Other persistent and transient elevations of water pollutants in groundwater and drinking water makes imperative the development of newer techniques to control water-borne exposure to chemicals in agriculture.

2.2.2. BIOLOGICAL POLLUTION OF WATER SUPPLIES

Biological pollution of water supplies used or intended for human drinking water represents the most immediate water-borne threat to human health.

A growing understanding of the epidemiologic characteristics and patterns of disease associated with human pathogens distributed in drinking water has led to the development of a competent infrastructure of potable and waste water collection, storage, treatment, disinfection, and distribution in the urban areas of most developed countries.

As the microbiological integrity of the supply of potable water has improved, a significant reduction in human disease due to water-borne pathogens has occurred. Nonetheless, recent experience pathogens has demonstrated that the potable water supply throughout the world is always at risk.

Serious water borne disease epidemics with recognized and new pathogens continue to occur in immunocompetent and immunocompromised humans in both developed and developing areas of the world.

Acute diarrheal diseases characterised by loose or watery stools are often accompanied by vomiting and fever. Many of these diarrheal episodes are the result of water-borne infection with bacteria, viruses, or parasites, or the ingestion of their enterotoxins.

Cholera, shigellosis, salmonellosis, coliforms, yersiniosis, giardiasis, campylobacter iosis, cryptosporidiosis, and viral gastroenteropathies produce diarrheal signs and symptoms.

Infectious diseases are transmitted primarily through human and animal excreta, particularly faeces. If there are active cases or carriers in the community, then faecal pollution of water sources will result in the causative organisms being present in the water. The use of such water for drinking or for preparing food, contact during washing or bathing, and even inhalation of water vapour or aerosols may then result in infection.

Pathogenic agents have several properties that distinguish them from chemical pollutants:

- Pathogens are discrete and not in solution;
- Pathogens are often clumped or adherent to suspended solids in water, so that the likelihood of acquiring an infective dose cannot predicted from their average concentration in water.
- The likelihood of a successful challenge by a pathogen, resulting in infection, depends upon the invasiveness and virulence of the pathogen, as well as upon the immunity of the individual.
- If infection is established, pathogens multiply in their host. Certain pathogenic bacteria are also able to multiply in food or beverages, thereby perpetuating or even increasing the chances of infection.
- Unlike many chemical agents, the dose response of pathogens is not cumulative.

The human pathogens that can be transmitted orally by drinking-water are presented below.

2.2.2.1. PATHOGEN-CAUSED WATER-BORNE DISEASE

Water-borne bacterial disease includes the most classic infections of large populations: enterocolitis due to coliforms, cholera, typhoid and paratyphoid fevers, shigellosis, and salmonellosis. Campylobacter infections have also become significant in recent years.

CAMPYLOBACTER DIARRHEA

Campylobacter jejuni was responsible for three documented outbreaks of water-borne diarrheal disease in the United States during the 1993-1994 period.

Campylobacter species are believed to cause 5-14% of cases of diarrhea worldwide.

In developed countries, children and young adults have the highest frequency of disease.

In developing coutries, the illness occurs primarily in children under 2 years of age.

The use of unchlorinated drinking water is highly associated with Campylobacter infection.

CHOLERA

Cholera remains a threat throughout the world. A major epidemic of cholera has been in progress in South and Central America for more than five years.

Recent outbreaks of cholera in Ecuador in 1991 with characteristics acute massive diarrhea were demonstrated to be highly associated with the drinking of un unboiled water, the drinking of beverages supplied by street vendors, and eating raw seafood.

Always drinking boiled water at home was protective against the illness, as was the presence of soap in either the kitchen or the bathroom of the home.

A recent large outbreak of cholera in Riohacha. Colombia was directly associated with contamination of the municipal water supply. This outbreak was highly associated with the consumption of unchlorinated and unboiled water from the piped municipal water system.

An epidemic of cholera was recently reported in the montaneous region of the Daghestan. The source of this epidemic was traced to consumption of raw river water massively contaminated with V. cholerae from wastewater effluents.

A major cholera outbreak occurred during the recent civil war and population upheaval in Rwanda.

Management of cholera cases requires strict oral-fecal precautions and other measures designed to confine the spread and mitigate the illness.

