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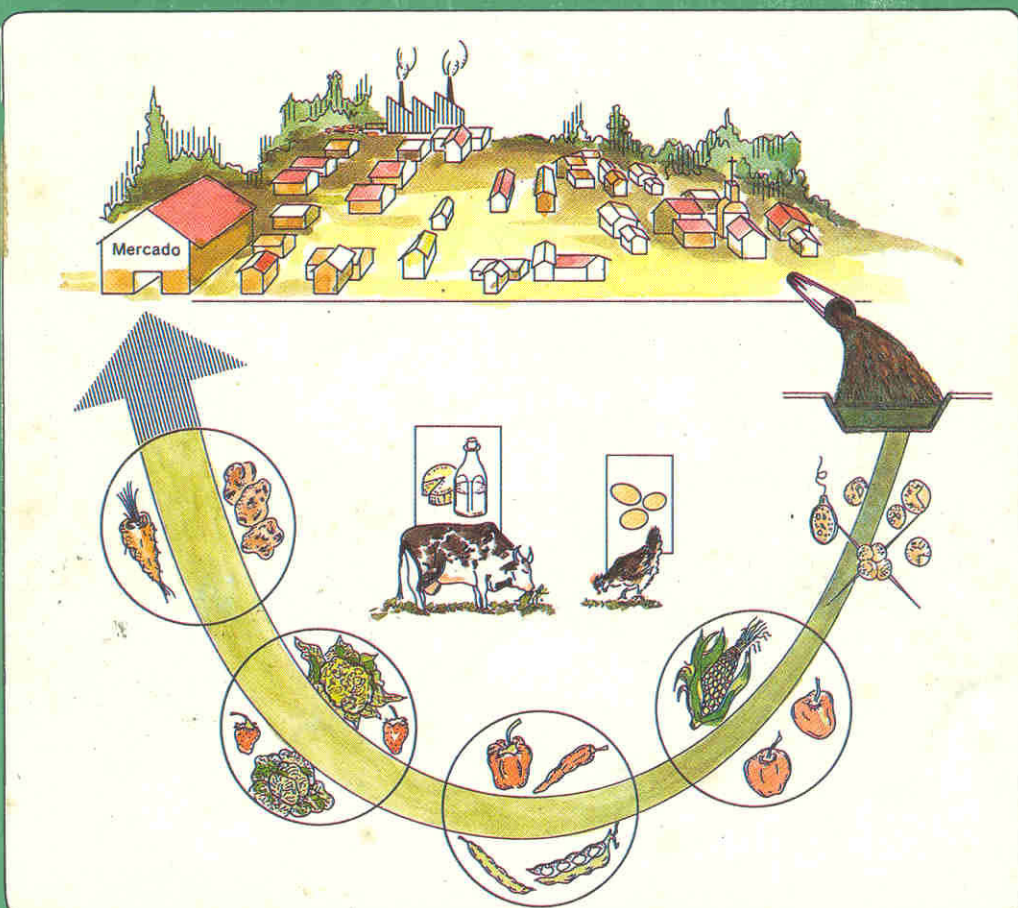
HEALTH RISK EVALUATION DUE TO WASTEWATER USE IN AGRICULTURE

EXECUTIVE SUMMARY

Volume I

Microbiological Aspects



Environmental Health Program
Pan American Health Organization
World Health Organization

HEALTH RISK EVALUATION
DUE TO WASTEWASTER USE IN AGRICULTURE

EXECUTIVE SUMMARY

VOLUME 1

MICROBIOLOGICAL ASPECTS

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VOLUME I: MICROBIOLOGICAL ASPECTS

Executive Summary

1. INTRODUCTION

The indiscrimate use of raw wastewater to irrigate crops for human consumption is linked to high morbi-mortality rates caused by gastroenteritis, dysentery and helmithiasis. Approximately 4,000 hectares of farmland on the Peruvian coast are irrigated with raw wastewater that may potentially reach 11,200 ha if all wastewater discharged by the cities on the Peruvian coastline were used.

Semi-desert valley cities which have a cyclical seasonal variation in the water supply used for households and agriculture may justify a change towards the use of treated wastewaters instead of surface waters for irrigation.

This approach optimizes the use of water resources improving the domestic water supply service and guaranteeing its use at the agricultural level and possibly increasing the agricultural frontier.

A lack of knowledge about the health risks involved in using raw wastewater to irrigate crops for human consumption, as well as the effects on exposed farmers led to the proposal and development of this study in order to contribute to the knowledge of wastewater re-use in countries with a high rate of gastro-intestinal diseases.

This initiative became a reality thanks to the technical and financial support provided by the Canadian International Development Research and Center (IDRC) and the Canadian Department of Health and Welfare together with the efforts of the Panamerican Sanitary Bureau (PAHO) through its Environmental Health Program (HPE). CEPIS was responsible for the execution of the project and received support from the Peruvian Government through the Latin American Teaching and Research Center in Food Microbiology (CLEIBA) of San Marcos National University, the National Laboratory of Enterobacterial Reference (LANARE) and, the Environmental Health Directorate of the Ministry of Health (DITESA).

2. OBJECTIVES

2.1 The general objective of the project was to evaluate the degree of sanitary acceptability of those un-processed agricultural products most frequently used for human consumption which are irrigated with raw and treated wastewater throughout the crop growing areas surrounding Lima.

a) To study and quantify certain types of parasites and bacteria considered to be fecal pollution indicators in surface waters and raw and treated wastewaters.

b) To study and quantify certain types of fecal pollution indicator organisms in food products from farming areas irrigated with surface water and raw and treated wastewaters during harvest and marketing.

c) To compare the health risks linked to fecal pollution indicator organisms found in agricultural products for human consumption irrigated with surface water and raw and treated wastewater.

d) To define the criteria needed to establish sanitary quality control programs and to indicate the treatment levels required for agricultural re-use of domestic and industrial wastewaters.

e) To develop human resources in this field through training courses and by encouraging active participation of national researchers.

3. METHODOLOGY

In order to determine the impact of different water qualities on agricultural products, the following four representative zones were selected:

- An area irrigated with a mixture of domestic and industrial wastewater and river water (Fundo San Agustín-Callao).
- An area irrigated with raw domestic wastewater (Fundo Santa Rosa-San Martín de Porres).
- An area irrigated with partially treated domestic wastewater (Lagunas de San Juan-San Juan de Miraflores).
- An area irrigated with surface waters (Cieneguilla-Lurín River).

FIGURE 1 indicates the location of each of the selected areas

In order to evaluate sanitary conditions, samples of the different types of irrigation water and agricultural products in each of the selected areas were collected. In the specific case of the samples gathered from San Juan de Miraflores, these came from areas irrigated with raw wastewater and effluents from stabilization ponds.

Seventy samples of irrigation water were taken to carry out the following microbiological analysis: total and fecal Coliforms and Salmonella and identification of enterotoxigenic and enteropathogenic Escherichia coli and Salmonella serotypes. Protozoa and helminths were detected during analysis.

