ENVIRONMENTAL SERIES NO. 10

PAN AMERICAN HEALTH ORGANIZATION
WORLD HEALTH ORGANIZATION
-ENVIRONMENTAL HEALTH PROGRAM-

ENVIRONMENTAL HEALTH AND THE MANAGEMENT OF FRESH WATER RESOURCES IN THE AMERICAS

WASHINGTON D.C. 1992

ENVIRONMENTAL HEALTH AND THE MANAGEMENT OF FRESH WATER RESOURCES IN THE AMERICAS

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January 1992

ACKNOWLEDGEMENT

The contribution of Eng. W. Castagnino, who prepared draft material on management of drinking water sources and human health in Latin America and the Caribbean, is herewith acknowledged. This material was edited and incorporated in Chapter 4 of the present text.

FOREWORD

There exists a long tradition of water management planning in the Americas. At first it was almost entirely centered on the exploitation of water resources, but recently greater consideration has been given to associated economic and environmental factors. With rapidly growing populations and concomitant economic development, it has begun to embrace social impacts as well. Questions are being posed, for example, on how given water resource development schemes are affecting the health of local populations and their lifestyles.

Stimulated in large part by the resolution of the United Nations Conferences on the Human Environment (Stockholm, 1972), on Human Settlement (Vancouver, 1976), and on Water (Mar del Plata, 1977), a wide variety of programs were initiated by international agencies, including the Pan American Health Organization, to provide safe water to all people. Important progress was made as a result of these efforts but the gap between what is desired and what has been attained remains large. The reasons for this shortfall are complex, but rapidly growing populations coupled with increasing water demands for economic development are, in part, responsible.

Studies made of the current situation with regard to water resource development schemes indicate that the potential impact on health can be very serious, particularly because of the rapidly increasing demand for water. The effects range from ill health due to associated increases in vector transmitted diseases, low standards of water and food quality due to contamination with human or chemical waste, to health impacts associated with social upheaval of local and indigenous people. There are at present also concerns for the equitable apportionment of water among the different sectors including energy, industry, agriculture, and, last but not least, water for human consumption.

Because of the many interactions that shape and affect water resource development, decision-makers in an increasing number of countries are coming to the realization that planning and implementation should be carried out on an integrated basis.

This document has been prepared to facilitate integrated decision-making by presenting an in-depth overview of the current water resources development and management issues. Special attention is being given throughout the text to the relevant health problems that are commonly associated with different types of water schemes.

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Washington, D.C., January 1992

EXECUTIVE SUMMARY

Water is important for the continuation of life and socio-economic development. In Latin America, availability of water in itself is not a major issue. However, there are water supply problems in relation to the distribution of population and economic activity in the Region. Summarizing the situation: 60% of the population are concentrated in 20% of the land area of Latin America that only has 5% of its water resources. Therefore, water problems in the Region tend to be localized and can be severe.

Broadly, three types of environmental effects of water development can be recognized.

(i) Damage to the source - this refers to the physical alteration of rivers, lakes, aquifers and associated ecosystems as a consequence of human activities, such as dam construction, large irrigation projects, large scale deforestation, large urban settlements, or more regional/global impacts arising from acid rain, global warming, etc. The effects on human health of this type of modifications exert themselves through major changes in the transmission of various types of vector borne diseases; through large scale displacements of native populations with all the incumbent hardships of destruction of social and cultural fabrics, loss of employment, disease and violence, and through increasing competition for water among various categories of users.

(ii) Damage to the water itself - this refers to the changes in water quality due to man's domestic, industrial, agricultural and other activities which contaminate the water with biological and chemical waste. Thus, the water is rendered unsuitable for human consumption, and in many cases also for other applications, such as growing of food, leisure activities, etc.

The health impact of water contamination includes the acute effects of the presence of human waste in drinking water which is causing widespread diarrhea and gastroenteritis in the Region causing particularly high morbidity and mortality among children. Also, the irrigation of food produced with contaminated water is causing widespread health problems, particularly in the arid areas in the Region. On the other hand, water contaminated with a variety of chemicals, such as pesticides, resulting from agricultural practices, heavy metals and organic substances, produced as by-products from various industrial activities, are known to be responsible for a number of acute and chronic illnesses including, for example, methemoglobinemia in infants in the case of elevated nitrate levels in drinking water, and low birth weight of new born when the mothers ate fish contaminated with chemicals. Other effects are concerned with small, but significant increased risk of bladder, colon and rectal cancer.

(iii) Water economies - water resources are often perceived as "free" public goods, that can be used up as fast and wastefully as one group in society is capable of appropriating them. Failing to account for the environmental effects of the by-products of economic activity, and the inadequate definition of costs and of institutions to protect them, are direct causes of environmental degradation. Without clear identification of property rights and responsibility for its management, there can be no economic or political accountability for the use of public goods and the "tragedy of the commons" (floods, droughts, decertification, rampant disease) becomes the rule.

Considerable reductions in water consumption can be achieved through recycling and other applications of the reuse of water, such as in irrigation. Also, irrigation techniques themselves can often be improved to conserve water. These techniques become especially important in the more arid zones of the Region. Further controls can be exerted through an adequate fee structure. Finally, it is recommended that pristine (ground) water be reserved for drinking purposes as a priority use. The national health agencies should continue to be vigilant in promoting the adequate management of water resources and drinking water quantity and quality for the protection of the people.

Over the past decades, attention to the evaluation of water resources development plans has gradually shifted from technical considerations to economic and environmental factors. More recently, it has begun to embrace social and health impacts as well. Among the responses made features the requirement to make comprehensive impact assessments relating to water development and usage projects. Experience with the adoption of this concept has resulted in a variety of institutional arrangements for water resources management, which vary from country to country according to differences in political culture.

There appear two principal trends in institutional arrangements for water management. One is designed toward centralization in an attempt to internalize effects of decisions. The establishment of national water authorities, with responsibilities for managing both water quantity and water quality, typifies such a model. The other is designed toward decentralization in which case the water authority must have power to influence and coordinate the action of each and all the water users. These two models should not be seen as mutually exclusive options.

The important point to be made here is that the development of water resources projects (as well as other large scale undertakings) should include the necessary health care infrastructure. Such infrastructure development should include both capital expenditures for buildings, clinics, outpatient facilities, as well as recurrent costs for health services, vector control and health education. Both are essential to prevent water resources development projects from becoming health hazards for nearby populations.

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1. *INTRODUCTION*

Water resources are determined by their hydrological features and their boundaries are naturally confined to drainage areas, such as river basins, lake basins or groundwater aquifers. The availability of water within a given basin determines, and often limits, the possibilities for social, health and economic development. Therefore, fresh water is not only a renewable natural resource for the preparation of food and for sanitary purposes, but it also forms an important part of our ecosystem and, thus, is involved in economic development activities.

1.1 *Water quality and quantity*

Fresh water is derived both from rivers and lakes, as well as from underground aquifers. Figure 1 shows a map of Latin America which depicts the amount of reliance the various countries place on groundwater (Foster et al, 1987). It may be noted that some 50% of all drinking water in Latin America and the Caribbean comes from aquifers.

FIGURE 1

Importance of groundwater for potable water supply in the Latin American and Caribbean Region

Source: Foster et al, 1987

Currently, 20% of the total water consumed in the U.S. is drawn from groundwater sources and it is estimated that this usage will increase to 33% in the year 2000. It is estimated that some 60 million people in the USA are being served by public water supplies using groundwater and that about 54% of rural populations and 2% of urban populations obtain their water from individual wells (Gerba, 1985). In Canada, drilled wells are the primary source of drinking water for rural populations (Environment Canada, 1986).

Table I lists the major water uses and their effects on water quality. It should be noted that there are vast differences in the quantities required for each use, that their impact on the hydrological cycle varies, and that they are accompanied by divergent quality requirements (WHO, 1988).

TABLE I
Links between water use and water quality

A. Uses Affecting Water Quality	
(i) Municipal:	sewage discharge, stormwater run-off
(ii) Agricultural:	manure disposal, use of agro-chemicals, drainage water discharge
(iii) Industrial:	wastewater effluents, cooling water discharge, mine drainage
B. Uses Affected by Water Quality	
(i) Municipal:	drinking, domestic uses, public uses
(ii) Agricultural:	domestic farm supply, livestock watering, irrigation
(iii) Industrial:	boiler feeding, cooling, processing, mining
(iv) Recreational:	water-contact sports (swimming), aesthetic enjoyment
(v) Aquatic life:	aquatic and wildlife, fishing, swamp and wetland habitat, aquaculture
C. Uses not Linked to Water Quality	
(i) Commercial:	hydropower generation, navigation
(ii) Recreational:	recreational sports, boating

Source: WHO, 1988

Quantitative needs for water vary widely among different water uses. On a global scale, needs for irrigation account for about two-thirds of all human uses as the need for food and fiber products grows. For example, it takes approximately 1,000 tons of water to grow one ton of grain, and some 2,000 tons to grow one ton of rice. It should be noted, however, that many irrigation activities have associated water losses, estimated to be between 50% and 80%, thus, offering a considerable potential for technological improvement resulting in substantial water savings (WRI, 1987). Improvement in the handling of irrigation water is therefore considered to be a most important task for the future. Also, the potential for reuse of municipal wastewater in arid and semi-arid zones in order to meet some of the irrigation water demands is gradually being realized, although this would not be clearly reflected in the global balance (see also Section 3.2).

TABLE II
Sectoral water use in selected countries

Country	Sectoral Use in %			
	Public Supply	Industry (Processing)	Cooling (Power Prod.)	Agriculture (Irrigation)
Canada	13	39	39	10
USA	10	11	38	41
Mexico	5	7	0	88
Venezuela	37	4	0	59
Peru	7	0	0	93
Argentina	9	8	10	73

Sources: OECD, 1985; WRI, 1986

Table II shows that depending on the status of industrialization and agricultural practices, shifts in the pattern of water use are noticeable in many developing countries. In the more rural countries irrigation is frequently the crucial factor determining progress in crop production. In developing countries undergoing moderate to rapid industrialization, competition between users for water resources with limited availability, becomes a predominant factor in water resource management. Projected water demands for the year 2000 have shown that the total national water resources in many countries situated in arid and semi-arid zones will not be enough to satisfy these demands. Maintenance of the planned pace of economic progress inevitably necessitates that water be re-used, either by passing it from one user to the next or by recycling it within one sector, as occurs in many industrial manufacturing plants. As an example, Figure 2 shows the progression of water demands in Mexico over the years.

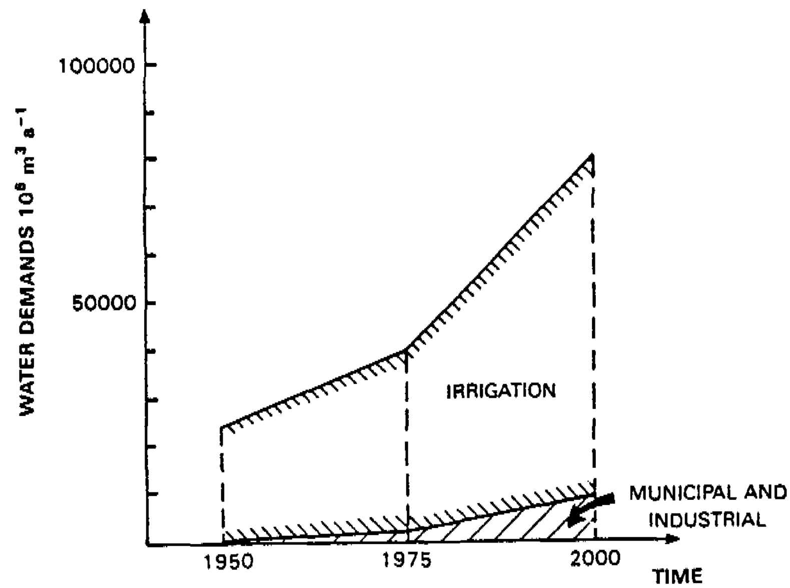

FIGURE 2
Water demands in Mexico

Source: Urroz, 1982

Land use in the watershed and the nature of the water source (e.g., surface water or groundwater) will often dictate the need for standards to control the chemical, biological and aesthetic variables. Thus, in some localities, the risk posed by the presence of certain toxic industrial chemicals in the water may be of importance, in others human settlements and the lack of proper sanitation procedures may lead to a potential danger from fecal contamination. Based upon practical considerations of water use requirements, pollution problems and health effects, guideline values have been established for various use categories, such as drinking water, irrigation, livestock watering and fisheries. A summary of this information is presented in Annex I (WHO, 1988).

1.2 *Aquifers*

An aquifer is a water body located in a rock formation. Usually major aquifers are found in sedimentary or volcanic rock. They always have an intake area, a storage and circulation area, and a discharge area. Aquifers may be confined, when they are between relatively impermeable layers, or phreatic, when they do not have an upper confining layer.

For a number of reasons, aquifer protection has not received much consideration in the Latin American and Caribbean Region. Much of the contamination of surface waters and soils will ultimately pollute groundwater. The migration of pollution from the land surface tends to be relatively slow which may lead to complacency. On the other hand, once groundwater is contaminated it is extremely difficult to clean it again.

Groundwater contamination stems from different sources including:

- the increasingly widespread practice of onsite disposal of untreated domestic and industrial effluents to the ground, due to much higher costs of alternative arrangements;

- intensive agricultural practices introduce large quantities of inorganic fertilizers and pesticides into the soil and ultimately into groundwater; intense irrigation practices can cause considerable increases in salinity of groundwater, particularly in arid areas;

- the wells to extract the groundwater themselves can cause contamination of the groundwater as, for example, in Lima, Sao Paulo, or Mexico City, where the number of wells ranges from 1,500 to 4,000.

The contamination of groundwater can range from organic matter derived from domestic waste, nitrates and other inorganic materials, heavy metals (cadmium chromium, lead, mercury), different types of solvents (chlorinated alkanes, alkenes, and benzenes), some pesticides which do not absorb very strongly on soils, and fecal coliform indicator bacteria. In some industrial areas, an accident may give rise to groundwater being contaminated with any number of substances including PCBs, fuel oil, etc. (Foster et al, 1987).

In many countries rapid growth in groundwater exploitation for municipal water-supply is occurring as, for example, in Costa Rica as shown in Figure 3.

