WORLD HEALTH ORGANIZATION
ORGANISATION MONDIALE DE LA SANTÉ

WHO/DDC/80.5

ORIGINAL: ENGLISH

DIARRHOEAL DISEASES CONTROL PROGRAMME

ENVIRONMENTAL HEALTH AND DIARRHOEAL DISEASE PREVENTION

Report of a Scientific Working Group

(Kuala Lumpur, Malaysia, 3-6 July 1979)

This report contains the collective views of an international group of experts and does not necessarily represent the decisions or the stated policy of the World Health Organization.

CONTENTS

LIST OF PARTICIPANTS

Members:

Professor T. Alisjahbana, Bandung Institute of Technology, Bandung, Indonesia

Professor D. Bradley, Director, Ross Institute of Tropical Hygiene, London School of Hygeine and Tropical Medicine, London, England (Chairman)

Dr J.M. Hughes, Chief, Water Related Diseases Activity, Enteric Diseases Branch, Bacterial Diseases Division, Bureau of Epidemiology, Center for Disease Control, Atlanta, GA, USA

Mr A. Sekarajasekaran, Chief Public Health Engineer, Environmental Health and Engineering Unit, Ministry of Health, Kuala Lumpur, Malaysia

Professor C. Widstrand, Director, The Scandinavian Institute of African Studies, Uppsala, Sweden

Professor A.M. Wright, Civil Engineering Department, Faculty of Engineering, University of Science and Technology, Kumasi, Ghana

Representatives of other organizations:

International Development Research Centre

Dr M. Koblinsky, Programme Officer, Health Sciences Division, Asia Regional office, Tanglin, Singapore

United Nations Children's Fund

Mr U. Tun Aung, Programme Officer, UNICEF Office for East Asia and Pakistan, Bangkok, Thailand

Secretariat:

Mr R.F. Davies, Environmental Health Criteria and Standards, Division of Environmental Health, WHO, Geneva, Switzerland (Co-Secretary)

Dr R. Feachem, Public Health Engineer, Ross Institute of Tropical Hygiene, London School of Hygiene and Tropical Medicine, London, England (Temporary Adviser)

Dr M. Islam Sheik, Regional Adviser on Environmental Health, WHO Regional Office for the Eastern Mediterranean, Alexandria, Egypt

Dr M.H. Merson, Diarrhoeal Diseases Control Programme, Division of Communicable Diseases, WHO, Geneva, Switzerland (Co-Secretary)

Dr W.L. Reyes, Sanitary Engineer, WHO Regional Office for South-East Asia, New Delhi, India

Dr K.M. Yao, Water Quality Management Adviser, Western Pacific Regional Centre for Promotion of Environmental Planning and Applied Studies (PEPAS), Kuala Lumpur, Malaysia

Mr F. Co, Director, Western Pacific Regional Centre for Promotion of Environmental Planning and Applied Studies (PEPAS), Kuala Lumpur, Malaysia*

---

*Unable to attend

1. INTRODUCTION

The long-term prevention of the diarrhoeal diseases rests largely upon the provision and use of adequate facilities for safe water and excreta disposal. The attainment of this objective requires, among other things, a large capital investment in the construction of water and sanitation facilities and a better understanding of behavioural factors influencing water use and defecation practices. To help attain these goals the 1980s have been designated as the International Water Supply and Sanitation Decade, during which a concerted effort will be made by 7 United Nations agencies to improve the environmental health of the world's poorer populations.

This report presents available knowledge on environmental health as it relates specifically to diarrhoeal disease prevention, and defines priorities for further research that could contribute to the environmental control of diarrhoeal diseases. It covers in depth the areas of environmental microbiology, epidemiology (transmission), and related human behaviour. The latter area is felt to be particularly important, since if water supply, sanitation, and food hygiene interventions are to control diarrhoeal diseases, changes in behaviour are required to ensure that facilities are correctly utilized. Conversely, the interventions must be so designed that they are acceptable to the recipient community[1]. The report focuses particularly on populations living in rural or urban fringe areas, where the problem of diarrhoeal disease and environmental hygiene is greatest. Because of the multidisciplinary nature of the topics discussed, the report also indicates supportive action that could be taken to facilitate implementation of the recommended research activities.

2. SOME DEFINITIONS

For the purpose of this report the Group agreed to the following definitions.

The term sanitation is used in the restricted sense of excreta disposal systems, unless otherwise indicated.

In discussing the etiologies of diarrhoeas, the Group distinguished between the classical bacterial agents, comprising Vibrio cholerae, Salmonella, and Shigella, and the recently recognized agents, such as rotaviruses, enterotoxigenic Escherichia coli, Campylobacter jejuni, and Yersinia enterocolitica, whose means of transmission and environmental survival have received little study.

It is now clear that there exist[2] at least 3 groups of pathogenic E. coli - enterotoxigenic, enteropathogenic, and enteroinvasive - as well as the vast population of commensal E. coli found in the faeces of most healthy persons; however, as most environmental microbiological studies have been concerned only with the latter group, reference to E. coli refers to this species sensu lato.

The Group was conscious that, whereas studies in environmental microbiology might yield results with wide geographical implications, many behavioural and operational research studies would provide culture-specific results that would have limited application in other settings. A study of the latter kind is referred to as a case study, while a comparative analysis of findings from a series of case studies is referred to as a comparative study.

---

[1] In this regard, the Group found the report of the South-East Asian Regional Research Study Group Meeting on Appropriate Technology for Improvement of Environmental Health at the Village Level (unpublished document SEA/RES/15 - SEA/EH/217, 19 March 1979) complementary and particularly helpful.

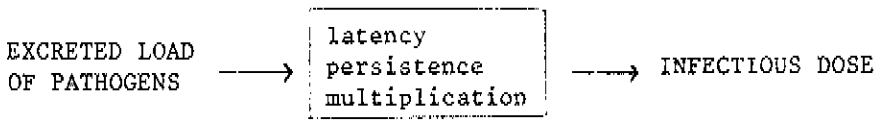
[2] Escherichia coli diarrhoea - Report of a Sub-group of the Scientific Working Group on Epidemiology and Etiology. Unpublished document WHO/DDC/EPE/79.1, 1979 (to be published in Bull. Wld Hlth Org., 1980, 58)

3. PRESENT KNOWLEDGE ABOUT ENVIRONMENTAL HEALTH AND DIARRHOEAL DISEASE CONTROL

3.1 Environmental basis of transmission

The major infectious causes of diarrhoeal diseases are transmitted by the faecal-oral route; but whether such spread occurs and results in infection in a new host depends upon the number of organisms excreted, the way in which they are influenced by the environment, and the dose required to infect a new host which is partly related to his susceptibility. In addition, three properties of the etiological agent need to be considered in determining how the environment affects an excreted load of organisms: these have been termed latency, persistence, and multiplication. The inter-relationship of all these factors is shown in Figure 1 and discussed in more detail below.

Figure 1. The environmental basis of transmission



3.1.1 Excreted load of pathogens

The concentration of pathogenic organisms passed by an infected person varies widely but is generally greater in cases than in asymptomatic excretors. For example, a cholera carrier may excrete 10^2 - 10^5 vibrios per gram of faeces while a case may excrete up to 10^{13} vibrios per day. When large numbers of organisms are excreted they can often be detected in high concentrations in nightsoil and sewage. Even in a developed country such as the United Kingdom, raw sewage has been found to contain 10^4 Salmonella per litre, and when such sewage has been treated by facilities having removal efficiencies of 99%, 100 organisms per litre have still been found in the effluent. The excreted loads of cases infected by one of the classical diarrhoea pathogens are usually in the range of 10^4 - 10^9 organisms per gram of faeces; there has been no systematic study of the load excreted by cases infected with any of the recently recognized pathogens.

3.1.2 Properties related to environmental survival

3.1.2.1 Latency

Some pathogens require a certain period of time in the environment to become infectious. The diarrhoea pathogens are immediately infectious on being excreted and thus have no latency period.

3.1.2.2 Persistence

Persistence is the ability of a pathogen to survive for a period of time in the environment. This property is one of the best indicators of an organism's capability of being transmitted: a very persistent pathogen will survive most processes for the treatment and re-use of excreta. The persistence of the diarrhoeal pathogens has not been studied comprehensively. Most available data come from studies of the classical bacterial pathogens under controlled laboratory conditions or in long-established sewage treatment processes.

A pathogen that persists for a short time must rapidly find a new susceptible host. In such instances (e.g., shigellosis), transmission most often occurs by person-to-person contact and as a consequence of poor personal hygiene. More persistent organisms can more readily give rise to new cases in a population, and as duration of survival increases so also must concern for the ultimate disposal of excreta containing these organisms.

The estimated survival times of the diarrhoeal pathogens in the environment are summarized in Table 1.

Table 1. Estimated survival times of diarrhoeal pathogens in the environment

	Pathogen	Survival time
increasing	Entamoeba histolytica Vibrio cholerae Shigella	under 1 month
persistence	Giardia lamblia Salmonella typhi Yersinia	under 6 months
	[1] Enteric viruses Salmonella Escherichia coli	under 1 year

[1] Data are available on the persistence of enteroviruses, most of which are not considered pathogens. There are no data on the persistence of rotaviruses or the Norwalk-like agent.