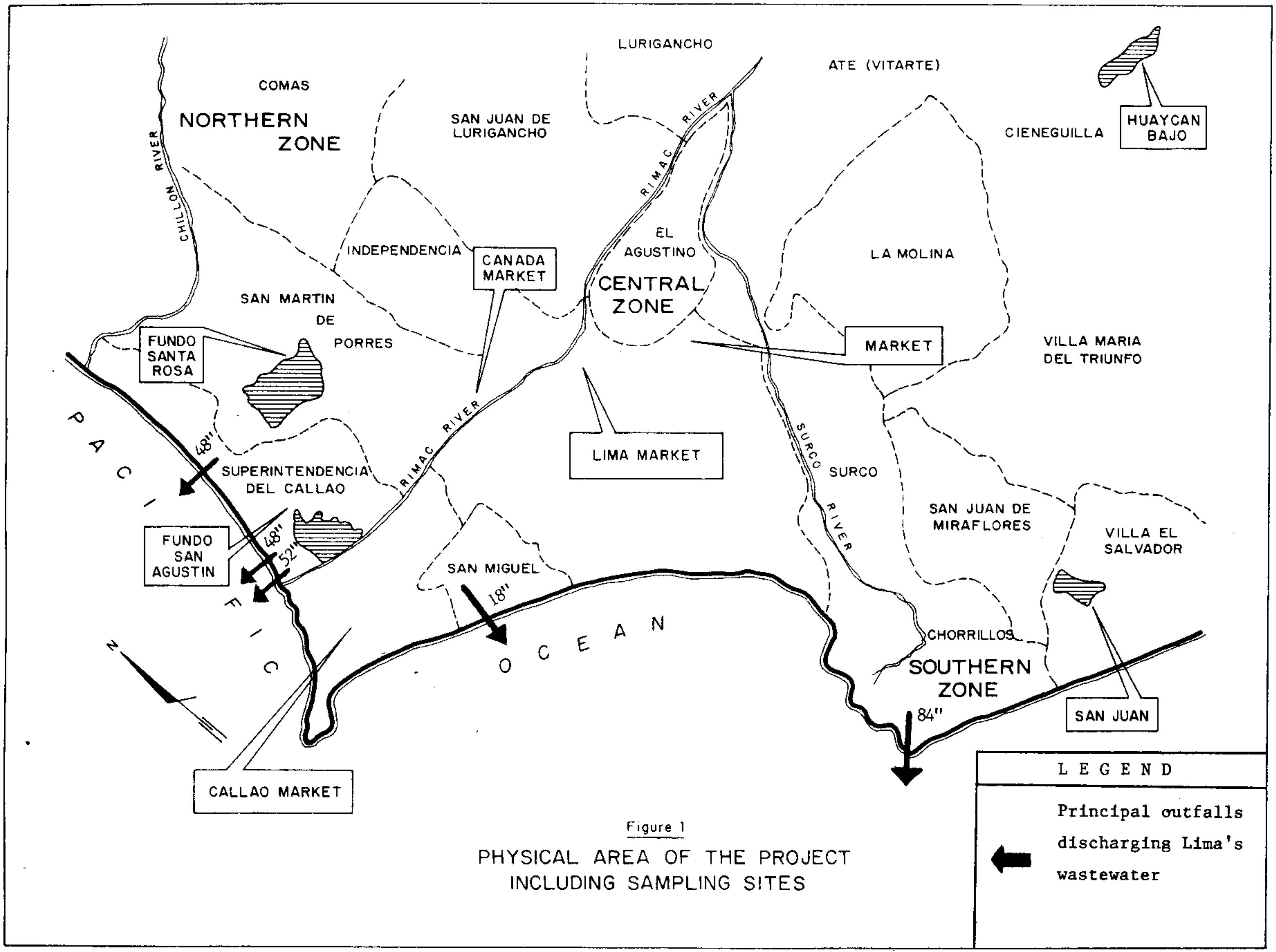


Figure 1

PHYSICAL AREA OF THE PROJECT INCLUDING SAMPLING SITES

During microbiological analysis of agricultural products, a total of 29 vegetable species equivalent to 5,625 units were sampled, both in the crop growing zones, as well as in the markets of Lima and Callao. Agricultural products were classified according to the level at which the edible portion grows: either beneath the soil surface, on the soil surface and on a tall stem; and, the manner in which it is eaten: raw, cooked or mixed. The type of irrigation water used, as well as the time elapsed between sample collection and last irrigation, were considered.

Parasite analysis were carried out on 168 samples of agricultural products collected from zones with access to raw and treated wastewater. An additional 365 samples were collected in markets.

3.1 Sanitary qualification of agricultural products

The program used to qualify agricultural products applied the food quality criteria recommended by the International Committee in Microbiological Specifications for Food (ICMSF). Three quality levels were established: i) total acceptability, when the five sample units analized contained less than 10 E. coli and there were no Salmonella present, ii) conditional acceptability when, of the five sample units analyzed, three fell within the previous level and two had values fluctuating between 10 and 100 E. coli and there were Salmonella present and, iii) rejected, when there were more than 1000 E. coli per gram of sample or there were Salmonella present.

The analysis of E. coli and the test for absence/presence of Salmonella were carried out using the most probable number per gram of sample method (MNP/g).

Organism	Category	Class Program	Sample Size	Samples accepted, not exceeding the limit	Limit Min.	per g Max.
Escherichia coli	5	3	5	2	10	10^3
Salmonella	11	2	10	0	0	--

Other indicators such as total count of mesophyllic aerobic bacteria and total and fecal Coliforms were also analyzed and the results on population density (geometric average of the five units which made up one) were grouped into three levels and qualified according to the ranges marked by the minimum and maximum limits recommended. These are 10 and 10^4 for fecal coliforms and 10 and 10^3 for E. coli.

Other determinations were enterotoxigenic Escherichia coli, classic enteropathogenic Escherichia coli, Campylobacter, Shigella and a Clostridium sulphite reducer.

In order to evaluate the risk due to the presence of parasites, pathogens were isolated and identified (protozoa and helminths), taking special interest in those of a health concern and those which are potentially pathogenic. A series of viability tests were run on ascaris eggs in soils.

A social-cultural and sanitation evaluation was carried out to complement this study based upon surveys to 134 families distributed throughout the four selected areas. The questions asked were oriented towards obtaining information concerning the availability of potable water, hygiene habits, basic health conditions, frequency of gastrointestinal diseases and other socio-cultural data. Obviously, data on diseases only helped to indicate trends.

The incidence of parasites was evaluated through coprological tests made on 102 inhabitants from the San Juan de Miraflores stabilization pond zone. These analysis were not carried out in any of the other three areas.

3.2 Analytical procedures

3.2.1 Water and wastewater

Physical, chemical, bio-chemical and bacteriological analytical procedures for water samples were carried out according to "Standard Methods for Analysis of Water and Wastewater" APHA (16th edition). Some additional procedures developed in the CEPIS laboratory were also used.

3.2.2 Food

The evaluation of the microbiological quality of agricultural products was carried out based on the methods recommended by the International Committee for Microbiological Specifications for Food (ICMSF). Procedures developed by the Latin American Teaching and Research Center in Food Microbiology (CLEIBA) and CEPIS were also used.

4. RESULTS

4.1 Quality of Water for Irrigation

a) Wastewaters used for irrigation in the are of Callao and San Martín de Porres had a joint geometrical mean of 7 x 10^7/100 ml fecal Coliforms and 2 x 10^3/100 ml Salmonella.

b) Surface waters from the Lurin River revealed a geometric mean of (2 x 10^2) fecal coliforms per 100 ml. Salmonella were not detected in 10 liter water samples.

c) Effluents from stabilization ponds (partially treated) revealed fecal Coliform levels of 5.2 x 10^6/100 ml in the primary 2.5 x 10^6/100 ml in the secondary and 1.7 x 10^5/100 ml in the tertiary pond.