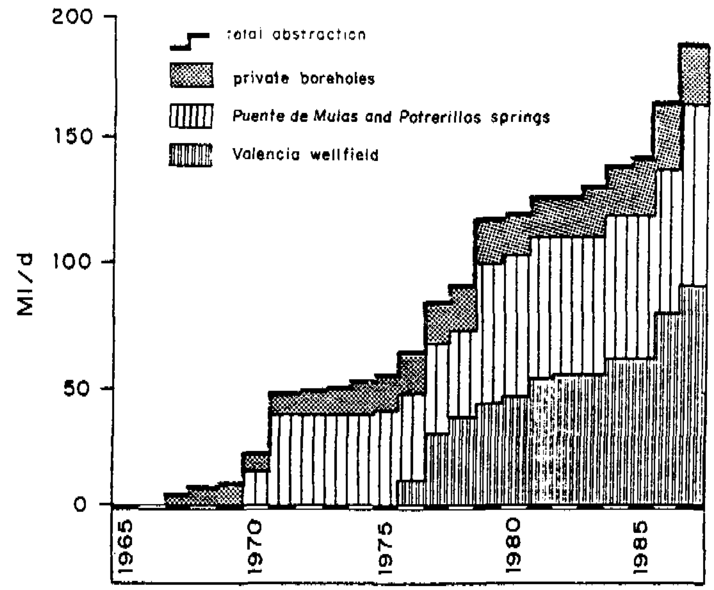

FIGURE 3
Growth of groundwater extraction from the Colima Aquifer of the Valle Central, Costa Rica development

Source: Foster et al, 1987

2. *DEVELOPMENT OF WATER RESOURCES AND HEALTH*

The input to the water resource is precipitation. Where forests exist some of the rain is intercepted by the leaves and either evaporates or falls to the ground. Forests, therefore, act as buffers of rainwater, but when they are removed the water regulatory capacity of the system is lost. When there is no vegetation cover to retain moisture then water during heavy downpours runs off the land quickly carrying eroded soil that pollutes our streams and rivers. As consequence, extensive flooding may occur especially on land with steeper slopes. The overall result is that we have too much water when we do not need it, and too little when we do need it (Caribbean Forest Conservation Association, 1989). The consequences of this phenomenon on human health and on agricultural practices is generally devastating, particularly because it tends to affect mostly the poorer sections of the population.

In many tropical areas, water development schemes are the key to economic and agricultural development. This implies on the one hand better utilization of existing water resources mainly for agricultural purposes, or electric power production, and, on the other hand, the draining of swamps and marshes for land reclamation and pisciculture. Dam constructions, irrigation schemes and man-made lakes are some of the major devices to achieve these aims. Along with the economic benefits arising from these schemes, they can, however, affect the normal development of human rural activities and also of settlements. Moreover, occasionally, such disruptions are very large and careful attention needs to be given to resettlement sites and changes in occupation, lifestyles, health and social conditions, infrastructural services, etc. There are many examples, including the Sao Simao, Itumbiara, and Paulo-Alfonso hydroelectric projects in Brazil, in which settlement problems had to be dealt with as integral parts of project construction (World Bank, 1975).

Other major changes that may affect the health conditions of the nearby populations are the preservation of wildlife and domestic animals, and the epidemiology of parasitic infections, thus, usually increasing the health hazards of man. The realization of the health implications and the early implementation of control measures can greatly reduce or even prevent these health hazards.

2.1 Changes to the landscape

The construction of dams, formation of man-made lakes and development of irrigation projects in tropical areas introduce important changes in the environment and, in parallel, produce a number of risks to human health, apart from the benefits brought to the economy of the country or the Region.

While natural changes in the landscape represent a slow and inexorable process irreversible in time, those caused by man with great modern technical resources are capable of bringing about rapid degradation of the environment and the emergence of risks for human health which appear even before there is any awareness of the danger, or preparations made to overcome it.

The dissociation, which is almost always the case, between those who decide upon and carry out water development projects, and those who can evaluate the results, and propose solutions, often explains the lack of foresight and late recognition of the problem.

As an example, Figure 4, shows the formation of flood plain impoundments in the Amazon region. (A) Normal dry season level of the river below its flood plain level. (B) After heavy rains with water streaming from deforested slopes, breaking over its banks into the flood plain. (C) After the rains subside, but leaving flood plain impoundments along its margin providing extensive breeding grounds for mosquitoes. Note that silt resulting from erosion increases the banks between the flood plain impoundments and the river, causing this water to take on a more permanent character.

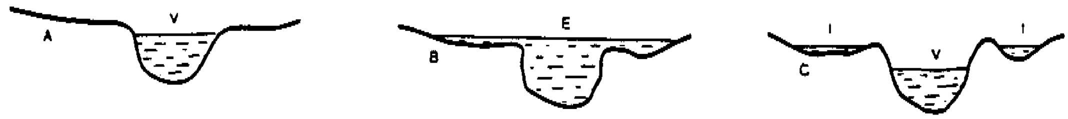

FIGURE 4
Formation of flood plain impoundments

Source: Cruz Marques, 1987

Table III shows the situation with regard to the number of dams that exist in different Latin American countries.

TABLE III
Number of dams over 15 meters high completed in Latin America

Country	Pre-1950	1951-1960	1961-1970	1971-1980	After 1981*	Total
Argentina	13	16	30	17	98	174
Bolivia	-	2	1	1	2	6
Brazil	119	111	97	113	93	533
Chile	34	7	10	13	15	79
Cuba	2	2	17	28	-	49
Colombia	-	10	18	3	10	41
Costa Rica	1	2	1	1	5	10
Dominican Republic	-	-	-	8	6	14
El Salvador	-	2	1	1	1	5
Ecuador	-	1	1	2	7	11
Guatemala	1	-	3	1	5	10
Haiti	-	1	-	-	-	1
Honduras	-	-	1	6	1	8
Jamaica	2	-	-	-	-	2

Country	Pre-1950	1951-1960	1961-1970	1971-1980	After 1981*	Total
Mexico	75	45	132	150	55	457
Nicaragua	2	-	-	2	4	8
Panama	2	-	2	1	-	5
Paraguay	-	-	1	1	1	3
Peru	35	5	13	4	6	63
Suriname	-	-	1	-	-	1
Trinidad & Tobago	-	2	-	1	1	4
Uruguay	1	2	-	1	2	6
Venezuela	10	22	20	20	81	153
Total	297	230	349	374	393	1,643

* Completed or under construction

Source: ICOLD, 1988; WRI, 1987

The construction of a dam, for whatever purpose it is built, inevitably affects the river up, as well as downstream. Upstream of the dam the water level rises over long distances, sometimes creating lake-like water reservoirs, the water edges are pushed inland, and the velocity of the water is usually reduced considerably.

The changed situation can have either a detrimental or a beneficial effect as regards water-related parasitic diseases. As far as vector-borne diseases are concerned, former breeding sites may be covered by water over large areas. The reduced velocity of the raised water will be unfavorable for the breeding of the Simulium vectors of onchocerciasis, thus, reducing or even eliminating transmission sites.

A nearly stagnant water upstream of a dam, often accompanied by rapid growth of aquatic vegetation, provides ideal living conditions for the malaria mosquito, and thus, creates a potential danger for a wider spread and increase of transmission of the infection in the area, with all its detrimental effects on the community. The most appropriate methods of bringing this hazard under control are by the careful designing of the dam and reservoir, by the application of pesticides to the water and/or weed control.

The downstream effect of a dam construction is usually the opposite to that upstream. The outflowing water is mostly very turbulent and remains so for some distance, creating thereby very favorable breeding conditions for Simuliidae. As the aquatic stage of the black fly is highly susceptible to insecticides, treatment of the downstream water at intervals is most effective in eliminating or reducing this vector population, at least to a negligible level regarding public health importance. For larger dams, insecticide treatment devices can be built into the construction itself; in others the treatment has to be done in the more conventional way. Undoubtedly, water treatment for the purpose of Simulium control will have some effect on the other insect populations, which also use the river as their breeding sites.

The health hazards involved in smaller dams, mainly created for irrigation purposes, lie mainly in the favorable breeding conditions they provide for the vectors of onchocerciasis, involving often the spillways themselves. The specific design of the spillways, controlled fluctuation of the water level and the proper maintenance of the dam site are recommended control methods.

Table IV presents data on the development of irrigation schemes in a selected number for Latin American countries.

TABLE IV
Irrigation area in some countries of Latin America

Country	Area irrigated in 1984 (thousand hectares)	Percentage change over 1974-1984
Argentina	1,660	15
Brazil	2,200	69
Chile	1,275	1
Colombia	322	16
Cuba	1,030	74
Ecuador	537	6
Mexico	5,100	13
Peru	1,200	6
Venezuela	322	8
Total	13,646	23
Source: UN Food and Agriculture Organization		

Any irrigation system which brings surface water to dry areas where water was previously scarce or non-existent requires very close attention with regard to its possible effect on water-related parasitic diseases. Not only may specially favorable conditions be created for the proliferation of water-dependent vectors or intermediate hosts, but also the increase or inflow of human population may provide specially favorable opportunities for disease transmission (Hunter et al, 1990).

2.2 *Ecological changes and disruption*

Depending on their ecology, certain mosquito species may disappear or remain confined to small territories untouched by the development of the Region. Other species may find more favorable living conditions there, either because of the increase in water surface for their larval cycle, or because of physical, chemical or nutritional factors which suit them better in the new water bodies: lakes, irrigation canals, excavations, marshes and seepage zones or, again, because a reduction or disappearance of predators increases their abundance and effectiveness to transmit diseases, such as malaria, arboviruses and filariasis. Similar circumstances seem to exert an influence on snail populations. Both the extension of the aquatic habitat and the state of the ecosystem at a certain stage of the eutrophication process can favor the implantation or multiplication of species acting as intermediate hosts for schistosomes or other trematodes.

Ecological changes often modify the incidence and prevalence of diseases already present in the Region. There will be a tendency for these to decrease if, for example, the specific vectors or those playing the most effective role in transmission are reduced. Destruction of primeval forests in Brazil reduces the population of the sandfly species which is most important for the propagation of cutaneous leishmaniasis. Thus, after an increase of leishmaniasis following the first contact with the forest, a change is observed as the latter is destroyed or submerged, and new cases become rarer and finally disappear.

Usually, however, there is a tendency for increased incidence or prevalence of waterborne diseases and of diseases whose vectors develop in water. In South America, the multiplication of malaria mosquitoes (Anopheles darlingi, A. pseudopunctipenis and A. albimanus) is favored by the construction of dams and irrigation networks. A. albimanus also transmits arboviruses.

Culex tarsalis, which is very characteristic of irrigated regions, is an important vector of St. Louis encephalitis. In California, more than 80% of the breeding places of mosquitoes responsible for annual outbreaks of encephalitis are man-made.

Three different types of vectors are involved in water-habitat type disease transmission:

- **snail vectors** which are the essential link in transmitting schistosomiasis. More than 70 countries in the tropics and sub-tropics are affected, and the disease is spreading and intensifying due to new irrigation projects which create a favorable environment for the aquatic host of the disease vector.

- **mosquito vectors** which are responsible for the widespread occurrence of malaria, filariasis and arboviruses. The malaria parasite is transmitted by a mosquito which depends on the aquatic environment for breeding. About 1.2 billion people live in areas where malaria is currently endemic.

- **fly vectors** which transmit onchocerciasis (river blindness) and trypanosomiasis (sleeping sickness). Highly aerated, running water is the preferred habitat for breeding of the vector (Simulium fly) of onchocerciasis. Parts of South-West Africa and Central America are suffering very badly from blindness rates of up to one third of the adult population in the affected rural areas.

2.3 Community vulnerability and environmental receptivity

Two factors are critically important in the changes in vector transmitted diseases, commonly associated with the development of water resources in a hydraulic basin: community vulnerability and environmental receptivity (WHO, 1989). These factors are further discussed in this section.

The vulnerability of a community to infection depends on their proximity to areas where vector-borne disease occur, their immune status, previous history of exposure, general health status, the potential effect of an influx of infected migrants and the community's main activities. There may be a human group who maintain close contact with vector populations because of the place in which they live or because of their occupation. In this way they may also provide a potential source of infection to members of other communities.

Human behavior has a profound effect on the degree of contact with vectors or unsafe water. Contact can occur near or far from the domestic environment. Contact near the domestic environment often ensures that disease prevalence is more widely distributed between age and sex classes. Contact far from the domestic environment is often associated with economic activities and may restrict disease prevalence to certain age and sex classes. The economic activities may be associated with the project and could include construction or agricultural work. In these cases, special means of individual protection should be considered. However, villagers usually have a large number of informal occupations in addition to their main occupations.

In order to determine how the human community will be affected by the project, it is necessary to classify the human groups which form the community and to consider the health status of each group. It may be appropriate to group together families of construction workers, settlers, spontaneous immigrants and prior occupants of the proposed site and peripheral sites. The age structure of communities associated with development projects is often very different from the national norm because a greater number of children are born and survive, or because settlers are in their prime child bearing years. Immigrants from different regions or different climatic zones may be especially at risk.

In order to assess the vulnerability of a community, adequate data and information should be sought to the following questions (WHO, 1989).

(i) Which diseases are important in the region?
(ii) How prevalent are these diseases?
(iii) Is there any drug resistance?
(iv) Is there a human parasite reservoir?

Environmental receptivity to transmission of the pathogen is determined by abundance of the vector, human contact with vectors or unsafe water, and with other ecological or climatic factors favoring transmission. Suggested ranks for receptivity include:

- transmission possible, but not occurring at present;
- easily resumed; and
- likely to lead to explosive outbreaks of the disease.

Environmental receptivity will increase if the water development project creates, or enhances, either vector breeding sites or opportunities for human contact with vectors or unsafe water sources, or leads to an expansion of the disease reservoir population.

The pathogen responsible for some vector-borne diseases, such as malaria, does not survive in mammalian hosts other than humans. However, other pathogens such as those associated with African sleeping sickness and leishmaniasis are found in wild animals which are referred to as reservoirs of infection.

Most vectors have enormous capacity to colonize and recolonize breeding sites. Flying insects can migrate substantial distances, especially when helped by a prevailing wind. Snails are adapted to seeking passive transport on floating materials in rivers, the legs of animals, and on vehicles. If a vector, or intermediate host, is present in a Region it will, sooner or later, colonize or recolonize the breeding sites created by the project.

2.4 *Socioeconomic and demographic changes*

From the public health viewpoint, the new ecological conditions and their repercussions on the vectors and mechanisms of diseases transmission take on their full significance when considered in relation to socioeconomic and demographic changes occurring at the same time.

First, the original occupants of the flooded region, expelled by the project, must bear the consequences of abandonment of crops, field sites, homes and the local organization of their lives. This is stressful even if new properties, dwellings and economic resources are offered to them so that they can reorganize their existence elsewhere (Schorr, 1984). For example, "Environmental Refugees" numbered about 65,000 in the Itaipu basin (Brazil). The sudden rupture of the economic and social structure of displaced communities risks exposing them, especially the children, to more serious inadequacies than usual as regards nutrition, housing and hygiene, at a moment when health risks will be increased, possibly by rehousing on the shores of the lake, or in the irrigation zone with increased vector density and contact with new immigrants.

Furthermore, other workers go there to take part in building the dam, and the irrigation network, and they are often very numerous. For example, in Itaipu (Brazil), where the number of employees once attained 38,000, the turnover at the end of 1978 was around 2,000 departures and new arrivals per day. Job candidates and their facilities increased the population of nearby villages from three to seven times. These workers and their facilities, sometimes coming from very distant regions, affect the epidemiological situation in several ways:

a) by the introduction of diseases new to the Region;

b) by the introduction of new strains of a parasite, or new vectors of that parasite, possibly better adapted to the ecological conditions which have been created by the water project installations;

c) by the introduction of a population not immune to local pathogens; and

d) by increasing the population density in the transmission foci.

Often reservoirs and irrigated agriculture are implanted in a Region, where formerly there was only stockraising or primitive subsistence farming. New types of employment then become available to the population: as construction laborers; on the lake as fishermen; or in the irrigated fields as agricultural workers, adapting to new techniques involving more contact with water, pesticides and chemical fertilizers.

Figure 5 shows a proposed matrix which can be used in the assessment of potential health risks associated with various types of water resources development (WHO, 1987).

