IRCWD Report No. 09/90

HUMAN WASTE USE IN AGRICULTURE AND AQUACULTURE

UTILIZATION PRACTICES AND HEALTH PERSPECTIVES

EXECUTIVE SUMMARY

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Photos on cover page:

Excreta use, a century-old practice of human waste use in China: a farmer fertilizing his potato plants with diluted excreta

Wastewater reuse: farmers irrigating a chilli field with wastewater from Mexico City near Tula, State of Hidalgo

The photos in this document were made by the authors

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The Executive Summary document was prepared

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HUMAN WASTE USE IN AGRICULTURE AND AQUACULTURE - UTILIZATION PRACTICES AND HEALTH PERSPECTIVES

EXECUTIVE SUMMARY

CONTENTS

INTRODUCTION

• Foreword

The Project History

WHO (Geneva) and **IRCWD** jointly initiated a project in 1982 whose aim was to assess the health implications of excreta and sludge use in agriculture and aquaculture. This work should complement the resource recovery activities of the **UNDP/World Bank** which initiated a similar project on wastewater reuse at about the same time. WHO and UNDP/World Bank are faced with **increasing demands** by authorities in arid and semiarid countries for **guidance on the health aspects of waste reuse**. These demands originate from the widespread need in many different areas to introduce or to expand and improve the practice of faecal waste use. The immediate rationale for the WHO/IRCWD group, which joined forces with the London School of Hygiene and Tropical Medicine (LSHTM), and the UNDP/World Bank group, was thus to arrive at modern guidelines on the hygienically safe use of faecal wastes. Behind this rationale there was, however, a far-reaching, overriding objective: wastewater and excreta use should become integral parts of water resources and waste management planning. The reuse of faecal wastes, whether liquid or semi-liquid, as valuable resources should be promoted to the extent dictated by the climatic, socioeconomic and cultural conditions of each specific country or locality.

IRCWD/LSHTM first prepared state-of-the-knowledge reviews on the cultural (Part I), microbiological (Part II) and epidemiological (Part III) aspects of excreta use. Abstracts of these reviews are presented in one of the introductory sections below. The epidemiological review revealed very clearly that only a very **limited number of reliable epidemiological studies** existed at the time, on the basis of which firm guidelines could be formulated, and confirmed the findings of the Shuval et al. group commissioned by the UNDP/World Bank. An increase in the number of methodologically sound epidemiological studies was deemed desirable and necessary. At the same time, IRCWD/LSHTM considered an in-depth knowledge of actual reuse practices to be an important prerequisite for the formulation of new guidelines. These two **objectives**: initiating new **epidemiological studies and observing and understanding reuse practices and problems**, formed the rationale for the observation and contact missions which Ursula J. Blumenthal of LSHTM and Martin Strauss of IRCWD jointly undertook in 1985. This document "tells the story" of their observations, their deliberations with numerous persons involved in reuse and their study of relevant documents. Some of their information was later complemented and updated through comments and further documentation provided by persons they contacted during their visits.

On one hand, the document is a **compilation of case studies** which stand on their own, on the other, the authors have spun a "red thread" which allows it to be used as an armchair-guide on excreta and wastewater use. In the main report, there is, for each case, an in-depth discussion on the health implications of the particular use practice, leading to suggestions on how to improve, if necessary, public health protection. It contains comparative observations and deliberations in discussion chapters as well as synoptical views.

WHO and WHO/UNEP published new guideline documents in 1989 (see Annex 1 of this document). They constitute the indirect result of joint project meetings held in 1985 and 1987 in Switzerland among individuals and institutions[1] involved in applied research and programme management of human waste use.

One important message in those new guideline documents is that **health protection** may be achieved not only by waste treatment, but by a **combination of measures,** including crop restriction, choice of the irrigation or application method, exposure control and waste treatment. This concurs with the observations made in a number of places visited by Ursula Blumenthal and Martin Strauss. It also takes into consideration the economic situation of the less-industrialized countries which precludes, in many instances, the full treatment of all wastes prior to their use.

With this case-study document, IRCWD concludes the series of publications on the health impacts of faecal waste use. It will, however, continue to actively participate in providing advice, in disseminating newly acquired knowledge on the subject and in promoting the new guidelines.

Complementary Documents and Reference Institutions

A considerable number of documents covering various aspects of human waste use both in agriculture and aquaculture have been published over the past few years. Readers interested to enter deeper into specific subjects, with the particular perspective on health aspects, are referred to the list of publications presented in Annex 1 of this document.

Annex 2 contains a non-exhaustive list of institutions which are actively involved in human waste use, with special focus on public health aspects.

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1 WHO, UNEP, World Bank, UNDP, FAO, IDRC, LSHTM and IRCWD

• Acknowledgements

This Executive Summary of IRCWD Report No. 08/90 "Human Waste Use in Agriculture and Aquaculture - Utilization Practices and Health Perspectives" was prepared by **Professor M.B. Pescod,** Head of the Department of Civil Engineering at the University of Newcastle upon Tyne in the United Kingdom at the request of the International Reference Centre for Waste Disposal. IRCWD expresses its gratitude and appreciation for Prof. Pescod's diligent work in preparing this concise and informative summary from the voluminous main Report which contains of the order of 300 pages.

IRCWD thanks all the persons who reviewed individual chapters and the final draft of the full document. A list of their names is presented in the main document. We are also indebted to the many individuals who hosted Ursula J. Blumenthal and Martin Strauss during their visits to the various countries, who accompanied them to the reuse sites, who availed themselves as discussion partners and who provided them with useful documents, many of which would not have been easily accessible otherwise.

Finally, IRCWD is grateful to all the institutions and persons who were involved in this multi-stage project for their fruitful collaboration and support. They include, among many others: Somnuek Unakul, Ivanildo Hespanhol and Gunnar Schultzberg (WHO); Richard Feachem and Sandy Cairncross (LSHTM); Hillel Shuval and Carl Bartone (UNDP/WB); Alex Redekopp and Don Sharp (IDRC); Warren Pescod (University of Newcastle upon Tyne), Duncan Mara (University of Leeds), and Piers Cross (UNDP/World Bank, Zimbabwe).

• Scope and Structure of the Executive Summary

The **objective** of the Executive Summary is to provide a concise yet comprehensive review of the main IRCWD Report and to serve as a ready reference to the subject. It attempts to mention most substantive subjects touched on in the main Report but does not claim to discuss matters to any great depth.

Like the main Report, the Executive Summary is addressed to planners, decision-makers, support agency officials and any others involved or interested in the various aspects of human waste use. They are provided through this document with quick overviews of the wastewater and excreta use practices in the countries covered by the Report and the health implications of those practices.

The Executive Summary is available free of charge from IRCWD and will allow potential purchasers of the Main Report to assess its contents. The Main Report is available from SKAT, the Swiss Center for Appropriate Technology, St. Gallen, Switzerland (see front page for the full address).

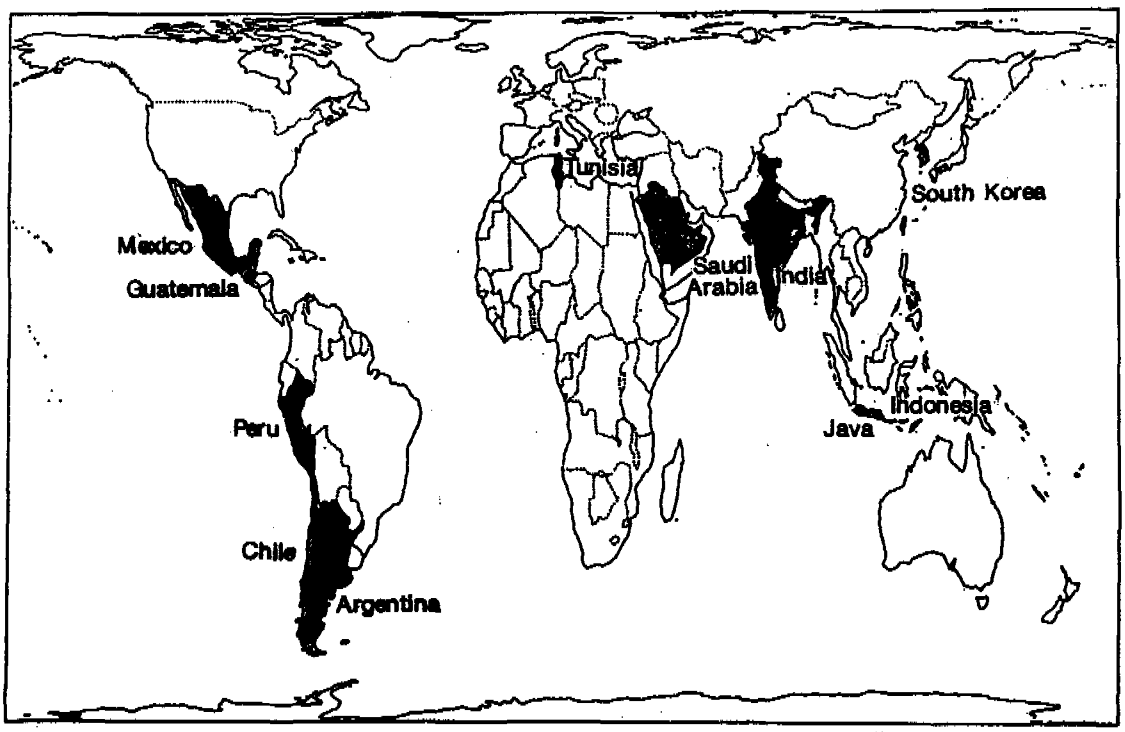
The **structure** of the Executive Summary follows that of the main Report and is divided into the following parts:

	Chapters in the main Report	
- Background	1	(24 pp)
- Untreated Wastewater Use in Agriculture	2-4	(68 pp)
- Treated Wastewater Use in Agriculture	5-8	(85 pp)
- Summary and Discussion of Wastewater Use in Agriculture	Ac	(11 pp)
- Excreta Use in Agriculture	9-11	(34 pp)
- Wastewater Use in Aquaculture	12-14	(30 pp)
- Excreta Use in Aquaculture	15	(27 pp)
- Synopsis and Recommendations	16+17	(7 pp)
- Annexes		(10 pp)

Unlike the main Report, the Executive Summary does not contain any references to the publications and documents used.

- **Scope and Structure of the Main Report**

The main Report reviews available information on practices and patterns of excreta and wastewater use in agriculture and aquaculture in ten countries of **Latin America, North Africa, Western and South-East Asia**. (see Fig. 1). It also presents anecdotal information and observations of the team responsible for the Report from visits they made to the various countries in the period July to December 1985. The commentary, interspersed with tables, figures and photographs, illustrates the reuse situation in each country or in parts thereof, summarizes the state of knowledge from reuse project studies and considers the health protection status and requirements for the various reuse schemes reviewed. Each case is structured so as to provide the reader with the **historical perspective, human waste use patterns, institutional and regulatory dimensions** and **health aspects**.



(This map is based on the Peters Projection. It shows the countries and oceans according to their actual areas).

Fig.1 COUNTRIES WHERE WASTEWATER OR EXCRETA USE IS PRACTISED AND WHICH WHERE VISITED BY THE AUTHORS

The countries covered are **Argentina, Chile, Guatemala, Mexico** and **Peru** in Latin America, **Tunisia** in North Africa, **Saudi Arabia** in Western Asia and **India, Indonesia** and **South Korea** in South-East Asia. The Report focuses on the situation and needs in less-industrialized countries and areas. Health perspectives are particularly emphasized by comments at the end of each case study report. Although the range of countries visited was limited by temporal and financial constraints, the examples presented cover a sufficient range of reuse practices to allow an overview of these practices and an understanding of their dependency on local, cultural, economic and climatic conditions

One notable omission is **China**, a country with a long history of human waste use; it was not possible for the team to visit that country in the course of the 1985 missions and they were unable to retrieve sufficient documentation to allow comprehensive presentation of Chinese practices and health impacts.

People's Republic of China (Zhejiang Province): a farmer demonstrating the fertilization of his potato plants with diluted faecal slurry from the family's jar toilet.

People's Republic of China (Zhejiang Province): an improved toilet with 3 interconnected jars allowing solids separation and excreta storage prior to their use in agriculture.

Chapter 1 of the full Report reviews the resource aspects of human waste use and the relevant health issues, and it provides a summary of available health protection measures. Information is provided on excreta-related diseases, survival of excreted pathogens in the environment and epidemiological aspects of human waste use. The microbiological quality guidelines recently recommended by the World Health Organization for the reduction of the health risks in wastewater and excreta use in agriculture and aquaculture are included in this Chapter. Alternative measures for health protection are discussed in the context of soil/pond and crop/fish contamination as well as worker and consumer protection.

Following Chapter 1, the full Report is structured so as to discuss case material under various generic headings, covering

Part A:	Wastewater Use in Agriculture	(Chapters **2-8**)
Part B:	Excreta Use in Agriculture	(Chapters **9-11**)
Part C:	Wastewater Use in Aquaculture	(Chapters **12-14**)
Part D:	Excreta Use in Aquaculture	(Chapter **15**)

Parts A, B and C are followed by a summary and discussion chapter.

Part A is divided into three sub-parts, Aa on the Use of Untreated Wastewater in Agriculture (Chapters 2-4), Ab on the Use of Treated Wastewater in Agriculture (Chapters 5-8) and Ac, a Summary and Discussion. Each case study presented in the Report usually starts with acronyms of relevant organizations in the country, a map of the country, geographic and demographic information and a review of waste use and ends with a reference list. A final **Part E** includes Chapter 16, a Synopsis, and Chapter 17, Recommendations.

- **The Previous Documents in this Series**

- **Cross, P. (1985).**
  Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part I: Existing Practices and Beliefs in the Utilization of Human Excreta. IRCWD Report No. 04/85.

This report highlights cultural differences in excreta management practices, discusses beliefs and habits and suggests ways to strengthen the role of sociocultural perspectives in programmes dealing with excreta disposal and hygiene-related problems.

- **Strauss, M. (1985)**

  Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part II. Pathogen Survival. IRCWD Report No. 04/85

  This Report presents compiled information on the survival of excreted pathogens in excreta and faecal sludges prior to utilization (i.e. during storage and treatment), and deals with the fate of these pathogens in the soil, on crops and in nightsoil-enriched fish ponds. The document is partly complementary to the publication *Sanitation and Disease - Health Aspects of Excreta and Wastewater Management* by Feachem et al. (1983) which is based on literature published prior to 1980. The publication by Strauss considers additional literature published between 1980 and 1983 as well as unpublished reference material.

- **Blum, D., Feachem, R.G. (1985).**

  Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part III: An Epidemiological Perspective. IRCWD Report No. 05/85.

  In order to be able to establish with reasonable certainty actual - as opposed to potential - health risks associated with excreta use, sound epidemiological data are required. Part III of the review was prepared with this end in view. It reviews critically and in detail available epidemiological information pertaining to the use of nightsoil and sludge in agriculture and aquaculture. Since there is a scarcity of sound and methodologically reliable data, particularly on the risk attributed to the use of treated excreta, the review therefore proposes epidemiological field investigations to fill gaps in knowledge and to guide future technical policy.

BACKGROUND

Chapter 1 - The Resource and Disease Aspects; Health Protection Measures

The introductory Chapter of the main Report considers the value of human wastes as a resource, reviews current knowledge on the health aspects of wastewater and excreta use in agriculture and aquaculture and covers the options available for health protection in such schemes. It closes with the honest admission that epidemiological studies on wastewater and excreta use schemes have generally not been carried out and that considerable reliance has been placed throughout the document on the judgement of the team visiting the various countries.

After pointing out the value of excreta and wastewater as components of closed cycles of organic material and water when used in agriculture and aquaculture, the Chapter compares the **nutrient value** (N, P_2O_5 and K_2O) of fresh human excreta with alternative organic fertilizers: fresh cattle manure, pig manure, chicken manure and plant residues. A 5-adult family's fertilizing potential is assessed in respect of the area of rice cultivation which nutrients in the excreta could sustain. The fertilization and watering potential of wastewater from 1000 people is likewise indicated in relation to maize cultivation. It is made clear that use of excreta and wastewater by farmers can help secure their subsistence and enhance agricultural production in addition to providing alternatives to scarce freshwater sources and helping to reduce surface water pollution.

The section of the Chapter dealing with **disease aspects** provides a foundation on which the assessment of health risks of the particular practices reported for various countries is based. In pointing out that there are approximately thirty excreted infections (bacterial, viral, protozoan and helminthic) of public health importance, the sequence of events necessary to result in an **actual** health risk, as opposed to a **potential** risk, is described in detail. The concepts of **restricted** and **unrestricted** wastewater irrigation are introduced and health risks related to product **consumers**, agricultural **workers** and **populations** living near human waste use schemes are outlined. Epidemiological evidence for disease transmission associated with wastewater irrigation, excreta use in agriculture and use of excreta and wastewater in aquaculture is reviewed and found to be very limited. However, it is concluded that crop irrigation/fertilization with untreated wastewater/excreta causes significant excess infection with intestinal nematodes (roundworms) in both consumers and field workers and that aquacultural use of untreated excreta/wastewater results in the transmission of certain trematode (fluke) diseases. Treatment of excreta and wastewater appears to reduce the risk of transmission of nematode infections in agricultural use schemes.