The effluents from the ponds revealed Salmonella levels below 100/100 ml. See Table 1.

d) Raw wastewaters showed a concentration of helminths and protozoa ranging from 100 to 1000 microorganisms per liter of sample.

e) Primary effluents from the stabilization ponds contained no helminths and few protozoa. Protozoa and helminths were not detected in the secondary effluents.

4.2 Quality of Agricultural Products

a) Table 2 shows the population density of fecal Coliforms and *Escherichia coli* found in 29 different types of vegetable species, corresponding to a total of 4,375 units of agricultural products analyzed from the four evaluated zones. A strong correlation is observed between both pollution indicators.

b) Agricultural products irrigated with raw wastewater reveal the presence of Salmonella in 20.5% of the samples taken in Callao; 13.9% in San Martín de Porres and 5.7% in San Juan de Miraflores. Salmonella were isolated in vegetables from areas irrigated with water from the Lurin River.

c) A substantial correlation was found between the number of fecal Coliforms in water samples and the number of *Escherichia coli* per gram of vegetable sample (See Table 2 and Figure 2). The following equation shows this correlation:

Log. *E. coli* (NMP/g) = 0.3954 + 0.3124 (Log Fecal coli NMP/100 ml).

d) The percentage of enterotoxigenic *Escherichia coli* indicates that there is not a significant difference between the values found in the four zones tested.

e) Of the samples analyzed, 34.5% revealed the presence of enterotoxigenic *Escherichia coli* and 59.6% showed the presence of enteropathogenic *Escherichia coli*. In the samples from zones irrigated with surface river water, 55.5% of the samples were positive when tested for *E. coli*.

f) Campylobacter or Shigella were not detected in vegetables, probably because they are sensitive to the environment or due to the fact that analytical techniques were not sufficiently sensitive.

g) The sanitary qualification of agricultural products following the program adopted and recommended by the ICMSF, is summarized in Table 3.

h) A list of the parasites which contaminate vegetables irrigated with raw and treated wastewater are shown in Table 4.

Table 1

Comparison Between Fecal Coliforms and Salmonella Values Obtained in Sampled Wastewaters

MPN/100 ml

Sampling Zones	Number of Samples Analyzed	Geometric Media		
		Total fecal Coliforms	Fecal Coliforms	Salmonella
Callao	14	1.94×10^{8}	8.51×10^{7}	2.38×10^{3}
San Martín de Porres	16	1.05×10^{8}	5.46×10^{7}	1.34×10^{3}
San Juan (raw water)	7	1.09×10^{8}	7.22×10^{7}	2.62×10^{3}
San Juan (quaternary pond)	7	6.47×10^{6}	5.22×10^{6}	3.76×10
San Juan (secondary pond)	5	3.79×10^{6}	2.54×10^{6}	2.99×10
San Juan (tertiary pond)	5	3.32×10^{5}	1.70×10^{5}	6.84×10
San Juan (quaternary pond)	3	8.57×10^{5}	4.79×10^{5}	4.52×10
San Juan (effluent from low battery)	3	3.88×10^{5}	1.96×10^{5}	3.15×10
San Juan (effluent from high battery)	3	2.38×10^{6}	1.37×10^{6}	1.59×10^{3}
Cieneguilla	7	5.66×10^{2}	2.06×10^{2}	

Table 2

Percentage* Distribution of Bacterial Density in Agricultural Products for Each Evaluated Zone According to Pollution Indicators

% of samples in MPN/gram, falling within levels shown**						
Zones	Fecal Coliform			Escherichia coli		
	100	100-10000	10000	10	10-10000	1000
Cieneguilla Lurin River	97	3	0	94	6	0
San Juan San Juan de Miraflores	66	34	0	39.5	58	2.5
Santa Rosa San Martín de Porres + San Agustín Callao	32	49	19	27	57	16

* Values given are the geometric mean of the five units which make up each sample.

** The levels used correspond to those of interest for their qualification.

Table 3

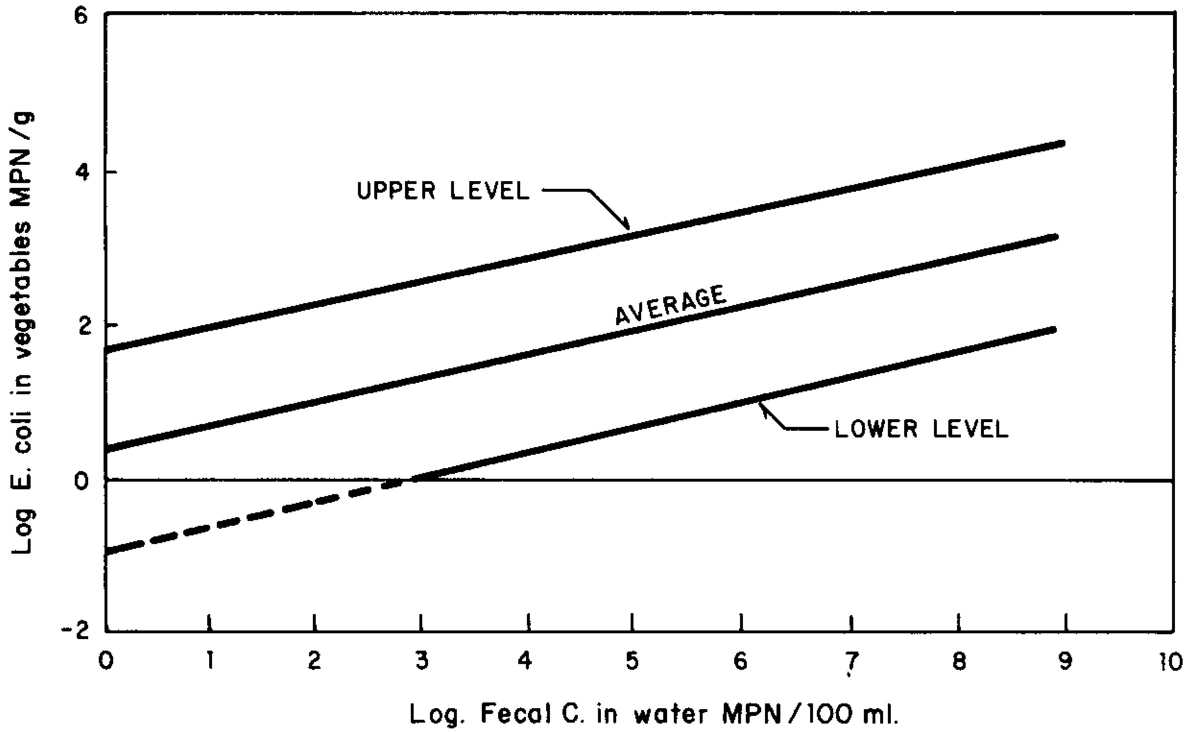
Sanitary Qualification of Agricultural Products According to the Type of Irrigation Water and Sampling Zone (according to the ICMSF)

Agricultural products qualification	TYPE OF WATER USED FOR IRRIGATION			
	Surface water (CI (%)	Treated water SJ (%)	Raw wastewater domestic & industrial CA (%)	Raw domestic SM (%)
Acceptable	80.7	18.4	18.5	11.5
Conditional Acceptance	16.1	29.0	14.8	11.6
Rejectable	3.2	52.6	66.7	76.9
Total Units of Samples	775	950	1,350	1,300

CI = Lurin River - Cieneguilla
SI = Stabilization ponds (San Juan de Miraflores)
CA = Callao
SM = San Martín de porres

Figure 2

RELATIONSHIP BETWEEN LOG. E. coli IN AGRICULTURAL PRODUCTS vs. FECAL C. IN WATER



$r^2 = 0.4788$ STD Estimated error = 0.6608

Log E. coli (vegetables) = 0.3954 + 0.3124 Log Fecal C. (water)

i) Of the agricultural products evaluated, lettuce revealed the highest level of parasite contamination followed by parsley, spinach and carrots. Table 5 indicates the percentage of contaminated samples.