POPULATIONS	HEALTH MEASURES AIMED AT													
	VECTOR-BORNE DISEASES					OTHER DISEASES					GENERAL SOCIO-ECONOMIC IMPROVEMENTS			
	Malaria	Schistosomiasis	Filariasis	Arboviral diseases	Others	Diarrhoeal diseases	Nutritional disorders	Parasitoses	Accidents	Sexually transmitted diseases	Education	Housing	Infrastructure	Employment
Original residents														
Construction workers														
Spontaneous migrants														
Downstream residents affected by hydrological change														
Planned settlers														
Migrant populations (f.i., seasonal)														
Adjacent populations														

FIGURE 5
Matrix for the study and assessment of the impact on public health of water resources development projects

Source: WHO, 1987

3. *WATER CONTAMINATED WITH HUMAN WASTE*

3.1 *Water supply and sanitation*

Natural and treated waters vary in microbiological quality. Ideally, drinking water should not contain any microorganisms known to be pathogenic. It should also be free from bacteria indicative of pollution with excreta. The detection of fecal organisms, in particular Escherichia Coli, is taken as definite evidence of fecal pollution in water quality analysis (WHO, 1984).

There are cities in Latin America, including some large metropolitan centers, that have such high average concentrations of coliform bacteria in the raw water of their drinking water sources that populations are still at risk even though drinking water treatment efforts are already being intensified. The concentrations of coliform bacteria in the raw water (surface water) intakes of plants in Buenos Aires, Porto Alegre, Caracas, and Lima exceed an average 100,000 per 100 ml over prolonged periods. A conventional plant cannot treat raw waters with such concentrations and still produce drinking water that meets accepted standards (less than 1 fecal coliform per 100 ml of water treated). For this reason, intense prechlorination is being resorted to. However, this however introduces another risk referred to in Section 5.3 below.

It should be noted that the concentrations of coliform bacteria, referred to above, are also an indication of other dangers. Although coliform bacteria are basically an indicator, there are cases in which they are enterotoxigenic (Sato et al, 1983), inasmuch as high concentrations of these bacteria have been shown to be accompanied by pathogenic bacteria and viruses (Martins et al, 1986). Since the control of drinking water quality is based on tests for probable presence of fecal coliform bacteria in treated water delivered to consumers, the water may be safe in terms of absence of pathogenic bacteria if the standard is adhered to, as has been established time after time in many drinking water supply systems over the decades. Nevertheless, this procedure does not cover certain viruses that are highly resistant even to the high doses of prechlorination used to combat the concentrations of coliform bacteria in raw water.

Information gathered in 1988 as part of the Program on the International Decade for Water Supply and Sanitation shows that in Latin America and the Caribbean urban water supply services through household connections attained 78% coverage of the population, and with the inclusion of public fountains (access within 200 meters of housing), reached 80% of the population. Urban sanitary sewage services reached 48% of the population. In the rural areas, averages are lower: around 55% for water supply and 22% for sanitary disposal of excreta.

These numbers show that progress has been made during the Decade of the 1980s in bringing water to the people. However, it is known that 75% or more of the water supply systems did not disinfect or had serious operational problems that interfered with effective and continuous disinfection. This is all the more serious in the light of fact that it is estimated that at present only some 5-10% of all waste water, including that coming from sewage systems is treated in the Region (PAHO, 1990a).

In the USA, incidents of groundwater contamination and well closures have been increasingly documented over the past several years. In 1984, approximately 4,900 year groundwater supplies (10% of the total) were reported by the states to exceed EPA's standard for microbiological contaminants (The Conservation Foundation, 1987).

3.2 Water-reuse

Untreated waste water disposal constitutes a critical problem in all the countries of the Region. The waste contaminates and damages water courses and also the groundwater which are the sources of drinking water supply for large and small communities. In addition, this water is often used for bathing, pleasure activities, irrigation and to yield fish all of which become much increased potential for ill-health. Also, the increased loading with organic material encourages excessive algae growth, known as eutrophication, which, aside from being unsightly, chokes out all other forms of biological life in streams.

The large scale reuse of untreated domestic sewage for irrigation is commonplace in many arid and semi-arid zones of Latin America, in response to increasing population pressures, water shortages and protein shortfalls. Twenty percent of the land is arid or semi-arid, having only 5% of the water resources of the Region, supports 60% of the population. Rivers which in earlier periods adequately served the inhabitants' water supply, waste disposal and irrigation requirements, today cannot meet these needs. This suggests the suitability of some form of land disposal of waste water and the increased importance of reuse (Bartone, 1985).

However, this practice may pose some health risk for the farm workers and for the general population consuming agricultural produce from sewage reuse sites (WHO, 1989a). High rates of enteritis, other diarrheal diseases, typhoid and hepatitis occur in populations which generate the sewage, and the environmental survival of the pathogenic organisms associated with these diseases is favored by the existing tropical conditions. It is essential that any sewage reuse project have effective sanitary control measures to mitigate potential public health risks.

Some examples of the reuse of sewage in Latin America are:

In Chile, the "Zanjon de la Aguada" irrigation canal receives 80% of Santiago's domestic and industrial sewage and is used together with the polluted waters of the lower Maipo River to irrigate some 16,000 ha of land near the city. Of this, an area of 6,200 ha irrigated with 6 m^3/s of raw sewage supplies the city with horticultural products. There are problems with Salmonella, E. Coli, Shigella, Hepatitis A, Entamoeba histolytica, Giardia lambia, and other pathogens. Salmonella antibodies have been detected in 57% of the population and typhoid antibodies in 30%.

Irrigation District No. 3 near Mexico City comprises 41,500 ha irrigated with raw or mixed sewage. Other irrigation districts near the city also use raw sewage.

Average fecal coliforms in the irrigation water have been measured at 10^8 MPN[1]/100 ml. Edible crops for raw consumption from these reuse sites have been shown to be contaminated with fecal coliforms on the order of 3,000 MPN-E. Coli/10 g.

Along the Peruvian desert coast 33 reuse projects have been identified; many using waste stabilization pond effluents. However, there are some uncontrolled reuse sites in and around Lima which irrigate a total of 2,800 ha with 2 m^3/s of raw domestic and industrial sewage. Peruvian authorities are currently planning the reuse of 4 m^3/s of treated sewage to irrigate 5,000 ha of desert land to the south of Lima.

These and other experiences throughout the Region clearly show that reuse is a reality and that economic demand often creates spontaneous indiscriminate reuse. The responsible public health authorities must anticipate these economic pressures and plan for and implement adequate sanitary control measures. In addition to the risk of microbial contamination by bacteria, virus and parasites, there are potential problems of chemical contamination of edible crops, livestock, dairy products and fish through the bioaccumulation of trace metals and organic toxic substances. Clearly, there is a pressing need for field research aimed at evaluating sanitary control strategies for reuse.

Thus far, no outbreaks of disease have been attributed to waste water land application systems in the USA (Gerba, 1985).

4. WATER CONTAMINATED WITH CHEMICAL SUBSTANCES

The mining and processing of ores and minerals contribute significantly to the pollution load of the water resources of Latin America and the Caribbean in a number of different ways. It is particularly serious in the water deficient areas of Peru and Chile, the two countries with the greatest economic reliance upon mineral production. In many other countries of Latin America, mining is also among the leading industries. Copper, aluminum, silver, gold, tin, chromium, lead, iron, manganese, nickel and zinc are the principal metallic ores being mined. Other minerals which are mined include antimony, arsenic, beryllium, bismuth, selenium and sulfur. Mine drainage and dewatering, mineral tailings and leeching beds, sediment, are the primary causes of water contamination by inorganics, especially heavy metals.

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[1] MPN = Most Probable Number

4.1 *Heavy metal contamination*

Surface water bodies (rivers, streams, estuaries, lakes) may contain heavy metals in solution or in matter suspended in the water. It may be assumed that a contaminant is in solution if it is not retained when the water is filtered by a filter membrane with pores measuring 0.45 um. The principal mechanism of these water bodies for reducing the concentrations of metals is through sedimentation of their suspended solids. Different examples of water contamination by heavy metals are presented in the remainder of this section.

The Rimac River feeds into the La Artajea treatment plant, which supplies approximately 70% of the 6 million inhabitants of metropolitan Lima, Peru. The Rimac River basin descends from an altitude of more than 4000 meters in the peaks of the Andes to Lima, and to the Pacific Ocean in slightly over 100 km in the river's principal course. Numerous mining concentrators, which currently process more than 5000 tons of ore each day, discharge their wastewaters into the river and its tributaries some 80 km upstream from La Atarjea.

The extraction plants are located high in the mountains and have so-called tailing beds, which are sedimentation basins for treating the waters used in extracting metals from the ore. On average, approximately 2.5 m^3 of water is used to process each ton of ore. In the area of the extractor plants there is little space for the tailing beds because of the rugged terrain, and the construction of their retaining walls leaves much to be desired. Sometimes the basins are located in valleys subjected to torrents or flooding caused by thaws and rains. When the processing water leaves the extraction plants there are always concentrations of unrecovered metals, and the tailing beds retain only part of these concentrations, which are finally discharged into the river. A metal that is highly concentrated in the river's water is lead.

For several years SEDAPAL and the Peruvian Ministry of Health have taken samples from seven sampling stations located over 80 km upstream from the treatment plant. The average concentration of lead in the water during the critical low-water periods is approximately 0.15 mg/l of lead. This is more than three times the permissible limit in the standards for the developed countries that have been adopted in the Latin American countries, including Peru.

For the purpose of studying the possible reduction of lead concentrations that could be achieved by pre-sedimenter-regulators, research was performed by CEPIS with the support of SEDAPAL. The results indicated that the concentration of lead is significantly reduced by passing the water through a pre-sedimenter, if it is operated properly (Castagnino, 1989).

A case similar to this one has been resolved in Antofagasta, Chile. The source of supply is located more than 200 km away, high in the Andes, and the water is piped to the city. The Toconce River is the only source, and it was found to have an average concentration of arsenic of 0.8 mg/l (Puga, 1973). This is 16 times the permissible limit for the American States, including Chile (0.05 mg/l). The presence of arsenic in the Antofagasta water supply was causing damage to human circulatory and respiratory systems, as well as foot and nail lesions. In 1970 a water treatment plant was built to reduce concentrations of arsenic through coagulation, flocculation, sedimentation, and filtration, and clinical and epidemiological studies show that it has been effective (Borgono, 1977).

There also are dangerous concentrations of arsenic in Central American waters. The possibility is being studied to treat the waters of Lake Ilopango, which supplies the city of San Salvador. Perhaps useful information about the Antofagasta experience could be furnished in this case.

In the Lagunera Region of Mexico, many towns have been supplied with groundwater that contains 0.20 mg/l of arsenic. This produced skin lesions in a relatively high percentage of the consumer population. Although gold only represents a small portion of mining activity on a weight basis, from a public health standpoint, it is probably the most serious problem due to indiscriminate use of mercury in the separation process. These mercury concentrations are produced through the use of mercuric amalgams, mainly in the Amazon basin, although some of the tributaries in the Plata River basin are also being affected (Eysink, 1988).

In Brazil which presently accounts for almost half of the gold produced in Latin America and the Caribbean, it is estimated that about 300 tons of mercury are used annually for the separation of gold. Figure 6 indicates the primary locations where mercury is being discharged into the aquatic environment. In Brazil, most of this enters the Amazon basin. It is also presently in use in Venezuela and Colombia. On a regional basis, gold production rose from about 54.8 metric tons in 1950 to 147.8 metric tons in 1985. The major gold producing countries (Brazil, Chile, Colombia, the Dominican Republic, Mexico, Peru and Venezuela) account for more than 98% of the total production in the Region.

The problem has increased recently because the separation of gold from the rocks and auriferous sands is no longer done manually. Powerful water jets are now being used to pulverize auriferous cliffs followed by the collection of the sandy waters with suction pumps that direct the waters to inclined chutes with screens and special cloths that hold back the separated gold through formation of the mercury amalgam. Hydraulic excavation of gold placer deposits causes a serious problem with the introduction of massive amounts of sediments in the receiving waters, wrecking havoc with most aquatic life over many kilometers downstream.

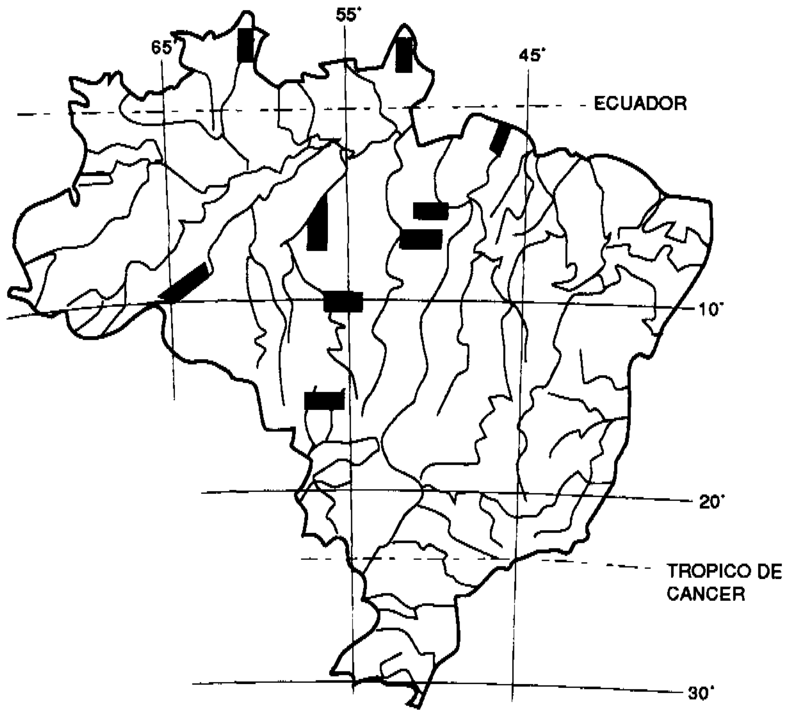


FIGURE 6
Location of major releases of mercury from gold mining activities in Brazil

Although it is difficult to ascertain the amount of mercury that is discharged into the aquatic environment, it is thought to be around 50% of the annual use. Likewise, the degree of methylization in the riparian environment remains to be determined, but is suspected to be considerable because hazardous levels of mercury are being reported and appear to be rising in fish and mother's milk. Cases of neurological effects are increasingly being reported, and are believed to be associated with both exposure to vapors as well as to food. It is estimated that continued uncontrolled discharge of mercury could affect almost a million people in the affected water basins and it has potential to affect far more upon contaminating the marine environment. The potential hazard is mainly among the rural river populations living near the affected water courses (Eysink, 1988).

Gold mining is also carried out in the Department of Madre de Dios in Peru, and, although there is a lack of data, it is likely that the same situation occurs with regard to the concentrations of methyl-mercury in the surface water of the Amazon-Madeira basin.

For more than 50 years waters have been pumped from the Tieté River basin in Sao Paulo to the Billings reservoir. The waters pumped contain a large proportion of wastewater from the industrial park, and from the Sao Paulo sewerage system. However, CETESB (Eysink, 1987) shows mercury concentrations above admissible levels at Billings. Located within the protected area is the intake of the plant that supplies the Sao Paulo industrial districts of Santo André, Sao Bernardo, and Sao Caetano. If the waters from Billings could be used to supply the city, enormous sums of money could be saved that could be invested in increasing the flow to the level that Sao Paulo will soon require.