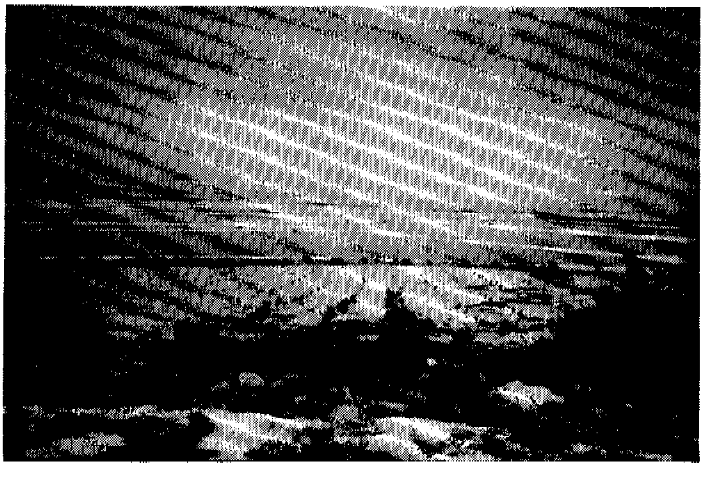
Microbiological quality criteria for excreta, excreta-derived products (such as wastewater sludges, compost containing faecal matter, septage and latrine contents) and wastewater are reviewed in a historical context. The latest microbiological quality **guidelines for wastewater use** in agriculture recommended by the **World Health Organization** in a 1989 Scientific Group Meeting Report (WHO Technical Report Series No. 778) are given in full, together with a discussion of the logic behind them. Also presented are the tentative microbiological guidelines for waste-fed aquaculture contained in the same WHO Technical Report and a reasoned discussion of their justification and application.

Next, in this introductory Chapter of the full Report, alternative **health protection measures** for excreta and wastewater use schemes are outlined. These are:

- waste treatment
- restriction of the crops grown
- choice of methods of application of the wastes to the crops
- control of human exposure to the wastes.

A generalised model of the **effects of the different control measures**, and some combinations, in **reducing the health risk** of waste use in agriculture/aquaculture is introduced and discussed (see Fig. 2).

Waste stabilization ponds often prove to be the most feasible technology for the removal of pathogens: here, the ponds at Al Samra, Jordan, treating the wastewater from the City of Amman; all the effluent is discharged into Zerqua River and King Talal reservoir, the waters of which are used in agriculture.



Wastewater treatment is reviewed to the extent that the advantages of stabilization ponds over conventional sewage treatment processes such as trickling filtration and activated sludge are emphasized in meeting the microbiological quality guidelines for effluent use in agriculture and aquaculture. The drawbacks of effluent chlorination are stated prior to suggesting the preferable

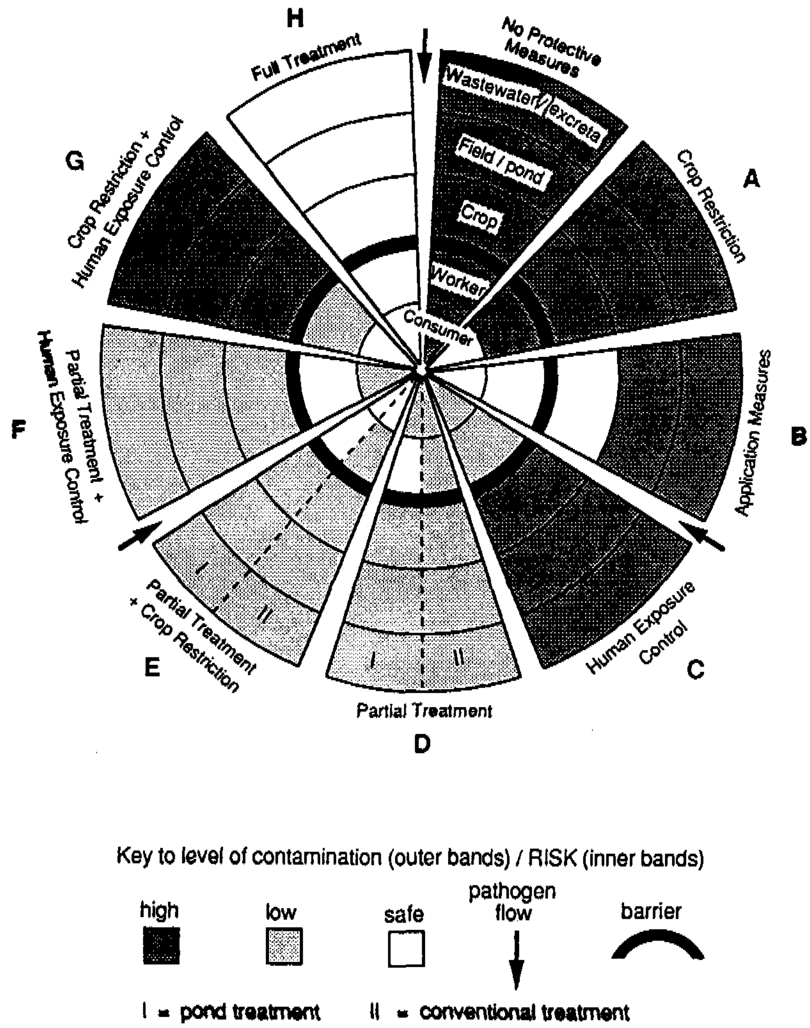


Fig. 2 Generalised Model of the Effect of Different Control Measures in Reducing Health Risks from Waste Reuse

use of polishing ponds to upgrade the microbiological quality of effluents from conventional secondary sewage treatment plants. Excreta storage and treatment are also discussed in the context of health risk.

Crop restriction is covered in some detail in the Report and attention is drawn to the fact that this measure alone does not provide protection to farm workers and their families and must be complemented by other health protection alternatives, such as partial waste treatment, controlled application of wastes and/or human exposure control. Conditions for the successful application of the crop restriction measure in agriculture are summarized. It is conceded that such a measure is not feasible in waste-fed aquaculture.

Alternative **methods of applying wastewater** in irrigating crops are introduced and the suitability of the various methods for protecting health are discussed for particular conditions. Controlled application of untreated or insufficiently treated excreta and nightsoil to land is briefly mentioned and depuration as a means of reducing the degree of contamination of fish grown in waste-fed aquaculture is touched on.

In covering **human exposure control** as a health protection measure in agricultural use schemes, agricultural field workers and their families, crop handlers, consumers (of crops, meat and milk) and those living near the affected fields are identified as potentially at risk. Direct measures to protect workers, such as the wearing of protective clothing, increased levels of hygiene, avoidance of contact with pathogens by behaviour modification, and immunization and chemotherapeutic control of selected infections, are considered in terms of their practical usefulness. Consumer risk reduction through health education (thorough cooking and high standards of hygiene) and meat inspection is briefly covered. A short discussion of human exposure control related to aquaculture mentions snail control (schistosomiasis), chemotherapy, public information and improved water supply and sanitation.

The **model in Fig. 2** illustrates how the **four health protection measures** discussed can be used **singly or in combination** to achieve reduced levels of contamination of wastewater, field or crop and/or reduced levels of risk to consumers or workers. In some situations, it is pointed out, economic and technical factors might militate against full treatment of all wastes and yet cultural factors (for example, the type of staple food crop), a strong institutional structure and the availability of the necessary personnel could create the right conditions for crop restriction, human exposure control and/or partial treatment to be successful in protecting health. For aquaculture, full or partial wastewater treatment and human exposure control are indicated as the more likely measures to protect health. The targeted approach offered by the model is further illustrated by an example of untreated wastewater use in agriculture with crop restriction in Mexico.

At the end of the first Chapter of the full Report, attention is drawn to difficulties encountered in attempting to make an accurate evaluation of the **health risks of a specific practice** in a specific area in the absence of an epidemiological study designed to assess the risks. Local epidemiological, sociocultural and environmental factors give rise to differences in the health effects of a particular practice in different situations. Consequently, the team visiting human waste use schemes in various countries was forced to make judgements on the possible health risks based on a consideration of data on the prevalence or incidence of the diseases of interest, data on the microbiological quality of the wastes, an understanding of the prevailing socio-economic and cultural conditions, and on basic epidemiological reasoning. Since much of the data needed were not readily available in many of the countries visited, it is stressed that subsequent sections of the Report dealing with the health risks of reuse practices contain judgements made on the few data available and are not the result of strict scientific analysis.

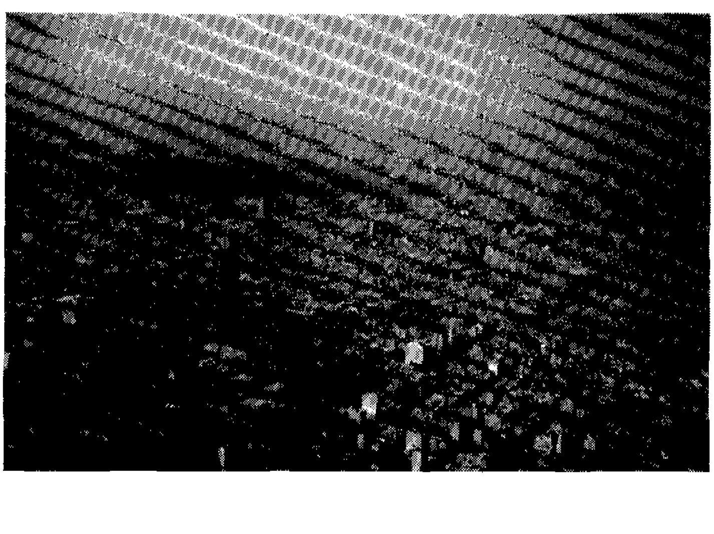
The first Chapter ends with a Reference List of the major documents dealing with the health aspects of human waste use in agriculture and aquaculture. Associated with this Chapter, the full Report has two annexes, one on 'Basic Information on Excreta-Related Infections' and another on 'Institutions Dealing with Public Health Aspects of Excreta and Wastewater Use' (see also Annex 2 of <u>this</u> Report).

UNTREATED WASTEWATER USE IN AGRICULTURE

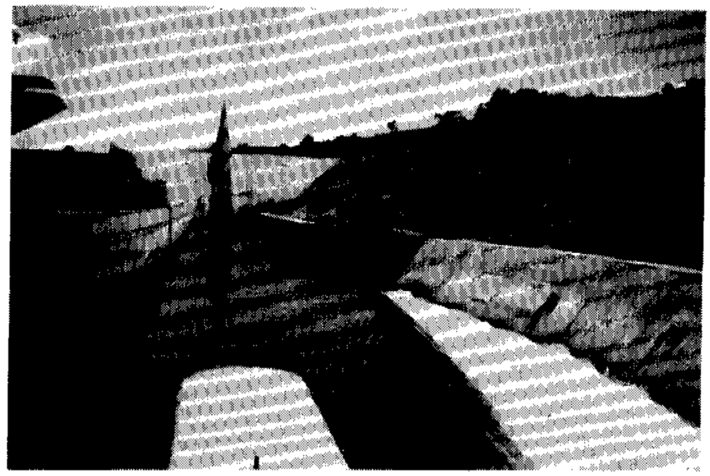
Chapter 2 - Mexico

Mexico has a highly developed system of physical and organizational infrastructure catering for wastewater reuse in a number of areas. Six **Irrigation Districts** manage the distribution of wastewater and surface runoff from urban areas (four use sewage from **Mexico City**) and plans are developed for wastewater use in eleven more Districts (details are given in a Table). Following a historical review of water supply and drainage in the Valley of Mexico, the Chapter concentrates on the use of wastewater from Mexico City in the **Mezquital Valley,** Tula River Basin. The proportions of untreated wastewater and 'uncontaminated' surface water flowing through the basin's irrigation schemes vary seasonally and geographically. During the dry season, irrigation water in the Valley is exclusively wastewater and most is used without passing through impoundment reservoirs. Fig. 3 shows the hydrographic details of the scheme. An estimate of irrigation water supply indicates that 80 per cent (40 m^3/s) of the total use of 1,580 million m^3/year is provided by sewage and storm runoff from Mexico City.

The concentrations of contaminants in the irrigation water varies temporally and spatially but generally faecal coliform (FC) levels are 10^6-10^8/100 ml. However, **crop restriction** is enforced by the Irrigation District, with **lettuce, cabbage, beet, coriander, radish, carrot, spinach** and **parsley** being specifically excluded. Maize, beans, chilli and green tomatoes, the staple food in the area, are not restricted and neither is alfalfa. Farmers interviewed by the visiting team expressed concern about the high concentration of non-biodegradable ("hard") detergents in the irrigation water (causing 'burning' of plant leaves), complained about loss of work due to diseases such as stomach problems ('amoeba') and skin infections attributed to the use of wastewater for irrigation but indicated that they still preferred to irrigate with wastewater, rather than freshwater, because of its nutrient content. The farmers also reported about diarrhoeal diseases suffered by their children.



Mexico City: ~90% of the city's wastewater is reused in agriculture in the Mezquital Valley (Tula), 10% is used for green-belt irrigation.



"Canal Central": one of the three trunk canals carrying untreated waste and stormwater from Mexico City to the Mezquital Valley (Tula) where it is used for irrigation.

Brief summaries of wastewater use to reclaim desert land as pasture in **Lago Texcoco,** Mexico Valley, and for **green belt irrigation** in Mexico City are also given in this Chapter. The institutional and regulatory framework for planning, implementation and control of water resources development, wastewater collection and treatment, wastewater reuse and related public health aspects on a nationwide basis and for the Federal District of Mexico City is provided in some detail. Quality standards for water used to irrigate crops or for recreational purposes have been defined in a 1973 ordinance and are given in the Report.

In a section dealing with health and epidemiological aspects, the importance of water and excreta-related infections which might be associated with waste use are placed in perspective against predominant diseases in the area. Some mortality and morbidity data are given for Mexico as a whole and for the Tula Health District in particular. The findings of previous studies on the health impact of the use of raw wastewater in agriculture in the Mezquital Valley are reviewed. In one study, no consistent significant excess prevalence of gastrointestinal complaints or protozoan or helminth infections was found in children from communities irrigating with wastewater as compared with children from a control community using clean water for irrigation. In another study it was found that the risk of amoebiasis was greater in the area where wastewater was used for irrigation than in the control area not practising wastewater irrigation. A third study on the effect of the use of wastewater on agricultural workers in Guadalajara concluded that a high prevalence of parasitic diseases in both exposed and control group workers was due to poor environmental sanitation, poor hygienic habits and lack of health education. However, a significant excess prevalence of infection in the exposed group was found for Giardia lamblia (17 per cent in exposed vs 4 per cent in control group) and Ascaris lumbricoides (50 per cent in exposed and 16 per cent in control group).

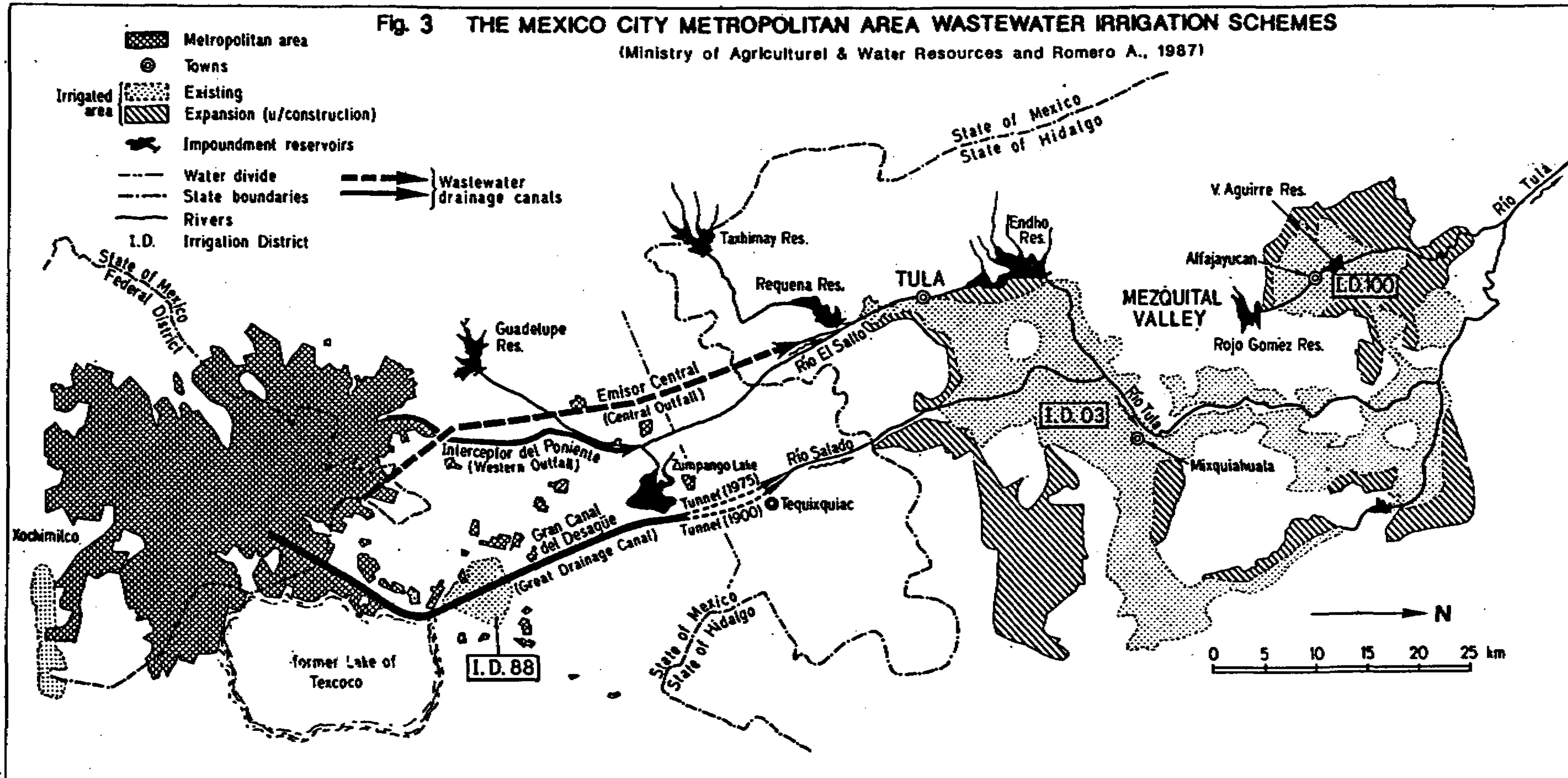


Fig. 3 THE MEXICO CITY METROPOLITAN AREA WASTEWATER IRRIGATION SCHEMES
(Ministry of Agriculturel & Water Resources and Romero A., 1987)

Note: Not shown are the irrigation canals which branch off the wastewater intercepters, the rivers and reservoirs.