These data are generalizations based upon a very limited number of studies. Little is known about the persistence of any of the diarrhoeal pathogens in different habitats, such as small ponds, hut floors, water storage containers, body surfaces, and clothes. Studies of the survival of V. cholerae in natural waters in densely populated endemic rural areas of Bangladesh have indicated that survival of this organism may be prolonged on the root surface of certain water plants.

3.1.2.3 Multiplication

Under some conditions the diarrhoeal bacterial pathogens can multiply in the environment, especially in food, to concentrations sufficient to lead to ingestion of an infectious dose. It is generally believed that the bacterial pathogens and protozoa do not multiply in most waters, and that the diarrhoea-associated viruses and protozoa cannot multiply in any environment outside their animal hosts. However, the recently reported isolations of non-toxigenic V. cholerae from shellfish and from natural waters, some of which were unassociated with human infections, suggest that this organism may have the ability to multiply in certain aquatic environments. Few studies have been conducted in developing countries on the multiplication of even the classical diarrhoea pathogens in domestic and personal environments. There is one report indicating that V. cholerae can multiply rapidly in human sweat, but the epidemiological significance of this finding under normal environmental conditions is not known.

3.1.3 Infectious dose

Studies to determine the infectious dose of the diarrhoeal pathogens have been limited by the practical and ethical constraints of such research. Volunteer studies conducted in

healthy young adults in the USA have shown the infectious dose for cholera and typhoid fever to be several logs higher than the concentrations found in most polluted waters. However, administration of an alkaline substance prior to challenge with cholera vibrios to temporarily reduce gastric acidity, or the feeding of the organism with food, has been shown to lower the infectious dose by three logs; this suggests that in the natural setting the infectious dose of a pathogen may be influenced by the gastric acidity of the host and the type and amount of food in which the ingested pathogens are contained. The available data on the infectious dose of the bacterial diarrhoea pathogens in volunteer experiments are summarized in Table 2. Unfortunately, except for one recent study from Bangladesh which suggested that persons with cholera usually ingest less than 10^4 organisms in contaminated water, there are very few data available on the inoculum necessary under natural conditions to cause illness in children or in populations living in developing countries.

Table 2. Median infectious dose of diarrhoeal pathogens in adult volunteers in USA

Pathogen	Median infectious dose (organisms)
*Shigella**	$10^1 - 10^3$
*Salmonella**	$10^5 - 10^8$
Enterotoxigenic *E. coli*	$10^8 - 10^{10}$
V. cholerae (classical)	$10^8 - 10^9$

* Dose dependent in part on serotype.

3.1.4 Modes of tranmission

The behaviour, i.e., persistence and multiplication, of an organism in the environment, combined with the excreta disposal and other behavioural practices of the population, determines the most important transmission routes of the organism in that community. Thus, for environmental control, it is important to know whether a particular diarrhoeal disease is transmitted primarily because drinking water, food, hands, clothes, or household items are contaminated, or because some particular group, such as children, have specific behaviour patterns that promote transmission. In fact, transmission may, and probably usually does, result from a combination of these factors. The fundamental distinction is between transmission due to polluted water, where improved water quality is the necessary intervention, and all other routes, where improved personal and domestic cleanliness are more important control strategies.

3.2 Effect of environmental interventions upon diarrhoeal diseases

Field studies of the health benefits of water supplies and sanitation facilities have involved either the comparing of disease incidence or prevalence in communities with different facilities, or the monitoring of disease patterns before and after the improvement of facilities within a community. In both types of studies there have been difficulties in ascribing health benefits to the improved facilities because of the presence of other related confounding variables. For example, people who have better water supplies or sanitation facilities often also have higher incomes and better personal hygiene. Similarly, when a single population is followed over time, an improvement in sanitary facilities, for example, is unlikely to be the only beneficial change that occurs in the community. To attribute all the benefits to improved water supplies or sanitation in such circumstances is unjustified. Conversely, a change in water or sanitary facilities that results in no health improvement does not imply that the facilities are useless. The facilities may have been left unused because of inadequate health education, because they were inappropriately designed, located, or maintained, or because they were socially, culturally or aesthetically unacceptable.

As water supply and sanitation affect a range of diseases that cannot all be measured in a single study, usually a few indicators or index diseases are used to assess benefits. Examples of studies in which diarrhoeal disease or related conditions were used as an indicator are summarized in Table 3, while studies in which particular agents such as Shigella or worm eggs in the faeces were used as indicators are summarized in Tables 4 and 5 (see pages 25 - 31). A brief description of these studies is given below.

3.2.1 Health effects of improvements in water supply

A number of studies have attempted to relate diarrhoeal disease incidence or prevalence to water quality and/or availability. Such studies have used different indicators of disease incidence or prevalence and have been of three general types: retrospective reviews of clinic or hospital records, cross-sectional studies in communities or clinics, and longitudinal studies conducted in a community or clinic. Most studies have included a study population and a control population with less adequate water supply facilities. In a few studies the impact of a planned specific water supply project was evaluated. The indicators most commonly used in these studies have been the incidence of acute diarrhoeal disease or related conditions and the prevalence of intestinal microbes or parasites in stools. The findings of these studies have been inconsistent and sometimes even contradictory. Four studies (Nos. 4,9,13,23) have attempted to evaluate the impact of a planned specific water supply intervention on diarrhoeal disease morbidity. Two of these studies (Nos.13 & 23) also included an excreta disposal intervention and these were the only ones that resulted in a decrease in diarrhoeal disease morbidity; in the other two studies the intervention had no demonstrable impact. Data from many of these studies have given rise to problems in interpretation. For example, in the majority of studies summarized in Table 3, no clear definition of diarrhoea was given. In studies in which data were collected by interview, inappropriately long recall periods of up to 3 months were sometimes used. Confounding variables such as differences between study and control populations in wealth, housing, education, dietary habits, and willingness to use available health care facilities from which indicator data were derived were frequently not considered. Finally, very few studies considered the extremely important issue of water use.

In spite of these deficiencies, the results of these studies taken together do suggest that improvements in water quality and water availability can often lead to a reduction in acute diarrhoeal disease, while improvements in water availability can result in a decrease in the prevalence of Shigella infection.

3.2.2 Health effects of improved excreta disposal facilities

A number of studies have attempted to correlate level of sanitation with diarrhoeal disease incidence or prevalence. The study designs employed have been similarly retrospective, cross-sectional, or longitudinal, and have most frequently attempted to identify an association between the level of sanitation and the incidence of diarrhoea as measured by one or several indicators, which were the same as those used in the water supply impact studies. In most of these studies, the different levels of sanitation in the study and control populations evolved independently.

The results of these studies have also been inconsistent and sometimes contradictory, and most suffer from the same deficiencies as those attempting to relate water supply to diarrhoeal disease. Confounding variables were frequently not considered and the utilization of the facilities provided was rarely evaluated. However, in aggregate, the results indicate that improvements in sanitation lead to a reduction in acute diarrhoeal disease, in the prevalence of Shigella infection, and in the prevalence of intestinal parasites.

Three studies (Nos. 13,21,23) have attempted to assess the impact of a planned improvement in sanitation on diarrhoeal disease morbidity; as mentioned above, two of these (Nos. 13 & 23) also included improvements in water supply. All three studies suggested that improvements in sanitation alone or in conjunction with water supply lead to a reduction in diarrhoeal disease morbidity.

3.2.3 Impact of health education

Numerous studies have attributed the failure of water and sanitation programmmes to communities' lack of appreciation of the potential health benefits that could accrue from such improvements. Although there is now an increasing educational input into water supply and sanitation programmes, the formal evaluation of this element has often been neglected and rigorous impact studies are thus lacking. Unfortunately, emphasis has rather been placed on the descriptive evaluation of programmes, using questionnaires and the 'KAP' (knowledge, attitude and practices) approach, to measure the impact of educational intervention.

An example of effective educational activities is furnished by the Banki water supply project in India[1,2] which focused on the following: (i) dissatisfaction in the community with current conditions and motivation towards improving the quality of life (sickly children cannot develop properly); (ii) arguments with relevance to people's daily lives, which they could easily integrate in their frame of reference; (iii) provision of correct information to counteract people's misconceptions; (iv) use of common-sense arguments, particularly regarding the payment of water charges. The activities were effective because the positive methods used in identifying people's attitudes to water did not downgrade traditional thinking, and people actively participated in the discussions. This led to fewer negative reactions and an increase in the number of private house connexions, which in turn resulted in decreased morbidity.

3.2.4 Conclusions drawn from health impact studies

The variable effect of changes in water supplies and sanitation upon the incidence of diarrhoeal disease observed in the studies mentioned above has been due to the differential use of facilities, the variable levels of service provided, and the epidemiology of the causative organisms. The use made of the facilities, especially those for excreta disposal, is perhaps the most important factor. It depends upon human behaviour which in turn is related to the beliefs, culture, and education of the community (see section 3.4), the design of the facilities, and their attractiveness to potential users. It is now widely recognized that users must be intimately involved in the designing of facilities if they are to be attracted to them.