Concentrations of mercury have also been found on the shores of rivers in Paraguay, but their origin has not been properly investigated (ITED, 1985). It should be noted that the Paraguay River's source is located in the Brazilian Pantanal area, as is also the case for the river's other tributaries. But this is not sufficient to establish a cause-and-effect, especially with respect to heavy metals. It is, therefore, advisable to carry out further research, since the water supplies of Asunción, Formosa, and other cities are involved.

Some water supplies of major metropolitan centers may be cited as cases in which concentrations of heavy metals and other toxic substances from industrial discharges should be assessed. For example, mention should be made of the new drinking water treatment plant in Guadalajara, Mexico, which receives water from the Santiago River, which in turn receives diluted waters discharged by the enormous industrial complex in Salamanca and other towns on the Lerma River. Identified in the National Water Plan and the Urban Development Plan for Mexico, this river constitutes a high-priority basin whose water quality is receiving priority attention from the Ministries of Agriculture and Water Resources, Health and Welfare, Human Settlements, and Public Works.

This situation also potentially applies to the water for the city of Rio de Janeiro, Brazil, from the Guandú plant, which supplies several million inhabitants. The Guandú River is formed by a diversion of waters from the Paraíba do Sul River. More than 4,000 industrial plants in the State of Sao Paulo, and a substantial number in the State of Rio de Janeiro, discharge waste-waters into this river. These industries include to an extensive range of types, and their effluents contain not only toxic metallic substances but also many other kinds of substances, despite the fact that the states involved have required (and this has been largely carried out) the establishment of large-scale wastewater treatment plants.

In the USA, data show that aside from lead, which shows improvement, the trends for many of the other heavy metals in surface waters are deteriorating (The Conservation Foundation, 1987). Arsenic concentrations generally increased from 1974 to 1982, most frequently in the Great Lakes and Ohio basins and in the Pacific Northwest. Generally, little correlation exists between arsenic levels in water and the natural occurrence of this metal in soils and other natural materials. Cadmium measurements also showed predominantly deteriorating trends, particularly in the Great Lakes, upper Mississippi and Texas Gulf regions. For other metals, such as chromium, manganese, selenium, mercury and zinc no significant trends up or down are being reported.

Selenium and arsenic were the metals most frequently reported to exceed US water quality drinking water standards. Mercury levels above the drinking water quality standards were observed in almost one quarter of rural wells nationwide. Cadmium and lead exceed the standard in about 10-15 percent of all measurements.

4.2 Nitrate contamination

Nitrate concentrations are mainly of organic origin and are the consequence of bacterial oxidation of ammonium and other nitrogenous groups. Because of the mobility and persistence of nitrates in groundwater, there are major health hazards in certain aquifers in Latin America and the Caribbean, examples of which are mentioned below.

In the northwestern part of the metropolitan area, in the districts of Tres de Febrero, Morón, and General San Martín, there is a major aquifer, the Puelche formation. These areas do not have sewerage services, and sanitation of houses and small property holdings is accomplished by means of septic tanks and subsurface drainage of the water from the tanks. The effluent from the drainage, with the nitrogenous matter converted into nitrates, infiltrates the water of the Puelche aquifer (see Figure 7 below). Since for the most part these areas have no water supply from a central system with pipelines, the houses are generally supplied by individual wells that tap into the waters of the aquifer. Some beverage and food-processing industries also have private wells that draw on the Puelche waters. More than 800,000 people reside or spend weekends in these districts.

Concentrations of nitrates in some areas of the Puelche aquifer are much higher than the permissible maximum level of 10 mg/l as N, and in Tres de Febrero and Morón they sometimes exceed 60 mg/l. Cases of methemoglobinemia have been confirmed in children.

On islands, such as Bermuda, as well as on certain peninsulas in the Caribbean Sea, there are populated areas without sewerage systems where the wastewater is emptied into unlined pits. The drinking water supply comes partly from rainwater catchment and partly from groundwater which is affected by the practice of disposing the wastewater in the manner described. In certain areas of Bermuda, where the population density is higher, the captured groundwater attains nitrate values much higher than the limit of 10 mg/l.

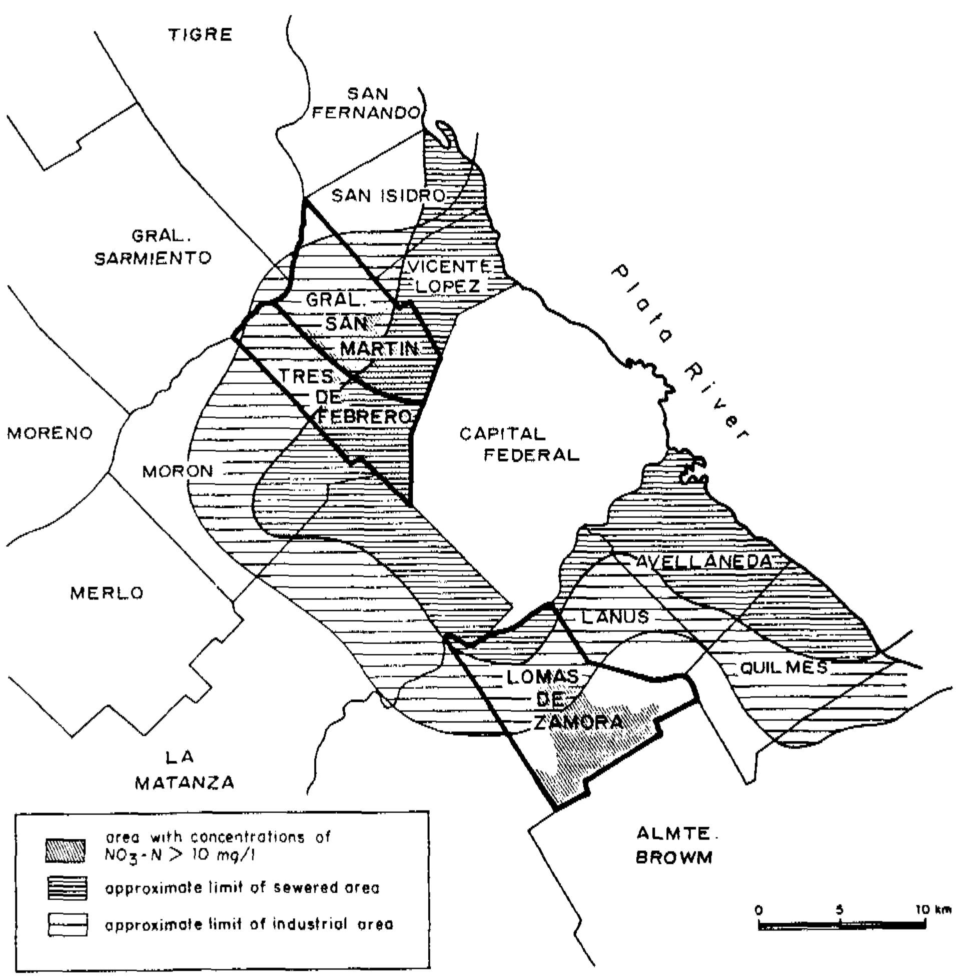


FIGURE 7
Distribution of groundwater nitrate in parts of Greater Buenos Aires in relation to urban and industrial development

Source: Foster et al, 1987

In both these examples and in other cases of health hazards from high concentrations of nitrates in groundwater, the wastewater disposal practices, the recharging of groundwater, the vulnerability of the aquifers to the infiltration of nitrates and other pollutants, and the hydrogeological characteristics of the formations involved should be reevaluated. It should also not be forgotten that irrigation practices and inorganic fertilizers may also lead to this type of pollution.

Nitrates may be the most common groundwater contaminant in the USA. It is estimated that some 20% of wells have nitrate-nitrogen concentrations greater than 3 mg per liter, a level that may indicate contributions by human activities. About six percent of the wells have concentrations exceeding 10 mg/l, EPA's drinking water standard. The most shallow wells (less than 100 feet) are most likely to have elevated nitrate contractions (The Conservation Foundation, 1987).

4.3 Industrial chemicals pollution

A recent USA report on the Toxic Release Inventory, National Perspective states that industrial facilities discharged larger amounts of chemicals to surface water than to land or air in 1987 as shown in Figure 8.

However, as the figure below shows, there are several other ways in which industrial waste streams can be discharged. They can follow entirely different

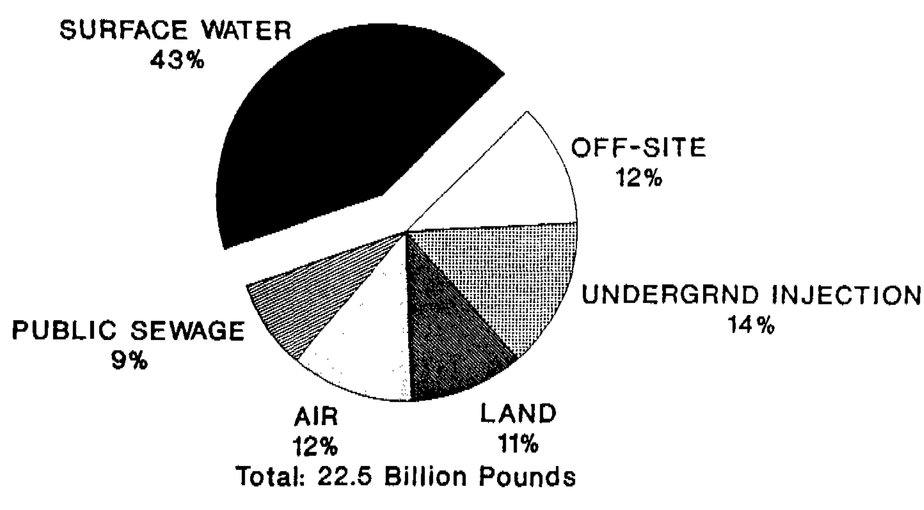


FIGURE 8
Discharges to surface water as a proportion of total releases and transfers, 1987

Source: USEPA, 1989

pathways into other compartments of the environment, such as sewage systems, deepwell or by releases on to land. All of these methods, if not implemented with much care, will result in contamination of drinking water.

Twenty-five chemicals (see Table V), accounted for 99.9 percent (9.6 billion pounds) of the total discharges of chemicals to surface waters. Sodium sulfate above accounted for 94 percent of the total.

TABLE V

Chemicals with the largest surface water discharges in the USA, 1987

Chemical Name	
Sodium sulfate (solution)	Ethylene glycol
Phosphoric acid	Acetone
Ammonium sulfate (solution)	Zinc compounds
Sodium hydroxide (solution)	Formaldehyde
Sulfuric acid	Chloroform
Aluminum oxide	Methyl isobutyl ketone
Ammonia	Manganese compounds
Methanol	Melamine
Nitric acid	Total for mixtures
Hydrochloric acid	Xylene (mixed isomers)
Ammonium nitrate (solution)	Zinc (fume or dust)
Chlorine	1,3 - Butadiene
Arsenic compounds	
Source: USEPA, 1989	

The risk that concentrations of certain chemicals reach levels that maybe harmful to human health is generally speaking quite great. Figure 9 shows the trends for water quality for various parameters, including a number of chemical substances.

Less information is currently available on the presence of toxic substances. However, several studies indicate the existence of a problem. For example, in one study, 41 states perceived toxic materials as a major problem, with at least 14,000 miles of streams and rivers in 39 states, 638,000 acres of lakes in 16 states, and 920 square miles of estuaries in 8 states affected. The National Fisheries survey reported toxic contamination of fish populations in 10 percent of all waters.

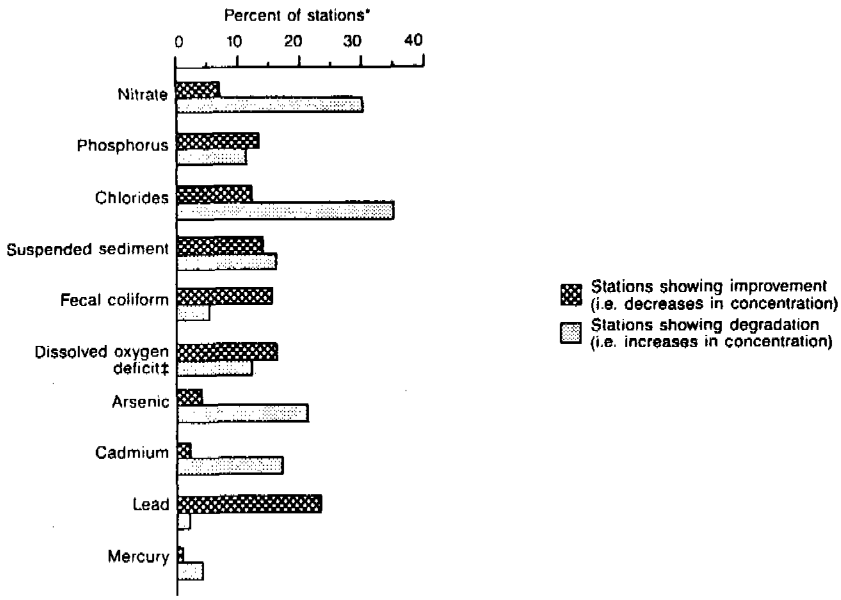


FIGURE 9

Water quality trends in the USA for selected pollutants, 1974-1981

Source: The Conservation Foundation, 1987

In the USA, 175 different organic chemicals have been measured in groundwater supplies (The Conservation Foundation, 1987 and 1987a). Particularly disturbing is the discovery that the concentrations of synthetic organic chemicals in groundwater are often a magnitude higher than those found in water drawn from the most contaminated surface drinking water supplies. For example, concentrations of trichloroethylene in groundwater reach 27,300 parts per billion (ppb), whereas the highest concentration reported for a surface water supply is 160 ppb. Several analyses done of the available data conclude that the contamination of drinking water supplies by toxic organic chemicals is a greater problem for groundwater supplies than for surface water. Solvents such as trichloroethylene, tetrachloroethylene, chloroform, and carbontetrachloride occur most frequently, both singly and together at high concentrations.

In Puerto Rico, a recent survey of synthetic organic compounds in some 240 public water supply bore-holes revealed that more than 3% had concentrations of at least one hazardous compound in excess of 10 mg/l. The most frequent contaminants were the common industrial solvents chloroform, trichloroethylene and tetrachloroethylene. Numerous sources at widespread locations on the island were closed as a result of the survey (Foster et al, 1987).

For Latin America and the Caribbean relatively little information is available on the thousands of organic chemical substances that are currently being used and which, modified or not, are making their way into water bodies. Some of these organic chemicals do not have a toxicity "threshold", which means that theoretically traces would be sufficient to cause adverse health effects. Moreover, even in the case of known chemicals, a monitoring effort would be required, which implies personnel, equipment, and laboratories that in many cases are not available. As a result, only a few cases are mentioned, with the warning that there are undoubtedly other location where the presence of organic chemicals in drinking water sources can represent a serious hazard to health.

Because of their location, it is important to mention the petrochemical complexes that are established upstream from or near water bodies that can affect water intakes. Such is the case in Porto Alegre, Brazil, where despite the complete and even tertiary treatment of wastewater, with final lagoons, the latter is connected to the Caí River, which is one of the tributaries of the Guaíba, where there is a water intake for a large treatment plant that serves Porto Alegre. A similar situation exists in Salvador, Brazil, and perhaps at the complexes in Campana, near Buenos Aires, Argentina, and on the Paraná River in Rosario, Argentina.

