+	-		-	+
4. Shig[illegible]	Identific.	+	-		-	+
5. Proto[illegible]inth						
- Entamo[illegible]	Identific.	+			+	+
- Ascaris	Identific.	+			+	+
- Anquilost[illegible]	Identific.	+			+	+
B. Macrobiological						
1. Species composition						
- Algae	Class/N°		+	+	-	+
- Insects	Class/N°	+	-	+		-

+ Greater interest
- Lesser interest
(a) Data to be obtained from the nearest meteorological station

Table 3

COMPONENTS OF THE EXPERIMENTAL PROGRAM

Parameters	Units	Frequency	Analytical method
I. NON BIOLOGICAL			
A. Meteorological			
1. Wind velocity	km/d	Daily	Data to be obtained from a nearby meteorological station
2. Wind direction	Degrees	Daily	
3. Air temperature	°C	Daily	
4. Evaporation	mm	Daily	
5. Solar radiation	h/day	Daily	
B. Hydraulic			
1. Average flow	l/sec	Daily	Flow recorder
2. Maximum hourly flow	l/sec	Daily	Flow recorder
3. Maximum daily flow	l/sec	Daily	Flow recorder
4. Minimum water balance	mm	Monthly	By calculation
5. Level fluctuation	m	Weekly	Field measurement
6. Depth	m	Annual	Field measurement
C. Physical factors			
1. Sludge depth	m	Monthly	Field measurement
2. Liquid temperature	°C	Monthly	Electrometric (in situ)
3. Temperature profile	°C	Monthly	Electrometric (in situ)
4. Oil and grease	mg/l	Monthly	Gravimetric (SOXHLET)
5. Solids			
a. Total	mg/l	Weekly	Gravimetric 103°C/550°C
b. Suspended	mg/l	Weekly	Gravimetric 103°C/550°C
c. Dissolved	mg/l	Weekly	Gravimetric 103°C/550°C
d. Settleable	ml/l/h	Weekly	IMHOFF cone
6. Light penetration	m	Daily	SECCHI disk
7. Pond appearance	Qualitative	Daily	Field observation

Table 3 (continuation)

Parameters	Unit	Frequency	Analytical method
8. Odor	Qualitative	Daily	Field observation
9. Scum and floating matter	Qualitative	Daily	Field observation
10. Vegetation in dam	Qualitative	Daily	Field observation
D. Physical-chemical factors			
1. Conductivity	μs/cm^2	Weekly	Electrometric
2. pH (profile)	Units	Montly	Electrometric
E. Chemical factors			
1. Dissolved oxygen profile	mg/1	Monthly	Galvanometric (Winkler)
2. Oxygen chemical demand	mg/1	Monthly	Volumetric (Dichromate)
3. Alkalinity			
a. Carbonates	mg/1	Weekly	Volumetric
b. Bicarbonates	mg/1	Weekly	Volumetric
c. Hydroxides	mg/1	Weekly	Volumetric
4. Calcium	mg/1	Weekly	Volumetric (EDTA)
5. Magnesium	mg/1	Weekly	Volumetric (EDTA)
6. Total hardness	mg/1	Weekly	Volumetric (EDTA)
7. Chlorides	mg/1	Weekly	Volumetric (EDTA)
8. Sulfates	mg/1	Weekly	Volumetric (Mercuric nitrate)
9. Nutrients	mg/1	Weekly	Turbidimetric
a. Total nitrogen	mg/1	Weekly	Volumetric (Kjeldahl)
b. N Organic	mg/1	Weekly	Volumetric (Kjeldahl)
c. N Ammonia	mg/1	Weekly	Photometric (Nessler)
d. N Nitrites	mg/1	Weekly	Photometric (Diazotation)
e. N Nitrates	mg/1	Weekly	Electrometric (Specific ion)
f. Total phosphorus	mg/1	Weekly	Photometric (Dig. with persulfate)
g. Orthofosfate	mg/1	Weekly	Photometric (Vanadomolybdo-phosphoric)
F. Biochemical factors			
1. BOD 20°C, 5 days	mg/1	Weekly	Volumetric (Sodium azide)

Table 3 (continuation)