4.3 Quality of agricultural products in markets

a) The results for fecal Coliforms per gram in agricultural products sold in the markets show that 42% of the samples are below one hundred, 52% are between one hundred and ten thousand and 6% an over ten thousand. As concerns *E. coli*/g, 39% of samples showed levels lower than ten, 54% were between ten and one thousand and 0% had levels higher than ten thousand.

b) Agricultural products purchased in markets revealed positive results for Salmonella, enterotoxigenic *Escherichia coli* and enteropathogenic *Escherichia coli* of 13.8%, 27.3% and 83.3% respectively.

c) Concentration levels of the Clostridium sulphite reducer in vegetables are higher than those of *E. coli* in each of the reuse zones. In markets, the situation is reversed where *E. coli* concentration levels are higher than the Clostridium sulphite reducer levels.

d) The sanitary qualifications of agricultural products purchased in markets, during summer and winter following the program adopted by the ICMSF, is shown in Table 6.

e) The presence of protozoa and helminths in agricultural products sold in the markets is shown in Table 7. *Entoamoeba coli* is the most frequent species of Protozoa, found in 37.8% of the vegetables, followed by *Giardia lamblia* with 24.1% and *Entamoeba hystolitic* with 0.3%. As concerns helminths was found in 30.74% and *Trichuris trichiura* in 2.7% in the samples analyzed.

4.4 Time between the last irrigation and harvest

a) The time between the last irrigation and harvest influences the quality and quantification of agricultural products. An eight day period will increase the level of acceptability by an additional 25% and conditional acceptability by 15% (See Figure 3).

b) The most significant reduction of bacteria in this non-irrigation period is found in tall stemmed vegetables, while this is less apparent in short stemmed vegetables or those which grow at ground level.

4.5 Health trend in reuse zones

a) This study revealed that farmers in Cieneguilla have the highest rate of diarrheal diseases and typhoid fever as compared to the other areas.

b) Population in crop fields, surrounding the San Juan stabilization ponds, 96.7% have protozoa and helminth parasites. This population lacks sanitary instalations and defecates in the open fields.

Table 4

Parasites Found in Agricultural Products According to the Quality of Irrigation Waters and Sampling Zone (according to the ICMSF)

Parasite Species	TYPE OF WATER USED FOR IRRIGATION							
	Raw wastewaters						Partially treated wastewaters	
	Callao		San Martín		San Juan		San Juan Lagoons	
	No.	%	No.	%	No.	%	No.	%
Entamoeba coli	37	68.52	32	59.26	12	80.00	8	17.78
Entamoeba histolytica	0	0.00	0	0.00	1	6.67	0	0.00
Endolimax nana	18	31.49	16	29.63	7	46.67	0	0.00
Iodamoeba butschlii	5	9.26	7	12.97	4	26.67	0	0.00
Giardia lamblia	21	38.89	19	35.19	8	53.34	4	8.89
Ascaris lubricoides	15	24.08	19	35.19	8	53.34	2	4.45
Trichuris trichiura	7	12.97	6	11.12	4	26.67	0	0.00
TOTAL NO. OF SAMPLES	54		54		15		45	

No. = Number of positive samples

Table 5

Percentage of Samples of Agricultural Products Parasites According to Water Quality

Parasites	Waste-water quality	Growth at soil (leaves)		Growth level beneath the soil surface (roots)	Growth at a distance from the soil surface (leaves and stems)
		Lettuce %	Spinach %	Carrot %	Parsley %
Entamoeba coli	Raw Treated	60.00 20.00	70.00 20.00	75.00 20.00	75.90 33.00
Entamoeba hystolytica	Raw treated	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
Idoamoeba butschlii	Raw Treated	20.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
Giardia lamblia	Raw Treated	40.00 20.00	60.00 0.00	62.50 20.00	46.15 0.00
Ascaris lumbricoides	Raw Treated	35.00 10.00	40.00 20.00	22.50 0.00	30.76 0.00
Trichuris trichiura	Raw Treated	25.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
TOTAL OF SAMPLES	Raw Treated	20.00 10.00	10.00 5.00	8.00 5.00	13.00 3.00

Table 6

Sanitary Qualification of Agricultural Products Markets in Two Sample Periods, According to Each Season (according to the ICMSF)

Vegetables qualification	SAMPLING PERIODD		Total
	Summer %	Winter %	%
Acceptable	0.00	15.0	6.0
Conditionally Acceptance	16.7	15.0	16.0
Rejectable	83.3	70.0	78.0
Total of sample units	750	500	1,250

Table 7

Protozoa and Helminths of Health Concern Found in Agricultural Products in the Markets of Metropolitan Lima April - June 1987

Vegetables	Number of samples	Protozoa %	Helminths %	Mixed %	Total
Lettuce	(73)	36.96	17.80	28.74	83.60
Spinach	(73)	34.22	15.05	28.74	78.10
Parsley	(73)	42.43	9.58	13.69	65.80
Coriander	(73)	36.96	8.21	17.80	63.10
Raddish	(73)	35.59	8.21	10.95	54.80
TOTAL SAMPLES	365	342	122	81	252

4.6 Discussion

4.6.1 Comparison of the pollution risk level of agricultural products in reuse zones, markets or control areas.

a) Table 8 shows the microbiological risk terms of the probability that the use of different water qualities for irrigation of agricultural products for human consumption will result in levels equal or greater than ten E. coli per gram in more than two units of the sample and/or the presence of Salmonella and/or enteroparasites.

Upon analyzing the table, one can infer a high parasite risk due to the consumption of agricultural products irrigated with raw wastewater (91%). This risk diminishes by using surface and treated water. With respect to the risk generated by E. coli + Salmonella (sanitary quality), it is very high when products irrigated with raw and treated wastewater (85%) are consumed. Products irrigated with non-polluted surface water have a low risk level (19.3%).

With respect to the risk due to the presence of Salmonella in vegetables, it is significant in products irrigated with raw wastewater (17.2%). On the other hand, the risk is minimal in products irrigated with treated wastewaters (5.7%) and there is no risk in products irrigated with surface water.

However, comparing the risk levels between the products irrigated with raw wastewater with those sold in the markets (13.8%), these are very similar. This indicates that there is a recontamination which occurs during handling of the goods between the field and the market.

b) Based upon the results obtained in this study, for the case of Lima, Figures 4 and 5 show the risks due to the consumption of agricultural products irrigated with different qualities of wastewater. The sanitary quality in terms of acceptance, conditional acceptance and rejection levels of agricultural products for human consumption, is indicated as a function of the bacteriological quality of the irrigation water.

c) Risk reduction, as a consequence of the application of hygiene and sanitation measures, both in the crop growing areas as well as during marketing is highly significant, as the results in Figure 4 show.