Large complexes such as those on the Gulf of Mexico, and on the rivers of the Pacific coast of Ecuador, Peru, and Chile may also have long-term effects on water supplies. The assessment of hazards may be both lengthy and expensive. The location of these complexes is usually dictated by factors such as oil production, transportation, and consumption, but there is no doubt that increased consideration should also be given to the management of health hazards, aquatic biota, and other uses and protection of water bodies that are nearby or affected in some way.

4.4 Herbicide and pesticide contamination

There are no comprehensive studies on the impact of the use of these chemicals on the water resources of the Region, but spot checks and small scale studies indicate it is significant. Case studies on pesticide contamination of rivers is presently underway in Argentina, Brazil and Mexico. In Saint Lucia, a fish tank precedes the country's largest water treatment plant as an indicator of toxic substances in the water to be treated. The water treatment has been interrupted a number of times because of fish kills found to be related to the heavy use of pesticides for the culture of bananas within only a few meters of the water reservoir and its intake. The casual manner in which pesticides are controlled is reflected in the number of pesticide poisonings. In Central America, 1,800 pesticide poisonings annually per 600,000 population were reported when there was only 1 per 600,000 in the United States. In a recent five-year period, there were slightly more than 17,000 medically certified such poisonings in Guatemala and El Salvador alone. In such a serious and dramatic scenario, the less obvious long term chronic health effects of water resource contamination tend to receive secondary consideration.

Pesticides use in agriculture is increasing. Brazil alone consumes about 150,000 tons annually, placing it among the top five users in the world. Some areas of other countries have reached application rates exceeding those of the United States, but generally the use is somewhat less. However, the risk may be much greater because these countries have relatively few restrictions on the use of these chemicals and there is little user education. Only 20% of the products which are banned, withdrawn, or severely restricted, in the United States are subject to any restriction in Latin America and the Caribbean countries. One outstanding example of this tendency is the pesticide dibromochloropropane (DBCP), which is classified by the World Health Organization as extremely hazardous, and which is banned in most developed countries, but continues to be used in Colombia, Costa Rica, Ecuador, Honduras and Panama. Brazil continues to use aldrin, eldrin, ethilic parathion, heptachlor and lindane.

The drainage water from irrigation is usually contaminated with fertilizers, pesticides, and other agro-chemicals, and frequently with dissolved salts. Since most sources for irrigation are contaminated with untreated municipal sewage, both the irrigation water and the return flow usually contain pathogenic organisms. Throughout Latin America, the reuse of irrigation return flow for further irrigation adds contaminants to the water. In arid climates, this practice leads to accelerated salt buildup in the soil, with as much a 30% of the land suffering from salination and drainage problems. Traditionally, organic fertilizers from animal wastes have been used, but the consumption of chemical fertilizers is growing. In Cuba, Dominica, El Salvador, Saint Lucia, and Trinidad and Tobago, it has already reached a level of application similar to developed countries. Its overall use nearly doubled between 1974 and 1984 and this trend will probably continue.

The Corporación de Desarrollo del Guayas (CEDEGE) in Ecuador, with a loan from the IDB, is developing vast irrigation areas (up to 50,000 ha). The large Daule-Peripa dam was built for the regulation of flow, the supply of water for irrigation, the production of energy, and the control of saline intrusion.

Owing to the heavy tides in the Guayas estuary, saline intrusion in this water body would increase the concentration of chlorides in the water intake of the Guayaquil plant to an unacceptable level unless there were a flow of fresh water to control the intrusion. Like any conventional operation of its kind, the Guayaquil water treatment plant cannot reduce chloride concentrations. Calculations made also demonstrated that during critical periods advance treatment plants for wastewater from the Guayaquil sewerage system were not necessary to avoid hazards for the water intake; only smaller plants were needed, to avoid aesthetic damages.

In light of the planned irrigation development in the Daule River basin, the IDB asked CEDEGE to predict the concentrations of pesticides and herbicides that might occur at critical points along the Daule River and in the Guayas estuary, such as the intake of the treatment plant and the inlets to the shrimp culture ponds. Calculations were made of estimated concentrations at the irrigation return flows (results from the experimental parcel are not yet available), and the values are favorable with regard to the protection of aquatic biota. Is not known, however, exactly what the admissible concentration is in the water intakes of the treatment plants. According to information from CEDEGE, at the moment extra heavy flows are being released from the Daule Peripa dam to control intrusion, thereby diluting even more the irrigation return flows that might carry concentrations of pesticides.

It should be noted here that the foregoing is a classic case of conflict in the use of a water body, since it involves competition between drinking water supply, irrigation, and the production of hydroelectric power. The evaluation and management of the hazards for human health should be taken into account in these considerations.

In the USA, monitoring results for pesticides, both organochlorine and organophosphate, and herbicides indicate that fewer than one percent of the water samples showed detectable amounts of these chemicals. The exception was atrazine, which was detected in almost five percent of the samples, and insecticides lindane and diazinon, which were found in one to two percent of the samples (The Conservation Foundation, 1987).

5. *RISK ASSESSMENT AND HEALTH EVALUATION*

There is ample evidence that man himself often creates the basic environmental conditions for widespread occurrence of various diseases, such as diarrhea, malaria, trachoma or illness associated with chemical substances in drinking water, such as methemoglobinemia. Modern techniques and science offer the means to prevent, or at least reduce, the dangers of such conditions provided the health factor is taken into account, and the necessary remedial action integrated into each development scheme.

5.1 *Disease associated with development*

The impact of development related causes of disease and its control techniques are still not fully understood. The reason is that development projects tend to impact quite widely on the local ecological conditions for which formal analytical techniques are still in their formative stage. Table VI provides a global distribution of some of the major vector transmitted diseases that are most often associated with water resources development projects.

TABLE VI
Global distribution of major parasitic diseases associated with water resources development

	Number Endemic Countries	Exposed Population	Infected Population
Schistosomiasis	76	600 million	200 million
Lymphatic filariasis	75	905 million	90 million
Onchocerciasis	34	166 million	25 million
Malaria	98	2,117 million	264 million
Source: WHO, 1989			

The table shows that of all water-related diseases associated with development projects malaria is the most common. Wherever the disease is endemic, it is considered to be one of the most serious public health problems. The risk is greatest in all countries of the Region that are actively promoting economic development projects. Agricultural settlement of new lands and the construction of highways, hydroelectric plants, dams and the like always bring immigrants and workers to areas where living conditions are precarious (WHO, 1987).

The public health problem of malaria in the countries of the Region is influenced by sociocultural factors that are tied to development and to the adverse economic situation. In the past 20 years, the geographic extension of the malarious area has increased as and when new areas have been opened up to development and resettlement. Data show that the Malaria situation worsened during the 1960-1988 period when the estimated population at risk of contracting malaria went from 143.6 million (30% of the total) to 280.7 million (39% of the total) (PAHO, 1990).

The case of Brazil is a dramatic illustration of the effect of man-made environmental change on the epidemiology of vector-borne diseases. As recently as 1970, Brazil reported only 53,000 cases of malaria, but the incidence had risen to 600,000 by 1989. The vast majority of cases came from the Amazon Region. Extensive mining and forest exploitation in Amazonia resulted in rapid immigration of non-immune people from malaria-free areas. For example, the population of Rondonia doubled to more than two million people between 1975 and 1985. Subsequently, many of the immigrants returned to their homes, reintroducing the infection into areas previously cleared of malaria. When these "extra Amazonian" cases were investigated, only seven percent were found to be due to local transmission. In all, 26 foci of malaria were established in the country (Cruz Marques, 1987).

The Brazilian experience exemplifies the role that changing human ecology has had on the local resurgence of malaria. It also indicates the difficulty of developing the health services required to keep pace with such rapid human changes. The government of Brazil is negotiating a large loan with the World Bank (in the order of $400 million) to address the malaria problem in Amazonia and its reintroduction into formerly cleared sections of the country.

The movement of refugees, displaced persons, and workers engaged in socioeconomic development projects has contributed to increases in the incidence and spread of the disease. In general, malaria mainly affects territories in, or adjacent to, the Amazon basin in Brazil and the surrounding countries of Bolivia, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, and Venezuela. These areas share similar geographic and ecological characteristics, as well as risk factors related to socioeconomic development, such as migration and land colonization for the extension of the agricultural frontier, road building and stock raising, mining and urban development projects, see example in Table VII below.

TABLE VII
Influence of the Trans-Amazonia road on the distribution of malaria prevalence

State	Prevalence of Malaria % positive blood examination	
	Trans-Amazonia road area	Other areas of the State
Maranhao	12.3%	5.0%
Para	14.5%	3.9%
Amazonas	17.7%	7.4%
Acre	22.8%	1.9%

Source: Situacao de saude na area da influencia de hidrelectrica de Itaipu (Unpublished document, Ministry of Health (SUCAM), Brazil, 1976)

Major malaria prevention and control activities are concerned with the diagnosis and treatment, as well as various environmentally oriented measures, such as spraying with pesticide and management of the environment through small and large-scale engineering modifications that aim at the reduction of mosquito breeding sites.

Schistosomiasis ranks among the other important public health problems in the Region that is connected with water resource management. In recent years, the incidence and prevalence of schistosomiasis has decreased in some parts of the Region, while in others this endemic parasitic disease has become more widespread. The latter is due mainly to large-scale hydroelectric and agricultural irrigation projects, many of which involve the creation of artificial water resources, and to associated increases in population numbers and massive population movements.

The control of schistosomiasis and limitation of human contact with water requires an integrated and multisectoral approach to overcome logistic, economic, and cultural problems. Two of the more important of these health interventions are reducing fecal contamination of the soil, thereby, avoiding snail infection by reducing the number of viable eggs in the soil, and adequate design and epidemiological surveillance of irrigation projects which represent a high risk for the establishment of new foci of transmission.

Onchocerciasis is a vector borne infection that occurs in circumscribed areas of Mexico, Guatemala, Venezuela and Colombia; possibly other foci exist as yet to be discovered. The most serious onchocercal lesions lead to eventual impairment of vision and ultimate blindness. In Mexico and Guatemala, infections occur mainly among the workers in the coffee growing areas.

Common to all species of this vector is their requirement for fast flowing or turbulent water for the development of their aquatic stages. Particularly favorable conditions are, therefore, found at waterfalls, rapids, spillways, etc.

Jungle yellow fever in the Americas, although not normally associated with large bodies of water, continues to be a problem, mostly in Bolivia, Brazil, Colombia and Peru. Migrating workers recruited from non-endemic areas to work in areas of yellow fever comprise most of the victims, particularly in Bolivia and Peru. The disease occurs at the highest frequency during the late rainy season when mosquito populations are high and people are engaged in clearing forests in preparation for planting.

No cases of urban yellow fever have been reported on the South American continent for many decades. However, the situation is aggravated by the recent introduction of Aedes albopictus, a vector that, due to its habitat choices, could serve as a bridge between the jungle and urban areas (PAHO, 1990).

Dengue has had a major impact in the Americas, especially during epidemic periods when hundreds of thousands of people are affected by the disease. To date, the spread of dengue has not been directly linked to water resource development projects, but populations of the vector, Aedes aegypti, are certainly influenced by settlement patterns in populated tropical areas where there is little distinction between rural-agricultural practices and associated human populations in small urban conurbations, see Figure 10 below.

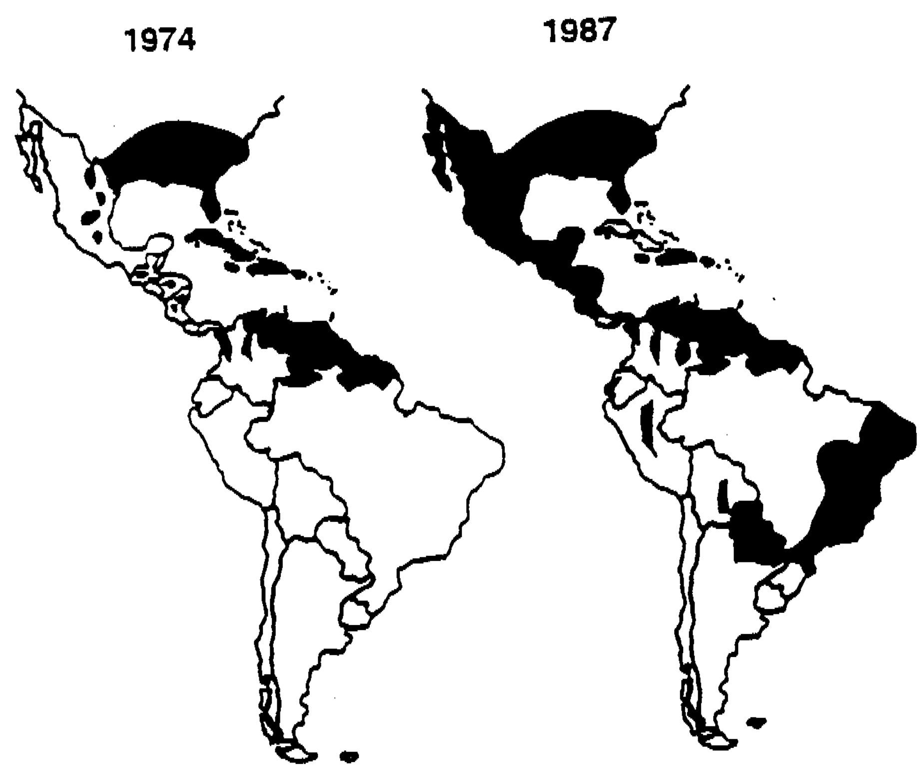


FIGURE 10
Distribution of Aedes aegypti, principal vector of Dengue in the Americas

Source: PAHO, 1989

In the Table below, some recent epidemics of Dengue are listed for selected countries in Latin America.

Dengue (epidemic): 350,000 cases in Havana 1981
400,000 cases in Guayaquil 1988
500,000 cases in Rio de Janeiro 1987
160,000 cases in Santa Cruz, Bol 1987

Climate changes are expected to develop over the next several decades, which will among others cause changes to natural ecosystems affecting such aspects as food production and vector borne diseases. The possible effects of climate change on vector-borne diseases can best be analyzed through epidemiological models. An example of this type of analysis is presented in Table VIII.

Slow climatic changes are also accompanied, as feared by an increase, at least in intensity of some natural disasters, such as cyclones and floods. Such catastrophes can generate large refugee and population movements with the concurrent need for resettlement in what may already be densely populated areas.

TABLE VIII
Global status of major vector-borne diseases

No.	Diseases	Populations at risk (millions) a/	Prevalence of infection (millions)	Present distribution	Possible change of distribution as a result of climatic change b/
1.	Malaria	2,100	270	tropics/ subtropics	+++
2.	Lymphatic filaria-ses	900	90.2	tropics/ subtropics	+
3.	Onchocerciasis	90	17.8	Africa/ L. Americ	+
4.	Schistosomiasis	600	200	tropics/ subtropics	++
5.	African typanosomiasis	50	(25,000 new cases/ year)	tropical Africa	+

No.	Diseases	Populations at risk (millions) [a]	Prevalence of infection (millions)	Present distribution	Possible change of distribution as a result of climatic change [b]
6.	Leishmaniases	350	12 million infected + 400,000 new cases/ year	Asia/ S. Europe/ Africa/ S. America	?
7.	Dracunculiasis	63	1	tropics (Africa/ Asia)	0
	Arboviral diseases				
8.	Dengue			tropics/ subtropics	++
9.	Yellow fever	no estimates		Africa/ L. America	+
10.	Japanese encephalitis	available		E/S.E. Asia	+
11.	Other arboviral diseases				+

[a] Based on a world population estimated at 4.8 billion (1989).
[b] 0 = unlikely; + = likely; ++ = very likely; +++ = highly likely; ? = not known.

