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CHAPTER 2
WATER CONTAMINATION RISKS

2.1. Waterborne Diseases

2.1.1. Waterborne diseases causative agents

Waterborne diseases are generally spread by contamination of drinking water systems by the urine and faeces of infected animals or people.

This is likely to occur in places where public and private drinking water systems get their water from surface waters (rain, creeks, rivers, lakes, etc.), which can be contaminated by infected animals or people. Runoff from landfills, septic fields, and sewer pipes, residential or industrial developments can also contaminate surface water.

This contamination has been the cause of many dramatic outbreaks of faecal-oral diseases such as cholera and typhoid. However, there are many other ways in which faecal material can reach the mouth, for instance through the hands or on contaminated food. In general, contaminated food is the single most common path in which people become infected.

The germs in the faeces can cause a disease by even slight contact and transfer. This contamination may occur due to floodwaters, water runoff from landfills, septic fields, and sewer pipes. The following picture shows the faecal-oral routes of diseases transmission (Fig. 2.1).

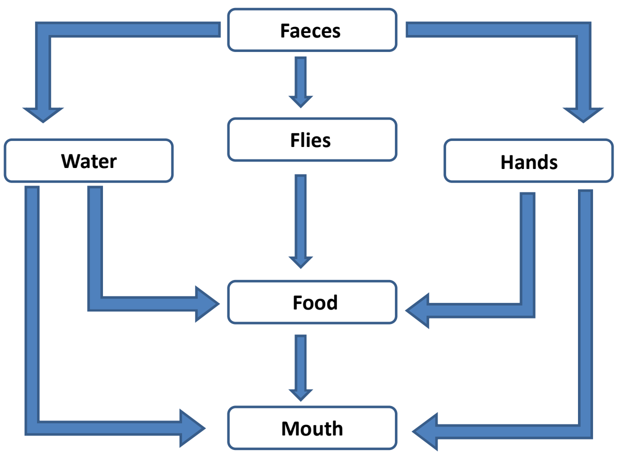

Figure 2.1. Faecal-oral route of disease transmission

The only way to break the continued transmission is to improve people's hygienic behavior and to meet their basic needs of: drinking water, washing and bathing facilities and sanitation. For example, malaria transmission is facilitated when large numbers of people sleep outdoors during hot weather, or sleep in houses that have no protection against invading mosquitoes. Malaria mosquitoes, tropical black flies, and bilharzias snails can all be controlled with efficient drainage because they all depend on water to complete their life cycles.

2.1.2. Prevention

Clean water is a prerequisite for reducing the spread of waterborne diseases. It is well recognized that the prevalence of waterborne diseases can be greatly reduced by provision of clean drinking water and favorable conditions for safe disposal of faeces.

Water is disinfected to kill any pathogens that may be present in the water supply and to prevent them from growing again in the distribution system. Disinfection is then used to prevent the growth of pathogenic organisms and to protect public health; the choice of the disinfectant depends upon the water quality and water supply system. Without disinfection, the risk of waterborne diseases is increased. The two most common methods to kill microorganisms in the water supply are: (i) oxidation with chemicals such as chlorine, chlorine dioxide or ozone, and (ii) irradiation by ultraviolet (UV) radiation (URL8).

2.1.3. Chemical contamination of drinking water

The health risk related to the presence of toxic chemicals in drinking water differs from the risk caused by microbiological contaminants. There are few chemical constituents in the water that can lead to acute health problems apart from the chance of massive accidental contamination of a water supply. Moreover, experience shows that, in such incidents, the water usually becomes undrinkable due to unacceptable taste, odor, and appearance.

New compounds continually enter the environment, either through intended use (such as in pesticides and fumigants), or via industrial, human, or animal waste (such as detergents, pharmaceuticals, antibiotics, and synthetic hormones). Because chemical contaminants are not normally associated with acute effects, they are, unfortunately, placed at lower priority than microbial contaminants, whose effects are usually acute and widespread.

The problems associated with the chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties, and substances that are carcinogenic.

Among compounds found in water that accumulate in the environment and in the human body, the principal ones are:

- nitrate
- fluoride
- toxic metals (lead, cadmium, arsenic, aluminium, etc.)
- bromate and trihalomethanes
- pesticides
- persistent organic pollutants or POPs (PAHs, PCBs)
- metals (As, Pb, Cu)
- hormonal disrupters

However, it is unlikely that all these contaminants occur in all water supplies or even in all countries. For the chemical contaminants, in particular, some factors should be considered, including the geology of the region and the types of human activities that take place (agriculture, industries, etc.).