Oral rehydration is effective in most areas. Rehydration with polyelectrolyte solution that contains glucose is effective.

Some experienced physicians recommend the use of tetracycline prophylaxis or cotrimoxazole prophylaxis in family outbreaks.

Immunization of contacts is not indicated in epidemic situation. The value of currently available vaccine is not high.

It provides protection only for a brief period, not more than 90-120 days.

Some countries where cholera is endemic continue to require vaccination, but the protective value of the procedure is uncertain.

Prophylaxis must rest on the avoidance of water, food, and contact, as in any oral-fecal transmitted disease.

TYPHOID FEVER AND PARATYPHOID INFECTIONS

Disease due to water-borne Salmonella typhi is quite rare in developed countries. It can usually be associated with a particular food-borne event.

Recent reports of outbreaks of typhoid fever in Spain have demonstrated that despite the important progress in water engineering that has occurred since 1985 in that country, the threat of typhoid fever remains. A major outbreak of typhoid occurred in Bages County, in Catalonia, in the City of Barcelona in 1994. This epidemic was traced to a break in sewer pipes near a drinking fountain. Epidemiologic study of water and biologic markers confirmed the common source outbreak and identified the organism.

In endemic areas where sanitation is poor, many cases occur annually. The disease has a case fatality rate of 10%, although appropriate treatment with antibiotics result in a case fatality rate of less than 1%. 10 percent of patients discharge bacterium for up to 3 months after infection. A chronic carrier state may be established among 2% of cases who become bladder disease seem most likely to develop the carrier state. Available laboratory tests permit identification of the responsible organism and permit distinction between typhoid and paratyphid disease.

Vaccination against typhoid is not generally employed in developed countries. Currently, it is recommended that travelers to endemic areas who have significant potential for exposure due to their occupation be vaccinated. The primary series of inoculations requires two injections, several weeks apart.

Booster doses every 3 years are also recommended. An oral vaccine is available that causes considerably less reaction than traditional injectable vaccine. It appears effective for standard doses of the bacterium, but may not protect against massive ingestions of contaminated water or food.

Treatment of most cases of typhoid fever is readily accomplished with fluid replacement and several antibiotic regimens, including amoxicilin, cotrimoxazole, or tetracyclines.

The emergence of some resistant strains of S. typhi is a continuing challenge.

Usual and customary management may not be effective in cases of typhoid fever due to resistant organisms. In that instance, and for the carrier state, chloramphenicol may be indicated. The use of chloramphenicol carries a significant risk of irreversible aplastic anemia and the drug should be employed only when no other antibiotic is suitable.

Systemic paratyphoid fever occurs frequently, but may not be reported. The case fatality rate is much lower than in typhoid fever. Epidemiologic parameters are similar to typhoid fever. The infections may be due to several different organisms and many phage types. When the infection is confined to the gastrointestinal tract, the illness is more properly called salmonellosis. Chronic carrier states do not occur. No vaccination is available for paratyphoid fever.

NONTYPHOIDAL SALMONELLOSIS

Disease due to nontyphidal salmonella strains occurs frequently but is rarely reported unless very large members of people are involved. Industrial cattle and chicken breeding and food production facilitate the water-borne spread of nontyphoidal salmonella.

In immunocompromised patients, these disorders can be life-threatening, although most patients recover fully without treatment.

SHIGELLA AND OTHER PATHOGENIC BACTERIA

Shigella sonnei and other related shigella strains arte often responsible for diarrheal diseases that occur under adverse conditions. Elsewhere in the world, Shigella dysenteriae type 1 causes large numbers of cases of diarrhea in children who live under crowded and unsanitary conditions and drink water from ad hoc and untreated water supplies. The case fatality rate in S. dysenteriae infection is particularly high in children.

ESCHERICHIA COLI DIARRHEA

E.Coli are frequently responsible for diarrheal episodes. "Traveler's diarrhea" is often the result of E. Coli infection. Most episodes are not etiologically identified, although abnormal coliform counts in water supply during such episodes are the rule rather the exception. E. Coli can cause a variety of syndromes. Water and food are common vehicles of transmission of E. Coli. The gastrointestinal and systemic disease may present in one of five forms:

1. Enterotoxigenic (ETEC);
2. Enteroinvasive (EIEC);
3. Enteropathogenic (EPEC);
4. Enterohemorrhagic (EHEC);
5. Enteroaggregative (EAggEC).