Source: WHO 1990

5.2 *Disease associated with inadequate sanitary protection*

Waterborne diseases are largely associated with inadequate sanitary protection as a result of which pathogenic organisms, such as bacteria, viruses, protozoa and parasitic worms, that are almost always present in domestic sewage, are ingested. The ingestion occurs mostly either directly from drinking contaminated water, or indirectly from the consumption of crops, such as raw vegetables, that have been irrigated with contaminated water. Other pathways of ingestion are by depositing sewage sludge in the land, or by eating meat from animals who fed on contaminated crops.

In Table IX below, an overview is presented of the various types of organisms that can occur and the associated diseases caused.

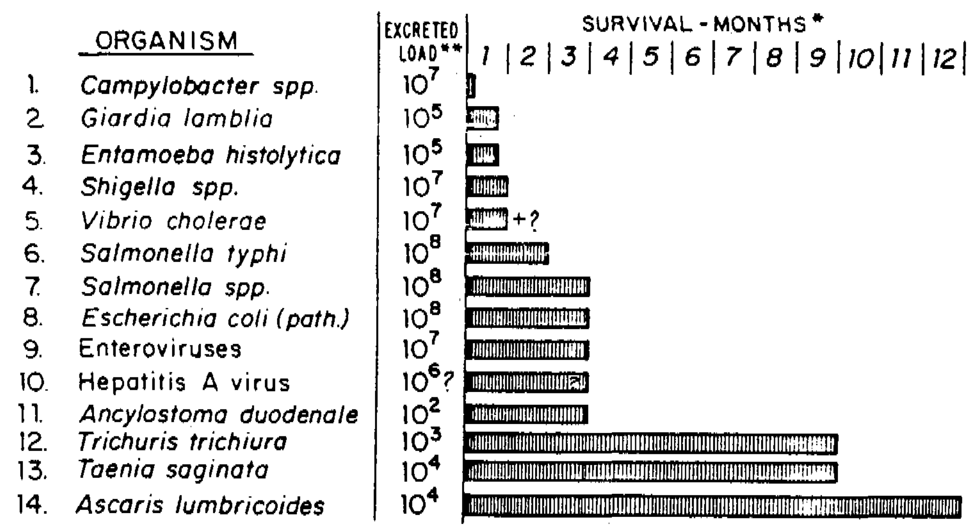
TABLE IX
Bacteria, parasites and viruses in human waste

Group	Pathogen	Disease Caused
Bacteria	Salmonella (1700 types) Shigella (4 spp.) Enteropathogenic Escherichia coli Yersinia enterocolitica Campylobacter jejuni Vibrio cholerae Leptospira	Typhoid, Paratyphoid, Salmonellosis Bacillary dysentery Gastroenteritis Gastroenteritis Gastroenteritis Cholera Weil's disease
Protozoa	Entamoeba histolytica Giardia Lamblia Balantidium coli	Amoebic dysentery, liver abscess Colonic ulceration Diarrhea, malabsorption Mild diarrhea, colonic ulceration
Helminths	Ascaris lumbricoides (Round worm) Ancylostoma duodenale (Hookworm) Necator americanus (Hookworm) Taenia saginata (Tapeworm)	Ascariasis Anemia Anemia Taeniasis

Group	Pathogen	Disease Caused
Virus		
	Enteroviruses:	
	Poliovirus	Meningitis, paralysis, fever
	Echovirus	Meningitis, diarrhea, rash, fever, respiratory disease
	Coxsackievirus	Meningitis, herpangina, fever, respiratory disease
	Coxsackievirus	Myocarditis, congenital heart anomalies, pleurodynia, respiratory disease, fever, rash, meningitis
	New enteroviruses (Types 68-71)	Meningitis, encephalitis, acute hemorrhagic conjunctivitis, fever, respiratory disease
	Hepatitis Type A (enterovirus 71?)	Infectious hepatitis
	Norwalk virus	Diarrhea, vomiting, fever
	Calicivirus	Gastroenteritis
	Astrovirus	Gastroenteritis
	Reovirus	Not clearly established
	Rotavirus	Diarrhea, vomiting
	Adenovirus	Respiratory disease, eye infections
Source: Gerba, 1985		

It should be emphasized that not all these organisms may be present in a given location. Also, the number present varies from community to community depending upon the level of urbanization, population density, sanitary habits, season of the year and rates of disease in the community. However, their concentrations are sufficiently high and their persistence in a generally unfavorable environment with sunlight and drying is sufficient to theoretically allow for the infection of exposed population groups. Figure 11 provides the estimated average persistence of selected enteric pathogens which shows that most can survive for weeks or even months.

However, infection of humans does not result from the mere presence of pathogens in the water or on edible crops. A number of intervening factors operate which control the possibilities of human infection. The minimal infective dose of a pathogen required to cause infection or human disease varies greatly. Some, such as helminths and viruses can cause infections, in a susceptible host, by a single organism, while others, such as Salmonellae will cause infection or disease only if many millions of organisms are ingested.



* Estimated average life of infective stage at 20°–30°C
** Typical avg. number of organism/gm feces

FIGURE 11

Persistence of selected enteric pathogens in water, wastewater, soil and on crops

Source: Gunnerson et al, 1985

Diarrheal diseases constitute one of the most important health problems affecting the child population. The prevalence of these diseases is closely associated with the level of development. Thus, there are countries in the Region where they rank among the first five causes of death in infants under one year, and constitute the highest ranking cause of death in children aged one to four years. In developed countries of the Region, on the other hand, diarrheal diseases are no longer among the first five causes of death in either of the two age groups. These observations are illustrated in Table X.

TABLE X
Percentage of deaths[a] due to diarrheal disease in children under 5 years, in selected countries, around 1986

Country	Under 1 year	1 to 4 years
Canada	0.1	0.5
Brazil	17.8	14.5
Chile	3.7	2.2
Cuba	4.2	2.5
Ecuador	20.9	31.4
El Salvador	16.9	30.9
Guatemala	12.9	35.6
Paraguay	21.3	35.0
Peru	18.2	25.3
United States of America	0.3	0.2

[a] The percentage is based on the total number of deaths from defined causes in each age group

Source: PAHO (1990)

Progress has been made during the 1980s in the reduction of both mortality and morbidity due to intestinal infections. However, the percentage reductions generally appear to be larger for the developed countries. In spite of this improved clinical management of children with diarrhea through emphasis on the early use of oral rehydration and appropriate nourishment appears to be making an impact.

From 1984 to 1987, the rate of oral rehydration therapy grew from 12% to 39% in the Region.

Infant and child mortality can be reduced by more than 50% and one-quarter of all diarrhoea episodes may be averted by improving water and sanitation conditions. These reductions have been quantified in a recent review of all available studies relating to water and sanitation improvements to diarrhoeal disease morbidity and infant and child mortality. The results are shown in the following table.

TABLE XI

Health impacts from improvements in water and sanitation

Health Indicator	Number of Studies	Median	Upper Range
Diarrhea incidence	55	26	68
Diarrhea mortality	3	65	79
Total child mortality	9	60	91
Source: Esrey, 1990			

Another problem in the indiscriminate use of raw waste waters in the irrigation of crops for human consumption which results in notoriously high morbidity - mortality rates due to gastroenteritis, dysentery and helminthiasis. A sample of some data collected during a study carried out in Peru on the analysis of selected vegetables commercialized in the markets for the presence of protozoa and helminths is shown in Table XII below.

TABLE XII

Protozoa and Helminth presence in vegetables from Lima markets, April/June 1987

Vegetables	Number of Samples	Protozoa (%)	Helminths (%)
Lettuce	73	36.96	17.80
Spinach	73	34.22	15.05
Parsley	73	42.43	9.58
Coriander	73	36.96	8.21
Radish	73	35.59	8.21
Source: Draft PAHO Document, undated			

5.3 *Disease associated with exposure to chemical substances*

As reported in Chapter 4, many chemicals have been detected in surface and underground water. A number of these have been designated as hazardous (Grisham, 1986). Annex II shows a list of general categories of substances considered hazardous. Determination of the potential extent or magnitude of the threat, and of the probability that the health effect will ensue, depend on the exposure conditions, i.e., contact with the chemical by humans, and by which route(s). For the purpose of assessment, chemicals in drinking water may be classified into two categories (de Koning, 1987).

(i) Substances exerting an acute and/or toxic effect upon consumption; the severity of which mounts with increasing concentration. However, normally below a certain threshold, no effects are observed. Various metals, nitrates and cyanides fall within this category.

(ii) Genotoxic substances which cause health effects, such as carcinogenicity, mutagenicity and birth defects. For these, substances no threshold exists. Synthetic organics, many chlorinated organic substances, some pesticides and arsenic fall in this category.

There are literally thousands of different chemical substances that may occur in surface and groundwater as a result of man's industrial and other activities.

Fortunately, a much smaller number occurs usually in detectable quantities for which some information on associated health effects can be assembled from the scientific literature. A compilation of the most likely routes of chemical exposure associated with specific organ systems, liver, reproductive system and fetus, hematopoietic and lymphatic system, genitourinary system, lung and respiratory tract, gastrointestinal tract, cardiovascular system. These are tentatively ranked with the skin and central nervous conditions being judged to be the most likely effects from direct contact with chemicals, whereas hepatic, hematopoietic, renal, reproductive and CNS effects seem to be the most likely indicators of chronic low dose exposure from ingestion.

Although measurements to date have been relatively crude, exposure to organic chemical-contaminated water appears to be associated with a small but significantly increased risk of bladder, colon, and rectal cancer. Large case-comparison and cohort studies are needed because of the low frequency of these disease endpoints. Definitive questions about these and related issues are proposed for cooperative effort and resolution by water chemists, engineers, and epidemiologists (Erisham, 1986).

The adverse effects of different classes of chemicals on human health, such as biological, inorganic and organic chemicals are reviewed periodically in the supporting documentation for the establishment of drinking water quality standards and guidelines, i.e., WHO, 1984. As an illustration, guideline values for DDT are derived from the acceptable daily intake values set by the FAO/WHO Joint Expert Committee on Pesticide Residues; 1% of the ADI has been adopted as the basis for values in drinking water. Estimates of potential carcinogenic risks to the recommended values indicate that they are unlikely to result in an incremental cancer risk per life time exceeding one per 100,000 of the population.

Because of the threat posed by excessive average concentrations of coliform bacteria for the water intakes of treatment plants in large cities such as Buenos Aires, Porto Alegre, and Caracas, it was indicated that heavy prechlorination was used because conventional treatment cannot reduce the bacterial concentrations in the runoff water sufficiently to comply with accepted quality standards for drinking water. In these cases the raw water usually contains alkanes or methanes which together with the chlorine form so-called halomethanes. These halogenated hydrocarbons, the most conspicuous example of which is chloroform, are highly toxic. Accepted standards require values lower than 0.35 mg/l. Investigations conducted with Obras Sanitarias de la Nación authorities in Buenos Aires revealed the presence of halomethanes in the water produced at the General San Martín plant. The situation improved when the practice was changed to add the chlorine after flocculation and sedimentation. However, non-chlorinated groundwater is by no means free of organic chemicals either, as is shown by data collected in the USA in Table XIII.

TABLE XIII
Some organic chemicals detected in USA groundwater wells used for drinking water

Chemical	Maximum Concentration Reported (ppb) *	Location *	Evidence for Carcinogenicity **
Acetone	3,000	New Jersey	NR
Benzene	330	New Jersey	Group 1 (1982)
Bromoform	20	Delaware	NR
Butyl benzyl phthalate	38	New York	Group 3 (1982)
Carbon tetrachloride	400	New Jersey	Group 2B (1982)
Chloroform	490	New Jersey	Group 2B (1982)
Chloromethane	44	Massachusetts	NR
Cyclohexane	540	New York	NR
Dibromochloropropane (DBCP)	137	Arizona	Group 2B (1979)
Dibromochlorophropane	55	New York	NR
1, 1-Dichloroethane	7	Maine	NR
1, 2-Dichloroethane	250	New Jersey	Group 2B (1979)
1, 1-Dichloroethylene	280	New Jersey	NR
1, 2-Dichloroethylene	323	Massachusetts	NR
Dichloromethane	3,000	New Jersey	Group 3 (1982)
Di-n-butyl phtalate	470	New York	NR
1, 4-Dioxane	2,100	Massachusetts	Group 2B (1982)
Ethylbenzene	2,000	New Jersey	NR
Ethylene dibromide (EDB)	300	Hawaii	Group 2B (1982)
bis (2-Ethylhexyl) phthal-ate	170	New York	NR
gamma-Hexachlorocyclo-hexane (Lindane)	22	California	Group 2B (1982)
Isoprophyl benzene	290	New York	NR
Parathion	4.6	California	NR
Tetrachloroethylene	1,500	New Jersey	Group 3 (1982)

Chemical	Maximum Concentration Reported (ppb) *	Location *	Evidence for Carcinogenicity **
Toluene	6,400	New Jersey	NR
1, 1, 1-Trichloroethane	5,440	Maine	Group 3 (1979)
1, 1, 2-Trichloroethane	20	New York	Group 3 (1979)
Trichloroethylene	27,300	Pennsylvania	Group 3 (1982)
Trifluorotrichloroethane	135	New York	NR
Vinyl chloride	50	New York	Group 1 (1982)
Xylene	300	New Jersey	NR

* As reported in USEOP/CEQ, 1981.

** As reported in WHO/IARC (year listed in parentheses):

Group 1: Sufficient evidence of carcinogenicity in humans.
Group 2A: Sufficent evidence of carcinogenicity in animals, limited evidence in humans.
Group 2B: Sufficient evidence of carcinogenicity in animals, inadequate data in humans.
Group 3: Cannot be classified due to inadequate data.
NR: Not reviewed by WHO/IARC.

Source: Grisham (1986)

Nitrate concentrations in groundwater reserves have been increasing in all parts of the Region, both North and South, giving rise to health concerns (WHO, 1985). Elevated levels of nitrate in drinking water present a health risk to young babies and infants. Low gastric acidity in infants permits the growth of nitrate reducing bacteria in the upper gastro intestinal tract allowing ingested nitrate to be reduced to nitrite. The effect is enhanced in the presence of infection causing diarrhea, which increases the numbers of bacteria that can convert nitrate to nitrite. The nitrite combines with haemoglobin to form methemoglobin which cannot transport oxygen. The infant suffers from cellular anoxia, manifest as clinical cyanosis, when approximately 10 percent of the total haemoglobin has been converted to methemoglobin. Cases of methemoglobinemia have not been reported in areas where the drinking water consistently contains less than 10 mg of nitrate-N per liter.

In Canada, there is no systematic national monitoring system to measure contaminants in drinking water. Various municipal and provincial drinking water monitoring programs exist. These indicate that until relatively recently there was little evidence that drinking water might constitute an importance source of exposure to toxic compounds (Environment Canada, 1977). More recent information (Environment Canada, 1986) indicates that tap water concentrations for Cadmium were below the drinking water guideline (5 ng/l), but that for lead the highest values recorded exceeded the guideline (50 ng/l). Water treatment facilities, serving about 80% of the population, are designed particularly to satisfy bacteriological requirements and do not remove organic contaminants that are of increasing concern.