Pollution of water by metals or persistent organic pollutants (POP) may directly or indirectly, through air and soil, contaminate food.

It should be noted that the use of chemical disinfectants for water treatment usually results in the formation of chemical by-products, some of which are potentially hazardous.

However, health risks owing to these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection should not be compromised in attempting to control the by-products.

2.1.4. Physical contamination

The radiological health risk associated with the presence of naturally occurring radionuclides in drinking water should also be taken into consideration, although the contribution of drinking water to total ambient exposure to these radionuclides is very small under normal circumstances. The guideline values generally recommended do not apply to water supplies contaminated during emergencies arising from accidental release of radioactive substances to the environment.

2.1.5. Microbiological contamination

Over the past century, deaths from infectious diseases borne by water (cholera, typhoid, diphtheria) declined significantly in Europe. However, water pathogens remain a significant cause of illness. In the last 20 years, new germs have emerged as additional threats while diseases once thought to be under control, have become increasingly prevalent. Infections can be rapidly and widely disseminated through water and are particularly threatening to communities that have little or no resistance to them (URL9). Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living in unsanitary conditions, the sick, and the elderly. For these most vulnerable people, the infectious doses are significantly lower than for the general adult population. The potential consequences of microbial contamination are such that its control must always be a priority.

The assessment of the risks associated with variation in microbial quality of the water is difficult and controversial because of insufficient epidemiological evidence, the number of factors involved, and the changing interrelationships between these factors. The greatest microbial risks, however, are generally associated with ingestion of water contaminated with human/animal excreta. There are indicator parameters that corroborate the presence of faecal contamination (total coliforms, faecal coliforms, faecal streptococci), but their absence does not prove the absence of contamination.

Microbial risk can never be entirely eliminated because waterborne diseases may also be transmitted through person-to-person contact, aerosols, and food intake; thus, a reservoir of cases and carriers is maintained. Provision of safe water supply in these circumstances will reduce the chances of spread by the other routes. Waterborne outbreaks are particularly to be avoided because of their capacity to result in the simultaneous infection of a high proportion of the community.

Aquatic environment systems and surface waters contain a great variety of micro-organisms (bacteria, viruses, yeasts, parasites, helminths, etc.), some of which are able to adopt a form that could resist living conditions that would otherwise be unsuitable. Some of these organisms are causative agents (pathogens) of human communicable diseases or such that find the right environment in water for the breeding and propagation of their vectors. For instance, irrigation and drainage project developments create great expanses of water and, provided there are a number of favorable ecological conditions, may lead to the introduction of disease vectors in areas where they have not occurred before, or to a rapid increase in their original density. Wherever a parasite or another disease causing organism is present, and a susceptible human population exists, environmental changes resulting from such projects may have a profound impact on the epidemiology of diseases through their effect on vector *bionomics*.

Typical waterborne microbial diseases and their importance worldwide are summarized in Tables 2.1 and 2.2.

This classification relates to the following conditions responsible for the persistent high prevalence of these diseases:

a) Insufficient water supplies and sanitation, as well as solid waste disposal services. The presence of adequate quantities of good quality water is a prerequisite for satisfactory personal and domestic hygiene. The installation of sanitation and waste disposal measures are equally essential if the standard of living is to rise for the population of an economically successful irrigation scheme.
b) Inadequate housing and lack of good hygienic conditions. The improvement of housing and hygienic conditions is mainly achieved through *education, demonstration,* and *economic changes*.
c) Lack of good healthcare due to economic, managerial or technical reasons. Attention should be given to vaccination of young children who are particularly vulnerable. Preventive medicine measures in addition to curative medicine should be promoted whenever possible.
d) Water resource management schemes. Water resource development projects such as operation of irrigation schemes often contribute to water-related diseases by increasing the number of vector habitats. Planning and designing of good water management structures may prevent problems with mosquito vectors and intermediate host snails at the same time; the development of insecticide resistance will no longer be a matter of concern.