In studies where the improvement of water supply or sanitation has not shown a reduction in diarrhoeal disease, it is most probably because they lacked a complementary behavioural intervention. This is consistent with the hypothesis that a larger number of inputs is necessary to make an impact in a population of low socioeconomic status than in a more prosperous community, and leads to the concept of a minimal effective package - the simplest and least expensive mixture of inputs, both material and social, required to significantly reduce diarrhoeal disease.

In impact studies where water supply improvements showed clear reductions in diarrhoea rates, the intervention was probably effective in two ways. First, the improvement of water quality reduced the load of water-borne pathogens. Secondly, the increased access to water (e.g., a piped supply in the home) reduced the incidence of diarrhoeal disease due to person-to-person transmission, especially in the case of Shigella, presumably because the intervention facilitated personal cleanliness and prevented water-washed transmission. Many agents

---

1 Misra, K.K. (1975) Safe water in rural areas. An experiment in promoting community participation in India. Int. J. Hlth. Educ., 18 (53-59).

2 UNICEF/WHO Joint Study on Water Supply and Sanitation Components of Primary Health Care, unpublished document J22/UNICEF - WHO/79.3 (1979)

of diarrhoea have both water-borne and water-washed[1] transmission but it has been extremely difficult, if not impossible, to study these independently in areas with poor environmental hygiene.

Although it is generally accepted that improvements in both availability and quality of water together with better excreta disposal facilities are necessary to control the diarrhoeal diseases, in view of the often inconclusive information obtained from the existing studies (Tables 3 - 5), it would be useful if more and better studies could be undertaken to demonstrate and quantify this impact. The Working Group was, however, aware of the expense and difficulty of these large, 'set piece' field studies and noted that although there was a better understanding of the epidemiological requirements for good study design, the difficulty of holding extraneous variables constant had, if anything, increased. Thus, the Working Group focused its recommendations for research on very specific types of impact study.

3.3 Environmental technology at the village level and diarrhoeal diseases control

3.3.1 Water supply technology

Village-level water supply technologies need to be technically and environmentally sound, economically efficient, financially affordable, and acceptable to the users from the social, cultural, and political standpoints. They need to be simple in design and easy to install, operate, and maintain.

In some instances these supplies can be provided through extensions of nearby urban water supplies, but for the majority separate village supply systems have to be developed. In such cases, shallow groundwaters requiring no treatment are often found to be the best sources of water; alternatives, in decreasing order of suitability, are: spring water supplied by gravity and requiring no treatment; deep groundwater requiring no treatment; groundwater requiring simple treatment; rain water; spring water, lake water, irrigation water, or run-off water (in that order) requiring simple treatment; or river water requiring extensive treatment.

Groundwaters may be exploited by wells of various types. Interest in shallow wells has increased in recent years and better manuals on their construction have been issued, utilizing more appropriate technologies. Water lifting and pumping devices in wells need to be as simple as possible. Rudimentary water lifting devices that are still applicable include a rope and bucket, chain buckets, and beam and bucket water wheels, but the most common devices are handpumps. Breakdowns in such handpumps constitute the weakest link in the reliability of village groundwater supplies. After a long period in which there was little interest in this area, several new handpump designs have recently been developed. Criteria for improved pumps often involve a conflict between robustness and long life, and ease of repair. International studies are under way to compare the performance of different designs under comparable rigorous conditions. Meanwhile, those selecting handpumps should be guided not only by their initial cost but also by their robustness, ease of operation and maintenance, potential for manufacture, and the availability of spare parts.

---

[1] Definition

Water-Washed Transmission: An inadequate quantity of water and poor personal hygiene create conditions favourable for spread. Lack of proper human waste disposal also plays a role.

Waterborne transmission: Water acts as a passive vehicle for the infecting agent. The contamination of the water occurs through poor sanitation.

Power sources for mechanised pumping include the internal combustion engine, electricity, wind energy, hydraulic energy, and solar energy. Solar energy pumps are still in the developmental stages but they hold promise as a pumping device for village-level water supplies.

The slow sand filter is the simplest system for village-level water treatment. It is efficient for the removal of turbidity, organic matter, and pathogenic organisms, and also improves the colour of the water.

Disinfection can be applied to village water supplies. Chlorine and its compounds remain the most widely used disinfectants. Dug well water cannot be disinfected easily within the wells. The use of pot chlorinators or continous drip, siphon-type, chlorine solution feeders is often recommended, although they have rarely been used outside the context of a research project.

Indirect evidence suggests that the distribution of water through house connexions results in maximum health benefits. A single tap in the compound has been associated with desirable rises in water use although the use of standposts is more common in low-cost programmes. Work is underway on low-cost designs for urban peripheries. In rural areas, the provision of laundry-shower units beside standposts has been studied as a schistosomiasis control measure. In general, however, the most recent research on the technology of water supplies at the village level has been concentrated on the abstraction of water from the source and on its treatment, rather than on the design of distribution and utilization systems. Even the fundamental question of optimal tap design requires more study.

3.3.2 Excreta disposal technology

Village-level sanitation systems need to be culturally and politically acceptable to the users, financially affordable, and technically simple to construct, operate, and maintain. It is very much easier to build an excreta disposal system than to ensure its proper use.

Excreta disposal systems may be grouped into 4 categories according to whether or not the system is dependent on a water supply and whether final disposal is on- or off-site. Water is essential for the proper functioning of the water-dependent systems; if it is not always readily available, they cannot be used. Off-site systems involve the use of sewers or cartage systems to transfer the excreta from the points of production to other sites for final disposal with or without treatment. As the latter systems always require a high degree of institutional support and are costly, they are not recommended for village-level sanitation systems, though they may be appropriate in urban peripheries.

On-site options for village-level sanitation include conventional pit latrines, vented indirect pit (VIP) latrines, compost latrines, pour flush latrines plus soakaway pits, aqua privies with soakaways, and water closets with septic tanks and soakaways. Conventional pit latrines continue to be widely installed, though their association with odours and fly-breeding, and fear of their collapse have discouraged people of all ages from using them. Furthermore, the need to relocate them when they become full tends to waste land. They are, however, very cheap and easy to construct. The VIP latrine is designed to overcome the limitations of the conventional pit latrine. It is readily emptyable by manual or mechanical means, gives off little odour, and helps to control fly-breeding. Compost latrines are used for both excreta and refuse disposal, and have an added advantage in that the end-product can be re-used. However, they are complicated to use. The pour flush latrine is a hand-flushed water seal latrine connected to a soakaway pit. When the first pit becomes full, the flushings (about 1.5-2 litres) can be diverted into a second pit. When necessary, the contents of the first pit can be dug out for re-use. This latrine is very cheap, easily installed, hygenic, and odour- and fly-free.

This summary illustrates the range of methods available for excreta disposal. As with water supply systems, there has been more interest in recent years in the designing of simpler technologies for excreta disposal, which has largely been stimulated by the realization that sewered sanitation is too costly for many communities in developing countries. One additional area of interest has been the reutilization of excreta in agriculture, aquaculture, or energy

production (see section 3.3.3).

Of the available methods for large-scale sewage treatment, waste stabilization ponds are the most suitable for tropical use as they destroy most pathogens and offer the possibility of using the sewage for fish culture and irrigation.

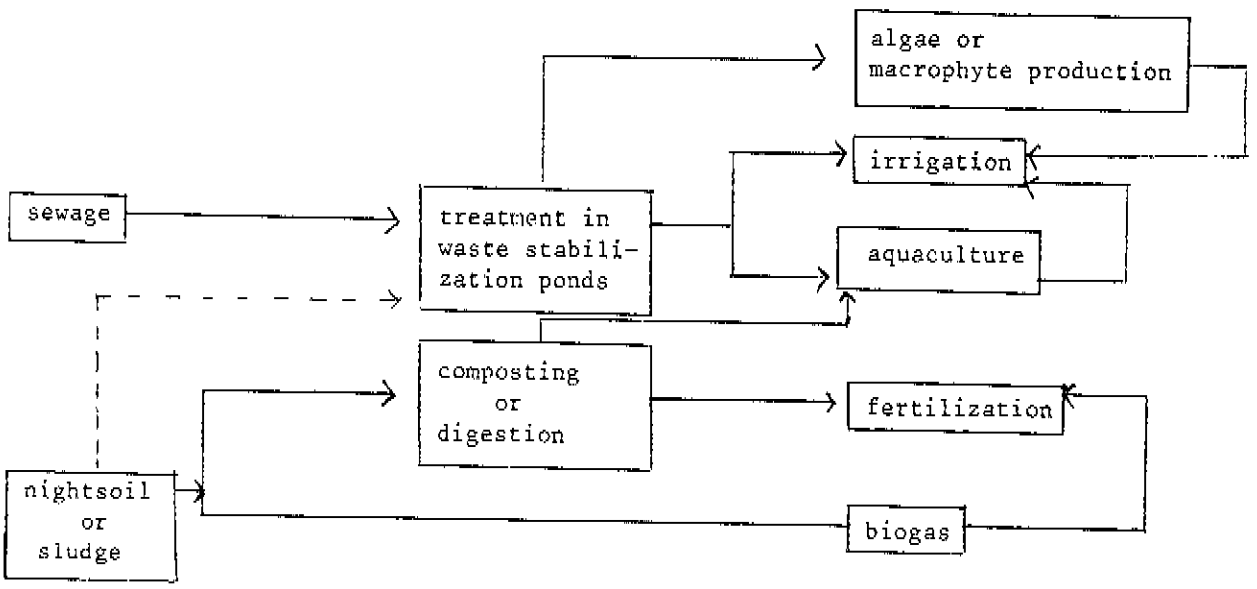
Excreta disposal has been the subject of much recent technological development and field research. Only a brief summary has been given in this report, which is mainly concerned with diarrhoeal disease prevention. A comprehensive account of the technical, economic, financial, social, and medical aspects of various excreta disposal, treatment, and re-use systems is provided by a recent series of publications and reports produced by the World Bank[1-4].