4.6.2 Technological alternatives for the reduction of risk of contaminaton of agricultural products

a) The stabilization ponds of San Juan de Miraflores, under the working conditions at the time of the evaluation (17 degrees C ambient and a loading rate between 250 and 350 kg BOD/hec-day in the primary ponds) presented a removal efficiency of fecal Coliform of approximately one log unit per pond, reaching a removal of 99.7% in three ponds in series and a 28 day total retention time. It should be pointed out that the removal efficiency of coliforms in ponds can be improved by controling the ponds operative conditions (see Table 9).

Table 8

Risk Level Due to the Consumption of Products Irrigated with Different Qualities of Wastewater and from the Markets

(given in percentages)

	PARASITES	E. coli + SALMONELLA	SALMONELLA
Raw wastewater (San Martín de Porres and Callao)	96.60	85.00	17.20
Partially treated water (San Juan)	16.60	81.60	5.70
Surface water (Cieneguilla)	14.28	19.30	3.20
Lima Markets	69.04	94.00	13.80

Figure 3

INFLUENCE OF TIME WITHOUT IRRIGATION ON THE INCREMENT OF PRODUCT ACCEPTABILITY (WASTEWATER)

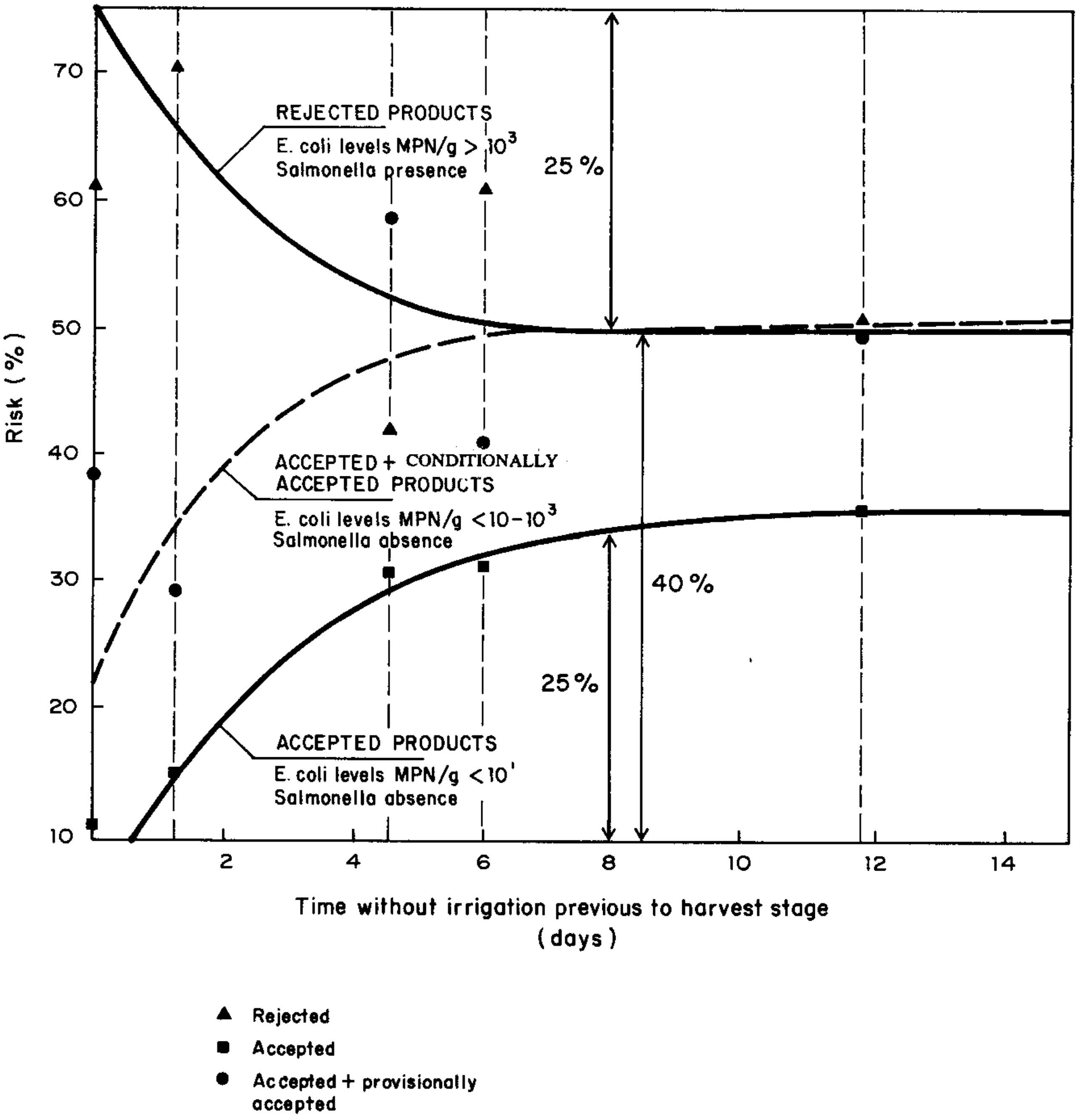


Table 9

Removal Efficiency of Fecal Coliform Bacteria in Stabilization Ponds* and Influence of the Bacteriological Quality of Vegetables**

Origin	WATER Fecal Coliform MPN/100 ml	WATER Fecal Coliform accumulated removal (%)	VEGETABLES Fecal Coliform MPN/g	VEGETABLES Fecal Coliform accumulated removal (%)	VEGETABLES Escherichia coli cfu/ml	VEGETABLES Escherichia coli accumulated removal (%)
CR	46'000,000	---	2,874.96	---	618.02	---
P1	2'760,000	94.0772	862.44	70.0016	255.59	58.637
S1	269,000	99.4227	319.87	88.8739	123.50	80.0168
T1	28,700	99.9384	123.30	95.7112	61.38	90.0682
C1	2,300	99.9950	42.07	98.5366	27.90	95.4855
P2	3'350,000	92.8111	936.63	67.4211	271.50	56.0693
S2	227,000	99.5128	297.55	89.6502	117.12	81.0491
T2	16,700	99.9641	97.90	96.5947	51.83	91.6135
C2	510	99.9989	22.15	99.2295	17.43	97.1797
Q2	158	99.9996	13.44	99.5325	12.09	98.0437

CR: Raw wastewater
P : Primary pond
S : Secondary pond
T : Tertiary pond
C : Quaternary pond
Q : Fifth pond

* Removal date of fecal coliform in ponds were taken from Bartone, C.R. (1986).

** Date on fecal Coliform and <u>Escherichia coli</u> in vegetables were calculated based upon the correlation pointed out in 4.2c and, Figure 2, which was calculated based upon the data from this study.

b) Under the above conditions, the San Juan stabilization ponds have demonstrated a 100% parasite removal efficiency in primary ponds with a 20 day retention period.

c) A correlation was found between the contents of Salmonella and fecal Coliforms in wastewaters. According to these, in a tertiary pond (approximately a 28 day retention period), six Salmonella would be obtained as MPN/100 ml and in the effluent of a quarternary pond less than one/100 ml (see Figure 7).