The situation is somewhat different in and around the Great Lakes Basin Ecosystem. Twenty percent of the globe's entire fresh water is contained in this system which is the source of drinking water to some 40 million Americans and Canadians. One out of three Canadians in fact draws his (or her) drinking water from the Great Lakes. Citizens in the Great Lakes Basin have used the lakes for many purposes over the centuries: drinking water, boating, swimming, fishing, shipping, industrial processing and disposing of wastes. The environmental quality of the lakes must be maintained or these benefits will be lost. The International Joint Commission, with representation both from the USA, and Canada ensures the preservation of the environmental quality of the Great Lakes Basin. In 1972, the Great Lakes Water Quality Agreement was signed by both countries to restore and maintain the environmental integrity of the Basin.

The lakes are essentially a closed system with less than 1% of the water flowing out of the St. Lawrence River. The risk of contamination levels rising is, therefore, considerable. There are now several ecological indications that show that the water is severely contaminated with organic substances, including Polychlorinated Biphenyls (PCBs). PCBs have been shown to be embryo toxic and teratogenic in animals. In the Great Lakes, fish, birds, reptiles, and small mammals effects such as population declines, reproductive problems, egg shell thinning, severe metabolic changes and immunosuppression have been observed. This threat is posed by continuing exposure to chemicals such as PCBs, dioxin, furans, hexaclorobenzene, DDT and its metabolites, dieldrin, lead and mercury.

The only rigorous study undertaken in humans living in the Great Lakes area was initiated in 1980 (International Joint Commission, 1989). In this study, infants of paired mothers from western Michigan were weighed and measured, and administered psychomotor and behavioral tests soon after birth, at seven months, and at four years. During hospital admission for delivery, mothers were administered a questionnaire concerning various socio-economic and lifestyle aspects, including questions on the history of their consumption of fish from Lake Michigan. The results of the study showed that those mothers who ate about one pound of fish per month gave birth about a week early to babies that weighed less (200-250 g) and had a smaller head (0.3-0.7 cm). The infants had lessened psychomotor development. These changes were correlated with the amount of PCB in the mother's blood and in umbilical cord blood. Subsequent testing into early childhood showed that these children did not catch up with their peers in terms of growth or mental abilities.

In view of the considerable risks posed by the environmental condition of the Lakes a major effort is underway to bring the situation under control. There is in fact evidence that for some contaminants, levels are declining in selected areas. Also, protective measures have been introduced to protect the population. For example, a Public Health Fish Consumption Advisory has been issued (Great Lakes Water Quality Board, 1989), which offers advice on the frequency with which fish from the lakes should be eaten and which species should be avoided altogether (Annex III).

6. *MANAGEMENT OF WATER RESOURCES AND WATER QUALITY*

The protection of water resources covers a very wide range of measures ranging from adequate national and regional policies and plans for their equitable and national development, to the prevention of water contamination, and finally the recycling and water conservation measures. The wide range of different institutional and technical issues involved renders the whole matter quite complex to deal with. In this chapter, the subject is divided into four sections: (1) planning of water resources development and impact assessment, (2) cost effective management, (3) control of water contamination, and (4) water reuse and conservation. This classification is only made to facilitate the discussion because in reality these topics are closely related to one another, and are all part of the same process.

6.1 *National water resources plans and impact assessment*

In the past, the common trend in the countries of the Region was to plan water resources development by user sector, especially irrigation, energy generation and the supply of drinking water. Frequently, these plans did not form part of national or regional development plans and did not incorporate environmental protection considerations or promote the multiple utilization of water.

In order to respond to these problems, many countries in the Region are seeking different options for the management, coordination and integration of activities associated with water resources.

In Mexico, for example, following a long process of development, a Commission for the National Water Plan was set up in 1972. More recently, there has also been the establishment of multinational plans comprising the integrated management of large basins, such as, for example, the River Plate Basin with the creation of the Intergovernmental Committee of the River Plate Basin (ECLA, 1990).

A national water plan is a framework made to enable the country to complete or develop the instruments for the coherent, technical and forward-looking planning of the water resource in order to: (a) meet future demands in respect to supply and quality of water for human consumption, (b) ensure the flows and qualities needed for the generation of hydro-electricity, navigation, aquaculture, irrigation, recreation and the sustained improvement of ecosystemic productivity, (c) ensure defence against the destructive action of water and protect water and soil from human action when this is detrimental to these resources.

Some plans also include as objectives a set of measures designed to achieve water management integrated with land and forestry resources, to promote better utilization and preservation of water in each of the user sectors, improve water management, improve the participation of the different sectors of the population in the efficient use of the resource, and intensify research and training in order to deal with aspects of the operation and maintenance of hydraulic works and the handling and conservation of the resources through an adequate organization and training of the users and those who are responsible for assisting them.

The foregoing contributes the basis for strategic decisions regarding the development of the national water policy. The next level down makes practical decisions as to the manner of intervention in the supply and demand which entails a more detailed approach within the context of river basins, leading to the identification and formulation of water resource development projects.

In the analysis of the supply of surface and groundwater, it is considered that the most important physical features are the following: precipitation, available run-off, soils, discharges into rivers, hydrology and charging of aquifers. A compilation of these data facilitates the identification of actual and potential problems in the short, medium and long-term. The development of water resources is closely related to the social and economic development of the Region, thus, relating it to several other sectorial activities, including drinking water supply, agriculture, energy generation and forestry.

Any attempt to develop water resources results in some modification of the environment. Sometimes the impact is expressed mainly in the river region, aquifer or lake itself as an alteration in the normal flow or the quality of the water body.

In other instances, the effects are much more wide spread and may result in considerable alterations in land resources, forests or fisheries. Beyond this, water development may have major impacts on human settlements and economic activities. The seriousness of these impacts, many of which are irreversible, depends on the ability of the various physical, natural and human systems to absorb them.

Any large development project will change the ecological balance in a watershed and will make its effect known throughout the basin (World Bank, 1990). Particularly far-reaching are the impacts of agricultural development which involve deforestation of large tracts of land, the development of dams and irrigation schemes, as well as the development of roads, towns and industry. From a public health point of view, the new ecological conditions and their repercussions on the sectors and mechanisms of disease transmission take on their full significance when considered in relation to socio-economic and demographic changes occurring at the same time.

The difficulty of aggregating a large number of different factors and associated effects in development projects has led to the development of the Environmental Impact Assessment (EIA) process. EIA is used to identify, predict and assess the likely primary and secondary changes, including in health, that may result from a proposed development or action, and then, as systematically and objectively as possible, present the results for review and decision (see also OAS, 1978). The main classes of human concern that are likely to be affected by a proposed project are listed in Annex IV. It certainly is not exhaustive and should be modified to fit the circumstances of each particular project.

The World Bank and the Regional Development Banks provide loans for development projects at low interest rates and are in the business of getting returns on these loans; therefore, economic viability is an important criterion for project support. Bilateral agencies provide technical collaboration supported mainly by grants with the principal goal of poverty alleviation and sustainable resource development, and they have therefore a special emphasis on social and ecological issues in their project criteria. Most of these agencies have adopted policies which make EIA a compulsory component of pre-feasibility and feasibility studies to be used in financial appraisal and negotiations.

While the introduction of EIA is a favorable change, the current policy framework still fails in most instances to incorporate health protection measures in the construction and operational phases of projects. Among the problems are: (1) attention is still being focussed more on the physical and conservation aspects than on the human dimension, (2) the internal rate of return will be the over-riding criterion of financing agencies in their decision making, (3) many countries dislike the "eco conditionality" of EIA and seek out project financing from agencies with less stringent rules.

6.2 *Cost-effectiveness management*

In terms of the inclusion of health protection measures in water resource development projects, there are two basic types:

(1) Environmental modification which covers lasting physical changes, usually structural engineering works. These changes in principle require high initial capital investment with little or no recurrent cost during the operation and maintenance phase, and

(2) Environmental manipulation measures which involve activities that need to be repeated at regular intervals and, therefore, make the anticipation of recurrent operation and maintenance costs essential.

The balance between capital and recurrent expenditures is of importance with fluctuating discount rates. Variations in discount rate can affect the choice of intervention methods. For example, at low discount rates eradication of Malaria might be considered with high initial expenditure; whereas at high discount rates, costs in the future are given less weight and control becomes preferable.

The foregoing clearly points to the need for experience in economic analysis among those responsible for health programs. If health authorities are to successfully convince those involved in planning, design and financial appraisal of a given water resources development project of the need to incorporate environmental measures as health safeguards, then they will have to be able to collect data on cost and effectiveness, analyze them, and present them in a way that is acceptable to the water resource authorities (Bos, 1991). This implies a need for standard methodology of cost-effectiveness analysis adopted to the requirements of disease control in relation to water resource development schemes, as well as other types of development projects.

An important point to be made here is that applications for financing of water resource development projects should conform with national regulations for health prevention. Capital costs of the care infrastructure made necessary by the project, such as buildings, clinics and outpatient facilities should be included in the cost of the project. Finally, recurring costs for health services, screening, treatment, vector control, and health education should be included in standard budget planning for the scheme. These funds should be derived directly or indirectly from the gross income of the scheme. Recurrent costs should also include the cost of regular health surveillance and evaluation.

The foregoing discussion on the strengthening of the health care infrastructure in relation to a large scale development project underlines the need for more permanent institutional arrangements for the management of the basin as a whole

(Schorr, 1984). Two models appear to be most favored. The first one of these concerns setting up a separate organization, such as, for example, the Tennessee Valley Authority (TVA) which operates as an independent Regional Development Agency, thus limiting interdepartmental conflicts. The other model involves the organization of a functional network among existing entities in the relevant sectors and to further strengthen them (WHO, 1987). Under this arrangement, some form of National Water Resources Development Agency is usually produced which coordinates (and possibly integrates) the activities of the national agencies in matters related to water resources development.

Both of the models described briefly in the previous paragraph have advantages and disadvantages (see also UNEP, 1989). The more integrated TVA-type model is probably more favorable in that it provides a stable long-term framework for development. Particularly in developing countries this aspect is important since a large part of the financial resources may come from abroad and a stable long-term infrastructure is required long after the construction of certain works is completed to maintain and prevent it from becoming a health hazard. For example, in the Tennessee Valley, a program of shoreline maintenance for all reservoirs. This included mowing and brush cutting and maintenance of drainage ditches to eliminate vegetation favorable to mosquito breeding.

Generally speaking, there are two categories of environmental management measures which can safely be claimed to be more cost-effective than others: those measures which have a dual effect and measures that can be incorporated in a project at zero cost.

Dual benefit measures, may, for example, improve agricultural production in addition to reducing vector born diseases. There is an important linkage between improved water management techniques and the reduction of vector breeding sites. For example, measures to conserve water, such as irrigation canal lining or more sophisticated water delivery systems, such as mini-sprinklers or drip irrigation, may at the same time lead to improvement of health status.

Zero-cost measures are basically changes in design or operational procedures. For example, improved dam design, such as the installation of two spillways that can be used alternatively, or the enlargement of drawdown gates to accelerate fluctuations and reduce vector breeding along shallow shorelines, are realistic options in reservoir creation.

6.3 Water quality control

Many aquifers and isolated surface waters contain water of high quality that can be pumped from the supply and transmission network directly to any number of end uses, including human consumption, irrigation and industrial processes. However, such clean water sources are the exception and most of the water supply must receive varying degrees of treatment prior to its use. The impurities in the water are mostly the result of man's activities. Thus, chemicals are introduced from industrial and agricultural activities, pathogenic organisms from human origin, silt and other solids from hydrological works and so on. These factors, together with the end use that is to be made of the water, determine the type and degree of water treatment. The topic of water treatment is extensive and in the remainder of this section a brief summary of the main features of water treatment and wastewater treatment is presented.

Water treatment, which has as its raw material, relatively clean water, is designed to remove odors, color, turbidity, as well as bacteria and other contaminants, from surface water. The treatments involved are:

- Coagulation and flocculation to coagulate naturally occurring silt particles in water,
- Settling to facilitate settling of coagulated particles,
- Filtration to remove impurities and colloidal material, and
- Disinfection to kill remaining bacteria, normally with chlorine.

Wastewater treatment, which has as its raw material water that has been severely polluted by various human activities. The composition of the wastewater can vary considerably. Particularly, the volume and character of industrial waste is important since it can affect adversely the functioning of the treatment plant. Nowadays, there is trend requiring a high level of pretreatment of industrial effluents prior to discharge.

Wastewater treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter, pathogens, and sometimes nutrients from wastewater. General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary treatment. A disinfection step to kill residual pathogens may follow the last treatment step. The individual process and operations commonly used in the various wastewater treatment steps are briefly described in this section. A generalized wastewater treatment flowsheet is shown in Figure 12.

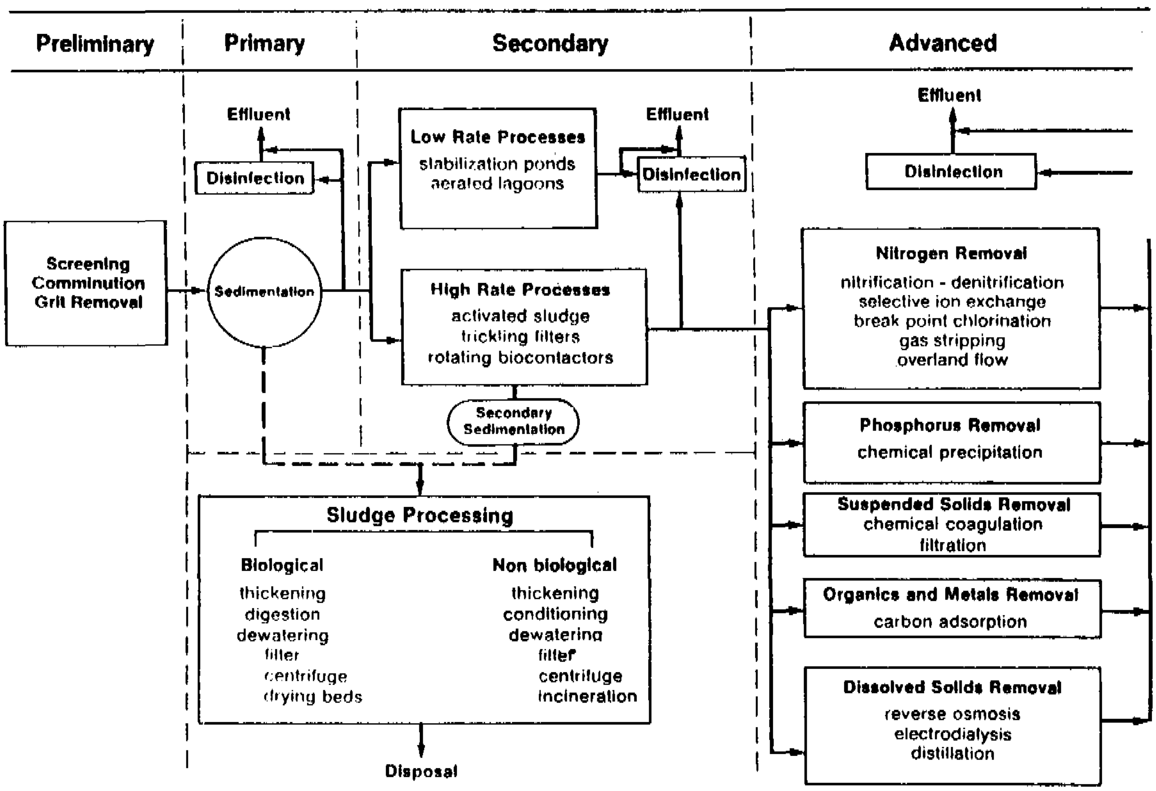


FIGURE 12

Generalized flow sheet for wastewater treatment

Source: Asano et al, 1985

Preliminary Treatment

Preliminary treatment operations include coarse screening, objects, and grit removal by sedimentation. In most small wastewater treatment plants, grit removal is not included as a preliminary treatment step.