In spite of methodological deficiencies in these health studies certain possible impacts are identified as being worthy of further investigation. For example, where raw wastewater is used in irrigation it is suggested that the increased risk to farm workers from Ascaris, Giardia and possibly Entamoeba histolytica infections should be tested. The increased risk of diarrhoeal diseases in the farm workers and their children, as well as the effectiveness of retaining wastewater in impoundments in reducing risks from helminth and protozoa infections, should be investigated. A new epidemiological study resulting from the team's visit to Mexico was started in 1989. It addresses the three issues of interest mentioned above.

A farmer near Tula (Mezquital Valley, Mexico) irrigating a field with untreated wastewater from Mexico City prior to sowing

The Chapter concludes with the suggestion that the Mexican experience with raw wastewater reuse proves that successful enforcement of crop restriction provides health protection for the general public, including crop consumers. However, to protect the **health of agricultural workers** some treatment of the wastewater to remove helminth eggs and protozoan cysts is desirable. In some cases, control of human exposure and control of irrigation methods might be attempted as health protection measures. For future wastewater use schemes, it is recommended that some treatment of the wastewater should be considered, but if only partial treatment is feasible crop restriction should also be introduced. The generally high incidence of infection of rural populations with intestinal parasites suggests the need to address environmental sanitation and personal hygiene issues in all areas of Mexico.

Chapter 3 - Chile

All of Santiago's sewage is used indirectly[1] to irrigate farmland in the immediate vicinity of the capital city's expanding residential and industrial areas. 70-80 per cent of Santiago's raw sewage is collected in a large open drainage canal (the Zanjón de la Aguada) which in dry weather has a BOD_5 of 100 mg/l and FC of 10^6-10^8/100 ml. The team visited the area irrigated with this flow situated to the west of the city in the municipalities of Maipú and Pudahuel. A few other waste reuse sites, of a minor scale, exist outside the Santiago metropolitan area.

Farm workers were observed furrow-irrigating land with raw sewage originating in the Zanjón de la Aguada, while others were seen to be harvesting lettuce from a field covered in faecal matter. The area receiving wastewater from this drainage canal provides most of the vegetables for the Santiago population, including lettuce, cabbage and celery, cereals, grapes and low-growing fruits. Because, theoretically, this canal water is drainage water rather than wastewater, the authorities have had great difficulty in enforcing crop restriction regulations.

A **sewerage master plan** for Santiago has been prepared. Plans exist to construct, in a first phase, a sewage interceptor along Río Mapocho and to have the wastewater treated by conventional secondary treatment, complemented by sand filtration and chlorination. Waste stabilization ponds, although better suited for pathogen removal than conventional processes, prove unfeasible in this situation due to excessive requirement of land which in the outskirts of Santiago is highly valued.

The Chapter includes a review of regulatory institutions and their functions and introduces the **landowners' organizations** which are reportedly quite strong and influential. A sanitation code imposes restrictions on the use of wastewater in agriculture and Chilean standards specify the water quality requirements for irrigation use and list the crops which require water containing less than 1000 FC/100 ml (including lettuce, chicory, parsley, radish, carrots, coriander and strawberries but not artichokes, celery or cabbage). Land owner associations as well as market and socioeconomic forces act against the effective control and enforcement of crop restriction.

Chile is very different from other countries which use untreated wastewater for agriculture. Being non-tropical, it does not have the same array of tropical and parasitic diseases as are found in tropical areas. Over 80 per cent of the population live in urban areas with a high coverage of

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1 "Indirect" use means the use of river or of other surface water into which wastewater is being discharged. In dry seasons, when rivers are at low or zero flows, indirect use is almost or fully equivalent to direct use.

potable water supply. The main transmissible diseases notified are **typhoid** (and paratyphoid) fever and **infectious hepatitis.** The rate of typhoid fever in Santiago is high (80-200 cases per 100,000) and consistently higher than in the rest of Chile. The available circumstantial evidence gained from epidemiological and microbiological investigations suggests that the use of untreated wastewater may explain the excess of typhoid infection in Santiago compared with the rest of the country where there is no sewage irrigation. This evidence is further supported by the observations that the seasonal increase in the disease coincides with the onset of sewage irrigation in summer, that the typhoid rates in infants (0-2 years) are low (suggesting that short cycle person-to-person contact, as is occurring within the family, is not an important form of typhoid transmission in Santiago), and that the cases of typhoid fever are distributed among all socio-economic neighbourhoods in Santiago. Also, Salmonella typhi have been isolated from wastewater canals used to irrigate land where salad crops are grown. The highest incidence of typhoid fever is in children aged 8-13 years, and studies have indicated that consumption of food and ice outside the home are important factors.

Use of raw sewage to irrigate crops in Santiago does not appear to be causing an increase in infection with **intestinal nematodes**, because the general level of nematode infection is low in Chile (Ascaris 1 per cent, Trichuris 3 per cent). As with typhoid fever, the prevalence of Entamoeba histolytica infection is greater in the Santiago region than in the rest of the country, possibly due to irrigation with wastewater, although other transmission routes are probably involved as well.

The Santiago experience suggests that improvements in the present conditions will only be possible following the construction of interceptor sewers to convey sewage away from drainage canals. Only then could farmers be forced to comply with restrictions on use but excluding salad crops would not be popular because of the large demand for these in Santiago. Treatment of sewage would be the preferable solution to allow unrestricted irrigation with the effluent. Since the main health risk is associated with bacterial infections, a treatment technology producing high bacterial removal is necessary. Stabilization ponds might not be economic, considering the low winter temperatures and the high land values. Tertiary treatment (filtration and chlorination) following conventional secondary sewage treatment might be justifiable in this case so as to remove amoebic cysts and kill bacteria.

Chapter 4 - India

The Chapter starts with a brief review of rural and urban sanitation provision in India and draws attention to the current focus on low-cost pour-flush latrines for excreta disposal in urban areas, due to centralized sewerage not being affordable. Nevertheless, it is pointed out, scavengers still collect large volumes of excreta in urban areas and transfer them to nearby rural areas for use on the fields. In addition, wastewater from many cities is used on farmland.

The pattern of rainfall in most parts of India results in long periods of drought and irrigation is, therefore, essential, with raw or partially-treated wastewater making up a significant proportion of the irrigation water. In the Ganges River clean-up programme, reuse of treated wastewater in agriculture has been proposed as a pollution control strategy. In addition, market demand for vegetables generally continues to increase, giving further impetus to wastewater and excreta use in agriculture.

The Chapter has drawn on a 1988 paper by Shende and his co-workers at the National Environmental Engineering Research Institute (NEERI) in reviewing the national situation in regard to wastewater reuse. These authors suggested that 73,000 ha of land were irrigated with wastewater in 1985 in at least 200 **sewage farms**, many of which had been in operation for five or six decades. Only surface irrigation is used, including uncontrolled flooding, ridge and furrow, border strip and check basin irrigation. Shortcomings as reported by Shende et al. of the 'crude and irrational manner' in which wastewater irrigation is practised in India are listed. Mainly forage crops are grown on sewage farms, although vegetables and paddy are produced on half of the farms and maize and cereals are also irrigated with sewage.

Table 1 shows the features of twelve sewage farms in various parts of India. Only in four of these schemes was the sewage treated, in one with only primary treatment and in one other by stabilization ponds. There is widespread and frequent informal use of sewage and sullage for irrigation and, although there is a law prohibiting raw-eaten vegetable irrigation with sewage, this is still practised. Apart from their involvement in wastewater conveyance and wastewater allocation to farmers, Government agencies apparently do not actively enforce the regulations and do not monitor or control the health and agricultural effects of wastewater irrigation.

Nightsoil is also widely used in agriculture and it is not known whether farmers apply it prior to sowing or planting only or also during the growing period. The health risks will vary with the practice adopted and also with the period of nightsoil storage before application. In Calcutta, nightsoil is reportedly co-composted with solid organic wastes (e.g. market refuse) before sale to farmers but the demand for this anaerobically produced product prevents it from being stored for sufficiently long a period to protect against health risk. In the main, nightsoil use in agriculture is not controlled but the move to pour-flush latrines with twin alternating leaching pits is expected to produce a faecal product which should be relatively safe for use in agriculture.

The first phase of the **Ganges River programme** includes sewage treatment facilities for six large cities in Uttar Pradesh, including Kanpur and Varanasi (Benares). Reuse of treated effluent in agriculture and forestry is strongly favoured and likely to be implemented. For populations in excess of 100,000, wastewater stabilization ponds are not considered feasible, because of the large land requirements, and conventional secondary treatment directed towards satisfying water pollution control standards is to be adopted. This form of treatment will not produce a safe effluent for use in irrigation and crop restriction is likely to be necessary. For several decades in

Table 1 **Features of Some Selected Sewage Farms in India (Shende et al. 1988)**

Location (State)	Command area (ha)	Volume of sewage used (1000 m^3/d)	Application rate (m^3/d,ha)	Application rate (ℓ/s,ha)	Treatment if any	Dilution if any	Soil type	Crops grown
Ahmedabad (Gujarat)	890	300	337	3.9	nil	nil	Sandy loam	- Paddy, maize, pochia grass, jowar, wheat, lucerne
Amritsar (Punjab)	1214	55	45	0.5	nil	1:3	Sandy clay	- Maize, sorghum, berseem, lucerne
Bikaner (Rajasthan)	40	14	337	3.9	nil	nil	Sandy	- Bajra, wheat, grasses, vegetables
Bhilai (Madhya Pradesh)	607	36	60	0.7	stab.ponds	nil	Sandy and clayey loam	- Paddy, maize, wheat, tuwar, vegetables
Delhi	1214	227	187	2.2	prim.+sec.	nil	Sandy loam, loamy sand	- Jowar, bajra, maize, barley wheat, pulses, vegetables
Gwalior (Madhya Pradesh)	202	11	56	0.6	nil	nil	Silty and clayey loam	- Paddy, maize, andguar, jowar cowpea, wheat, potato, berseem, vegetables
Hyderabad (Andhra Pradesh)	607	95	157	1.9	primary	1:1.5	Loam	- Paddy, para-grass
Jamshedpur (Bihar)	113	9	80	0.9	secondary	nil	Clayey loam	- Miscell. grasses, berseem, jowar, maize
Kanpur (Uttar Pradesh)	1416	32	22	0.25	nil	1:1	Loam and silty loam	- Wheat, paddy, maize, barley potato, oats, vegetables
Madras (Tamil Nadu)	133	7	51	0.6	nil	nil	Sandy to silty loam	- Para-grass
Madurai (Tamil Nadu)					nil	nil	Red sandy loam	- Guinea grass
Trivandrum (Kerala)	37	9	232	2.7	nil	1:1	Sand	- Para-grass

Calcutta, sewage has been treated in ponds, which also serve for fish production, and the effluent used for irrigation (this scheme is described in more detail in Chapter 12 of the Report). A similar approach in the Ganges programme, it is suggested, might be appropriate, with the economic benefits of fish production balancing the disadvantage of high land use for ponds.

The team visited India for only one week and the Chapter includes a review of wastewater irrigation in Uttar Pradesh (U.P.), specifically in Kanpur. In 1984/85, 24 sewage utilization schemes were listed by the U.P. Water Corporation (U.P. Jal Nigam) and the Department of Agriculture, comprising 3000 ha of irrigation area. The command areas ranged in size from only 10 ha up to 1300 ha (Kanpur), with an average size of 200 ha. Irrigation rates with sewage varied from as little as 0.1 l/s per ha to as much as 10 l/s per ha. Many schemes in the State do not function as projected or have completely broken down due to lack of maintenance and shortcomings in the construction, handing-over and operation of schemes. In the largest scheme, in the north-eastern sector of Kanpur, 50,000 m^3 of sewage are used daily in the 1300 ha command area. The sewage is diluted with freshwater (1:1 to 1:2), screened and conveyed by low-lift pumps through a 1 km force main for gravity distribution. Wastewater is used only during the dry season, but the supply does not meet the farmers' demand. At the time of the team's visit in November, the paddy fields had been harvested and the fields were being flooded to prepare for the sowing of 'winter' (dry season) crops. Wheat, forage crops and flowers (e.g. marigolds) are important dry season crops irrigated with wastewater, as are vegetables, which are officially prohibited. One of the first sewage farms to be set up in Uttar Pradesh (in 1913 in Lucknow) was abandoned in 1982, illustrating the growing competition between agriculture and urban expansion.

Included in the Chapter is a review of research carried out at the National Environmental Engineering Research Institute (NEERI) in Nagpur. Work reported in 1978 confirmed the superiority of wastewater stabilization ponds over conventional sewage treatment processes in removing parasites. Current research includes a study on the effect of irrigation with untreated, primary treated and secondary treated sewage at moderate and high intensities on the growth and yield of crops and on soil properties. Results of research on the survival of indicator bacteria, Salmonella sp., helminths and protozoa on vegetables are discussed.

The Institutional and Regulatory framework for water supply, sewerage and sewage irrigation in India is summarized in a section of this Chapter. Although national effluent standards exist, it is pointed out that legal power and enforcement rest with State authorities but, in practice, actual enforcement is non-existent. In Uttar Pradesh, effluent standards enacted in 1983 include 20 parameters but there are no microbiological quality parameters such as faecal coliforms; this is also the case in the Ganges pollution control project (status as per 1985). The State Health Department plays only a minor role in control and enforcement of standards.

In speculating on the health and epidemiological aspects of wastewater use for irrigation in India, the Report reviews the general disease, sanitation and hygiene situations. Since most of the sewage used for irrigation in India is untreated, little or no removal of pathogenic microorganisms is achieved before use. Sewage farm workers have been shown to carry a significant excess of hookworm and Ascaris infections compared with a control population of farm workers using fresh water for irrigation. A higher proportion of the sewage farm workers were anaemic and reported gastrointestinal symptoms. Many consumers of vegetable crops may also be at risk. With the increasing interest in land disposal and therefore use of sewage in irrigation, the numbers of sewage farm workers and crop consumers at risk are likely to increase in the future. The Chapter ends with suggestions for the control of health risks in sewage farm workers and consumers under various conditions of crop restriction, wastewater treatment and exposure control, and draws attention to the appropriateness of stabilization ponds as a treatment method.

TREATED WASTEWATER USE IN AGRICULTURE

Chapter 5 - Peru

In Peru, a 'wastewater reuse belt' extends from north to south all along the Pacific coast. More than 30 wastewater reuse sites have been identified in the coastal desert strip where cultivation can take place only by irrigation. Seasonal rivers from the Andean slopes, their water mixed with wastewater from nearby towns, is used to irrigate the valley plains. Apart from such indirect use of wastewater, sewage treated to varying degrees is used directly in irrigation and, for many farmers, is the only available source of water. With high demand for vegetables, cereals and fodder crops, availability of water for irrigation and crop nutrients limit agricultural production.

With more than 50 per cent of the urban and peri-urban population linked to sewerage systems, sewage flows are substantial and a valuable resource. **Stabilization ponds** are widely used but produce effluents of varying characteristics due to factors such as poor design and overloading. Aerated ponds and Imhoff tanks are also used for treatment but in some places farmers divert raw sewage for irrigation. Sewage application rates vary between 0.5 and 1 l/s per ha and crops grown include vegetables, fodder crops (e.g. alfalfa) and non-edible crops (e.g. cotton). The features of some reuse schemes at five locations visited by the team are tabulated and discussed in detail.

In **Lima**, the capital, about 5000 ha are irrigated with raw wastewater or heavily contaminated river water. Vegetables and fodder crops are grown in Callao and San Martín de Porras in the north of the city and forest trees are irrigated in San Juan de Miraflores in South Lima. Near San Bartolo, south of Lima, a project is being prepared to irrigate 4000-5000 ha with wastewater after either primary pond treatment plus infiltration or multi-stage pond treatment. A section of the Chapter is devoted to discussions the visiting team had with a particular farmer and his wife in the San Martín de Porras district. The San Juan de Miraflores wastewater stabilization ponds and the extensive research studies on their performance carried out by the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS) are reviewed in another section of the Chapter. Details of the effluent use for irrigation are also provided and personal observations of the team reported.