The equation showing the relationship between the presence of Salmonella and fecal Coliform is as follows:

$$\text{Log Salmonella} = -3.2836 + 0.8171 \ \text{Log fecal coliform}$$

d) The bacteriological quality of the effluents from stabilization ponds may be predicted through a mathematical model developed herein, which helps to determine the treatment required for irrigation waters as a function of the desired crop. The model developed of the stabilization pond design take into consideration the rate of application, flow, retention time, temperature and loss by evaporation and infiltration.

5. CONCLUSIONS

a) The probability of fecal contamination and parasite indicator present in agricultural products for human consumption is directly related to the microbiological quality of the irrigation water.

b) This study shows that, in order to reach the total acceptance of agricultural products, in keeping with ICMSF guidelines (10 E. coli/g) there should be a maximum concentration of 85 organisms of fecal Coliform/100 ml of irrigation water.

c) By applying the premise of the percentage of Salmonella in fresh vegetables according to the type of irrigation water used, we may conclude that in order to have Salmonella-free vegetables, the highest limit allowed of fecal Coliform in the water is 10,000 organisms/100 ml, which in turn, is equivalent to one Salmonella per 100 ml of wastewater.

d) The wastewater quality is not the sole factor influencing the microbiological quality of agricultural products (statistically only 48% of Escherichia coli in vegetables is influenced by fecal coliforms in water). Additional attention should also be given to the lack of basic sanitation in the field, health habits, farming practices, handling during harvest, etc.

e) Aside from polluting agricultural products through wastewater irrigation, an additional increase of micro-organisms occurs during the intermediary stage between harvest and selling in the markets. If the sanitary quality is considered for agricultural product sold in the markets, which are only influenced by the quality of irrigation water used, it is equivalent to products irrigated with raw wastewater.

Figure 4

RISK LEVEL FROM CONSUMPTION OF CROPS IRRIGATED WITH DIFFERENT WATER QUALITIES

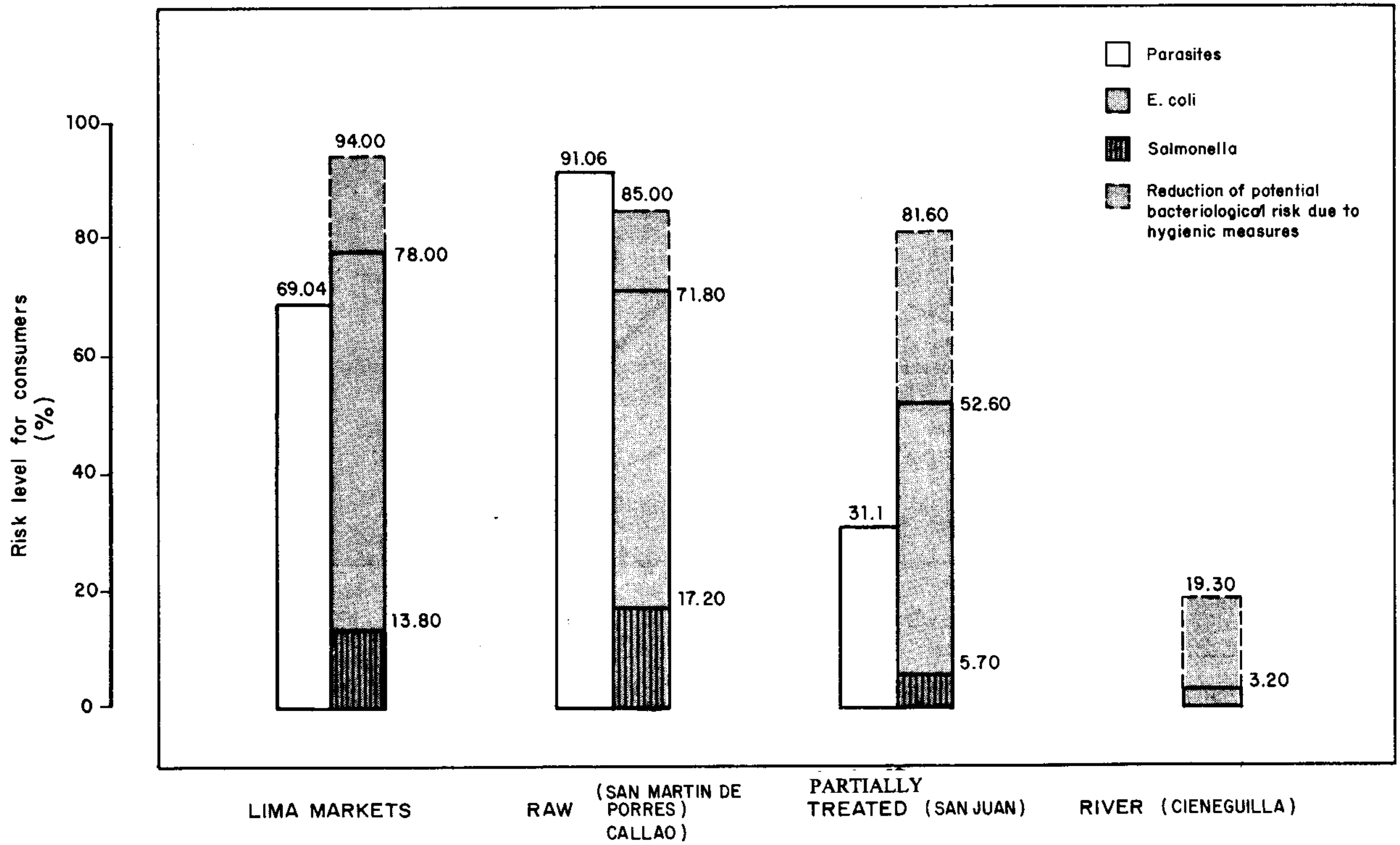
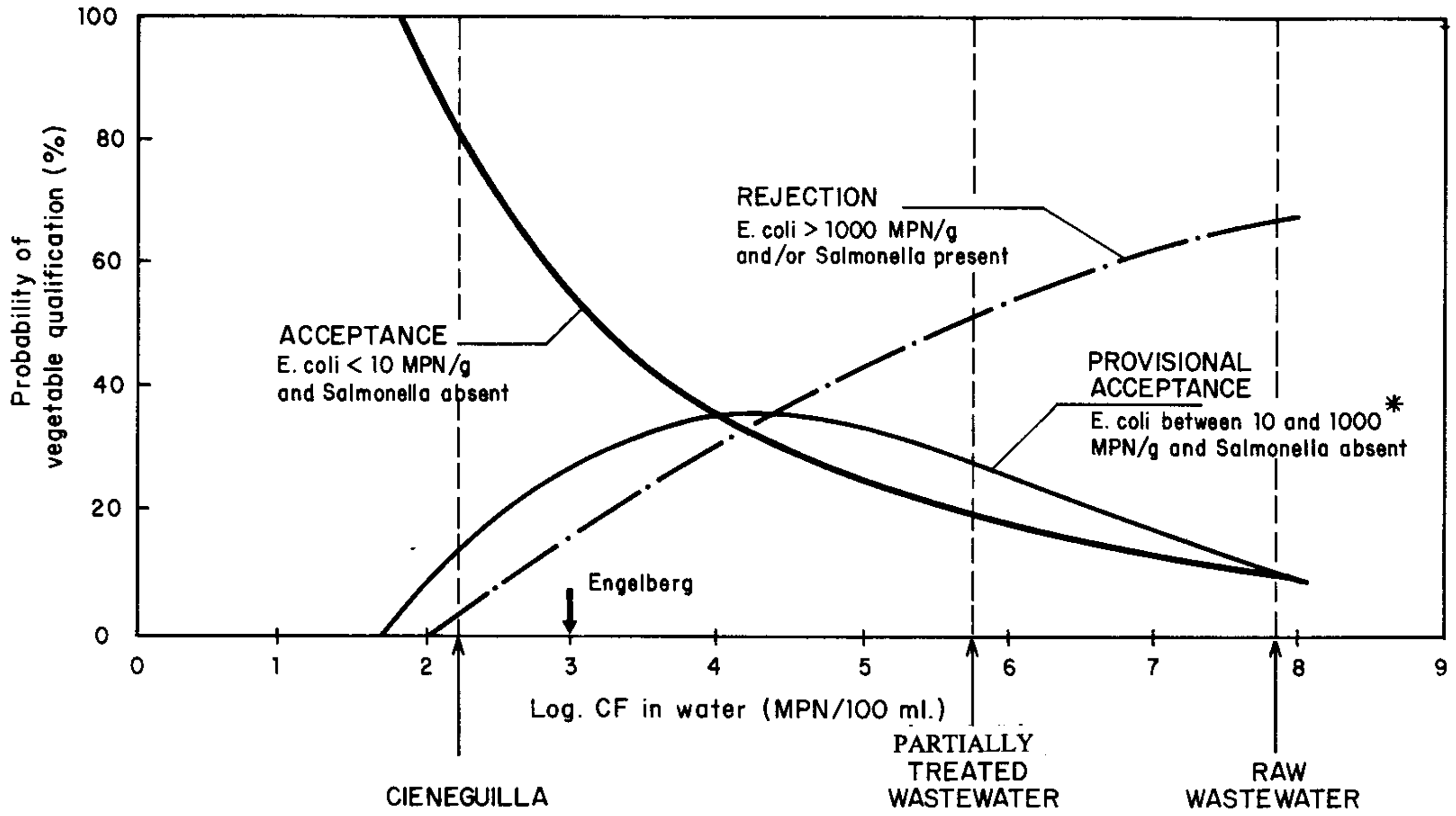