Table 2.1. The most common pathogenic microorganisms causing waterborne d

Disease	Pathogen	Symptoms	Causes
Adenovirus Infection	*Adenoviridae* virus	Varying depending on which part of the body is infected	Drinking contaminated w
Amebiasis	*Entamoeba histolytica* parasite	Diarrhea, stomach pain, stomach cramps	Fecal matter of an infec ingested from a pool supply)
Campylobacteriosis	*Campylobacter jejuni* bacteria	-	Chicken, unpasteurized m
Cryptosporidiosis	*Cryptosporidium* parasite	Stomach cramps, dehydration, nausea, vomiting, fever, weight loss	Fecal matter of an inf survive for days in chlor
Cholera	*Vibrio cholerae* bacteria	Watery diarrhea, vomiting, leg cramps	Contaminated drinking coastal waters
***E. Coli* 0157:H7**	*Escherichia coli* bacteria	Diarrhea (may be bloody), abdominal pain, nausea, vomiting, fever, HUS	Undercooked ground cheeses, unpasteurized alfalfa sprouts
Giardiasis	*Giardia lamblia* parasite	Diarrhea, excess gas, stomach or abdominal cramps, upset stomach or nausea	Swallowing recrea contaminated with *Giard*
Hepatitis A	Hepatitis A virus	Fever, fatigue, stomach pain, nausea, dark urine, jaundice	Ready-to-eat foods, fru products, shellfish, s sandwiches, water
Legionellosis	*Legionella pneumophila* bacteria	Fever, chills, pneumonia, anorexia, muscle aches, diarrhea, vomiting	Contaminated water
Salmonellosis	*Salmonella* bacteria	Abdominal pain, headache, fever, nausea, diarrhea, chills, cramps	Poultry, eggs, meat, m smoked fish, protein foo
Vibrio Infection	*Vibrio parahaemolyticus*, *Vibrio vulnificus* bacteria	Nausea, vomiting, headache (a quarter of patients experience dysentery-like symptoms)	Raw shellfish, oysters

Table 2.2. Some water-related diseases and their importance worldwide

Disease group	Disease	Estimated infection rate (1,000/year)	Estimated morbidity (1,000/year)	Estimated mortality (1,000/year)
Waterborne diseases	Diarrhoeal diseases	not available	1,000,000[1)]	5,000[1)]
	Typhoid fever	1,000	500	25
Water-washed diseases	Ascariasis (=roundworm infection)	800,000-1,000,000	1,000	20
	Ancylostomiasis (=hookworm infection)	700,000-900,000	1,500	50-60
Water-based diseases	Schistosomiasis (Bilharzia)	200,000	?	500-1,000
Water-related vector-borne diseases	Malaria	240,000	100,000	not available
	Lymphatic filariasis	90,200	2,000-3,000	Low
	Onchocerciasis	17,800	340	20-50
	Japanese encephalitis	not available	20-40	case fatality ratio between 10-30 %

Water-related diseases can be classified into 4 major categories (Table 2.3).

Table 2.3. Classification of water-related diseases (adapted from the WHO's definitio

1. Waterborne diseases	Diseases spread through faecal or chemical contamination of drinking water (cholera, bacterial dysentery, amoebic dysentery, amoebic meningo-encephalitis, cr methaemoglobinaemia, dental and skeletal fluorosis). Widely distributed in Europe. Prevention: the pathogen is usually carried in the contaminated drinking water and is d it. Nonetheless, dirty hands or food are at least as often to blame. Washing with water proper drying) is very important.
2. Water-washed diseases	Diseases due to the lack of water for proper sanitation and hygiene (e.g., trachoma, roundworm infection; ancylostomiasis = hookworm). The prevalence of these infe conditions; however, they are present in all parts of Europe. Domestic dogs and pregnant and nursing animals), with high rates of ascarid and hookworm infections, and with no nutritional value, such as dirt or paint) are the principal risk factors for human d Prevention: hand washing and good personal hygiene, eliminating intestinal parasites deworming, and making potentially contaminated environments (e.g., unprotected children.
3. Water-based diseases	Parasitic infections transmitted through an intermediate host (an invertebrate organism an aquatic or semi-aquatic environment for a part of its life cycle. Infection can occur b guinea worm infection), by direct contact with the infested water (schistosomiasis = insufficiently cooked snails. Usually not found in Europe. Prevention: avoid wading in the water or imbibing it; clear the snails or fleas from th drinking water; drink only water from underground sources that are free from conta with an open worm ulcer from entering ponds and wells with drinking water; cook snails
4. Water-related or vector-borne diseases	Diseases transmitted by insects that depend on water for their propagation (insects tha insects having aquatic immature stages (e.g., onchocerciasis, sleeping sickness, filiarios fever). Except for some isolated cases, not extended to Europe. Prevention: The vectors – flies and mosquitoes – have to be controlled by spraying and they carry have to be eradicated by eliminating the disease in humans. Environm management combined with chemical and biological control measures whenever appro