Wastewater reuse practice in **Ica**, located 300 km south of Lima, is summarized in another section of the Chapter. Most sewage from Ica is treated in four facultative ponds operating in parallel at Cachiche, south of the town, before being used to irrigate 400 ha of agricultural land. The major crops grown are cotton, maize and grapes because ground and river water are available nearby to irrigate vegetables. Interviews with a farm worker's wife revealed that crop restrictions were strictly enforced by the provincial health inspectorate. Near Ica, another community (Tinguiña) is served by a small wastewater stabilization pond (2-3 ha) at Parcona. Cotton and fruit trees are being irrigated on 120 hectares of land. At both these locations, wastewater is sold to farmers.

In Peru's southernmost town, **Tacna**, sewage is treated in two parallel aerated primary ponds and two parallel secondary stabilization ponds and the effluent is used to irrigate 210 ha. These ponds are now overloaded and produce an effluent with unsatisfactory bacteriological quality. Although the farmers are not allowed to plant vegetables, some grow potatoes, sweet potatoes, chilli and pumpkin. In this location, wastewater reuse appeared to be progressing satisfactorily although synthetic detergents were causing problems of foaming and 'burning' of plants.

Wastewater quality and treatment standards and reuse regulations are contained in the General Water Law (Ley General de Aguas) which also assigns Government Departmental responsibilities. These are reviewed in the Chapter and the system of permits is explained. Observations on the administration and arrangements and enforcement practices related to wastewater reuse in Lima, Ica and Tacna are summarized.

The Chapter concludes with a discussion of the health and epidemiological aspects of treated wastewater use for irrigation in Peru. A tabulation of selected data on the prevalence of intestinal helminth and protozoan infections in several areas of Peru indicates that the prevalence of helminth infections is low in the coastal area; only Enterobius vermicularis and Hymenolepis nana exceed a prevalence of 20%. Ascaris and Trichuris have a very low prevalence (under 20% and generally under 5%) in the coastal area but a high prevalence (> 70%) in the moister environment of the mountains and forests. Giardia lamblia is the most common enteric protozoan infection, reaching high prevalence rates in Ica. Acute diarrhoeal disease, typhoid fever and hepatitis A are common infectious diseases but because there are many possible transmission routes for these excreta-related infections, wastewater reuse might not be an important risk factor in this context. The results of CEPIS studies on pathogen removal in wastewater stabilization ponds are summarized and the findings of a descriptive parasitological survey of the population living near ponds mentioned.

It is suggested that both farmers and their families are at increased risk of contracting Ascaris, Trichuris and Giardia infections if raw sewage is used for irrigation and consumers will also be at risk if vegetables eaten raw are so irrigated. Use of effluents from short retention time stabilization ponds will avoid these risks only if a restricted range of crops is irrigated, as at Ica. Farmers and their families using effluent from the San Juan ponds (with less than 1000 faecal coliforms/100 ml) are probably at no increased risk compared with farmers using fresh water for irrigation and consumers should also have no increased risk of infection. Waste stabilization ponds are seen to play a key role in protecting health in reuse schemes in Peru. It is recommended that new wastewater stabilization ponds should be designed for maximum pathogen removal efficiency but if a suitable effluent quality is not achieved crop restriction should be strictly enforced.

It is important to distribute the effluent produced in new treatment systems equitably, ensuring that previous users of raw wastewater, whose plots may be located upstream of the new treatment works, gain access to the treated effluent. Misuse of raw wastewater will occur if this is not guaranteed.

Chapter 6 - Argentina

The team visited only Mendoza Province in the west of Argentina and observed wastewater reuse near the **City of Mendoza**. Sewage from the city is treated at two sites, Campo Espejo and Ortega (or Coquimbito). At the **Campo Espejo primary sewage treatment plant**, sludge is anaerobically digested, dried and sold to farmers and the effluent discharges into a major agricultural drainage canal, the Canal Moyano. The mixed water is used to irrigate an area of about 2000 ha in the Departamentos Lavalle and Las Heras. On the small farms (4-20 ha) visited by the team, lettuce, onions, tomatoes and artichokes were grown. At **Ortega**, heavily overloaded wastewater **stabilization ponds** appear to provide little improvement in faecal coliform levels, although the effluent is used, after mixing with river water, to irrigate vegetables in Guaymaltén area. Reuse of wastewater for irrigation in Mendoza is unrestricted at present and is giving rise to considerable concern. Many peasant farmers and farm labourers have a low socio-economic status, with poor health conditions and inadequate water supplies. There are plans to create a restricted irrigation zone in the area north of the existing sewage treatment plants but these would also require upgrading.

A tabulation of the various institutions regulating wastewater reuse in Argentina (and in Mendoza Province) together with their functions is presented in the Chapter. The role of Canal associations is described and the lack of a legal framework to safeguard health is emphasized. Investigations on wastewater reuse in the Mendoza area are reviewed and indicate that although examination of stool samples indicated higher incidence of Giardia intestinalis and Salmonella in residents from the wastewater irrigation zone than in a control population, the difference in infection rates could not be attributed to the wastewater use practice. Comparison of the health status of two similar rural communities, one from a wastewater irrigation zone, suggested that the inadequacy of domestic water supplies in that area plays a greater role in the transmission of diarrhoea and intestinal parasitic infections than use of wastewater in irrigation.

It is concluded that pathogen removal at the Campo Espejo primary treatment plant and at the Ortega wastewater stabilization ponds is likely to be inadequate. Use of the effluents poses a relatively high health risk. There are **no crop restrictions** in Argentina and both workers and consumers are at risk. Because irrigation water rights are intrinsically linked with property rights, enforcement of crop restriction would be difficult. Under these conditions, upgrading treatment at Campo Espejo and at Ortega would be the most appropriate health protection measure. Properly designed wastewater stabilization ponds would be the most effective form of treatment but their large land requirement would be a disadvantage. There is also an urgent need to improve domestic water supply for farm workers in the wastewater irrigation areas and this would be likely to contribute substantially to the reduction of bacterial and viral enteric infections, particularly diarrhoeal diseases.

Chapter 7 - Tunisia

Wastewater reuse during dry spring and summer months has been practised in Tunisia for several decades and is an integral part of the national **water resources strategy**. A 1985 listing of existing and planned wastewater reuse schemes is provided to accompany the discussion on sewage treatment and effluent use for irrigation of mainly fruit and olive trees, forage crops, golf course, and hotel lawns. The **use of wastewater**, even when adequately treated, **for the irrigation of vegetables** is **prohibited**. Nightsoil is reportedly used in admixture with cattle dung in Gabes and Cap Bon but excess risks associated with this practice have not been assessed.

Fig. 4 shows the existing and planned treated **wastewater irrigation schemes** in the **Tunis metropolitan area**, and Table 2 lists the salient features of the various schemes. About 600 ha of land in Soukra municipality, 10 kilometres north of Tunis have received effluent from the Charguia activated sludge sewage treatment plant since 1964 but the effluent is of relatively poor

Table 2 **Data on the Current (1990) and Future Reuse of Wastewater from the Tunis Metropolitan Area**

Irrigation scheme	Actual/proposed cultivation	Name of station supplying irrigation water	Sewage Treatment Plant: System	Present plant capacity[1] m^3/day	Effluent quality[2] E.coli/100 ml (geom. mean)
Existing					
Soukra 600 ha	Citrus fruits	Charguia	Activated sludge	60,000	$2 \cdot 10^5$
Henchir Tobias-Cébala 2670 ha [3]	Cereals, forage	Charguia expanded	Stabil. ponds	16,000	600
		Côtière Nord (existing) Choutrana	Activated sludge	40,000 ?	$2 \cdot 10^5$
Future (under planning or Implementation)					
Soukra + 200 ha	Fruit trees	Charguia expanded	Activated sludge	100,000	
Mornagh 940 ha	Fruit trees	Sud Miliane	Oxidation channel	40,000	

[1] Projected dry-weather-flow of all 4 STP (1987): 250,000 m^3/d
Expected demand for irrigation of all perimeters (4450 ha): 187,000 m^3/d
[2] Data collected during 1987/89 (Trad-Raïs 1989, personal communication)
[3] Put under irrigation in 1989

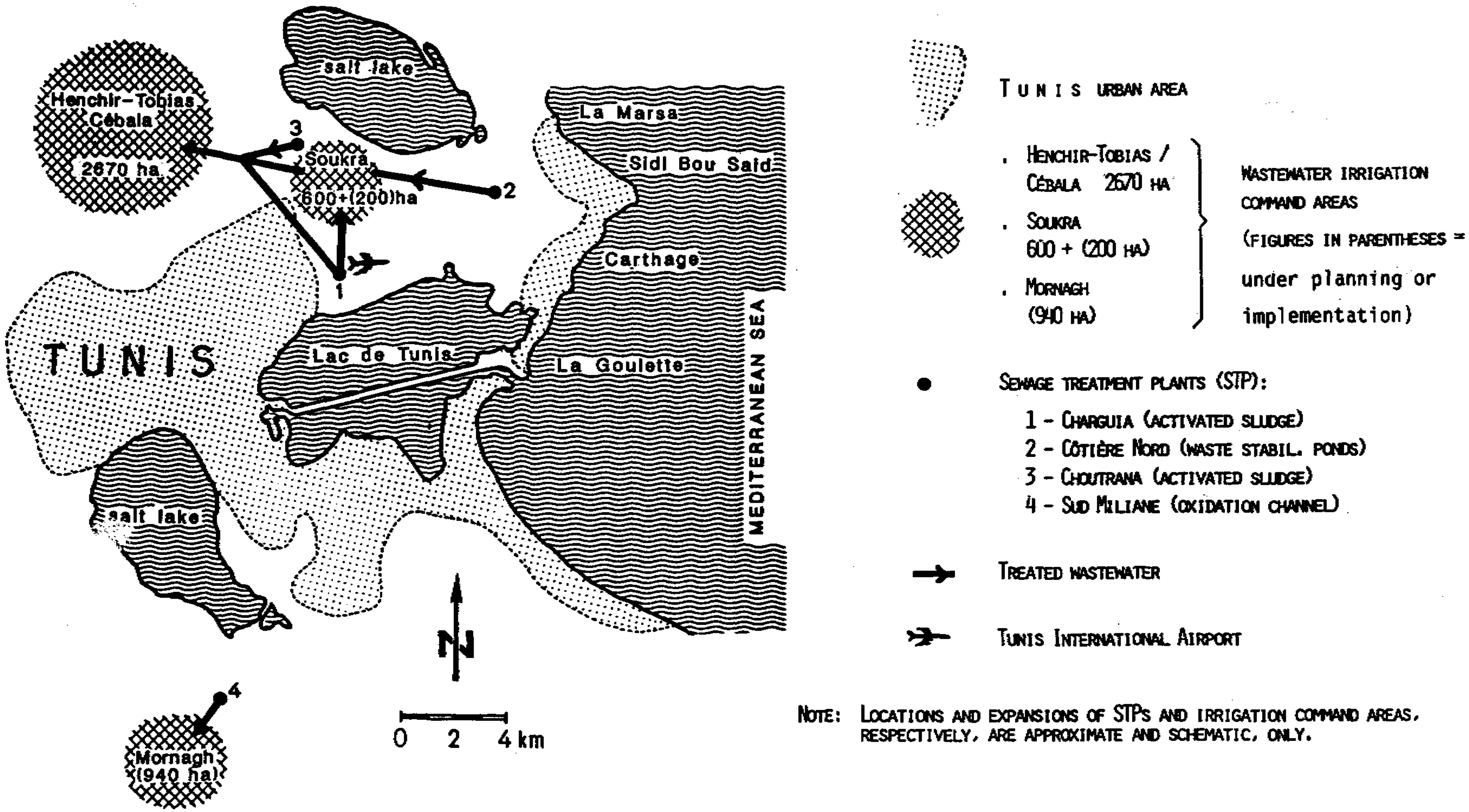


Fig. 4 Current (1990) and Future Irrigation with Treated Wastewater in the Tunis Metropolitan Area

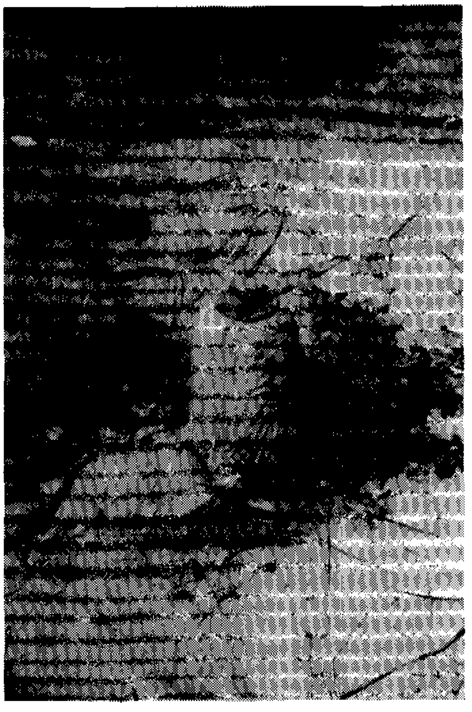
hygienic quality. Large-scale expansion of the wastewater- irrigated area north of Tunis was scheduled for 1986. A large wastewater stabilization pond scheme has been operated at Cotière Nord since 1981 and has produced a good quality effluent (600 E. Coli/100 ml) except for high salinity (EC ≥ 7 mS/cm) caused by infiltration of saline groundwater into leaking sewers.

Soukra (near Tunis): orchard irrigated with secondary effluent from the City of Tunis.

The team visited the Soukra-Ariana irrigation area and reports discussions with farmers and irrigation network operators. In the Ariana suburban area mainly citrus trees are grown and here, as elsewhere in Tunisia, **crop restriction** is enforced. The responsible agency, the Medjerda Valley Development Authority (OMVVM) regularly collects fees from the farmers (U.S.$ 0.02/m^3) and check on the proper functioning of the system. Treated wastewater from Tunis is received twice a day for a total of 7 hours, 3-4 times per week during the dry season, through an underground pipe system delivering through valved outlets ("vannes") to surface furrows. One farmer consulted used cattle manure for soil fertilization but did not purchase mineral fertilizer.

Where treated wastewater is used for irrigation, the Ministry of Agriculture acquires effluent from the Office National de l'Assainissement (ONAS), the national sewerage and sanitation agency, and controls its use according to the Code des Eaux, the National Water Law, now supplemented by regulations specifically relating to reuse of wastewater in agriculture. Although domestic water supply is under the jurisdiction of agencies of the Ministry of Agriculture, the Ministry of Public Health is responsible for the control of the health aspects of wastewater use and authorizes wastewater reuse permissions issued by the Ministry of Agriculture.

This Chapter includes a broad review of the endemic disease situation in Tunisia, using routine data collected by the health services as a background to discussing the health risks of wastewater reuse.



Soukra (near Tunis): a farm hydrant ('vanne') dispensing treated municipal wastewater (secondary effluent); this wastewater is distributed to individual farm plots by underground pipelines.

In the period 1983-86, the Ministries of Agriculture and Public Health, with assistance from the United Nations Development Programme (UNDP), undertook studies designed to assess the effects of using treated wastewater and dried, digested sludge on crop productivity and on the hygienic quality of crops and soil. The results comparing irrigation with treated effluent and irrigation with groundwater are summarized in a series of tables and figures, including bacterial (FC) contamination of and die-off on soil and on crops (millet and chilli), and qualitative observations of the effects are made. The results of the various investigations confirmed previous findings on excreted bacteria survival that die-off on soil and on crops is exponential and that differences in the level of bacterial contamination between fresh water and effluent-irrigated soil and crops tend to be significant immediately after irrigation but diminish as more time elapses. A 1985 epidemiological study allowed certain tentative conclusions to be postulated but further extended studies on larger sample sizes are required to confirm these findings.

Waste stabilization ponds (WSP) are considered as the first choice treatment technology of ONAS, the national agency responsible for wastewater treatment, in view of the cost and ease of operation and maintenance. This is also compatible with the need for effluent of a good hygienic quality for treated wastewater reuse. Where activated sludge effluent is being used without chlorination, precautions to prevent farm worker exposure to the wastewater, such as wearing of protective clothing or use of drip-irrigation, are recommended by the authors. Upgrading of these treatment plants by the addition of maturation ponds is also suggested as a means of producing a higher quality effluent for use on a less restricted range of crops.

It is suggested that different health protection measures are adopted depending on the crops farmers want to grow. In case vegetable irrigation with wastewater is ever permitted in future, provision should be made to treat the wastewater to the guideline level for unrestricted irrigation. WSP is then the favoured treatment method if land is available at economic cost. Where citrus or olive trees are grown, a lower quality effluent can be used together with measures to reduce the exposure of workers to the effluent.

Chapter 8 - Saudi Arabia

This Chapter starts with a review of Saudi Arabia's geography, economic development and water resources situation. In view of the limited fresh water availability and the reliance on desalination for about 20 per cent of the Kingdom's water demands, it is now a declared policy to utilize all available treated municipal wastewater for various purposes. Existing and planned wastewater reuse in 1985 is discussed and summarized in a tabulation, which indicates that approximately 400 ha of land were being irrigated with chlorinated secondary sewage effluent near Riyadh and about 400 ha near Medina.