3.3.3 Technology and microbiology of excreta re-use

Prior to and during the International Drinking Water Supply and Sanitation Decade, a large invesment is being made in the improvement of excreta disposal facilities in rural and peri-urban areas, with emphasis on systems that allow the utilization of human excreta in agriculture or gas production. Possible re-use systems are illustrated in Figure 2. Their economic importance may also help to motivate the local community to make proper use of facilities. However, clear public health hazards exist in all these systems and it is necessary to design the processes in such a way that maximum pathogen destruction is achieved.

FIGURE 2.

Sewage Re-use Systems



1 World Bank (1978) Appropriate sanitation alternatives - a technical and economic appraisal. Energy, Water and Telecommunication Dept., World Bank.

2 World Bank (1978) Appropriate sanitation alternatives - a field manual. Energy, Water and Telecommunications Dept., World Bank.

3 World Bank (1978) Socio-cultural aspects of water supply and excreta disposal. Energy, Water and Telecommunications Dept., World Bank.

4 Feachem, R., Bradley, D., Gareleck, J. and Mara, D. Health aspects of excreta and wastewater management. World Bank/Johns Hopkins University Press (in press).

3.3.3.1 Irrigation and fertilization

There is a considerable amount of literature, which has recently been reviewed[1], on the survival of pathogens in sewage and sludge applied to the land. Most of the information available is from developed countries. The eggs of certain intestinal helminths, especially Ascaris, are able to survive for particularly long periods and to infect people who work in the fields, or handle or consume crops. There is evidence that several of the classical diarrhoea pathogens can survive for a few days on vegetables under laboratory conditions, but little is known about their survival in simple waste application systems. There have been no studies on the survival of the recently recognized pathogens in waste treatment facilities or after land application.

3.3.3.2 Aquaculture

The use of nightsoil and sewage in fish ponds, a custom widespread among the Chinese and Indonesians, has raised questions about the importance of these fish as a source of human diarrhoeal disease. The Clonorchis group of helminths is known to use fish as an intermediate host, but data on the role of fish in the transmission of other pathogens are limited. Work is under way in Israel and elsewhere on the transmission of E. coli and Salmonella.

A technology that is attracting increasing attention is the use of waste stabilization ponds to produce algae or water plants, such as the water hyacinth (Eichhornia crassipes), that can be dried and fed to chickens or pigs, composted to produce fertilizers, or digested to produce biogas. Little is known about the dissemination of diarrhoeal pathogens through such systems.

3.3.3.3 Biogas

The slurry produced by a biogas plant is generally used for agricultural purposes. Studies have indicated that biogas production is economically attractive only when the slurry is used in this way. The data on pathogen survival in biogas effluent come mainly from China and indicate that the slurry may contain large quantities of some bacterial and helminthic pathogens. The studies do not allow any general conclusions to be drawn about the quality of the slurry produced by biogas plants of different designs. Virtually nothing is known about the survival of the recently recognized diarrhoeal pathogens in biogas slurry.

3.3.4 Microbiological indicators of pollution

The access of pathogenic organisms to water may be intermittent, even where an epidemic of diarrhoeal disease is occurring due to faecal contamination of the water. In such cases, pollution is often detected by looking for indicator bacteria. The most commonly used indicator has been E. coli. Group D (faecal) streptococci and Clostridium perfringens have also been used. Novel indicator organisms, such as Bifidobacterium, Bacteroides fragilis, and coliphage, have been the subject of recent research, and the role of Ascaris eggs as an indicator of the quality of digested sludge or compost has been recognized.

Two major problems exist with the currently available standard methods for enumerating E. coli. First, the incubation temperature ($44.5^{\circ} \pm 0.2^{\circ}$) of the test is often inconvenient in laboratories possessing only one incubator set at 37°C for routine bacteriological work. Second, studies in Tanzania and the Gambia have revealed an alarmingly high false-positive rate; this is undoubtedly because the test has not been standardized for use in tropical climates.

---

1 Feachem, R., Bradley, D., Garelick, J. and Mara, D. Health aspects of excreta and wastewater management. World Bank/Johns Hopkins University Press (in press).

It is also now recognized that there are many situations in which E. coli may not be an ideal indicator. For example, it is doubtful whether E. coli levels are a good indicator of enteric viruses, and it is almost certain that they are not a good indicator of the pathogenicity of nightsoil or sludge. Their relationship to the presence of the recently recognized pathogens in not known.

Faecal streptococci, the most commonly used alternative, are easy to enumerate and require incubation at 35-37°C. However, some reports indicate that a high proportion of the colonies that appear on the agar plates are S. faecalis var liquifaciens, a strain that is not primarily of faecal origin. This matter requires clarification before faecal streptococci can be reliably used as an indicator of faecal contamination.

3.3.5 Food safety and diarrhoeal disease prevention

The predominant health problem associated with food in the developing countries is that of faecal contamination resulting from an unsanitary environment including low levels of personal and domestic hygiene and poor food preparation practices. In the developed countries, the largest proportion of food-borne disease is probably caused by food prepared at home, in institutions, or in food catering establishments rather than by commercially processed foods.

To ensure the safety and wholesomeness of food requires a broad range of actions at different stages of the food chain, from its growth, production, or manufacture to its final consumption. In most countries, there is no single programme that addresses itself to all of these aspects; the state of economic and social development greatly influences strategies for the implementation of such programmes. In many developing countries, food distribution is not centralized and there is very little commercial food activity. Many fresh foods such as vegetables, fruits, and meat are home-produced and processed for family use. In these situations, the focus needs to be on reducing biological contamination of food through improvements in basic sanitation and education of the public in simple safety measures for the production and preparation of food. Some studies suggest that food is the most important source of weanling diarrhoea, and that faecal contamination of both food and water in the home may be an important factor. Further weight is given to the role of food in the transmission of enteric diseases by reports of food-borne outbreakes of cholera in a number of countries. The microbiological aspects of food hygiene were recently considered by a WHO Expert Committee[1], which paid special attention to the relative public health importance of the various food-borne disease agents as judged by the severity and incidence of the diseases.

3.4 Behavioural aspects of environmental control of diarrhoeal diseases

It has been emphasized that, if diarrhoeal diseases are to be prevented, water supplies and excreta disposal facilities must be used appropriately. This requires community cooperation in the operation and maintenance of facilities and especially in the planning of excreta disposal. Thus, the culture and perceptions of communities must be understood when designing facilities and planning health education programmes. In comparison with the technological aspects of environmental health, this subject has been much neglected.

3.4.1 The cultural background to use of facilities

Attitudes towards the prevention of disease and the containment of illness vary in different societies. Illness itself is more than a medical condition; it has an intense social and cultural character which is influenced by religious beliefs and ideas about how the world functions and by the motivations of people. Health care systems must be understood in the context of a community's social organization. Knowledge of such facts is necessary to understand any health benefits a population may derive from a given water supply system or sanita-

---

[1] Wld. Hlth. Org. Techn. Rep. Ser., No. 598 (1976)

tion facility. Unfortunately, the cultural parameters that are needed to understand how people perceive diarrhoeal disease have not been well studied and there is no unified method for categorizing or even identifying the social and cultural processes that are most relevant to health. Social science techniques and methods for evaluating the community's sanitary perceptions and needs are still only partly developed.

We know that cultural constraints operate much more forcefully in sanitation programmes than in water supply programmes. Successful sanitation programmes have shown quite clearly that participation by members of a community in decision-making, planning, implementation, and sharing of benefits is essential. This implies that human behaviour and attitudes should not be viewed as elements to be modified to suit the technology, but rather as critically important variables that need to be considered when designing the technology of facilities in order to ensure user participation in their operation and maintenance.

The major cultural constraint in many environmental programmes has been an unawareness of the importance of operating and maintaining both water installations and sanitation facilities. Other important cultural variables concern attitudes towards purity (e.g., ablutions) and defecation. Although the causes of failures may lie elsewhere, these cultural constraints are often used to explain them and often lead to a call for health education. However, there is little evidence that a health education programme is a cost-effective way of reducing diarrhoeal disease unless it is carried out in conjunction with the installation of new water supplies or sanitation facilities (see sections 3.2.3 and 3.4.3).