Figure 5

POTENTIAL RISK AND ACCEPTANCE LEVELS, PROVISIONAL ACCEPTANCE OR REJECTION OF VEGETABLES

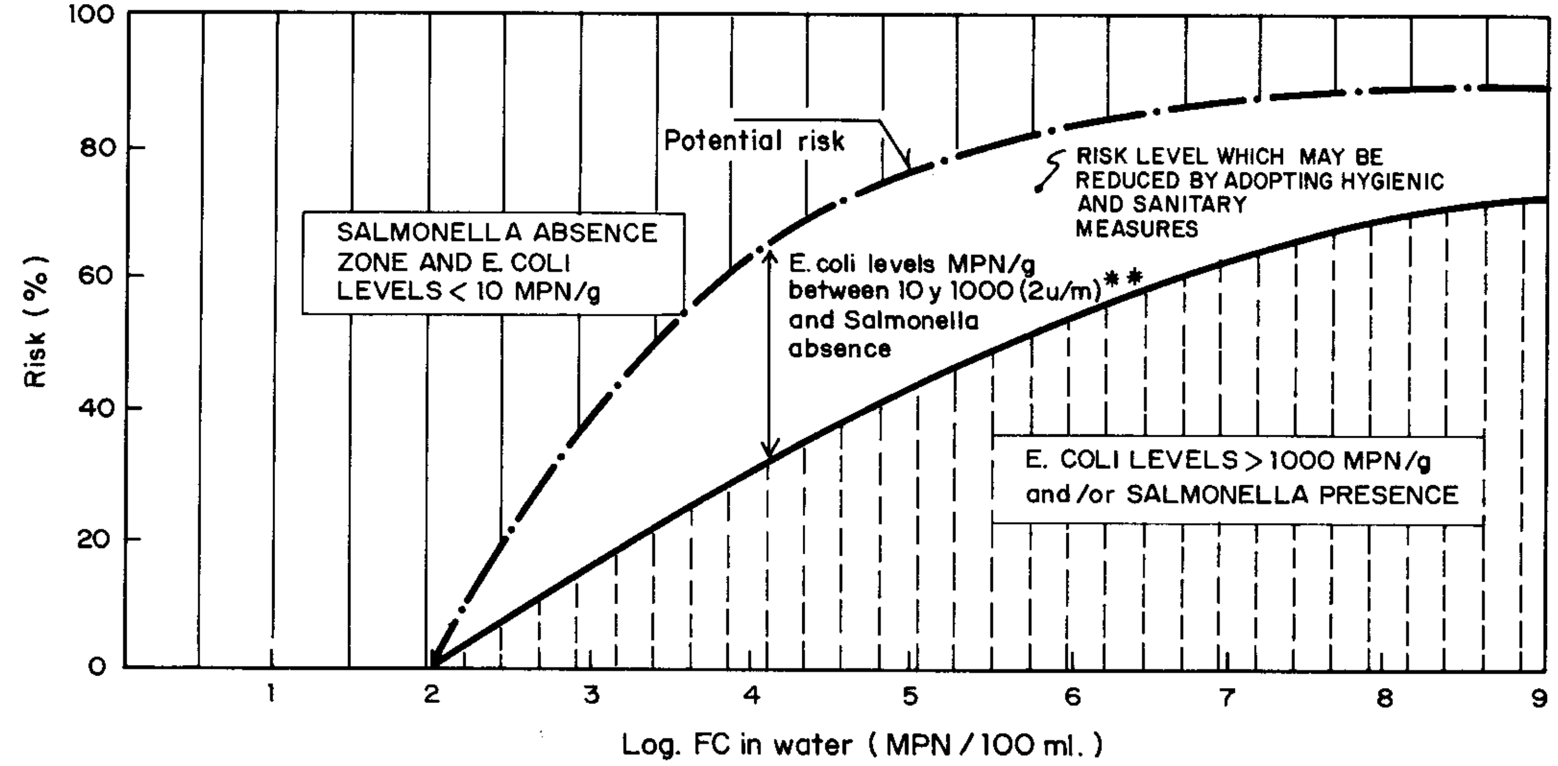
PROBABILITY QUALIFICATION MODEL OF A PRODUCT CONDITIONED TO THE WATER QUALITY USED FOR IRRIGATION



* In 2 units in a sample of 5 units

Figure 6

RISK TO CONSUMERS * DUE TO VEGETABLES CONSUMPTION AS A FUNCTION OF WATER QUALITY USED FOR IRRIGATION



(PR/LCFA) P (PR/LCFA) + P (PAp/LCFA)