The **Riyadh reuse scheme**, for which effluent from the expanded South Riyadh sewage treatment plant is used, irrigates 145 small farms at Dariyah, with date palms as the prevailing crop, 13 larger farms (average 65 ha) at Dirab, growing wheat and fodder crops, and an unspecified number of farms making up 1200 ha at Amariyah. The team talked to workers at a farm in Dirab where wastewater is used for alfalfa production, whereas groundwater is used to irrigate cucumbers and other vegetables. On this particular farm, wastewater is spray irrigated and groundwater is applied through furrows. In the Dirab command area in general, farmers use various types of irrigation technologies besides spray irrigators, i.e. also furrow, drip and sprinkler systems.

In **Medina**, a city receiving millions of Muslim pilgrims during 'Haj' each year, treated effluent use for irrigation had been practised for a number of years before being prohibited in 1985, to exclude the risk of disease transmission through vegetables irrigated with reclaimed wastewater that was not of a consistently high standard. Now vegetable cultivation is totally prohibited in the area even though only groundwater is used for irrigation. A new sewage treatment plant including activated sludge, sand filtration and chlorination has been in operation since 1988 and the Ministry of Agriculture and Water is preparing an effluent reuse project.

National **wastewater regulations** drafted in 1984 require secondary or tertiary treatment, depending on the planned reuse practice, and specify very strict effluent quality standards. It is likely that all sewage treatment plants in the country will be upgraded gradually to include tertiary treatment but the team expresses concern about both the need for such strict standards and the ability to meet strict effluent standards at all times. The reuse of treated wastewater, which is part of the Kingdom's declared water resources strategy, might be difficult to put into practice because the stringent effluent standards might not always be met unless even more sophisticated treatment technologies are used. Effluent standards and permitted crops or activities are tabulated under the Draft Regulations. The uses include restricted and unrestricted crop irrigation, recreational use, stock watering, afforestation, open land disposal and direct injection for groundwater recharge.

The endemic disease situation in Saudi Arabia is influenced by the large expatriate working population and the large annual influx of pilgrims. Tables are included to show the incidence of principal notifiable diseases in 1983 and 1987 and the trends in typhoid and paratyphoid, infectious hepatitis and amoebic dysentery from 1975 to 1983. The cautious approach which the authorities have taken on wastewater reuse is understandable, given the concern for epidemic outbreaks of disease. A combination of advanced wastewater treatment and crop restriction, however, seems to have limited effluent use in agriculture. Upgrading of existing treatment plants is costly and subject to financial constraints and is not always necessary where crop restriction is applied. The team suggests that a revision of the national strategy for wastewater reuse might be worthy of consideration.

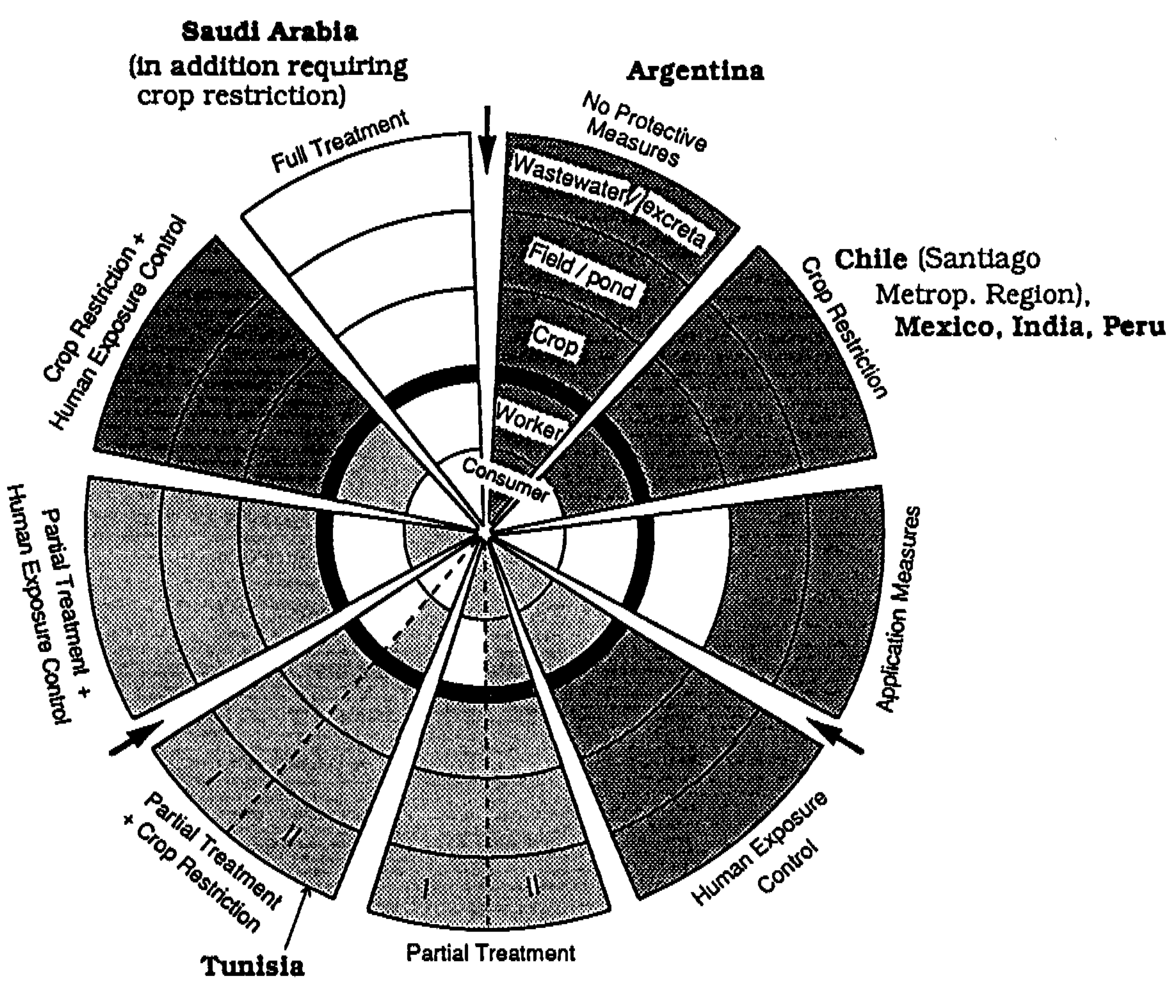
According to the Fatwah (verdict) no. 64 of 1978 a.d. (1398 Hajra) of Religious Scholars in the Kingdom (in a 1978 Verdict), the Chapter concludes, Islamic laws permit the use of wastewater in agriculture provided it is adequately treated and the necessary precautions are taken to avoid the transmission of disease.

Summary and Discussion of Wastewater Use in Agriculture

In discussing the rationale for reusing wastewater, attention is drawn to the arid or semi- arid climatic conditions in the countries described in Chapters 2-8, making rain-fed cultivation impossible over long dry periods. Under such conditions wastewater becomes a valuable water resource, especially where high groundwater salinity is experienced. Consumer demand for vegetables and staple food crops provides a considerable incentive to wastewater irrigation of land near large cities.

In the countries reviewed, **regulations** governing wastewater reuse include either **wastewater quality standards** or **crop restriction**, or a combination of both. A tabulation provides an overview of the current wastewater regulations and their enforcement in the countries mentioned and indicates that both wastewater quality standards and crop restrictions vary rather widely. Existing regulations seem to have been developed exclusively with the consumers' health risk in view. In practice, since the wastewater is frequently not treated at all or the stipulated wastewater quality is either not attainable or not enforced, **farm workers** are often at serious risk of becoming infected. Fig. 5 a+b shows for the seven countries, the effects of current regulations and, of actual practice on wastewater quality, soil and crop contamination and worker and consumer protection.

Enforcement of regulations is discussed at some length and the team's opinions on which factors contributed to the enforceability of regulations are given. Freshwater source availability in the area for irrigation of raw-eaten vegetables, is seen as an important influence, as is the legal and organizational form of wastewater allocation. Market demand for specific, perhaps restricted, crops will often cause farmers to go against regulations and the power of farmers or farm owners' associations to influence controlling authorities is a feature in some situations. Finally, the resources available to regulating authorities often limit their ability to enforce the laws, which are often not adequate or not socially and politically supported.



I = pond treatment II = conventional treatment

Fig. 5a Health Protection Strategies in Selected Countries as per **Current Regulations**
(see Fig. 2 for complete legend)

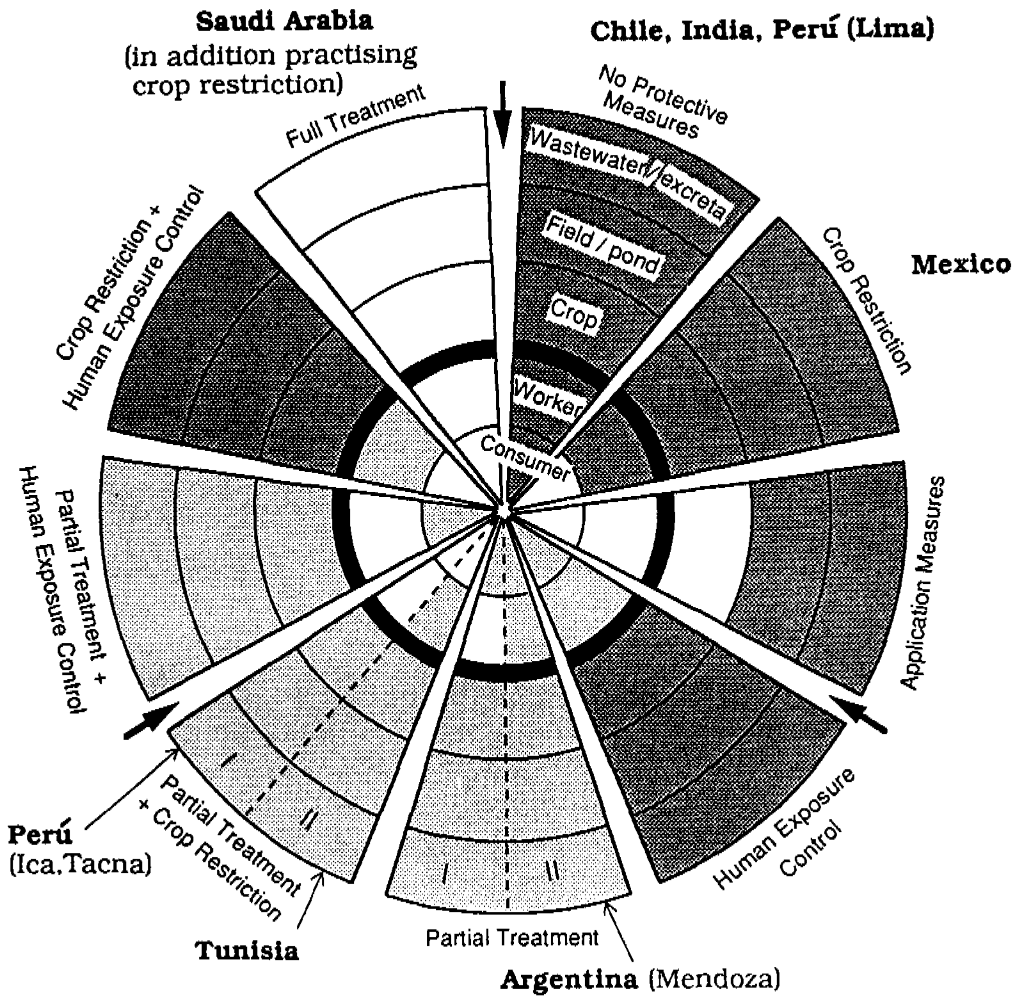


Fig. 5b Health Protection Strategies in Selected Countries as per **Actual Practice** of Enforcement and Observance

(see Fig. 2 for complete legend)

The reported and observed **health situations** in the seven countries covered are summarized in Table 3 which relates the health impacts to current reuse practices and makes proposals for health protection measures which would improve on existing conditions. It is inferred that theoretical or potential health risks exist where raw or insufficiently treated wastewater is being used to irrigate crops but concurrent routes of transmission for excreta-related infections also exist in most locations reviewed by the visiting team. A **minimum set of health protection measures** are proposed for each country as a continuation or expansion of existing practices. Partial treatment is proposed for some countries as a protection measure for agricultural workers. Wastewater stabilization ponds are recommended as appropriate treatment technology wherever they are feasible. Crop restriction is recommended for continuation in those countries where it is effective and for introduction in Argentina and India.

Table 3 **Health Impact from the Current Reuse Practice and Proposed Health Protection Measures**

Country	Health Impact: No risks	Health Impact: Risks	Current (c) or recommended new (n) health protection measures	
MEXICO	• to consumers where crop restrictions are enforced	• parasite (worm + protozoa) infection through the use of raw wastewater • residual risk of protozoal infections with reservoir-settled wastewater	• partial low-cost waste water treatment • crop restriction	n c
CHILE (Santiago)	• of worm infections since helminths are not endemic in Chile (although raw wastewater irrigation is still being practised)	• increased consumer risks to contract typhoid fever from use of raw wastewater • increased risk of amoebiasis and other gastro-intestinal infections to workers and consumers	• Tertiary wastewater treatment (incl. chlorination or polishing ponds)	n
INDIA		• intestinal nematode infections and other parasites (+ bacteria ?) to farm workers and consumers through the use of raw or insufficiently treated wastewater	• partial, low-cost treatment • crop restriction	n c/n
PERU	• to farmers and consumers using partially treated wastewater on restricted crops	• from use of raw wastewater (Lima): parasitic and bacterial infections to workers and consumers	• protective wear • partial low-cost treatment • crop restriction	n c c/n
ARGENTINA (Mendoza)	• to farmers and families using partially treated wastewater when compared to non-wastewater users	• to consumers and farmers as no crop restrictions exist	• partial low-cost treatment of primary effluent • crop restriction	n n
TUNISIA	• to farmers and consumers since secondary effluent is used for non-vegetable crops only	• slight risks to farmers contracting protozoal or bacterial infections if they irrigate without proper protection	• expanding pond treatment, incl. polishing ponds for secondary effluents • crop restriction	n c
SAUDI ARABIA	• of endemic or epidemic diseases due to the combination of tertiary treatment (incl. chlorination) and crop restriction		• partial relaxation of quality standards in order to facilitate wider implementation of reuse	n

[1] c/n: measure already introduced by regulation but needs to be enforced (everywhere in the country)

EXCRETA USE IN AGRICULTURE

Chapter 9 - Guatemala

The southern highlands are among the most densely populated parts of the country. Soils are fertile and rainfalls are plentiful. Maize, beans and wheat are the main subsistence crops cultivated in the highlands. More recently, some farmers have expanded and intensified the cultivation of vegetables much of which is exported. On the steeper slopes, soils are deteriorating due to deforestation and erosion. There, in particular, the use of human faecal matter can help to counteract soil losses and to maintain the organic fraction of the soil. The highland climate is temperate and yearly temperatures average 17-20 ^{0}C.

Since the earthquake in 1976, the Centro de Estudios Mesoamericano Sobre Tecnología Apropiada (CEMAT) developed a **double-vault latrine** with **urine separation,** designated the 'DAFF' (dry alkaline family fertilizer) latrine, and more than 4000 have been constructed by government and non-government organisations. Ash, or a mixture of ash and soil or lime and soil is added after use and the relatively dry contents (~40% water) become alkaline. High pH, around 9, enhances the die-off of bacterial pathogens and after an average of 10 months retention in the latrine, the mixture, called 'abono' (fertilizer), is further dried and stored in bags until applied to the fields at the time of tilling. The separately collected urine is diluted and used to water plants with a high nitrogen preference. Operational and product data for the 'DAFF' latrine are summarized in a table.

CEMAT has established a routine monitoring programme using Ascaris lumbricoides eggs and faecal coliforms (MPN) as hygienic quality parameters. Bacterial pathogen die-off has been found to be high at pH 9 but the effect diminishes if the moisture content of the mixture is greater than 60 per cent. However, pH from 6 to 12.5 had no effect on die-off of Ascaris eggs and moisture content between 34 and 44 per cent in well- operated latrines had no influence on egg viability. Only in the sun-dried 'abono' does the viability reduce to zero or very low levels. Viable Ascaris egg concentrations of several thousands per gram in fresh faeces were found to reduce to an average of 300 eggs/g in faeces stored for about one year at average temperatures of 17-20 oC.

San Juan La Laguna (Lake Atitlán, Guatemala): opening the access door of a double-vault latrine for the removal of stored and decomposed faecal material which is later used in agriculture.

San José Calderas (Dpto. Chimaltenango, Guatemala): intermediate storage of decomposed faecal material from a double-vault latrine

The authors infer from these observations that a one-year storage period is not enough to achieve very low or zero egg viability within the vault at temperatures of 17-20 ^{0}C, even though the latrine contents are dry and pH is high relative to the contents in other types of latrines. The following tentative periods for vault storage and sun drying are proposed to obtain "abono" with very low or zero egg viability:

	Vault storage period required	
	Without subsequent sun-drying	With subsequent sun-drying
• at 17-20 ^{o}C average (highlands, subtropical)	18 months	12 months
• at 28-30 ^{0}C average (lowland, tropical)	10-12 months	8-10 months

It has been found that the nutrient content of 'abono' varies from one latrine to another but the nitrogen level is generally much lower and the potassium level higher than in fresh excreta. Farmers use 'abono' before sowing as well as during the growth phase of crops such as maize, coffee, beans, fruit trees and vegetables, applying 2500-3000 kg/ha for each plant cycle. Because of the nitrogen deficiency of 'abono', nitrogen supplementation (possibly with the separated urine) or rotational planting of nitrogen- fixing crops, such as beans and soybeans, should be applied. Past agronomic experiments have been inconclusive but more carefully controlled tests are now in progress and preliminary results indicate substantial benefits on crop yields from the use of 'abono' as compared with no use of fertilizer.