3.4.2 Water use behaviour

During the last decade, field studies have been carried out on water use in three main contexts: to determine the pattern and volume of domestic water used in communities without piped supplies (e.g., in East and Southern Africa and Papua New Guinea); to analyse the effects of tubewell use in cholera-endemic areas (Bangladesh); and to measure water contact in several areas endemic for schistosomiasis. The results of these studies cannot readily be summarized as the communities concerned varied greatly in their use of water. However, the following conclusions can be drawn: bringing water supplies closer to the home but not inside has little effect on water use if the original water source is less than 2 km distant; stopping the use of unimproved sources is more difficult than achieving substantial use of new supplies; the provision of tubewell water for drinking does not necessarily affect the incidence of cholera in endemic areas; and urban migration consistently increases water consumption but the increase is not large in the absence of piped supplies.

Most studies of water use have been concerned only with the adult and older child population. With the exception of a few observations in Bangladesh, the youngest age groups, who are at greatest risk of diarrhoeal disease and responsible for excreting the greatest loads of pathogens in many environments, have been neglected. This is important, as it is felt that their patterns of excreta disposal and water use can differ qualitatively from those of older people.

3.4.3 Health education

Health education should aim at constructive reorientation rather than the denigration of traditional beliefs and thinking. At the community level education, to be effective, requires a two-way dialogue. An important element in planning education and communication programmes is their timing and duration. Educational approaches have often not taken into account the constraints of free time in the population and the need to have programmes not only during outbreaks of disease, but on a continuing basis.

During the last few decades, very extensive research has been done on the effective utilization of the mass communication media to inform, to change behaviour, and to motivate people. A broad consensus has been reached that the multi-media approach - the most natural one - is the most effective way of communication. However, such programmes are expensive and we currently lack data on the relative economic merits of differing levels and types of investment in health education.

One area of concern is that health education programmes have been didactic, advertised as educational, and very often too packed with information or advice. Often they have comprised development-by-exhortation with little relevance to the clients' needs. They have lacked the light touch of commercial "jingles." This type of appraoch, comprising short simple messages that are broadcast repeatedly, has been tried but not properly evaluated.

3.5 Organizational issues in environmental control of diarrhoeal diseases

The problems involved in community organization for environmental control of diarrhoeal diseases have received minimal attention. The key area that requires study - that of operation and maintenance of facilities - has been almost entirely ignored. The desire for coverage, encouraged by the International Drinking Water Supply and Sanitation Decade, has further diverted attention from operational problems, which are very great and may be soluble only in the context of the general primary health care system.

3.5.1 Operation and maintenance

The proper operation and maintenance of water supply and sanitation facilities cannot be over-emphasized if an adequate and safe water supply and hygienic means of excreta disposal are to be provided to the population, especially in the rural areas. The technical procedures and skills necessary for this purpose are fairly well developed and known. However, the relatively high percentage of inoperable water supply systems and the insanitary condition of excreta disposal facilities, frequently reported in the literature, are indicative of the lack of operation and maintenance systems.

This breakdown is often ascribed to inadequate financial support and lack of trained manpower, spare parts, and community participation. One study has pointed out the need for an examination of entire maintenance delivery systems, their equipment, financing, management, public information channels, and suitability to the local environment. Very few detailed case studies exist but methodologies for them are being produced[1].

It is now recognized that the operation and maintenance of water supply and excreta disposal facilities, especially in rural areas, have to be considered early in the planning stage of an environmental health programme (see section 3.4.1). A greater effort is being made to select technologies that are appropriate to the local situation, with due attention to their operation and maintenance, and the necessary methodology is being developed. There is a need, however, for a systematic study, evaluation, and analysis of operation and maintenance systems to provide a basis for determining which are best suited to specific environments.

3.5.2 Primary health care and environmental control of diarrhoeal diseases

The intensified effort to improve water supplies and sanitation in the 1980s coincides with the drive to extend primary health care coverage and it is clear that the two must be closely related. UNICEF and WHO have carried out a joint study of the issues involved.[2]

There is a consensus of opinion that water supply and sanitation are essential components of primary health care, that national plans and close cooperation between the several

---

[1] For instance:
Cairncross, S. et al. Evaluation for village water supply planning. The Hague, WHO International Reference Centre for Community Water Supply (in press).

[2] UNICEF/WHO Joint Study on Water Supply and Sanitation Components of Primary Health Care, unpublished document JC22/UNICEF-WHO/79.3 (1979).

ministries involved are necessary, and that communities need to be closely involved in the selection, construction, and maintenance of environmental health facilities. The implementation of these broad principles is a far more difficult matter and much operational research is needed to work out precisely what, in a given community, can be expected from the primary health care workers and what support structures are needed. Often the construction and maintenance of water supplies will not be a health ministry responsibility and the integration of activities will require a considerable effort. The long-term costs of alternative strategies, and the economic consequences of participatory programmes, are questions about which we still know little.

Organizational issues include the provision of water supply and sanitation concurrently, together with health education, in order to derive the maximum benefit. It may be important to introduce an economic motive. The Chinese "consumer-oriented" approach is an example, in which farmers cooperate whole-heartedly when they realize that the use of compost and treated nightsoil as fertilizer increases agricultural production and income. This approach would favour the use of technologies that lead to by-products of economic value, such as bio-gas plants, waste stabilization ponds for fish production, and systems producing effluents for irrigation (see section 3.3.3).

This is obviously an area that reaches far beyond the more precise research objectives of a diarrhoeal disease programme, but it is important to note that in most successful sanitation and water programmes, community participation sensu lato has been an important ingredient.

4. RECOMMENDATIONS

4.1 General considerations

The review of the subject in the previous sections has identified a variety of topics on which further research is required. In considering the research priorities, the Working Group attempted to strike a balance between fundamental research on basic scientific problems, and operational and applied research of immediate relevance to the aims and activities of the International Drinking Water Supply and Sanitation Decade. The specific aim of diarrhoeal disease control was kept firmly in mind.

The Group discussed at length several general features of the research needed on the environmental control of diarrhoeal diseases. The majority of the research can only be done in countries, and more specifically in rural villages and urban peripheries, where the endemic diarrhoeal diseases are a major public health problem. Unlike other kinds of diarrhoeal disease research, there is little or no possibility that highly sophisticated research facilities in the developed countries could generate results that would be of relevance to the developing countries. It will also be necessary for research in the developing countries to develop logistics for collecting data and maintaining research staff in remote areas. Such arrangements can be expensive and the Group recognized that there might be a need to finance organizational arrangements to permit rural research to take place effectively.

The Working Group's discussions frequently returned to the highly multidisciplinary nature of the research needed. Nearly all the research studies listed require a combination of major disciplines, and some require very unusual combinations - such as microbiology and social anthropology. This could make the research difficult to organize because there are very few research institutes in the world that employ both microbiologists and social anthropologists. WHO will therefore have to make efforts to encourage and support a multidisciplinary research capability.

A related problem is that of the availability of individuals able to design, lead, coordinate, and write up research of a highly multidisciplinary nature. It requires a very unusual background and training to be able to work comfortably in a field encompassing anthropology, economics, education, engineering, epidemiology, microbiology, and public health. In general, WHO may have to support training that will upgrade the competence of individuals in fields other than their own (see section 4.3).

4.2 Research priorities

The research recommendations of the Group are presented below in three general areas.

4.2.1 Environmental aspects of diarrhoeal disease transmission

These research topics all require a strong local competence in, and facility for, environmental microbiology. Studies will tend to be of a 'set piece' type in which a team may design and carry out a discrete study designed to answer a clearly defined set of questions. The results will often have global applicability or, at least, some relevance to workers in other regions or countries.

Pathogens in domestic environments

Studies should be undertaken of the persistence and multiplication of diarrhoeal pathogens in micro-environments in and around the homes of poorer populations in developing countries. Attention should be paid to the presence of pathogens on skin, clothes, utensils, and household surfaces, and in food and water. These studies may be combined with detailed epidemiological and behavioural observations to elucidate transmission routes for diarrhoeal pathogens with a view to improving intervention strategies. They might also yield information on the use of environmental microbiology as a means of conducting surveillance of diarrhoeal diseases.

Environmental effects on microbial pathogenicity

More information is required on the effect of the extra-intestinal environment on the antigenic and biochemical properties of diarrhoea pathogens, especially *V. cholerae*, and the consequent effect on persistence and virulence. The possibility of an environmental reservoir, or at least very long-term environmental survival, of *V. cholerae* merits special attention, especially when *V. cholerae* is isolated from the environment in the absence of cases.

Food microbiology

There is a need to further develop microbiological specifications for food to help in providing a basis for evaluation of the hygienic quality of foods and in preventing food-borne infections and intoxications. In particular, it is recommended that further studies be carried out on the survival of *V. cholerae* and other enteric pathogens in foods under different natural conditions.