Prophylaxis of "traveler's diarrhea" can be accomplished with bismuth subsalicylate taken orally for several days prior to travel, through the period of travel, and than for 2-3 days after travel is completed.

Adequate fluid intake must be maintained during the use of this medication because of the salicylate load.

Prophylaxis with norfloxacin, 400 mg daily, is also effective. Most often, hydration alone is indicated for treatment of the infection and diarrhea that results. In severe cases, particularly in children, early treatment of infection with cotrimoxazole is also indicated. No vaccines are available.

WATER-BORNE LEGIONELLA ILLNESS

Legionella species have repeatedly been identified as the cause of outbreaks of the respiratory disease known as Legionares' disease. The disease is transmited by water droplets contaminated with the organism. Hot tubs, cooling tower aerosols, air conditioning systems, and other water-facilitated machinery have been the source of the aerosol that carries the pathogen.

Recent reports of major outbreaks of Legionnaires' disease among cruise ship passengers who favored the use of the whirlpool spa, either by immersing themselves in the spa or sitting beside it, have suggested a need to alter the management of water resources aboard cruise ships. In this outbreak, a clear dose-response curve was demonstrated, which associated hours at the spa with risk of Legionnaires' disease.

CYCLOSPORA

Recent reports have associated cyclospora species with outbreaks of food-borne enteritis. The food that carries this emerging bacterial pathogen has variously been identified as strawberries and raspberries.

One outbreak of diarrheal illness in the United States due to cyclospora was traced to the tap water in a physicians' dormitory in Chicago. Whether the organism was locally introduced or entered the tap water from the municipal water supply is unknown.

An outbreak of cyanobacterial illness occurred in Brazil during impoundment of water in a dam building project. It is not clear whether this outbreak was due to cyclospora organism. Another outbreak of cyclospora-caused disease associated with chlorinated drinking water in Nepal was briefly reported in 1994.

2.2.2.2. PROTOZOA-CAUSED WATER-BORNE DISEASE

Among the traditional and emerging water-borne diseases, protozoan-induced illness has become the major threat to human health. While amebiasis, which was once a major cause of diarrheal and systemic disease, is now rare in developed countries, other organisms such as Cryptosporidium parvum and Giardia lamblia now exact a heavy toll.

AMEBIASIS

Amebic dysentery and systemic amebiasis is ubiquitous.

Fortunately, it is now rarely detected in developed countries. Slow sand filtration or its equivalent is required to remove infectious amebic cysts from potable water.

Most infections with ameba are asymptomatic, although severe enterocolitis and systemic disease may occur.

Entameba histolitica is the usual cause of the disease, although other pathogenic ameba are recognized.

Acanthameba and Leptomyxida have not been noted to cause progressive granulomatous encephalitis in immunosuppressed hosts. Five cases of disseminated cutaneous amebiasis without CNS findings were recently noted in AIDS patients.

Other nonpathogenic ameba may be found in the intestine and should not be confused with the pathogenic species. The disease is always water-borne.

Acutely ill individuals are only of limited danger to others because they do not excrete the infectious cysts and the live trophozooite does not survive for a long period in stools, water, or food. Chronic carriers of amebic cysts may pass the cysts for years and are infectious throughout this period.

GIARDIASIS

Giardiasis is a major water-borne protozoal disease. Often reported in cold countries, outbreaks have occurred in Vail, Colorado and Zermatt, Switzerland. Both of these towns are high altitude, winter resorts where water was drawn from cold surface mountain sources believed to be pure. Prior to these outbreaks of disease in the 1970 s, the survival of the protozoan in cold mountain strems was not recognized. Outbreaks have also been experienced in Saint Petersburg, Russia, and other large cities with older wastewater disposal systems. In 1993-1994 in the United States, 75% of the water-borne gastrointestinal disease outbreaks were due either to Giardia or Cryptosporidium.

Recent outbreaks of giardiasis in Canada were shown to be water-borne. Contaminated community drinking water was identified as the source in a community in British Columbia where two successive outbreaks were traced to the

same strain of Giardia by ELISA (enzyme linked immunoabsorbent assay) techniques.