The **health situation** in Guatemala is reviewed and statistics on major causes of death and the prevalence of Entamoeba histolytica and Giardia lamblia are included. Rural water supply and sanitation are more deficient than in any other country in Central America. The present studies will help to establish the hygienic safety of the double-vault latrine technology, which is an important link in the concept of using human excreta as fertilizer and soil conditioner. 'Abono' from a latrine providing good conditions and adequate retention and which has been sun-dried to attain zero or near-zero viable helminth eggs can be considered safe. With less-effective storage and drying of 'abono' the fertilizer should either be dug into the ground prior to planting and not added during the growing period or used on a restricted range of crops, excluding vegetables eaten raw. Persons using the fertilizer will need to avoid touching the inferior product to prevent exposure to viable helminth eggs.

San José Calderas (Dpto. Chimaltenango, Guatemala): a soil sampler is used to sample a profile of decomposing faecal material from the full vault of a double-vault latrine. Samples are processed to determine the die-off of Ascaris eggs.

Chapter 10 - South Korea

For many centuries, agriculture in Korea was based on the recycling of animal, plant and human organic 'wastes'. Now, with rapid economic development, farmers in South Korea have increased purchasing power and tend to substitute mineral fertilizer for the more organic wastes which have, in the past, maintained the humus fraction of the soil. Vault latrines, providing nightsoil storage for two to four weeks before emptying by vacuum tanker, are the traditional excreta disposal system for urban areas but sewerage is becoming more common. The Waste Management Law (1986) incorporating the 1973 Waste Disposal Law stipulates that nightsoil must be treated before being applied to land. Prior to this, most nightsoil was used raw as a soil conditioner and fertilizer. Since 1965, agricultural use of nightsoil has been drastically reduced and an intensive programme of **nightsoil treatment plant (NTP)** construction has been implemented.

Approximately 7000 m^3 of nightsoil are treated daily in the country's NTP's and about 170 m^3 of sludge cake are produced, representing only about 1 per cent and 0.5 per cent of the annual chemical fertilizer consumption (on the basis of nitrogen and phosphorus). However, as a humus builder and soil conditioner it can play a more important role. Details are given of nightsoil treatment at the Yongho (anaerobic digestion) and Umgung (Zimpro wet oxidation) NTP in Pusan and of sludge composting and packaging at the Chinyong, Kimhae District plant.

Traditional use of nightsoil in agriculture in rural areas is reviewed in another section of this Chapter. Following increased demand after World War II, the Ministry of Home Affairs (MOHA) responsible for rural sanitation introduced a three-vault latrine providing extended storage prior to use. Nightsoil collection and treatment in small towns, particularly Kimhae District of Chinyong, is also covered in the Chapter. The team interviewed one family owning 1 ha of farmland where nightsoil-containing compost is mainly used on rice fields. Another farmer growing vegetables in greenhoused fields indicated that he did not like to use nightsoil compost, although he uses compost made up of cattle and chicken manure.

The Waste Management Law lays down the standard for the liquid effluent of NTP's at 3000 tot. coliform (MPN)/100 ml but standards for the hygienic quality of composted NTP sludge did not exist in 1985. Several agencies are involved in the management of nightsoil and these are listed along with their major responsibilities.

With improved economic conditions since the 1960's, chronic diseases have generally replaced infectious diseases as the major causes of death in South Korea and there has been a dramatic reduction in the incidence of water and excreta related diseases. Improved water supplies, improved hygienic behaviour and greater public health awareness have all contributed to this situation. Tables showing trends in socioeconomic and health indicators are given, and specific information is provided for typhoid fever and parasite infections. Helminth egg positive rates in school children decreased from 73 % to 4 % between 1969 and 1985. This was partly due to a major control programme carried out by the Korean Association for Parasite Eradication where school children received chemotherapy twice a year between 1976 and 1985. It could also have been affected by a ban on raw nightsoil use in agriculture. In rural areas, nightsoil composting with agricultural wastes and manure is practised but there is a risk, particularly in areas where helminth infections might still be endemic, to compost handlers and, if vegetables are fertilized with the compost, to consumers. The nightsoil treatment process will affect the quality of the compost produced using the sludge from NTP's. Commercially produced compost is likely to present no risk to handlers or consumers. The level of helminth infection in the community is now generally very low, which will reduce the concentration of helminth eggs in nightsoil. Microbiological studies of the nightsoil sludge compost would help to promote the use of this product if it was demonstrated that it did not contain viable pathogens. Several methods are proposed for decreasing the health risk of using nightsoil composted with agricultural wastes in rural areas.

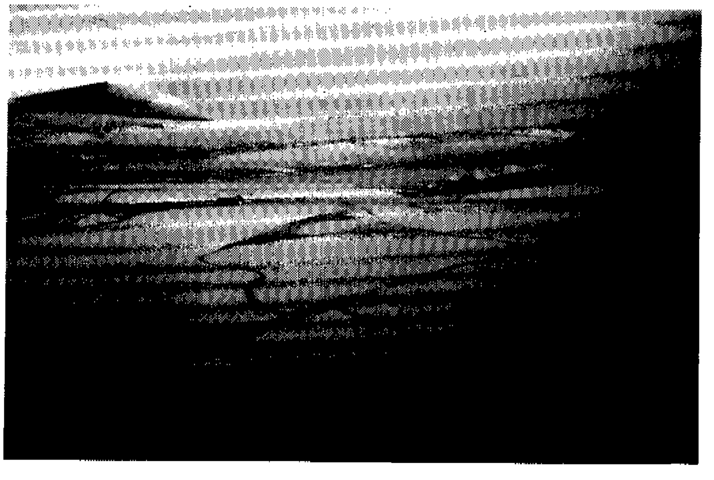
Chapter 11 - Discussion of Excreta Use in Agriculture

In this short Chapter.of the Main Report, the contrasting features of excreta use in agriculture in Guatemala and in South Korea are summarized.

WASTEWATER USE IN AQUACULTURE

Chapter 12 - India (Calcutta)

Fish are an important part of the diet of Bengalis and there are more than 100,000 ha of fish ponds in West Bengal. The **East Calcutta sewage fisheries** are the largest of their kind in the world with up to 5000 ha of ponds, the effluent from which is used to irrigate an area of 6500 ha downstream. The historical development of these fisheries is reviewed and an account given of the 'garbage farms' which reclaim and use the organic fraction of Calcutta's refuse. Ownership of the ponds is in the hands mainly of about 160 city dwellers who employ nearly 4000 families as fishermen. About 24,000 people live in the pond area and have strong social links which provide them with a significant political status. There are several fishermen's cooperatives, one of which was visited by the team.



Aerial view of the fish ponds in the East Calcutta wetlands receiving the city's untreated wastewater at low loading rates

Fish are mostly grown in **polyculture**, at stocking densities of 30,000-50,000/ha, with indigenous **Indian carp, Chinese carp** and **Tilapia** being the main species. Long-term yields are approximately 1200 kg/ha per year with the main harvesting between October and February. About 20 tons of relatively small (< 300 g) fish from the ponds provide 10-20 per cent of the fish consumed in Calcutta. Sewage feeding the extensive pond system is pumped and conveyed by gravity in two main canals and regulated on a batch basis by simple gates in tertiary feed channels. The fishermen have developed empirical skills in handling the wastewater and optimizing fish production over the years and estimates of organic loading rates are 6-22 kg BOD_5/d per ha giving minimum dissolved oxygen levels of 2.5-4.5 mg/l.

Total coliform counts of 10^5-10^6/100 ml in the influent sewage to the ponds and 10^2- 10^3/100 ml in the pond water have been reported. Vibrio parahaemolyticus, the second most important diarrhoea-causing agent (after V. cholerae) in the Calcutta area, has been found in the intestines of fish from the sewage-fed ponds. Heavy metals in sewage fed to the ponds have reportedly been below levels which would pose a risk to the ecosystem, the fishermen or the consumers.

No epidemiological studies have been carried out in Calcutta to assess the risk attributable to the use of sewage in the aquaculture ponds and few microbiological data are available. **Diarrhoeal diseases, typhoid fever** and hepatitis A are the diseases of greatest concern although immunity to viral diseases is likely to have developed in the fishing community. Intestinal nematodes, which are generally soil- transmitted, are likely to be less important. Trematode infections, including schistosomiasis and chlonorchiasis, are of no concern because Calcutta is outside the endemic area for these infections. Protozoan cysts (Giardia and Cryptosporidium) are likely to be present in the upper layers of the pond water and constitute a risk. The health of consumers will depend on the microbiological quality of the fish, the extent of cooking the fish before eating and home hygiene. With the relatively low levels of total coliforms in the ponds over the growing season, the fish are likely to be of good enough quality for human consumption providing the fish are well cooked and high standards of **hygiene** are maintained **during fish preparation.**

Some studies on the ecology of enteric microorganisms in freshwater habitats in the Calcutta area, including an aquaculture system, have been carried out by the National Institute of Cholera and Enteric Diseases (NICED) and the results are reviewed. Vibrio cholerae have been studied in open sewage channels (although not specifically in aquaculture ponds). Although V. Cholerae non-01 was abundant, V. cholerae 01 (the main cholera causing organism) was not recovered. Studies on V. parahaemolyticus have indicated that it could be transmitted to fish consumers or fish farmers during the summer months. On the whole, the public health effects of sewage fertilization of aquaculture ponds in Calcutta remain unclear. The **need for further scientific microbiological and epidemiological studies** is stressed and possible approaches to pond operation and improved hygiene among fishermen are proposed. The Institute for Wetland Management and Ecological Design (IWMED), which was established a few years ago, addresses these issues.

The Chapter ends with a summary of research into wastewater utilization in aquaculture conducted by the National Environmental Engineering Research Institute (NEERI), Nagpur. Demonstration pond studies included the production of Cyprinus carpio. Clarias sp., Channa sp. and Heteropneustes sp. but only limited data on microbiological parameters are available. Further studies on the removal of indicator bacteria and pathogenic microorganisms are required to assess the public health implications of sewage-fed aquaculture.

Chapter 13 - Peru (Lima)

This Chapter concentrates on **aquaculture studies** conducted at the San Juan de Miraflores wastewater stabilization ponds in South Lima, which are described in Chapter 5 of the Report. Since 1983, comprehensive studies have been carried out to investigate the use of tertiary, quaternary and quintenary **wastewater stabilization ponds** (WSP) for fish and prawn production. These ponds were stocked with Tilapia nilotica, Cyprinus carpio var. escamosa and var. specularis and the freshwater prawns Macrobrachium rosembergii. Also assessed were pathogen indicators and specific pathogens in the pond water and in fish organs. The most recent studies have concentrated on determining the optimum combination of stocking density and fish pond BOD loading for the production of marketable Tilapia at all times of year in Lima. Fig. 6 shows the functional sketch of the pond arrangement and fish stocking for the aquaculture study.

Detailed results for pond loadings and pond water quality parameters are summarized. The researchers observed that fish growth in the tertiary ponds was marginal while in the quaternary and quintenary ponds it was very satisfactory, coinciding with reducing **ammonia** gas levels. A conclusion was reached that the threshold value for total ammonia (NH_3 gas plus NH^{+4}) for

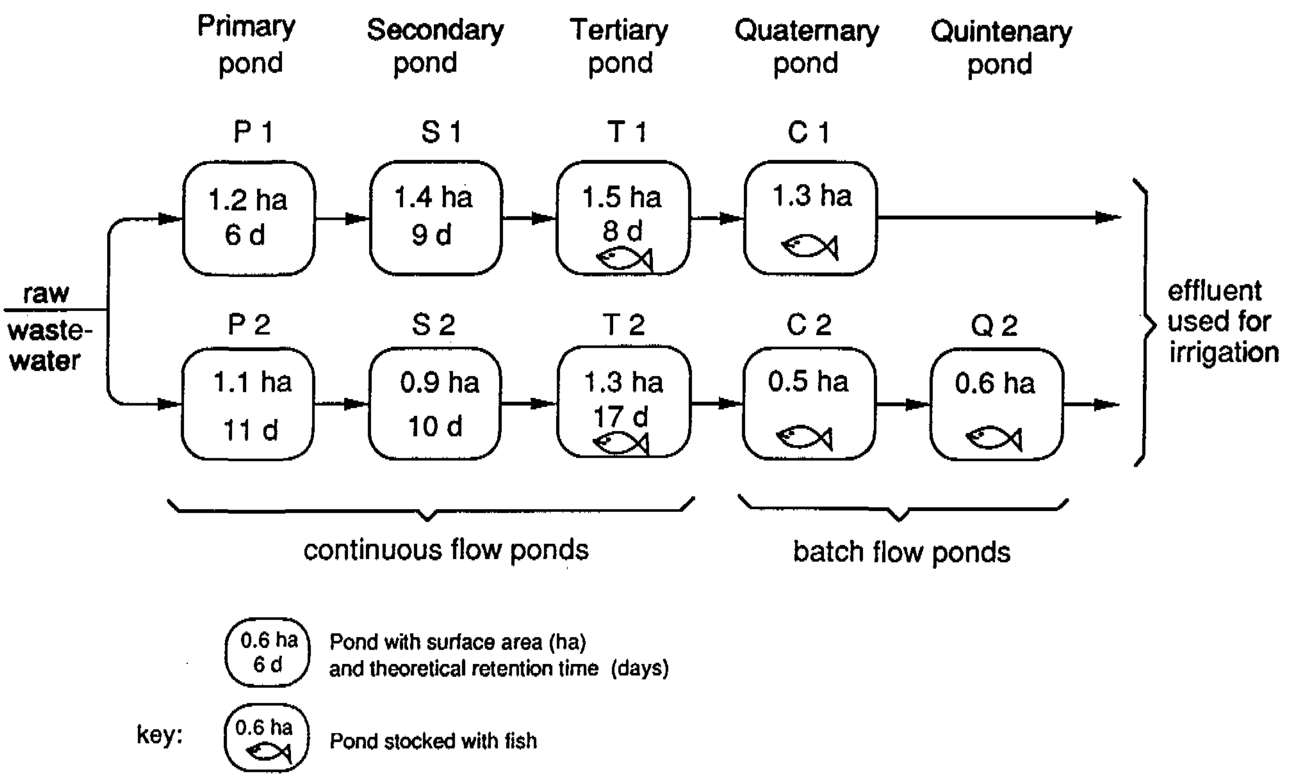


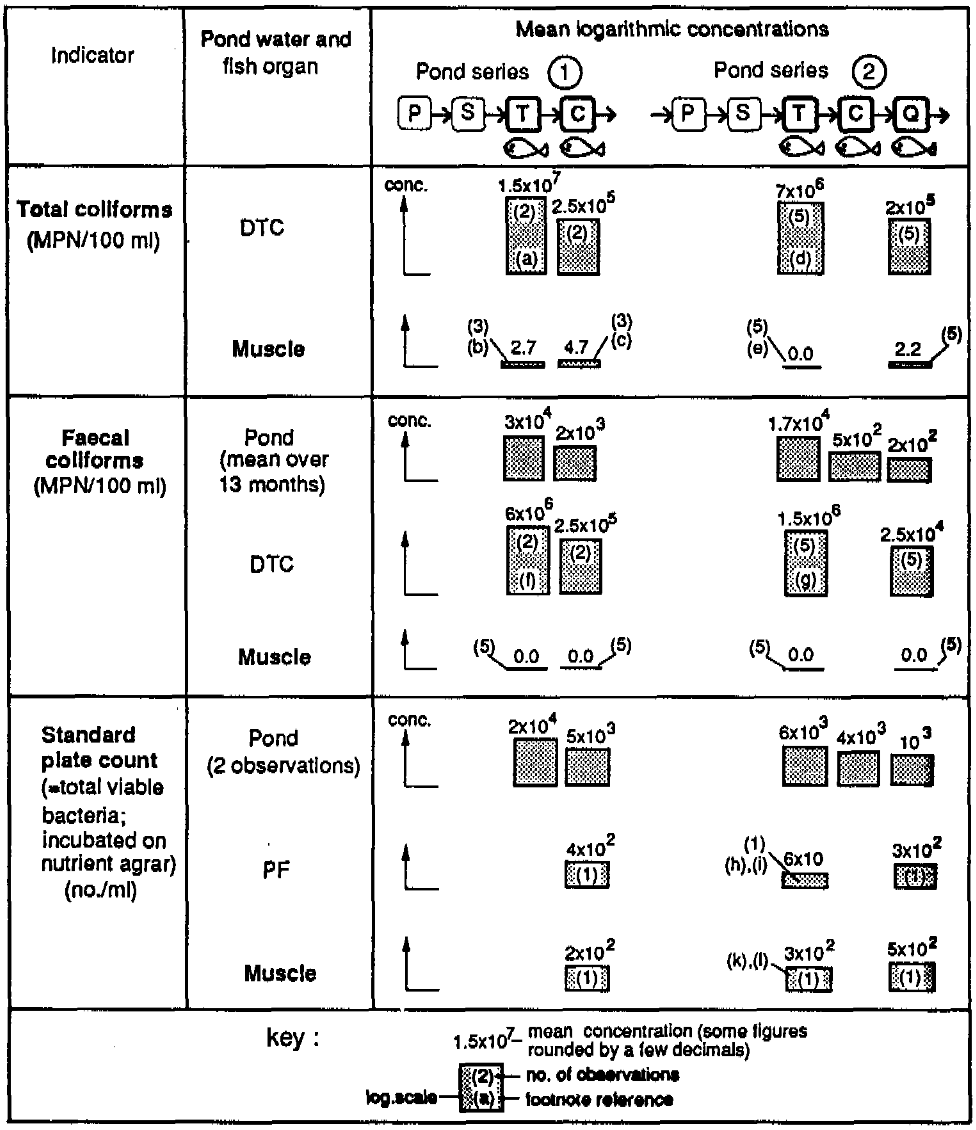
Fig. 6 San Juan de Miraflores WSP Scheme: Pond Arrangement for Aquaculture Study (functional sketch; after Bartone et al. 1985)

growth of Tilapia is 2 mg N/l with average un-ionized ammonia (NH_3 gas) levels not exceeding 0.5 mg N/l and short-duration NH_3 gas levels not exceeding 2 mg N/l. The maximum growth rate and pond carrying capacity were higher at warm than at cold temperatures, attributed to higher plankton production at higher temperatures.