Waste treatment microbiology

Further study is required on the persistence and multiplication of all the diarrhoea pathogens in waste treatment processes, such as waste stabilization ponds and composting plants, that are especially appropriate for developing countries. Such studies are especially needed for processes that discharge effluents into water sources from which downstream communities drink or into estuarine or marine environments from which shellfish are harvested. The studies should be undertaken by joint engineering and microbiological teams and should enable them to make recommendations for design or operational improvements of the treatment technology. In appropriate circumstances, an epidemiological component may be added to relate pathogen discharge to disease in the community.

Excreta re-use microbiology

Studies are needed on the dissemination of faecal pathogens through excreta re-use systems. Systems requiring special attention are fish culture, crop fertilization or irrigation with sludges, slurries or effluents, and biogas production. Studies should trace pathogens through the system to the eventual product (e.g., the fish) and should assess, where possible, the epidemiological significance of any contamination found. A multidisciplinary team should be used, incorporating engineering and food microbiology capabilities.

Indicator organisms for diarrhoeal pathogens

An improved and more convenient test should be developed for enumerating E. coli as a faecal indicator organism. It should have an incubation temperature of 35-37°C (instead of 44.5 ± 0.2°C as at present) and a high degree of specificity for E. coli in tropical waters and wastes.

The suitability of faecal streptococci as faecal indicator organisms should be further studied. In particular, the significance of S. faecalis var. liquifaciens isolation requires investigation.

The overall adequacy of E. coli and/or faecal streptococci as indicators of the presence of diarrhoea pathogens needs to be assessed with particular attention to the relationships between the indicators and the recently recognized diarrhoea pathogens.

Handbook of laboratory techniques

To assist in these and similar studies, the Working Group considered it important that a clear and well-illustrated handbook be produced, describing the most suitable techniques for isolating and identifying diarrhoea pathogens in samples of water, nightsoil, sewage, soil, vegetables, etc. The handbook should emphasize techniques that can be reliably carried out in modestly equipped research laboratories.

4.2.2 Components of effective environmental control of diarrhoea

These studies concern the social, technical, and economic issues in environmental health programmes. They are mostly multidisciplinary in nature and are mainly conducted through enquiry at the village level. Their results will often be country- or even site-specific, but they will be highly suggestive to workers in other countries and may in some instances provide advances in research methodology that have a general application.

Some studies, such as those of children, will best be done by patient observation by an anthropologist who is familiar with the particular culture and area. Surveys and questionnaires may be of limited value and should be used with caution.

Water use studies

Studies are needed to determine whether water-borne transmission results more commonly from water contaminated at its source or after storage in the home. In addition, the different types of water storage technology need to be studied to assess the risk of their becoming contaminated in the home.

Studies are required to develop technical innovations and educational programmes that will promote greater use of new water supplies for personal and domestic cleanliness. Technical possibilities include the optimal location of taps and the provision of public basins and showers. Combined engineering and behavioural inputs are required for these studies.

Studies of children

More information is needed on the water use patterns of infants and young children, and of their mothers in the provision of child care (e.g., washing). The attitudes of parents towards their infant's excreta should be studied. Specific cultural or religious beliefs held by parents that have a detrimental effect upon small child hygiene and could be influenced by educational programmes should be identified.

Studies should be carried out to learn more about the defecation habits of pre-school children in different societies and the attitudes of these children towards the use of latrines. More information is needed to determine whether pre-school children use the same water sources as adults.

There is a need to know more about school sanitary facilities and how they are used by schoolchildren. More knowledge is also required on the best ways of teaching hygiene, taking into account the fact that there may be different hygienic practices in the home and in school.

Manpower studies

There is a great need for studies into the appropriate role of primary health care workers in the environmental health aspects of diarrhoeal disease control programmes and in environmental health programmes in general. These are particularly important to ensure that the demands on these workers are not unreasonable and their training is congruent with their work. These studies might best be done in countries with well developed primary health care programmes and should be organized in a way that will allow comparison of results from different countries.

A comparative study of work, training, and potential usefulness of health inspectors is recommended. The health inspector is a well educated member of health teams in many countries who is often underemployed or misemployed on minor tasks and could form a valuable resource for diarrhoeal disease control programmes.

Indicators for assessing environmental effects on diarrhoeal disease

The incidence of diarrhoea in a community is usually assessed by periodic surveillance of the population and retrospective inquiry. A more objective and universal definition of diarrhoea is needed, especially for trans-cultural comparisons, though the Working Group had doubts about the feasibility of achieving this.

Water use variables are now well known. The way to measure the use made of sanitary facilities is much less easy and requires development.

Health education

Since vigorous educational programmes are a crucial part of any effective water supply and sanitation project, and are especially important in the effort to achieve an impact on diarrhoeal diseases, research directed at defining the most effective types of environmental health education programme deserves high priority. It is necessary to assess how education and communication can most effectively be undertaken to maximize the acceptance and use of water and sanitation facilities. The content of such educational efforts will need to be examined in detail, both in general and in country- or culture-specific terms. There is need for a comprehensive review of past experiences, both national educational efforts and smaller demonstration projects.

4.2.3 Health effects of environmental interventions

Perhaps the most usual, and certainly the most difficult and controversial type of research in this field is that on the impact of environmental interventions on diarrhoeal disease incidence. The Group wished to leave the way open for good research proposals in this field but, at the same time, to focus attention on approaches that might be particularly fruitful and practical. As these studies are of necessity multidisciplinary and methodologically complex, and take place over a number of years, they are highly demanding activities and should be undertaken cautiously. The detailed findings of impact studies will, in general, be site-specific. However, the results will be suggestive for other situations and each successful impact study will probably make methodological advances that will have global validity.

The two types of health evaluation studies given a high priority by the Group were the evaluation of 'mimimal effective packages' and what may be called 'opportunistic' impact studies.

Package effectiveness studies

These studies constitute the final stage of development of an effective intervention programme. Its components are developed using a number of intermediate studies and evaluations until what is considered an optimal, operationally feasible, and economically viable package of interventions has been prepared. This package is then assessed in the field for its impact on diarrhoeal disease using the previous situation in the community as a control; where there is a difference of opinion regarding possible programmes, these may be compared in two matched communities. In these studies intermediate indicators of the use of facilities, behaviour changes, etc. should be examined so that, if the impact on diarrhoeal disease is less than was expected, the reasons can be determined and the effectiveness of the package improved.

Opportunistic health impact studies

Large impact studies testing single interventions are not considered to be worth encouraging because of their cost and because the utility of, for example, water improvements with and without health education can be more easily assessed by measuring water use. However, circumstances occasionally occur when an elegant impact study can be undertaken at a fraction of the cost and effort needed for a similar study planned in a pre-established place. Such opportunities should be utilized, especially when they might provide an answer to a specific question. For example, an opportunity to determine in a rigorously controlled way, the effect of changed water quality alone upon a rural community previously supplied with reticulated untreated surface water would be worth exploiting. It is important for those involved in environmental programmes to be continuously alert for such opportunities.

Economics research

Although the Working Group was aware of the difficulties involved, and the need for various assumptions of uncertain validity, it felt that some research should be undertaken on the costs and benefits of diarrhoeal disease control. Such studies might include consideration of the economic effects of an outbreak of cholera and its consequences for tourism. It was felt, in view of the very complex effects of tourism on socioeconomic development, that an isolated analysis of tourism would be less informative than its consideration in the overall economic assessment of diarrhoeal disease control.

Studies on the cost effectiveness of different policies and possibilities in diarrhoeal disease control programmes would also be valuable.

4.3 Operational research in environmental health programmes

Whether or not it is termed research, it is reasonable to assume that some of the operational studies recommended can be carried out as part of the planning and evaluation efforts of national environmental health programmes and need not be conducted as isolated research projects executed by an academic or research-focused institution. For example, observations on water use by children may be needed in many countries for the planning of the educational component of these programmes. Studies of the impact of a water supply or sanitation programme on diarrhoeal diseases, however, will usually require the undertaking of a major research project involving epidemiological and microbiological expertise which is not usually found in a water supply or sanitation agency. Thus, the Working Group felt that intermediate indicators of health impact should be widely used in these programmes to measure the environmental changes that are believed to be essential for achieving a marked reduction of diarrhoeal disease. For example, if one aim of a programme is to increase water use for washing by providing standposts and health education, this is best assessed in the short run, not by health impact studies, but by studies of water use and observations of washing behaviour. With the exception of *E. coli* counts to assess the faecal pollution of water, these intermediate indicators, especially the behavioural ones, have not been studied systematically and methods for measuring them need to be improved.

The Working Group also discussed a series of research topics that are related to the overall operation and evaluation of environmental health programmes and that will need to be undertaken by countries if their water supply and sanitation investments during the Decade are to be effective. The Group felt that the WHO Diarrhoeal Diseases Control Programme should be especially concerned with those that have a particular bearing upon the impact of an environmental health programme on diarrhoeal diseases. These include specific studies related to technical, operational, behavioural, and other community aspects of appropriate technology. Examples of such studies are listed below:

- Studies to determine the importance attributed to water supply and sanitation in relation to other community priorities.