Parameters	Unit	Frequency	Analytical method
II. BIOLOGICAL			
A. Microbiological			
1. Total coliform	MPN	Weekly	Multiple tubes (Lauril triptosa)
2. Fecal coliform	MPN	Weekly	Multiple tubes (E.C.)
3. Salmonella	Identific.	Bimonthly	See diagram
4. Shigella	Identific.	Bimonthly	See diagram
5. Protozoan/helminth			
a. Entamoeba	Identific.	Weekly	Concentration (Flotation with Z_n sulfate and sedimentation with formalin-ether)
b. Ascaris L.	Identific.	Weekly	Concentration (Flotation with Z_n sulfate and sedimentation with formalin-ether)
c. Anquilostoma	Identific.	Weekly	Concentration (Flotation with Z_n sulfate and sedimentation with formalin-ether)
d. Glardia Lambia	Identific.	Weekly	Concentration (Flotation with Z_n sulfate and sedimentation with formalin-ether)
B. Macrobiological			
1. Composition of species			
a. Algae	Class/N°	Weeks	Direct (Sedwick-rafter and hemacytometer)
b. Insects	Class/N°	Weeks	Direct (Sedwick-rafter and hemacytometer)

Table 4

TENTATIVE SAMPLING AND ANALYSES PROGRAM FOR THE FIRST PHASE

Day	Group	Parameter	Sample volume	Preservation	Source	Frequency
Monday	Biological I	Salmonella Shigella	Raw 100 ml Effluents 200 1	Cooling at 4°C	Raw 1 Primary 1 Secondary 1	15 days
Tuesday	Biological II	Coli Helminth Parasits	100 ml Raw 500 ml Effluents 4 ml	Cooling at 4°C	Raw 1 Primary 1 Secondary 1	Weekly
Wednesday	Physical-chemical	Alkalinity Calcium Hardness Chloride Total Susp. Solids Fixed Susp. Solids Total Solids Fixed Solids Sodium Sulfate Conductivity BOD	2 1	Cooling at 4°C	Raw 1 Primary 4 Secondary 4 *	Weekly
		Plankton	200 ml			
Thursday	Nutrients	Nitrate Nitrite Ammonia N Organic Ortophosphate Total phosphate	2 1	40 mg/1 $HgCl_2$ and cooling at 4°C	Raw 1 Primary 4 Secondary 4 *	Weekly
Monday to Friday	Meteorological Hydraulic and Physical	Flow Evaporation Temperature Wind Transparency	-	-	-	Daily

Table 4 (continuation)

Day	Group	Parameter	Sample volume	Preservation	Source	Frequency
Monday to Friday	Meteorological Hydraulic and Physical	Solar radiation Appearance Odor Foam Vegetation	-	-	-	Daily
Continue sampling during 24 h		Dissolved oxygen pH Water temperature Air temperature Alkalinity	-	-	Raw 1 Primary 4 Secondary 4	Monthly