Campers and backpackers who use surface water sources for potable water during their travels should be particularly careful to use filters and treatment systems that are now commercially avilable to remove Giardia organisms from drinking water.

Treatment of giardiasis is effectively accomplished with metronidazole, although the diagnosis is sometimes difficult to confirm by stool examination. Severe diarrhea in a camper or backpacker who has been using surface water for drinking should alert the physician to the possibility of giardiasis. Empiric treatment with metronidazole may then be appropriate.

TOXOPLASMOSIS

Toxoplasmosis has occasionally been demonstrated to have been transmitted through a water-borne route. A report from British Columbia identified the source of an outbreak of toxoplasmosis as a municipal drinking water supply.

2.2.2.3. WATER-BORNE VIRAL DISEASE

ENTEROVIRUS (PICORNAVIRUS)

HEPATITIS A

Water-borne hepatitis epidemics are common throughout the world. In developed countries, hepatitis A is frequently spread from a single case through food-borne means; however, water-borne transmission is reported. Most often, water-borne transmission of hepatitis A in developed countries occurs as a result of sewage contamination of potable water supplies. In less developed countries and in the rural areas of developed countries, water-borne transmission of the hepatitis A and the survivors become immune. In less developed areas, where environmental sanitation is better, a reservoir of nonimmune adults is found, and epidemic disease in adults may be seen.

Identification of the disease is helpful in order to distinguish it from hepatitis E, which has a similar course and indistinguishable epidemiologic pattern.

Hyperimmune globulin has usually been given as prophylaxis if knowledge of an exposure to hepatitis A becomes known and the disease is not yet symptomatic.

The current availability of a well-tested and effective anti-hepatitis A vaccine throughout the world should help reduce the remaining pool of susceptible persons and limit the epidemic nature of the disease.

Travelers and workers who plan to work in areas with high rates of endemic hepatitis a should be vaccinated (in accord with CDC recommendation) long enough in advance of the trip to allow buildup of adequate antibody before departure to the endemic area.

HEPATITIS E

Like hepatitis A. hepatitis E is an enterically transmitted viral infection of the liver. The causative organisms has not been fully characterised, although recent studies identify it as a single strand polyadenilated RNA virus. Hepatitis E disease is often called enterically transmitted non-A, non-B hepatitis to distinguish it from hepatitis A and the blood-borne hepatitis B. It has also been called fecal-oral non-A, non-B hepatitis.

A serologic test to determine the presence of hepatitis E is available.

No specific treatment is available for hepatitis E and no vaccine is yet available. Immune globulin is not currently indicated for prophylaxis of the disease.

Chlorination of water, cannot be relied upon to reduce the risk of water-borne hepatitis virus. Slow sand filtration is required to remove the causal organisms.

OTHER WATER-BORNE VIRAL INFECTIONS

Other viruses have been associated with water-borne epidemics from time to time. Poliovirus, the cause of poliomyelitis, has long been suspect as transmisible through water routes, but little credible evidence has been found to support this view. In 1988, contamination of the drinking water supply of the City of Haifa, Israel with poliovirus was suspected. This led to an immunization campaign but no cases. In the developed world, where wild type poliomyelitis is now virtually eradicated, spontaneous cases of polio are usually associated with vaccines.

Norwalk virus has been identified as a cause of epidemic enteritis, in New South Wales, Australia.

From time to time, many other water-borne epidemics of viral disease occur. The sporadic episodes system in developed countries, and the use of fecally contaminated water in less developed areas for the potable water supply.

2.2.2.4. WATER-BORNE TREMATODE AND HELMINTH INFECTIONS

SCHISTOSOMIASIS (BILHARZIASIS)

Schistosomiasis due to S. hematobium is a major problem throughout Africa. S. mansoni causes the disease in the Arabian Peninsula, South America, some of the Caribbean Islands, and in areas of the Middle East. S. japonicum is endemic in Asia. A number of the other schistosomes are found regionally and locally. A blood fluke (trematode), the schistosome lives in blood vessels of the host for long periods of time.