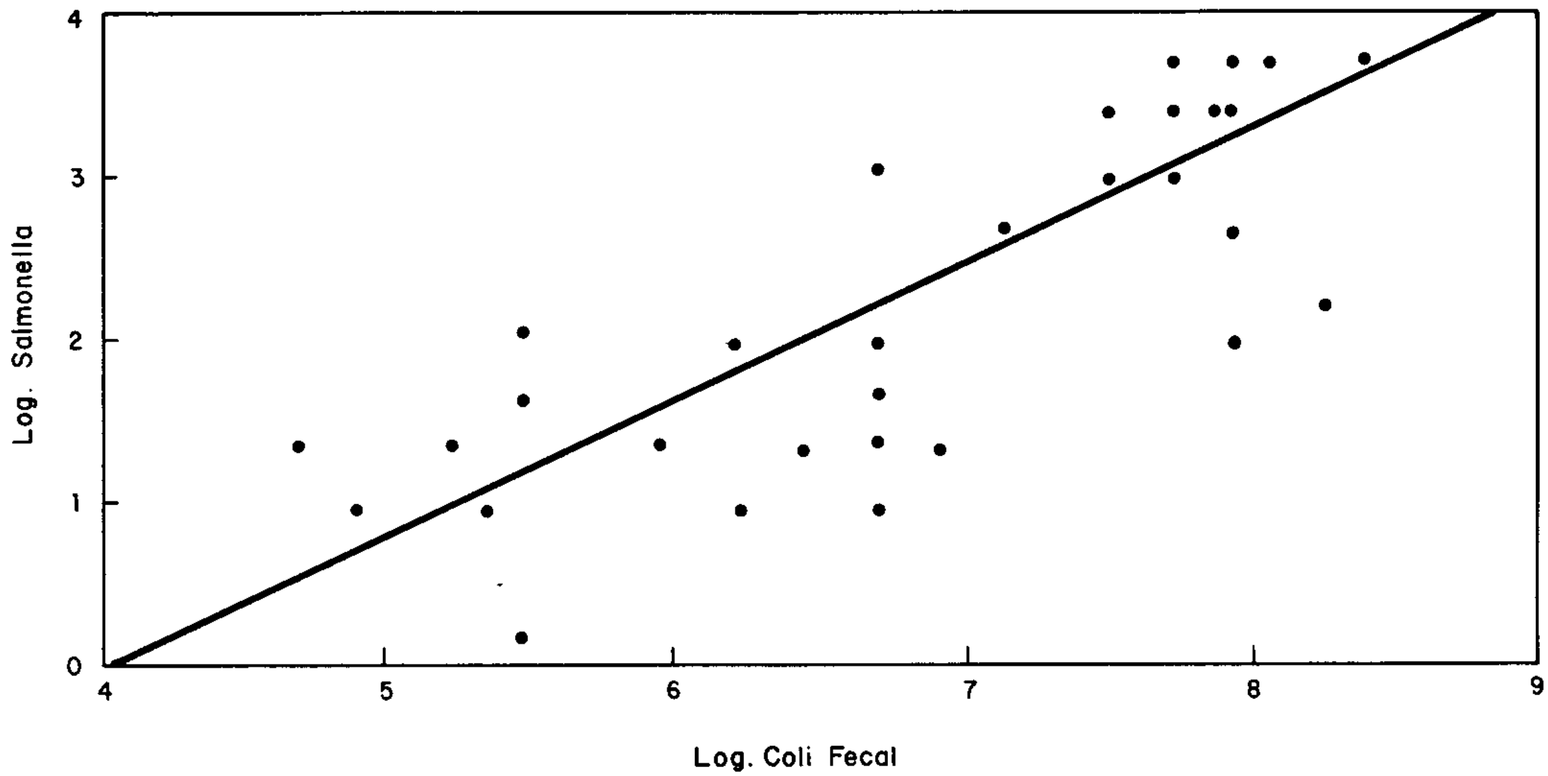
(Rejection probability / Log Coli Fecal in water) = Probability (Rejection probability / Log Coli Fecal in water) + Probability (Acceptance probability / Log Coli Fecal in water)

* *Due contamination of agricultural products according sanitary quality*

** *In 2 units in a sample of 5 units*

Figure 7

CORRELATION OF FC MPN / 100 ml. AND SALMONELLA MPN / 100 ml. IN WATER



Log. Salm. = − 3.2836 + 0.8171 Log Fecal C.

r^2 = 0.6497

STD. Estimated error = 0.6489

f) Stabilization ponds insure a high degree of parasite and bacteria removal and make wastewaters suitable for reuse in agriculture, when designed and operated according to technical criteria.

The presence of parasites in agricultural products from the San Juan zone is a consecuence of the fact that 86.7% of the farmers have nematode and protozoa infections and also because of the lack of sanitary instalations in the field.

g) The model developed in the design of stabilization ponds has proven to be a practical tool since it allows the prediction of bacteriological quality of effluents. Parasite removal requires a more in-depth evaluation since their presence is influenced by detergent waste and floating material in the ponds.

h) The analysis carried out has shown that clay or less sandy soils favor the evolution, development and survival of helminth eggs.

i) The time period between the last irrigation and harvest helps to obtain agricultural products of an improved bacteriological quality. In view of the fact that parasites have a longer survival span, these cannot be included in this conclusion.

j) A direct relationship exists betwen the sanitary qualification (E. coli + Salmonella) and fecal Coliforms in agricultural products which allows to simplify the activities of the surveillance program.

k) The microbial load in the agricultural products sold in the markets is probably generated during the refreshing process using polluted water during transportation or perhaps through the absence of hygiene measures.

6. RECOMMENDATIONS

a) Wastewaters used to irrigate agricultural products must be submitted to treatment in order to guarantee the absence of intestinal helminths and fecal Coliform must not exceed 10,000 organisms per 100 ml.

b) The basic surveillance program of agricultural products for human consumption irrigated with wastewaters and developed for the specific case of Lima can be carried out by measuring fecal Coliform per gram of vegetable, which considers the contamintion risk by E. coli and Salmonella in a joint manner. The control levels recommended are as follows:

- Size of sample 5 units
- Method of analysis multiple tubes MPN/100 ml)
- Limit per gram
  - Minimum: m 15
  - Maximum: M 150

- Number of units with values between m-M limits for conditional acceptance — 2 units

- Qualification levels
  a) acceptable
  b) conditional acceptability
  c) rejectable

When the values found exceed the established limits for the basic surveillance program in a certain percentage of the sample, the sanitary quality of the agricultural products must be confirmed following ICMSF recommendations.

Furthermore, the vegetables must also be checked for the absence of viable parasite eggs or protozoan cysts in the 5 sampled units.

c) The quality control of the effluents from the stabilization ponds must be done by determining the MPN of fecal Coliforms per 100 ml. There is no need for the routine identification of Salmonella since these can be easily estimated applying the mathematical expression shown in Figure 7.

d) The responsible sectors or entities must register and control the quality of wastewater and agricultural products. The surveillance and control program must be comprehensive, involving the treatment of wastewater, crops, harvest, transportation and marketing of agricultural products.

e) Authorization to use wastewater must be preceeded by educating farmers of the need to have potable water, adequate disposal of farming practices which contribute towards reducing the risk of contamination.

f) Reuse programs must be accompanied by a permanent epidemiological surveillance program which with prior diagnosis through indicators, will allow the risk of reuse to be controlled within a certain acceptable range.

g) In order to establish a surveillance, control and adequate treatment program, in keeping with each of the risk factors which affect the sanitary quality of vegetables and the exposed population EPIDEMIOLOGICAL STUDIES should be carried out to evaluate the real impact of each of the different factors affecting the sanitary quality of the products.

h) A more in-depth evaluation of the removal efficiency of parasites in stabilization ponds must be carried out.

i) In order to determine the mechanisms which lead to an increase of the microbiological contents of agricultural products during marketing stages, a study should be carried out to identify the critical points in the marketing route during which microbiological contamination takes place and the causes of deterioration in its microbiological quality.

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