* Total ponds included in the study

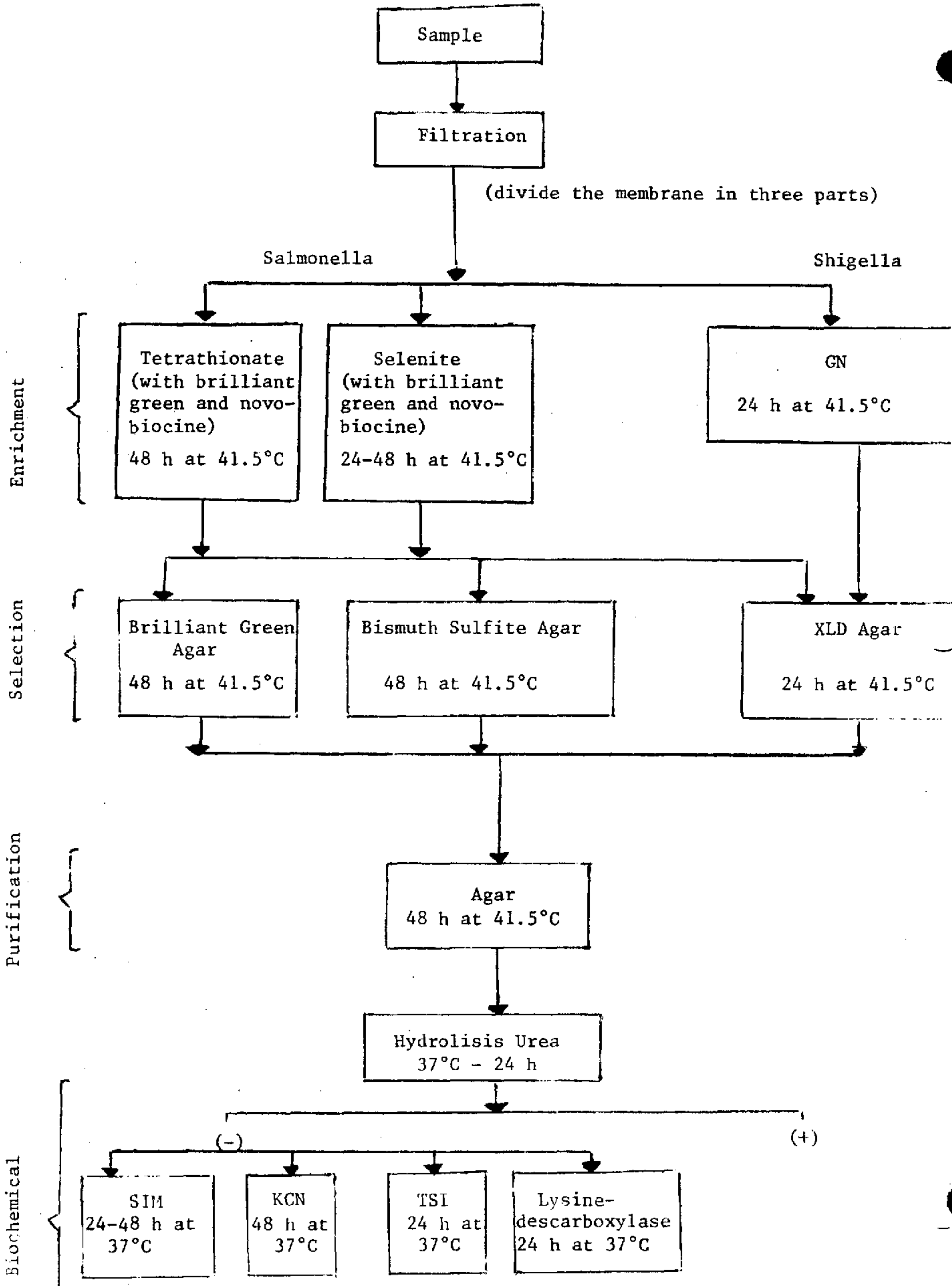

Figure 2

DIAGRAM FOR DETECTION OF SHIGELLA AND SALMONELLA IN WATER

BIBLIOGRAPHY

1. PAN American Center for Sanitary Engineering and Environmental Sciences. Planificación, proyecto y operación de sistemas monitorios comprehensivos de calidad de aguas, con énfasis en las necesidades de los países de América Latina y el Caribe. Technical Documents Series No. 1, 1975

2. GHADIALLY, J. Appropriate technology; a development strategy. Hunger, Vol. III, No. 1, 1973. Canadian Hunger Foundation, Ottawa

3. YANEZ, F. Consideraciones en la selección y aplicación de tecnologías de tratamiento. Presented at the Symposium on Wastewater Treatment and Disposal. Buenos Aires, Argentina, June 1976

4. SCHUMACHER, E.F. Intermediate technology; its meaning and purpose. Unpublished, 1975

5. PAN American Center for Sanitary Engineering and Environmental Sciences. Research needs in environmental health engineering. Presented at the Special Session on Environmental Health during the 16th Meeting of the PAHO Advisory Committee on Medical Research, July 1977

6. PAHO Advisory Committee on Medical Research. Report to the Director. 16th Meeting, July 1977

7. PAN American Center for Sanitary Engineering and Environmental Sciences. Project document of a CEPIS proposal to the International Development Research Centre. August 1976

8. AMERICAN Water Works Association. Standard methods for the examination of water and wastewater. APHA, AWWA, WPCF, 14th edition, 1975