Three forms of schistosomiasis are recognized: swimmer's itch or cercarial dermatitis, acute schistosomiasis, and chronic schistosomiasis. Chronic schistosomiasis causes severe illness in the host. Bladder, kidney, and other infections have been reported. Fibrosis, granulomas, obstructive uropathy, and bladder cancer may result from schistosomiasis. Bilharziasis, an older name for the same disease, is favoured as the disease designation in South America and in other parts of the world.

The schistosomal infection is acquired from water containing the free swimming larval form, the cercariae. The life cycle is complex, but in most mammals, the eggs leave the host in the urine, hatch in the water, and are then carried in snail hosts. From the snail host, the cercariae are released into water, from which they penetrate the skin of human waders or swimmers and the cycle progresses.

Schistosomiasis is not transmisible from person to person, but infected persons are able to transmit the disease through excretion of infective eggs in urine for a lifetime. Prophylaxis is dependent on avoiding exposure to contaminated water.

Praziquantel is the drug of choise for treatment of all species of schistosome infection. Other drugs are also available and are sometimes effective in treating the disease.

ASCARIASIS

Round worm, or Ascaris lumbricoides, generally causes an asymptomatic infection of the intestinal tract. The organism is ubiquitous. In tropical countries, infection rates of up to 50% have been noted.

Some patients develop pulmonary ascariasis and are symptomatic. Fever, cough, wheesing, and other pulmonary symptoms may occur. Ascariasis may contribute to nutritional deficiency.

Although soil contaminated with the eggs of the worm is the usual mode of transmission, water-borne transmission has also been reported.

Effective treatment is available with mebendazole, although reinfection commonly occurs. Mebendazole is contraindicated during pregnancy. Pyrantel has also been reported to be effective in single doses against Ascariasis. A number of other drugs are also reported to be safe and effective in treatment of the infestation.

2.2.3. EUTROPHICATION

When fresh water is artificially supplemented with nutrients, it results in an abnormal increase in the growth of water plants. This is known as eutrophication. The discharge of waste from industries, agriculture, and urban communities into water bodies generally stretches the biological capacities of aquatic systems. Chemical run-off from fields also adds nutrients to water. Excess nutrients cause the water body to become choked with organic substances and organisms. When organic matter exceeds the capacity of the micro-organisms in water that break down and recycle the organic matter, it encourages rapid growth, or blooms of algae. When they die, the remains of the algae add to the organic wastes already in the water; eventually, the water becomes deficient in oxygen. Anaerobic organisms (those that do not require oxygen to live) then attack the organic wastes, releasing gases such as methane and hydrogen sulphide, which are harmfull to the oxygen-requiring (aerobic) forms of life. The result is a foul-smelling, waste-filled body of water.

Eutrophication can produce problems such as bad tastes and odours as well as green scum algae. Also the growth of rooted plants increases, which decreases the amount of oxygen in the deepest waters of the lake. It also leads to the death of all form of life in the water bodies.

2.3. WATER AND WASTEWATER TREATMENT

Conventional wastewater treatment systems that employ sedimentation, activated sludge, biofiltration, aeration, and oxidation, combined with chemical disinfection, produce water with coliform counts that are very low.

In the absence of disinfection step, low coliform counts may not be achieved.

Without *slow sand filtration* of water and wastewater, protozoa, viruses, and other pathogens may also remain in the finished water.

The use of slow sand filtration should control the water-borne spread of the various hepatitis viruses, including hepatitis E, which is currently a major problem in many parts of the world.

The intensity of water treatment for a particular supply and distribution area must depend on the nature and quality of the source.

The degree of pollution will determine the required treatment.

Multiple treatment barriers are recommended by the WHO for polluted water sources to prevent to spread of pathogens.

The fundamental purpose of water treatment is to protect the consumer from pathogens and impurities in the water that may be unacceptable from a health or estetic point of view.

Tipical treatment processes for urban water drawn from lowland sources include *impoundment* and *reservoir storage*. If needed, predisinfection and storage in reservoirs may result in a 99% reduction in fecal indicator bacteria, salmonella, and enteroviruses.

During storage and impoundment, the microbiologic environment changes as a result of natural sedimentation, the lethal effect of ultraviolet light on the surface layers of the water, the deprivation of nutrients required by the organisms, and predation.