The microbiological **quality of pond water** and **fish organs** (the digestive tract, the peritoneal fluid and the muscle tissue) were observed over 15 months of pond operation. Pathogenic indicators and pathogens were measured, including total and faecal coliforms, total viable bacteria (as determined by the standard plate count), enterobacteria (Salmonella sp.), protozoal cysts (Entamoeba, Giardia and Endolimax) and helminth eggs (Ascaris, Trichuris, Toxocara and Taenia). The results on the levels of total colifoms, faecal coliforms and standard plate counts in pond water and fish are shown in Fig. 7. Observations on Tilapia suggested that faecal coliforms were not detected in **fish muscle** in any fish pond, even in the tertiary pond containing 10^4-10^5 FC/100 ml where the **digestive tract content** of the fish showed 10^6-10^7 FC/100 ml. Depuration of the fish in the cleaner pond water had beneficial effects (10- 350 fold reduction of indicator organisms in the digestive tract content and in the peritoneal fluid). As a conclusion, it is suggested that fish muscle tissue, the edible part, is relatively safe against uptake or invasion of indicator bacteria, even in tertiary wastewater stabilization ponds.

Salmonella species were reported in the digestive tract contents of fish in the tertiary and quintenary ponds of one series of ponds but no results of muscle tissue Salmonella were provided. The gills, digestive tract contents and muscle tissue of Tilapia and Carp were analyzed for protozoal cysts and helminth eggs and found to be free of these organisms, which must have been removed in the primary and secondary wastewater stabilization ponds providing 15-20 days retention. Viruses were not determined in the reported studies but E. coli bacteriophage have been assessed in more recent studies.

Being an experimental system, the fish produced at San Juan de Miraflores were not eaten and so no consumers were at risk. Speculating on the potential health impact on consumers of the fish, the Report concludes that the quality of fish grown were acceptable for human consumption on the basis of the bacterial content of fish muscle tissue. However, in view of the contamination of the digestive tract contents, it is possible that **cross-contamination** to vegetables eaten raw could occur in the kitchen. **Depuration** procedures, i.e. placing the fish in fresh water, appeared to reduce digestive tract contents contamination but further studies are required before such a procedure can be relied on as a health protection measure. The risk of **occupational exposure** will not be made clear until epidemiological studies have been conducted, nor will the real risk to consumers.



DTC	Digestive tract content	T	Tertiary pond
PF	Peritoneal fluid	C	Quaternary pond
		Q	Quintenary pond

(a) was reduced to 2.5×10^5 after 1 week of depuration in clean water
(b) 2 out of 3 samples had zero TC concentrations
(c) 2 out of 3 samples contained TC
(d) was reduced to 2×10^4 after 80 hours and 1 week, respectively, of depuration in clean water
(e) was increased to 1.3×10^1 after 80 hours and 1 week, respectively, of depuration in clean water
(f) was reduced to 2×10^5 after 1 week of depuration in clean water
(g) was reduced to 2×10^4 after 80 hours and 1 week, respectively, of depuration in clean water
(h) was reduced to 5.0 after 80 hours of depuration in clean water
(i) was reduced to 3.5×10^1 after 1 week " " " " "
(k) was increased slightly to 4×10^2 after 80 hours of depuration in clean water
(l) was reduced to 1.3×10^1 after 1 week of depuration in clean water

Fig. 7 Mean Concentrations of Total Coliforms (TC), Faecal Coliforms (FC) and Standard Plate Counts (SPC) in Organs of Tilapia Raised in Tertiary (T), Quaternary (C) and Quintenary (Q) Ponds (Based on Noé Moccetti et al. 1984 and Bartone et al. 1985)

Chapter 14 - Summary and Discussion of Wastewater Use in Aquaculture

The **Calcutta** and **Lima case studies** are compared and contrasted in this summary Chapter. In the case of the wetlands east of the city of **Calcutta**, an ecological niche has been created allowing low-cost treatment of part of the municipal wastewater and production of large amounts of fish protein. Considerable effort has gone into safeguarding the scheme from urban sprawl and real estate pressures but little attention has been paid, until recently, to the public health aspects of the practice. Neither epidemics nor particularly high endemic levels of enteric diseases have been reported in the pond area but epidemiological studies are needed to assess the true health status and levels of infection in exposed population groups.

In **Lima**, CEPIS has studied optimum fish growth and hygienic fish quality in demonstrating wastewater stabilization ponds used for aquaculture. Microbiological studies have produced useful results but no epidemiological studies have been carried out because the fish have not been eaten. In view of the similarity of pond loading levels at Calcutta and in the Lima (San Juan de Miraflores) tertiary ponds, extrapolation of microbiological data from Lima is attempted. It is suggested that the microbiological quality of the Calcutta pond water is likely to be of the same order of magnitude as in the Lima tertiary ponds or might be better due to the hotter tropical climate.

When comparing the Calcutta wastewater-fed fish ponds and the Lima waste stabilization pond (WSP) scheme, it is important to note the basic difference between the two systems: in **Lima**, the total wastewater flow is treated in facultative primary and in secondary (maturation) ponds in series operation prior to being used as fish pond water in tertiary, quaternary and quintenary ponds. In **Calcutta**, where **all** the ponds are operated as fish ponds, the system historically developed and came into use for fish production and not for wastewater treatment. The Calcutta ponds which receive raw wastewater are therefore operated with very low BOD loading rates in a batch-wise parallel mode. Through this, the Calcutta system occupies a much larger land area than it would if it had been designed as a WSP scheme where the wastewater is treated for BOD removal prior to fish cultivation. Land cost versus earnings, employment opportunities for fishing families and nutrition from fish production therefore have to be balanced against each other when comparing the two basically different systems and when planning wastewater-fed aquaculture schemes elsewhere. In the case of large cities and large sewage flows, the WSP-cum-aquaculture concept as applied in Lima is likely to be more feasible since land values at the outskirts of big cities tend to be high or very high.

The Report points out that the advantages and disadvantages of a reuse practice should be balanced and, in the case of Calcutta, a zero health risk strategy is not appropriate in view of the importance of the **nutritional and economic aspects** of the fisheries. Nevertheless, potential and actual health risks should be assessed so that improvements to existing systems can be proposed. It would appear that the adverse impact of industrial discharges to the Calcutta sewerage system pose a more serious threat to wastewater-fed aquaculture than the risks of enteric disease transmission, if reasonable health protection measures are taken. Epidemiological studies are still lacking and it is hoped that studies being carried out on the fish ponds in Java, Indonesia (see Chpt. 15) will be useful for other parts of the world, particularly as regards the use of pond water which is being fertilized with human waste for domestic purposes (but not for drinking). The Chapter ends with following main conclusions/recommendations drawn from the Calcutta and Lima experiences:

a) Fish of hygienic quality can be grown in wastewater which has been subjected to adequate treatment in WSP systems for the removal of organic matter and pathogenic organisms prior to its release into fish ponds.

b) The information available suggests that for fish consumers in Calcutta, disease risks are likely to be low as the wastewater loading rates on the individual ponds are low, thereby leading to long hydraulic retention times and correspondingly low pathogen levels. Moreover, all fish are cooked prior to consumption.

c) In contrast to the consumers, fishermen and their families are at a potentially higher risk due to their contact with the pond water and its sediments during fish harvesting. As a result of the scavenging effect of the sedimentation and entrapment processes, pond sediments are rich in pathogens.

d) As for wastewater reuse in agriculture, aquacultural use should become an integral part of wastewater management planning. This comprises a careful evaluation of industrial wastewater discharges and their treatment and disposal in order not to pose a risk to the fisheries and the consumers through the accumulation of toxic substances in the fish.

e) When planning and implementing a wastewater-based fish production scheme, not only the technical aspects of wastewater treatment and fish production must be taken into consideration, but also the organizational and institutional form of pond operation and fish production. Private, commercial enterprises are usually better suited than government agencies to manage successfully production and marketing. Suitable forms of joint venturing between the public agency responsible for wastewater collection and treatment, and the enterprise responsible for fish production and sales may still have to be found.

f) There is urgent need for full-scale demonstration WSP schemes with fish culture in order to collect more experience with "real-life" systems.

EXCRETA USE IN AQUACULTURE

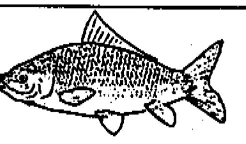
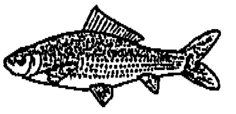
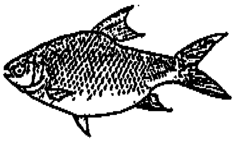
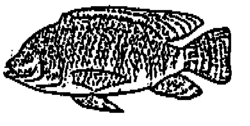
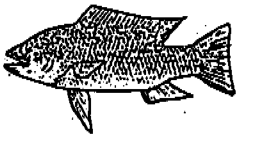
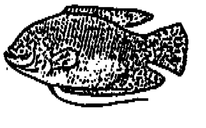
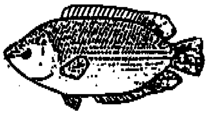
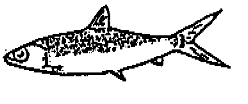
Chapter 15 - Indonesia

The Chapter starts with the visiting team's impressions of the journey from Jakarta into the highlands of Java to Bandung followed by a general geographical description of the country. **Traditional fish culture** in West Java is reviewed and the practice of nightsoil addition to ponds through the use of **overhung latrines** is mentioned as one form of fish feed. Table 4 lists and shows drawings of the fish commonly cultured in freshwater ponds in Indonesia, including carp, tilapia, gourami, snakefish, milkfish and catfish. The Table is based on information provided and published by Djajadiredja, Atmadja and Jangkaru of the Inland Fisheries Research Institute at Bogor. Generally, but especially in villages, pond fish culture is first for subsistence of the immediate family owning the pond and only secondarily for commercial purposes. Spawning is induced in small breeding ponds and the floating spawn transferred into hatching ponds. After about three weeks, fry are placed in rearing ponds to grow to consumption size, sometimes with an intermediate stage in paddy fields to convert fry into fingerlings. Yields are 1700-2000 kg/ha per year with an average of three catches per year of 100-200 g fish. A study carried out in West Java revealed that 85 per cent of the aquaculture ponds also served as excreta disposal ponds, with the latter purpose being first priority.

Near Bandung (West Java, Indonesia): a fish pond fertilized by excreta and wastewater from the latrine and wash place by the pond.

In some areas, production of fish in cages floating in a river is traditional and 10-15 years ago running water ponds were introduced, where a small (50 m^3) concrete pond stocked with about 300 kg of fingerlings (about 4000 fish) requires a freshwater flow-through rate of 50 l/s and pelleted fish feed. Urban fish consumers have recently started to favour larger fish and fish up to 500 g are now being produced. Also, because of the public health concern of urban consumers

Table 4 Fish Commonly Cultured in Freshwater Ponds in Indonesia (after Directorate of Fisheries 1977; Djajadiredja et al. 1979; Atmadja and Jangkaru 1985)

Fish name English (Scientific)	Specific information	Pictures of the fish
· Common Carp (Cyprinus Carpio)	Very common in western Java; exotic; feeds on macrophytes mainly	
· Nilem[1] Carp (Osteochilus hasselti)	Mainly in mountainous areas; periphyton[2] feeders; indigenous	
· Java Carp (Puntius gonionotus)	Very common in eastern Java; indigenous	
· Nile Tilapia (Tilapia nilotica)	Introduced from Taiwan in 1969; common in eastern Java; omnivorous[3]	
· Java Tilapia (Tilapia mossambica)	Observed for the first time in central Java in 1939; common throughout Java; omnivorous	
· Giant Gourami (Osphronemus goramy)	Omnivorous	
· Kissing Gourami (Helostoma temmineki)	Plankton feeder	
· Snakehead (Ophiocephalus striatus)	Animal (incl. fish!) feeder; grown in cages in Sumatra and Kalimantan	
· Milkfish (Chanos chanos)	Common in brackish water ponds	
· Catfish (Clarias batrachus)	Animal feeder; mainly in lowland areas; can also breathe in open air and can therefore live in deoxygenated water	
[1] a designation used specifically in West Java	[2] small plant and animal organisms (algae, protozoa, e.g.) growing on stones or water plants	[3] feeding both on plant and animal microorganisms

for fish grown in excreta-fertilized ponds, an **alternative culture and feed sequence** is being recommended by fisheries extension services. This allows excreta to be fed to ponds growing fish to fry and to fingerling stages (i.e. up to 100 g over about 3 months) but not during growth to consumption size (200-500 g). The team reports briefly on visits to two pond owners in Bogor, West Java, both feeding ponds with excreta. A more extensive description is provided in the Report of the team's visit to Cikoneng, a typical pond village located 20 km South East of Bandung in an area earmarked for an investigation into the impact of excreta-fertilized family and village fish ponds on the disease history of the villagers who use pond water for washing and bathing.

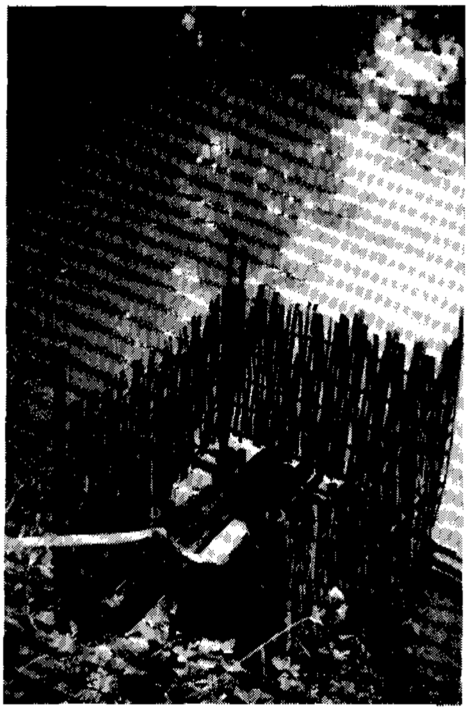
The son of a villager pond owner gave an account to the team of the **fish pond practice** in Cikoneng. Common carp, Java tilapia and Nile tilapia are cultured in the family's ponds and removed once a year, when the pond is drawn down and the bottom mud used on the family's rice fields as soil conditioner and fertilizer. The family eats fried fish once a week and also cooked water spinach which is grown in one of the ponds. A second pond owner, a Government official whose wife is a village health promoter, described his system of fish polyculture in five ponds, each having one or two overhung latrines and, on one pond, a communal latrine/bathing/washing facility. Fish are harvested by net from these ponds every three months and accumulated mud is removed at the same time. The owner reported fish yields from 1600-2800 kg/ha per year depending on the species of fish. A report on a visit to a village not using overhung latrines to fertilize fish ponds is also included.

The main document provides a detailed account of **institutional responsibilities** in the water and sanitation sector: under a new decentralization strategy adopted in Indonesia, **water supply and sanitation** are the responsibility of provincial, district and municipal authorities but the Ministry of Public Works (DEPPU), the Ministry of Health (DEPKES) and the Ministry of Home Affairs (DEP DALAM NEGERI) are also involved. One of the three Directorates General of the Ministry of Public Works, Cipta Karya, provides technical guidance under an 'integrated urban infrastructure' programme implemented by municipal administrations. DEPKES promotes rural sanitation schemes and controls and enforces water quality standards. Planning and implementation of rural water supply and sanitation projects are supported by Presidential Decree (INPRES) funding. Fisheries development is dealt with by the Ministry of Agriculture and its extension services. Its Inland Fisheries Research Institute at Bogor is concerned with production-related aspects of fish culture in ponds. The government's programme for "terrestrial" latrines has had limited success, even though a Presidential Decree banned the use of overhung latrines. The programme is now concentrating on areas where excreta fertilization of fish ponds is not practised.