- In-depth studies of village communities to determine existing social groupings and customs in relation to water supply and sanitation.

- Studies to develop effective approaches for the introduction or transfer of appropriate technological innovations, especially water supply and sanitation facilities.

- Studies to develop techniques and approaches for mobilizing community participation in, and utilization of, water supplies and sanitation.

- Studies on the relative effectiveness of different health education techniques aiming at changing behavioural patterns related to water supply and sanitation.

- Studies to determine the reasons why certain water supply and sanitation facilities are not maintained.

- Studies on the effectiveness of the primary health care worker at the village level in relation to water supply and sanitation activities.

- As a consequence of the International Drinking Water Supply and Sanitation Decade, it is likely that the use of untreated water sources will greatly increase. There will be a need for bacteriological surveillance of such sources. Research is needed on the organization and operation of low-cost surveillance services and on the appropriate operational responses to various bacteriological results of surveillance.

Some of these items have received more detailed discussion in previous sections of the report. Here the Group emphasizes their study in the context of operational research as an integral part of an ongoing water supply or sanitation programme. The aim will be to produce the most effective balanced package of interventions, within the available resources, for reducing diarrhoeal disease on a long-term basis.

4.4 Training for research

There is a very great need for the training of personnel to carry out the recommended research as well as for the development of better training methods. There is a special need for the training of certain types of workers, particularly sociologists and anthropologists, on the technical, scientific, and medical aspects of water and sanitation programmes, to ensure that their studies produce results that are innovative and applicable by programme administrators. This is best done by identifying persons who already have an interest in this field and awarding them study grants. Other categories of research workers who are in short supply are epidemiologists and environmental microbiologists from developing countries. More efforts are needed to identify persons who could usefully be trained in these disciplines. In addition, there is a need to expand the training of sanitary engineers in the areas of planning and evaluation.

4.5 Implementation of research

It is clear from the preceding section that the research needs in the field of environmental aspects of diarrhoeal disease control are very varied. They differ from much other

diarrhoea-related research in three main respects. First, many are multidisciplinary, requiring several different professional skills for their implementation. Second, they form a continum from basic research to applied, operational work sometimes to the point where it is unclear whether a particular topic should properly be called research or part of an operational programme. Third, many of the research topics are highly culture-specific; for example, the reasons for an adult failing to utilize excreta disposal facilities may be totally different in different countries.

These differences have important implications for carrying out the research. The majority of investigations in environmental microbiology (section 4.2.1) form orthodox scientific problems and can readily be handled as research projects. The same considerations apply to some aspects of projects on the effectiveness of environmental control (section 4.2.2). The results of such studies will have considerable global application; for example, the methodology of the proposed study of the behaviour of young children is likely to be tranferable, although the results will be culture-specific.

Many aspects of the projects in sections 4.2.2 and 4.2.3 will yield results that are primarily location- or country-specific. Furthermore, they may be of limited relevance when separated from operational water supply and sanitation programmes. As mentioned above (see section 4.2.4), they may in some instances be better organized as part of national environmental health programmes where they could be carried out by the unit responsible for evaluating the programme. The expanded activities during the International Drinking Water Supply and Sanitation Decade should provide a greater opportunity for special activities of this type. It is suggested that the responsible units acquire the capacity to do applied research in such areas as maintenance of water supplies, community participation in latrine improvements, or behavioural modifications needed to improve utilization, by enrolling multidisciplinary staff, perhaps including specialists from local universities. It is fully realized that very few countries have such units at present and that the WHO Diarrhoeal Diseases Control Programme may need to support their development. Meetings of these groups to exchange and compare results, and dissemination of their findings, would be important.

It would seem from the foregoing that, because of the interlocking nature of much of the proposed research, and the need for the vast majority of it to be carried out in areas endemic for diarrhoeal diseases and in conjunction with national environmental health programmes, the research programme might best be implemented by entrusting the work to a limited number of centres with the appropriate capacity. These centres should be held together in a network to allow the exchange of expertise, the standardization of methods, and the comparison of results.

Table 3. Studies assessing the association of diarrhoeal disease or related conditions with water supply and/or excreta disposal

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site of Collection of Indicator Data	Duration	Results
Water quality	1	Colorado, USA	Gastrointestinal illness* incidence	All	Cross-Sectional	Single-home visit (3 month recall)	3 months	Incidence 8.8% in communities with good, 13.9% in communities with poor water quality
Water quality	2	Bangladesh	Diarrhoea incidence	All	Record review	Clinic and hospital	11 years	Incidence 7.5/1000/yr in tube well users, 3.2/1000/yr in non-users
Water availability	3	California, USA	Diarrhoea incidence	All	Cross-sectional longitudinal	Home visits once or every 4-6 weeks (6 week recall)	6 months	Data not presented by type of water supply
Water quality and availability	4	Guatemala**	Diarrhoea incidence	All	Longitudinal	Home visits monthly (2 week recall) and clinic record review	3 years	Incidence 39.7/1000/yr initially, 39.5/1000/yr 3 years later
Water quality and availability	5	Zambia	Diarrhoea incidence	All	Record review	Clinic and hospital	4 years	Incidence 338/1000/yr before, 212/1000/yr 2 years after piped water
Water quality and availability	6	Lesotho	Diarrhoea incidence	All	Record review	Clinic and hospital	39 months	No difference in diarrhoea incidence in villages with and without improved supplies
Water quality and availability	7	Kenya	Diarrhoea prevalence	All	Cross-sectional	Single home visit (1 week recall)	1 week	Illness in 3.1% of households with, 19.0% of households without piped water

*Definition specified

**Specific intervention evaluated

Table 3 (continued)

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site of Collection of Indicator Data	Duration	Results
Water quality and availability	8	Kenya	Diarrhoea prevalence	All	Cross-sectional	Single home visit (? recall period)	Short	Prevalence 7%; no differences
Water quality and availability	9,10	Kenya**	Gastrointestinal illness incidence	All	Longitudinal	Home visits biweekly (2 week recall)	9 months	Decrease as percentage of total illness from 23% to 20% in infants and from 31% to 18% in children aged 1-2 yrs
Water availability, excreta disposal	11	Kentucky, USA	Diarrhoea incidence	All	Longitudinal	Home visits monthly (1 month recall)	29 months	Incidence 135/1000/yr with, 349/1000/yr without indoor plumbing
Water availability, excreta disposal	12	Arizona, USA	Diarrhoea incidence	≤1 year	Record review	Clinic and hospital	6½ years	Incidence 2.0/person/yr before, 0.9/person/yr after indoor plumbing
Water availability, excreta disposal	13	Five states,** USA	Diarrhoea incidence	All	Record review	Clinic	6 years	Incidence 159/1000/yr before, 136/1000/yr after indoor plumbing.
Water availability, excreta disposal	14	Venezuela	Diarrhoea incidence	All	Longitudinal	Home visits monthly (1 month recall)	1 year	in children <8y.o., incidence 11.8%, 12.0%, 12.5%, 17.9% in 4 communities with, 24.2%, 27.4% in 2 communities without available water
Water availability, excreta disposal	15	Ethiopia	Gastroenteritis* incidence	≤4 years	Longitudinal	Home visits biweekly (1 day recall)	1 year	When water available, lower incidence with private than non-private latrines

*Definition specified
** Specific intervention evaluated

Table 3 (continued)

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site of Collection of Indicator Data	Duration	Results
Water availability, excreta disposal	16	Seven Countries	Diarrhoea incidence	≤9 years	Cross-sectional	Single home visit (1 month recall)	~1 month	Incidence 2.0-39% where water available, 2.0-48.7% where less available
Water quality, water availability, excreta disposal	17	Guatemala	Diarrhoea incidence	All	Longitudinal	Home visits bi-weekly (2 week recall)	4 years	Incidence 168/1000/yr with, 224/1000/yr without privies; incidence 3 x higher with limited water availability.
Water quality, water availability, excreta disposal	18	Costa Rica	Diarrhoea* incidence	All	Longitudinal	Home visits weekly (1 week recall)	1 year	Incidence 240/1000/yr ≥3, 490/1000/yr with ≤1 household connection; 270/1000/yr with septic tank, 400/1000 /yr with privy, 210/ 1000/yr with no facility

*Definition specified
**Specific intervention evaluated

Table 4. Studies assessing the association of stool culture results with water supply and/or excreta disposal

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site and Method of Specimen Collection	Duration	Results
Water quality	19	Bangladesh	Cholera incidence	≤11 years	Longitudinal	Home and hospital; rectal swabs	2 years	Classical cholera: 3.7% incidence in those living close to, 25.3% incidence in those living further from tube wells.
Water quality	2	Bangladesh	Cholera incidence	All	Record review	Clinic & hospital; rectal swabs or stools	11 years	Incidence 14.2/1000/yr in tube well users, 8.4/1000/yr in non-users
Water availability	3	California, USA	Shigella, Salmonella prevalence	≤10 years	Cross-sectional/longitudinal	Home and clinic; rectal swabs	6 months	Shigella prevalence 2.1% in homes with water, 6.6% in homes without water
Water availability	20	California, USA	Shigella, Salmonella prevalence	≤10 years	Longitudinal	Home; rectal swabs	7 months	Shigella prevalence 0.7% in homes with water, 7.2% in homes without water
Excreta disposal	21	Georgia,* USA	Shigella prevalence	≤10 years	Longitudinal	Home;rectal swabs	31 months	Shigella prevalence 4.7% before, 2.8% after privies improved
Water quality and availability	22	Georgia, USA	Shigella prevalence	?	Longitudinal	Home;rectal swabs	3 years	Shigella infection in 4.1% of families with nearby, 5.8% of families without nearby water