Follwing *impoundment* and *storage*, *coagulation, flocculation* and further *sedimentation* or *flotation* to remove solids are employed. *Filtration* and *disinfection* complete the cycle of typical urban water treatment.

Aeration to improve the aesthetic quality of the final product may also be used.

This typical system meets the multiple barrier requirements of WHO's Water Quality Guidelines of 1993.

In rural and remote areas, multiple barrier concepts may also be used.

Typical protocols dictate impoundment and protection of the water, sedimentation and screening, gravel prefiltration and slow-sand filtration, and a final disinfection step.

The efficacy of these treatment protocols may be expected to be high, and the quality of the finished water is likely to be excellent.

WHO recommends that monthly sampling of public water supplies be performed. The number of recommended samples varies with the size of the water system.

Effective methods of microbiological and chemical treatment and surveillance of water supplies are in place in most public water supplies in developed countries. In less developed and developing countries, and in rural areas of developed countries where raw or untreated water from surface or groundwater sources is used as a potable water, effective control of microbiological water pollution is not always assured. In spite of the technological sophistication of civil engineering of water and wastewater supplies, outbreaks of water-borne disease occur frequently in both developed and developing countries.

On most occasions, epidemics of water-borne disease in developed countries are the result of technical flaws or unusual and unforeseen climatological events that disrupt the normal potable water supplies.

In less developed countries, the ordinary juxtaposition of human residence, agriculture, animal husbandry, and unprotected potable water sources are typically the cause of epidemic water-borne disease.

In some areas, the use of wastewater containing human excreta as agricultural irrigation water greatly increases the risk of pollution of local drinking water supplies and the transmission of enteric and other diseases through the consumption of food crops contaminated with pathogens by this process.

The Engelberg Guidelines for the microbiological quality of treated wastewater used for crop irrigation were developed by the World Health

Organisation (WHO) for use in developing areas where the scarcity of water dictates the reuse of wastewater for agricultural purposes. They are based on extensively studied use of wastewater in agriculture.

They utilise new coliform content guidelines that are higher than coliform counts recommended in the California guidelines, which were developed in the 1940 s By the California Health Department. Based on a "zero risk" concept, the California guidelines permitted only 2 fecal coliforms per 100 ml of irrigation water used on crops eaten row.

Their concept was that the mere presence of coliforms in the irrigation water presented an unacceptable risk of disease.

However, these guidelines were not based on epidemiologic studies of outcome of use of these salad crops.

The Engelberg guidelines suggest that a geometric mean of 1000 coliforms per 100 ml of irrigation water for unrestricted crop use is safe, based on epidemiologic outcome studies. This level is still less than half of that permitted in bathing water in Europe (<2000 fecal coliforms/100 ml).

The guidelines also create, for the first time, appropriate controls on the presence of helminth eggs in irrigation water.

If the Engelberg Guidelines are adhered to, the increased pathogen counts that are permitted are considered to be of little significance.

No adverse health effects or drinking water impacts are expected to result from the use of wastewater, sewage, septage, or sediment for agricultural irrigation. If they are not followed, the use of polluted water and human excreta for food or subsistence crops will lead to human disease and may adversely impact drinking water quality.

The spectrum of infectious diseases appears to be changing. Worldwide, explosive population growth, expanding poverty, urban migration, and increased international travel affect the risk of exposure to water-borne infectious disease.

These emerging diseases include water-borne cryptosporidial diarrheal disease and cholera, as well as hemorrhagic fevers, tuberculosis, and hantavirus.

Abnormal events such as earthquakes, hurricanes, tornadoes, snowstorms, and similar phenomena cause disruption of normal potable water supplies and may result of normal potable water supplies and may result in epidemic disease in humans.

In all such events, incresed surveillance of water supplies and rapid response with appropriate public health measures are indicated. Such responses include "boil water" advisories, temporary shift of water supplies to unpolluted resources, and microbiologic assesment of the supply for viral, bacteriologic, parazitologic, and helminthic contamination.

In addition, facilities and supplies for the immediate assesment and treatment of victims of water-borne epidemics, which may include typhoid, cholera, hepatitis, and other diseases, shoud be prepared and put in place.

General measures for public health action in emergencies caused by epidemics are reviewed in a WHO publication of 1986.