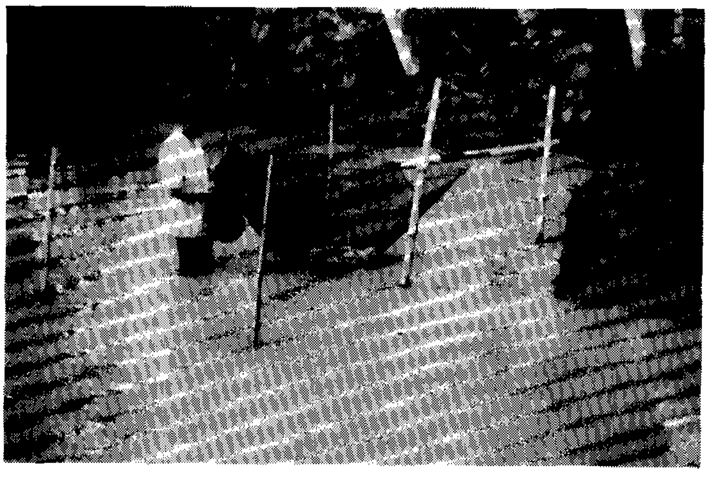
Indonesia has a high **infant mortality** rate and high incidence of and mortality due to communicable diseases. Poor sanitation, low utilization of health services and low levels of nutrition add to the health impact of infectious diseases. Tables are provided showing the principal causes of death and disease patterns. **Diarrhoeal disease** is a leading cause of death and disease in West Java. The disease pattern in the country is illustrated with data from specific household surveys conducted by the Government in 1972, 1980 and 1986. Although data on specific diseases related to environmental sanitation are difficult to obtain, some data on diarrhoea rates in various provinces are included. A morbidity survey of diarrhoea in Districts of West Java indicated a high prevalence in Garut, an area with the highest concentration of excreta-fed fish ponds, but the data were not in any way conclusive. Data on water supply and sanitation are presented in a table and it is mentioned that only 6.4 per cent of the rural population in West Java had improved sanitation facilities in 1985, whereas 39.9 per cent had improved water supplies.

The Ministry of Health and the Institute of Ecology, Padjadjaran University, Bandung have carried out studies on the impact of excreta-fed aquaculture. In one study, water and fish from 20 fish ponds were subjected to microbiological analyses and stool samples were taken from 230 fish pond users. The results were inconclusive because the 'exposure' of concern was not defined clearly enough and the sample size was too small for the detection of medium or low level risks. The Institute of Ecology's preliminary study of diarrhoea cases in five villages in Bandung District indicated that the risk of diarrhoea was 1.7 times higher in pond users' households than in households where people did not use the pond for defecation. Further epidemiological studies are necessary, the Report suggests, to establish and define real health risks.

The Report goes on to speculate about the **potential health risks** associated with the practice of **excreta-fed aquaculture**, including risks to **consumers** of the fish, the **occupational** risks of fish pond workers and risk from **domestic use** of the fish pond water. An epidemiological study now being carried out by the Institute of Ecology, Bandung is described in some detail. The study aims at determining whether the domestic use of water from excreta-fertilized ponds for washing and bathing leads to an excess risk for these users over those using fresh water for domestic purposes. Furthermore, the investigation aims at finding out whether persons having occupational or recreational contact with the pondwater and whether consumers of fish grown in these ponds are at risk. In considering the implications for control of health risks, the Report draws attention to the failure of the ban on overhung latrine use in West Java and suggests that modification of existing excreta-fed aquaculture practice is possibly the most feasible solution. If domestic contact with pond water is found to be a major risk factor, provision of clean water supplies and health education could reduce the risk. Should there be occupational risks, safer methods of catching fish could be suggested and better hygiene encouraged. Consumers risk, if that is proved to be significant, could be reduced by considering the effectiveness of depuration methods and improving food hygiene, particularly in relation to the handling of the digestive tracts of fish. In Indonesia, the Chapter concludes, the quality of water in fish ponds is likely to be worse than the tentative guideline level recommended by WHO (mentioned in Chapter 1), and the interventions suggested are all based on the control of human exposure.



Near Bandung (West Java, Indonesia): overhung latrine on a family fish pond.



Bogor (West Java, Indonesia): fingerling production in a pond fertilized with soybean processing waste.

SYNOPSIS AND RECOMMENDATIONS

Chapter 16 - Synopsis

This four-page summary of the principal features of the reuse practices reviewed in the Report points out that the increasing trend in wastewater reuse in arid and semi-arid countries contrasts with the general decrease in use of excreta. In many countries, the absence of regulations or their non-enforcement encourage excreta and wastewater reuse without health controls but in a number of countries visited by the team wastewater treatment and/or crop restriction control measures are enforced.

There are indications that the actual or true health risk of human waste reuse in agriculture and aquaculture is less than what has customarily been assumed. Regulating authorities in the countries visited adopt a variety of approaches in protecting, or not protecting, health, some having developed naturally and some having been introduced by regulation. Table 5 summarises the health protection measures adopted in the ten countries visited. It is concluded that there is no single best strategy and that each situation requires its own specific approach to health protection.

It is inevitable that many Government agencies play a role in the reuse process and, as a result, the effectiveness of the health authorities in formulating and enforcing health protection measures is often impeded.

Although it is difficult to change cultural habits, experience in Guatemala with excreta use has proved that people may be persuaded to adopt new sanitation and waste reuse customs if they can derive a sustainable benefit from them.

Chapter 17 - General Recommendations

The final Chapter of the report contains five global recommendations based on the team's observations and research on human waste use in agriculture and aquaculture. Authorities are first encouraged to consider introducing new or expanding existing wastewater or excreta reuse schemes but only if health protection measures are an integral component of the scheme. **Waste reuse** in agriculture and aquaculture should be fully **integrated into strategic water resources planning.** Industrial waste streams should be carefully controlled wherever wastewater or excreta is reused so as to prevent contamination of crops or fish.

Table 5 **Health Protection Measures: Overview of the Practice**

Country, location	Kind of Reuse	Health Protection Measures Practised
MEXICO Mezquital Valley	Irrigation of alfalfa, maize, cereal crops, tomatoes and beans mostly with untreated wastewater	Crop restriction, some exposure control for agricultural workers
CHILE Santiago	Irrigation of raw-eaten vegetables, cereal crops and grapes with untreated wastewater	None (treatment being planned)
INDIA Kanpur	Irrigation of rice, wheat, forage and flowers with diluted untreated wastewater	None
Calcutta	Fish growing in ponds receiving untreated wastewater at low loading rates	Cooking of the fish
PERU Lima (S. Martin de P.)	Irrigation of vegetables and non-food crops with raw wastewater	None
Ica (Cachiche)	Irrigation of maize and cotton with primary pond effluent	Partial wastewater treatment and crop restriction
Tacna	Irrigation of maize, alfalfa and fruit trees with effluent from overloaded WSP	Partial treatment and crop restriction
ARGENTINA Mendoza	Irrigation of raw-eaten vegetables with settled sewage	Partial treatment
TUNISIA Tunis	Irrigation of non-vegetable crops and fruit trees with secondary effluent	Partial treatment and crop restriction
SAUDI ARABIA Riyadh	Irrigation of wheat, forage and date palms with tertiary (filtered and chlorinated) effluent	Full treatment and crop restriction
GUATEMALA rural areas	Use of stored faecal material as a fertilizer in agriculture	Prolonged excreta storage
SOUTH KOREA Pusan	Use of sludge from nightsoil treatment plants in agriculture	Dewatering and composting of the sludge
INDONESIA Java	Use of excreta for fish pond fertilization	Cooking of the fish

All **four health protection measures** should be examined in assessing new reuse schemes or planned improvements of existing schemes. Flexibility in choosing between individual and combinations of the measures:

- wastewater/excreta treatment
- crop restriction
- appropriate waste application methods, and
- human exposure control

is recommended and attention drawn to the need for suitable administrative, legislative and political support systems. It is recommended that every effort should be made to promote the use also of faecal material, especially in rural and semi-urban sanitation schemes in which the use of double-vault or double-pit latrines proves feasible, and where the handling of stored excreta is not an absolute taboo. The importance of prolonged communication between the implementing agency and users in this type of scheme is emphasized.

Finally, the need for **field-level investigations** with an **epidemiological** perspective is re-stated. Study situations should be chosen so as to allow the effectiveness of individual health protection measures or of combinations of measures to be tested in avoiding excess risks from the reuse practice.

ANNEX 1 Reference Literature

Readers wishing to enter deeper into the subject of human waste reuse with a particular emphasis on practices in less industrialized countries and with a view on health aspects, are referred to the following published documents:

- **WHO** (1989). *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.* Report of a Scientific Group. Technical Report Series No. 778. (Obtainable through WHO country offices or headquarter.)

- **Mara, D.D., Cairncross, S** (1989). *Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture: Measures for Public Health Protection.* UNEP/WHO.

- **Pescod, M.B., Arar, A.** (eds.) (1989). Treatment and Use of Sewage Effluent for Irrigation. *Proceedings of the FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation,* 7-9 October, 1985, Nicosia, Cyprus. Butterworths.

- **Shuval, H.I., Adir, A., Fattal, B., Rawitz, E., Yekutiel, P.** (1986). *Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions.* Technical Paper No. 51, The World Bank. (Obtainable from the World Bank, Publications, 1818 H Street, N.W., Washington, D.C. 20433, U.S.A.)

- **Cross, P.** (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part I: Existing Practices and Beliefs in the Utilization of Human Excreta.* IRCWD Report No. 04/85. (Obtainable from IRCWD.)

- **Strauss, M.** (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part II: Pathogen Survival.* IRCWD Report No. 04/85. (Obtainable from IRCWD.)

- **Blum, D., Feachem, R.G.** (1985). *Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture, Part III: An Epidemiological Perspective.* IRCWD Report No. 05/85. (Obtainable from IRCWD.)

- **IRCWD** (1988). Human Wastes: Health Aspects of their Use in Agriculture and Aquaculture. *IRCWD News* 24/25, May. (Obtainable from IRCWD).

- **Edwards, P.** (1985). *Aquaculture: A Component of Low Cost Sanitation Technology.* World Bank Technical Paper No. 36. (Obtainable from The World Bank.)

- **Cointreau, J.S.** (1987). *Aquaculture with Treated Wastewater: A Status Report on Studies Conducted in Lima, Peru.* Applied Research and Technology, Technical Note No. 3, The World Bank.

- **Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D.** (1983). *Sanitation and Disease - Health Aspects of Excreta and Wastewater Management,* John Wiley & Sons, Chichester/New York.

ANNEX 2 Institutions Dealing with Public Health Aspects of Excreta and Wastewater Use.

The following Institutions are actively involved in the various aspects of wastewater and excreta recycling, particularly with respect to public health protection. The list below does not claim to be exhaustive, but contains those government, private and aid organisations as well as research institutions, with which, in recent years, the IRCWD and LSHTM have been in close collaboration on aspects of human waste use.

In Latin America	Activity	Contact persons
- CEMAT, Centro Mesoamericano de Estudios sobre Tecnología Apropiada Apartado Postal 1160 Guatemala GUATEMALA C.A.	Community development; latrine technology and microbiol. aspects of dry fertilizer latrines	Ms A. M. Xet M. Mr J. G. Flóres G.
- CEPIS, Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente P.O. Box 4337 Lima 100/PERU	Applied research and development in wastewater treatment and reuse	Ing. A. Flórez M.
- Instituto Mexicano de Tecnología del Agua Rio Usuma Cinta No.2 Col. Vista Hermosa Cuernavaca/MEXICO	Planning, monitoring, research	Ing. H. Garduño V.
- SARH, Secretaría de Agricultura y Recursos Hidráulicos Coordinación de Investigación Ave. San Bernabé No. 549 Col. San Jerónimo Lidice Del. Magdalena Contreras CP 10200 México, D.F. MEXICO	Research and monitoring	Ing. G. Ortega Fil
- Secretaría de Salud Salud Ambiental San Luis Potose No. 192 Col. Roma Del. Cuauhtemoc CP 10200 México, D.F. MEXICO	Monitoring and research enforcement	Ing. H. Romero Alvarez
- Instituto Nacional de la Nutrición Calle Vasco de Quiroga 15 Delegación Tlalpan 14000 México, D.F./MEXICO	Research on epidemiological aspects of wastewater reuse	Prof. G. Ruiz-Palacios Dr E. Cifuentes

In North America

- IDRC, International Development Research Centre Health Sciences Division 60 Queen Street P.O. Box 8500 Ottawa K1G 3H9/CANADA	Community-based research support	Dr. G. Forget
- US Env. Protection Agency Health Effects Research Laboratory Cincinnati, Ohio 45268/USA	Health effects monitoring; epidemiological aspects	Dr W. Jakubowski
- The World Bank Department for Infrastructure and Urban Development 1818 H Street, N.W. Washington, D.C. 20433/USA	UNDP/World Bank Resource Recovery Project (applied research, development and technical assistance)	Dr C. Bartone
- University of Arizona Dept. of Microbiology and Immunology Building No. 90 Tucson, Arizona 85721/USA	Development of analytical methods for virus and protozoa detection in wastewater	Dr Ch. P. Gerba Dr J. Rose
- International Association on Water Pollution Research and Control: Specialist Group on Wastewater Reclamation, Recycling and Reuse c/o Dr T. Asano 1125 Dartmouth Place Davis, California 95616/USA	Research, development and information transfer on wastewater reuse technology and health effects	Dr T. Asano (Chairman)

In Mediterrania

- Ministère de la Santé Public Département de l'Hygiène de l'Environnement Cité Welvert, Bab Saadoun Tunis/TUNISIA	Law-making, monitoring, enforcement	Mr S. Atallah
- Ministère de l'Agriculture Centre de Recherches du Génie Rural B.P. No.10 Ariana 2080/TUNISIA	Agricultural research; microbiological monitoring of wastewater-irrigated crops	Mr A. Bouzaïdi Mrs M. M. Trad-Raïs
- Agricultural Research Institute P.O. Box 2016 Nicosia/CYPRUS	Applied research in treated effluent use in agriculture	Dr C. Serghiou Dr J. Papadopoulos
- Water Authority of Jordan (WAJ) Directorate of Central Operation P.O. Box 150793 Amman/JORDAN	Wastewater treatment for effluent reuse; applied research on pathogen removal in conventional plant and in pond systems	Dr S. S. Alsalem
- The Hebrew University School of Public Health and Community Medicine Jerusalem/ISRAEL	Research in epidemiological aspects of reuse in agriculture and aquaculture	Prof. H. Shuval

In Asia

- AIT, Asian Institute of Technology Div. of Env. Engineering P.O. Box 2754 Bangkok 10501/THAILAND	Applied Research and development of treatment and reuse options	Dr Ch. Polprasert
- AIT, Asian Institute of Technology Div. of Agricultural & Food Engineering P.O. Box 2754 Bangkok 10501/THAILAND	"	Dr P. Edwards
- NEERI, National Environmental Research Institute Wastewater Agriculture Div. Nehru Marg Nagpur-440 020/INDIA	Applied research and development in engineering and agronomic aspects of wastewater reuse	Dr G.B. Shende
- Padjadjaran University Institute of Ecology Jalan Sekeloa Bandung/INDONESIA	Epidemiological aspects of excreta use in aquaculture	Dr B. Abisudjak

In Europe

- University of Leeds Dept. of Civil Engineering Leeds LS2 9JT/U.K.	Applied research and development in WSP treatment & in microbiological aspects of reuse	Prof. D.D. Mara
- University of Nancy Faculté des Sciences Pharmaceutiques et Biologiques 5, rue Albert Lebrun F-54000 Nancy/FRANCE	Development of analytical methods for parasite detection in wastewater	Prof. J. Schwartzbrod
- University of Newcastle upon Tyne Dept. of Civil Engineering Claremont Road Newcastle upon Tyne NE1 7RU/U.K.	Research and technical assistance in planning and implementation of wastewater reuse	Prof. M.B. Pescod
- Universidad Politécnica de Cataluña ETS de Ingenieros de Caminos Gran Capitán, s/n. E-08034 Barcelona/SPAIN	Applied research in wastewater treatment and reuse	Prof. R. Mujeriego
- Dott. Ing. F. Croce Studio Ambiente Via dei Cantieri, 58 I-Palermo 90142/ITALY	Design and implementation of reuse schemes	
- Division of Sanitary Engineering Laboratório Nacional de Engenharia Civil (LNEC) P-1799 Lisbon Codex/ PORTUGAL	Applied research on crop cultivation with treated effluent	Ms M.H. Marecos do Monte
- World Health Organisation Div. of Env. Health CH-1211 Geneva 27/ SWITZERLAND	Sector guidelines and technical assistance	Dr W. Kreisel Dr I. Hespanhol

- Food and Agriculture Organisation FAO Land and Water Div. Via delle Terme di Caracalla I-00100 <u>Rome</u>/ITALY	Sector guidelines and technical assistance	Dr. A. Arar
- London School of Hygiene and Tropical Medicine Dept. of Epidemiology & Population Sciences Keppel Street <u>London</u> WC1E 7HT/U.K.	Research in epidemiological aspects	Dr U.J. Blumenthal
- IRCWD/EAWAG Ueberlandstrasse 133 CH-8600 <u>Duebendorf</u>/ SWITZERLAND	Applied research and technical assistance in human waste use	Mr M. Strauss