*Specific intervention evaluated

Table 4 (continued)

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site and Method of Specimen Collection	Duration	Results
Water quality, excreta disposal	23	Philippines*	Cholera incidence	All	Longitudinal	Home; rectal swabs	4½ years	El Tor cholera incidence 10.8/1000/yr in community with improved water and excreta disposal, 12.5/1000/yr with improved water, 14.7/1000/yr with improved excreta disposal, and 46.0/1000/yr with no improvements.
Water availability, excreta disposal	11	Kentucky, USA	Shigella, Salmonella, EPEC** prevalence	≤5 years	Longitudinal	Home; rectal swabs	29 months	Shigella prevalence 0.7% with and 6.4% without indoor plumbing
Water availability, excreta disposal	13	Five States, USA	Shigella, Salmonella prevalence	All	Record review	Hospitals; stools	6 years	Low incidence; data not presented
Water availability, excreta disposal	24	Guatemala	Shigella, Salmonella prevalence	≤10 years	Cross-sectional	Clinics; rectal swabs	6 months	Shigella prevalence 6.3% in communities with private wells or municipal supply to ≥50% of houses, 9.4% in those with <50%; 4.8% in communities with privies or flush-toilets in ≥50% of houses, 11.2% in those with <50%

* Specific intervention evaluated
** Enteropathogenic Escherichia coli

Table 4 (continued)

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site and Method of Specimen Collection	Duration	Results
Water availability, excreta disposal	16	Seven Countries	Shigella, Salmonella, EPEC** prevalence	≤10 years	Cross-sectional	Home; rectal swabs	1 month	Shigella prevalence 2.0-6.4% where water available, 4-14% where less available
Water quality, water availability, excreta disposal	25	Panama	Shigella, Salmonella, EPEC** incidence	Infants	Cross-sectional	Clinic; stool examination method unclear	unknown	Shigella incidence 0% with, 0.9-2.5% without indoor plumbing
Water quality, water availability, excreta disposal	18	Costa Rica	Shigella, Salmonella, EPEC** prevalence	All	Longitudinal	Home and clinics; rectal swabs or stools	1 year	Shigella prevalence 1% with ≥3, 7% with ≤1 household connection; 0% with septic tank, 4% with privy or no facility

* Specific intervention evaluated
** Enteropathogenic Escherichia coli

Table 5. Studies assessing the association of intestinal parasites with water supply and/or excreta disposal

Variable(s) Assessed	Study No.	Location of Study	Specific Indicator	Age Group	Type of Study	Site of Specimen Collection	Duration	Results
Water quality and availability	8	Kenya	Prevalence of intestinal parasites	≤4 years	Cross-sectional	Home	Short	Prevalence 20-33%; no differences
Water quality and availability	9,10	Kenya	Prevalence of intestinal parasites	All	Longitudinal	Home	9 months	*Ascaris* prevalence 15% initially, 8.8% 4 years later
Water availability, excreta disposal	11	Kentucky, USA	Prevalence of intestinal parasites	All	Longitudinal	Home	29 months	Prevalence 21.4% with, 61.6% without indoor plumbing
Water availability, excreta disposal	13	Five States, USA	Incidence of *Entamoeba histolytica*	All	Record review	Hospitals	6 years	Low incidence; data not presented
Water availability, excreta disposal	16	Four Countries	Prevalence of intestinal parasites	≤6 years	Cross-sectional	Home	~1 month	Data not presented by type of water supply or excreta disposal
Water quality, water availability, excreta disposal	18	Costa Rica	Prevalence of intestinal parasites	All	Longitudinal	Home and clinics	1 year	*Ascaris* prevalence 24% with ≥3, 49% with ≤1 household connection; 25% with septic tank, 37% with privy, 69% with no facility

REFERENCES TO TABLES 3-5

1. Petersen, N.J. & Hines, V.D. The relation of summertime gastrointestinal illness to the sanitary quality of the water supplies in six Rocky Mountain communities. Am. J. Hyg., 71: 314-320 (1960)

2. Levine, R.J. et al. Failure of sanitary wells to protect against cholera and other diarrhoeas in Bangladesh. Lancet, ii: 86-89 (1976)

3. Watt, J. et al. Diarrhoeal diseases in Fresno County California. Am. J. publ. Hlth, 6: 728-741 (1953)

4. Shiffman, M.A. et al. Field studies on water sanitation and health education in relation to health status in Central America. Prog. Wat. Tech., 11: 143-150 (1978)

5. Bahl, M.R. Impact of piped water supply on the incidence of typhoid fever and diarrhoeal diseases in Lusaka. Med.J. Zambia, 10: 98-99 (1976)

6. Feachem, R. et al. Water, health and development. London, Tri-Med Books Ltd (1978)

7. White, G.F., Bradley, D.J. & White,A.U. Drawers of water: Domestic water use in East Africa. Chicago, The University of Chicago Press (1972)

8. Shaffer, R., Najai, D. & Kabuleeta, P. Environmental health among the Masai of Southern Kenya: The effect of water supply changes. Prog. Wat. Tech, 11: 45-48 (1978)

9. Strudwick, R.H. The Zaina environmental sanitation project. E. African med. J., 39: 311-331 (1962)

10. Fenwich, K.W.H. The short term effects of a pilot environmental health project in rural Africa: The Zaina scheme re-assessed after four years. Cited in: White,G.F., Bradley, D.J., & White, A.U. Drawers of water: Domestic water use in East Africa, Chicago, University of Chicago Press, pp. 154-157 (1972)

11. Schliessmann, D.J. et al. Relation of environmental factors to the occurrence of enteric diseases in areas of Eastern Kentucky. Publ. Hlth Monogr. No. 54, pp. 1-33 (1958)

12. Rubenstein, A. et al. Effect of improved sanitary facilities on infant diarrhoea in a Hopi Village. Publ. Hlth Rep., 84: 1093-1097 (1969)

13. Berg, L.E. & Mowery, T.M. Health program evaluation: Impact study of the Indian sanitation facilities construction act. Health Program Systems Center, Tucson, Arizona, pp. 1-14 (1968)

14. Wolff, H.L., van Zijl, W.J. & Roy, M. Houseflies, the availability of water, and diarrhoeal diseases. Bull. WHO, 41: 952-959 (1969)

15. Freij, L. et al. Child health and diarrhoeal disease in relation to supply and use of water in African communities. Prog. Wat. Tech., 11: 49-55 (1978)

16. van Zijl, W.J. Studies on diarrhoeal diseases in seven countries by the WHO diarrhoeal diseases advisory team. Bull. WHO, 35: 249-261 (1966)

17. Bruch, H.A. et al. Studies of diarrhoeal disease in Central America. V. Environmental factors in the origin and transmission of acute diarrhoeal disease in four Guatemalan villages. Am. J. trop. Med. Hyg., 12: 567-579 (1963)

18. Moore, H.A., de la Cruz, E. & Vargas-Mendez, O. Diarrhoeal disease studies in Costa Rica. IV. The influence of sanitation upon the prevalence of intestinal infection and diarrhoeal disease. Am. J. Epidemiol., 82: 162-184 (1965)

19. Sommer, A. & Woodward, WE. The influence of protected water supplies on the spread of classical/Inaba and El Tor/Ogawa cholera in rural East Bengal. Lancet, ii: 985-987 (1972)

20. Hollister, A.C.et al. Influence of water availability on Shigella prevalence in children of farm labor families. Am. J. publ. Hlth., 45: 354-362 (1955)

21. McCabe, L.J. & Haines, T.W. Diarrhoeal disease control by improved human excreta disposal. Publ. Hlth. Rep., 72: 921-928 (1957)

22. Stewart, W.H. et al. Diarrhoeal disease control studies. IV. The relationship of certain environmental factors to the prevalence of Shigella infection. Am. J. trop. Med. Hyg., 4: 718-724 (1955)

23. Azurin, J.C. & Alvero, M. Field evaluation of environmental sanitation measures against cholera. Bull. WHO, 51: 19-26 (1974)

24. Beck, M.D., Muñoz, J.A. & Scrimshaw, N.S. Studies on diarrhoeal diseases in Central America. I. Preliminary findings on cultural surveys of normal population groups in Guatemala. Am. J. trop. Med Hyg., 6: 62-71 (1957)

25. Kourany, M. & Vasquez, M.A. Housing and certain socioenvironmental factors and prevalence of enteropathogenic bacteria among infants with diarrhoeal disease in Panama. Am. J. trop. Med. Hyg., 18: 936-941 (1969)

= = =