Primary Treatment

The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Some organic nitrogen, organic phosphorus, and heavy metals are also removed during primary sedimentation, but colloidal and dissolved constituents are not.

The sludge from primary treatment is most commonly processed biologically by anaerobic digestion. In the digestion process, bacteria metabolize the organic material in sludge, thereby reducing the volume requiring ultimate disposal.

Secondary Treatment

Secondary treatment is the level of preapplication treatment required when the risk of public exposure to wastewater is moderate. In most cases, secondary treatment involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment is performed in the presence of oxygen by microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products. Several aerobic biological processes are used for secondary treatment. The processes differ primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter.

High-Rate Biological Processes are characterized by relatively small basin volumes and high concentrations of microorganisms. The growth rate of new organisms is much greater in high-rate systems because of a well-controlled environment. The microorganisms must be separated from the treated wastewater by sedimentation to produce the clarified secondary effluent. Common high-rate processes include the activated sludge processes, trickling filters or bio-filters, and rotating biological contactors.

Low-Rate Biological Processes are characterized by microorganisms suspended in the wastewater in large basins that are typically earthen ponds or lagoons. The concentration of microorganisms in the basin and their growth rate are lower than in the high-rate biological systems, and the microorganisms are not usually separated from the liquid. In small treatment plants, primary sedimentation prior to low-rate processes is often omitted. Commonly used low-rate biological processes include aerated lagoons and stabilization ponds.

Tertiary Treatment

Tertiary, or advanced treatment, is employed when individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals, and dissolved solids.

Table XIV shows a summary of the literature on pathogen removal by various sewage treatment processes (Feachem et al, 1980). In presenting these results, the authors comment "that talk of percent removal" can be misleading because a 99% removal of pathogens from raw sewage containing 10^5 pathogens per liter, will produce an effluent which still contains 10^3 pathogens per liter." This level may still be of great public health concern, depending on how the effluent is going to be used.

TABLE XIV

*Percent removal of pathogens by various sewage treatment processes**

Treatment	Enteric Viruses	Bacteria	Protozoan Cysts	Helminth Eggs
1. Primary sedimentation	0-30	50-90	10-50	30-90
2. Trickling Filter +	90-95	90-95	50-90	50-95
3. Activated Sludge +	90-99	90-99	50	50-99
4. Oxidation Ditch +	90-99	90-99	50	50-99
5. Waste Stabilization Ponds. Three cells; with 25 days retention	99.99	99.99	100	100
6. Septic Tanks	50	50-99	0	50-90

* Adapted from Feachem et al, 1981

\+ With sedimentation, sludge digestion, and sludge drying

Source: Gerba, 1985

Disinfection

The disinfection process normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the quality of the wastewater required and other factors, but dosages of 5 to 10 mg/l are common. Ozone may also be used for disinfection, but it is not in common use.

6.4 Water economy

Although the Region taken on the whole has a very adequate supply of water, there are now many areas, particularly those that are densely populated and are situated in arid zones, that are experiencing severe shortages. As a result, a trend can be noted from an era of water development to an era of water management.

Population growth and improvement of living standards contribute to the increased demand for water, one of the fundamental conditions for life. Also, in some countries, the demand for industrial consumption will greatly overtake water supply for the population. To offset this increased demand, there is a trend to utilize wastewater for applications that do not require water of the same or of the highest quality.

The reuse of water enables improvement in the water balance of certain areas. It will also allow more natural fresh water to be used for purposes which require higher quality water. Reuse will also decrease the quantity of discharged waste water, thus, helping to protect fresh water from pollution. Other advantages relate to the recovery of arid lands for agriculture, settlement opportunities and creation of recreational opportunities.

In Latin America and the Caribbean, heavy concentrations of people in arid zones lead to the large scale reuse of untreated water containing biological and chemical contamination for irrigation (Bartone, 1990). This practice may pose substantial health risks for farm workers and for the population consuming agricultural produce from such areas. The responsible public health authorities must anticipate these economic pressures, and plan for and implement adequate sanitary control measures for the practice of safe reuse.

The optimal treatment strategy to be followed for wastewater depends largely on the purpose for which the water will be used. If, for example, the water is to be used for agricultural irrigation, the following criteria would apply: (1) maximum removal of helminths; (2) effective reduction in bacterial and viral pathogens; and (3) freedom from odor and appearance nuisance so that the effluent is attractive for agricultural use. A series of stabilization ponds with a minimum of 20 days retention time would be suited to meet all three criteria. The WHO has recently published new public health guidelines for the use of wastewater in agriculture and aquaculture (WHO, 1989 and 1989a).

Before reuse, industrial wastewater must undergo treatment. The degree of such treatment depends on several factors, especially on the origin of the wastewater and its intended reuse. Chemical pollution of wastewater is characteristic for industry. When water is reused, it is impossible to work out standards for tens of thousands of chemical compounds that may be present. Many toxicologists, however, agree that the most harmful substances in industrial wastewater are heavy metals, cyanides and fluorides, organo silicon compounds, crude oils and hydrocarbons (WHO, 1988).

When reused for agricultural purposes, the quality distinctions for treated wastewater are made for fodder, fibre and seed crops, crops eaten cooked, crops eaten raw (not for direct consumption). When reused for industrial purposes, water quality will depend on whether it is used for cooling, steam production, washing and rinsing, or processing operations. Table XV shows the WHO recommendations for the reuse of water for agricultural and industrial purposes.

Considerable reductions in water consumption can also be achieved through recycling, a very special application of water reuse. For example, in the USA, industry as a whole has achieved a water recycling rate of 2.2, which means that water was used an average of 2.2 times before it was discharged. West Germany (before reunification) was reported to have a recycling rate of about 2.0 and in Japan it is 1.5.

As a final comment, it can be stated that there is a great diversity among various types of industry in terms of both the amounts of water needed and its efficient use. A few industries, principally primary metals, chemical products, petroleum refining, pulp and paper, and food processing, those involved for a full two thirds or more of all industrial withdrawals. The specific industrial processes used, heavily influence the amount of water needed. An "inefficient" plant may use up to 20 times more water than an "efficient" one in manufacturing the same product (WRI, 1986).

TABLE XV

Suggested treatment processes to meet the given health criteria for wastewater reuse

	Irrigation			Industrial reuse
	Crops not for direct human consumption	Crops eaten cooked, fish culture	Crops eaten raw	
Health Treatment criteria	**A + F**	**B + F or D + F**	**D + F**	**C or D**
Primary treatment	+++	+++	+++	+++
Secondary treatment		+++	+++	+++
Sand filtration or equivalent polishing methods		+	+	+
Nitrification			+	+
Chemical clarification				+
Ion exchange or other means of removing ions				+
Disinfection		+	+++	+

A - Freedom from gross solids, significant removal of parasite eggs;
B - As A, plus significant removal of bacteria;
C - As A, plus more effective removal of bacteria, plus some removal of viruses;
D - Not more than 100 coliform organisms per 100 ml in 80% of samples; and
F - No chemicals that lead to undesirable residues in crops or fish.

To meet the given health criteria, processes marked "+++" will be essential and those marked "+" may sometimes be required.

Source: WHO, 1973

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ANNEXES

ANNEX I

WATER QUALITY GUIDELINES FOR VARIOUS USES (1)

Water Quality Variable	Drinking Water	Irrigation Water (2)		Livestock Watering	Fish-eries
		No Use Restriction	Severe Restriction		
Microbiological Criteria					
- Total coliforms (per 100 ml)	0-10				
- Fecal coliforms (per 100 ml)	0		< 1,000		
- Intestinal nematodes (per 1)		< 1	< 1		
Particulate Matters					
- Total suspended solids (mg. 1^{-1})					
- Turbidity (NTU)	1-5				*
- Transparency (cm)					*
Organic Pollution Indicators					
- Diss. oxygen (mg. 1^{-1})					*
- BOD, COD, TOC					*
- Phosphate (mg. 1^{-1})					
- Chlorophyll a					
Temperature					*
Nitrogenous Compounds					
- Nitrate-N (mg. 1^{-1})	10	< 5	> 30	100	
- Nitrate-N (mg. 1^{-1})				10	*
- Ammonia-N (mg. 1^{-1})					*
- Kjeldahl-N (mg. 1^{-1})					
Salinity & Specific Ions					
- ph	(6.5-8.5)	6.5-8.4	6.5-8.4		*
- Electrical conductivity Cw (mmho/cm)		< 0.7	3.0		
- Total dissolved solids TDS (mg. 1^{-1})	(1,000)	450	2,000	1,000-10,000	
- Calcium (mg. 1^{-1})					
- Magnesium (mg. 1^{-1})		SAR < 3	SAR > 9		
- Sodium (mg. 1^{-1})	(200)				
- Potassium (mg. 1^{-1})					
Pesticides (ug. 1^{-1})					
- Aldrin/Dieldrin	0.03				
- Chlordane	0.3				
- 2,4 D	100				
- DDT	1				
- Heptachlor	0.1				
- HCB	0.01				*
- Lindane	3				
- Methoxychlor	30				
- TOC1					*

Notes:

*	=	criteria for freshwater fish established
R	=	variable monitored in rivers
L	=	variable monitored in lakes and reservoirs
G	=	variable monitored in groundwaters
SAR	=	sodium adsorption ratio (based upon Ca, Mg and Na
( )	=	aesthetic (organoleptic) quality requirement for drinking water only
(1)	=	Industrial uses are omitted due to the large variety of urequierments
(2)	=	Only indicative - highly dependent on plant species

Source: WHO, 1988

ANNEX II

LIST OF TOXIC OR DANGEROUS SUBSTANCES AND MATERIALS

Acids and/or basic substances used in the surface treatment and finishing of metals
Antimony and compounds
Arsenic and compounds
Asbestos
Beryllium and compounds
Biocides and phytopharmaceutical substances
Cadmium and compounds
Chemical laboratory materials, not identifiable and/or new, with unknown effects on the environment
Chlorinated solvents
Chromium (VI) compounds
Cyanide compounds
Ethers
Isocyanates
Lead and compounds
Mercury and compounds
Metal carbonyls
Organic solvents
Organohalogenated compounds, excluding inert polymeric materials and other substances referred to in this list or covered by other CEC Directives concerning the disposal of toxic or dangerous waste
Peroxides, chlorates, perchlorates and azides
Pharmaceutical compounds
Phenolic compounds
Polycyclic aromatic hydrocarbons (carcinogenic)
Selenium and compounds
Soluble copper compounds
Tarry materials from refining and tar residues from distilling
Tellurium and compounds
Thallium and compounds

Source: Grisham, 1986

ANNEX III

UNITED STATES GREAT LAKES PUBLIC HEALTH FISH CONSUMPTION ADVISORY 1987

There are some sites in the Great Lakes where certain species of fish have been found to be contaminated at levels requiring health advisories. There are listed on the chart below and the precautions noted should be followed in order to prevent or reduce human exposure to potentially toxic materials. It is especially important that nursing mothers, pregnant women, women who expect to bear children and children below age 15 not eat the fish listed below because of the uncertainties over the effect of chemical contaminants on the unborn, newborn or young child.

	RESTRICT CONSUMPTION ## (Important: see note below)	DO NOT EAT
Lake Michigan # (Applies to Michigan, Illinois,Indiana and Wisconsin waters)	Lake trout 20-23", coho salmon over 26", chinook salmon 21-32", and brown trout up to 23"	Lake trout over 23", chinook over 32", brown trout over 23", carp and catfish
Green Bay # (Wisconsin waters south of Marinette/ Menominee)	Splake up to 16"	Rainbow trout over 22", chinook over 25", brown trout over 12", brook trout over 15", splake over 16", northern pike over 28", walleye over 20", white suckers, white bass and carp
Lake Superior (Applies to Michigan, Wisconsin and Minnesota waters)	Lake trout up to 30"	Lake trout over 30"
Lake Huron #	Lake trout, rainbow trout and brown trout	-
Saginaw Bay	Lake trout, rainbow trout and brown trout	Carp and catfish
Lake Erie #	Carp and catfish (New York waters - Eat no more than one meal per month	Carp and catfish (applies to Michigan, Ohio and Pennsylvania waters)
Lake Ontario # (New York waters)	White perch, coho salmon up to 21", rainbow trout up to 25", and brown trout up to 18" (Eat no more than one meal per month)	American eel, channel catfish, lake trout, chinook salmon, coho salmon over 21", rainbow trout over 25", brown trout over 18"
Lake St. Clair	Walleye over 18", white bass over 14", smallmouth bass over 14", yellow perch over 12", carp over 22", rock bass over 8", black crapple over 10", largemouth bass 12-14", bluegill and pumpkinseed over 8", freshwater drum over 12", carp sucker over 18", brown bullhead over 10", catfish over 22" and northern pike	Largemouth bass over 14", muskie and sturgeon
St. Cair River	Gizzard shad over 10"	-
Detroit River	-	Carp

\# Also applies to tributaries into which migratory species enter.
\## Nursing mothers, pregnant women, women who anticipate bearing children, and children age 15 and under should not eat the fish listed in any of the categories listed above.

Source: International Joint Commission, 1989

ANNEX IV

AREAS OF HUMAN CONCERN (IMPACT CATEGORIES)

1.	Economic and occupational status	Displacement of population; relocation of population in response to employment opportunities; services and distribution patterns; property values.
2.	Social pattern or life style	Resettlement; rural depopulation; change in population density; food; housing; material goods; nomadic; settled; pastoral agricultural; rural; urban.
3.	Social amenities and relationships	Family life styles; schools; transportation; community feelings; participation vs. alienation; local and national pride vs. regret; stability; disruptions; language; hospitals; clubs; recreation; neighborliness.
4.	Psychological features	Involvement; expectations; stress; frustrations; commitment; challenges; work satisfaction; national or community pride; freedom of choice; stability and continuity; self-expression; company or solitude; mobility.
5.	Physical amenities (intellectual, cultural, aesthetic, and sensual)	National parks; wildlife; art galleries and museums; concert halls; historic and archaeological monuments; beauty of landscape; wilderness; quiet; clean air and water.
6.	Health	Changes in health; medical services; medical standards.
7.	Personal security	Freedom from molestation; freedom from natural disasters.
8.	Religion and traditional belief	Symbols; taboos; values.
9.	Technology	Security; hazards; safety measures; benefits; emission of wastes; congestion; density.
10.	Cultural	Leisure, fashion and clothing changes; new values; heritage; traditional and religious rites.
11.	Political	Authority; level and degree of involvement; priorities; structure of decision-making; responsibility and responsiveness; resource allocation; local and minority interests; defense needs; contributing or limiting factors; tolerances.
12.	Legal	Restructuring of administrative management; changes in taxes; public policy.
13.	Aesthetic	Visual physical changes; moral conduct; sentimental values.
14.	Statutory laws and acts	Air and water quality standards; safety standards; national building acts; noise abatement by-laws.

Source: WHO, 1983