2.1.6. Recreational water illnesses (RWI)

2.1.6.1. What is a recreational water illness?

Recreational water illnesses (RWI) refer to a spectrum of illnesses acquired through swallowing, breathing or coming into contact with contaminated water in recreational water locations, which include treated or disinfected venues such as swimming pools, water parks, and hot tubs, but also untreated or naturally occurring bodies of water, such as lakes, rivers, and the sea (URL8 and URL9). Emerging zoonoses that may be transmitted by faeces through the waterborne route have not been all well defined. However, a variety of infections (e.g., skin, ear, eye, respiratory, neurologic, and diarrheal infections) have been linked to wading or swimming in water, particularly if the swimmer's head is submerged. Water may be contaminated by other people and from sewage, animal wastes, and wastewater runoff. Some bodies of water may be contaminated by urine from animals infected with organisms like *Leptospira*. The spectrum of RWIs includes ear, eye, gastrointestinal, neurologic, and respiratory and skin infections. Diarrheal illnesses are the most reported RWIs. Waterborne diarrheal pathogens include viruses (noroviruses), bacteria (*E. coli*, *Shigella*), and parasites (*Cryptosporidium*, *Giardia*). People most susceptible to gastrointestinal RWIs are the young, the elderly, the pregnant and the immuno-compromised.

2.1.6.2. How could RWI transmission be prevented?

People who want to swim in nature should be advised to avoid beaches that may be contaminated by human sewage or dog feces. Therefore, it is recommended for people to avoid submerging their heads and to wear nose plugs when entering untreated water to prevent water getting up the nose.

Accidental swallowing of small amounts of fecal contaminated water can be sufficient to infect. Swimmers should be warned to try to avoid swallowing water while undertaking aquatic activities. Generally, pools that contain chlorinated water can be considered safe places to swim if the disinfectant levels and pH are properly maintained. However, some organisms (e.g., *Cryptosporidium*, *Giardia*, Hepatitis A virus, and *Norovirus*) have moderate to very high resistance to chlorine levels commonly found in chlorinated swimming pools, thus swallowing of chlorinated swimming pool water may also pose a risk of contracting the disease. People who have diarrhea should refrain from swimming to avoid contaminating recreational water.

When someone has open cuts or abrasions that might serve as entry points for pathogens, they should be advised to avoid swimming or wading. In certain areas, fatal primary amoebic meningo-encephalitis has occurred after swimming in warm freshwater lakes or rivers, thermally polluted areas around industrial complexes, and hot springs.

RWI transmission occurs in recreational water that is non-chlorinated or inadequately chlorinated, but may also occur in adequately maintained venues when chlorine-resistant pathogens are involved. Because of the complex nature of RWI transmission, it is essential to incorporate a multidisciplinary approach in prevention and control strategies.

Human behavior plays a crucial role in RWI transmission. Swimmers who are symptomatic with diarrhea, as well as toddlers and diaper-aged children may contaminate the water in which there are healthy co-swimmers.

In addition, high-risk groups such as the young, the elderly, the pregnant and the immuno-suppressed, should also be advised about healthy swimming habits. Healthcare providers may help to teach parents of sick children and patients about healthy swimming habits. These simple and practical messages include the following:

- Do not swim when having diarrhea.
- Do not swallow pool water.
- Shower with soap and water before swimming, being particularly meticulous about washing the crotch area.
- Wash your hands with soap and water after using the toilet or after changing diapers.
- Change diapers in the bathroom and not at poolside.
- Wash the child thoroughly with soap and water before swimming.

It is also judicious to recommend for patients with infectious diarrhea to refrain from swimming for two weeks after cessation of diarrhea, particularly if they are infected with *Cryptosporidium* or *Giardia*, as these may still be excreted for several weeks after symptom resolution.

2.1.6.3. What do health agencies do to prevent or control RWI transmission?

If a medical emergency in relation to water occurs, it is important to contact the physician and the local public health authorities/the regional epidemiologist.

In times of extreme crisis, local health authorities may urge consumers to be more cautious or to follow additional measures. When home water supply is interrupted by natural or other forms of disaster, limited amounts of water can be obtained by draining the hot water tank or by melting ice cubes. In most cases, water from wells is the preferred source of drinking water. If it is not available and river or lake water must be used, sources containing floating material should be avoided as well as water with a dark color or an odor.

Diarrhea and other serious waterborne infections can be spread when disease-causing organisms from either human or animal faeces are introduced into the water. However, even with the modern technology, specific detection of animal faeces in water is still not possible, because traditional bacterial indicators of faecal contamination cannot distinguish human faeces from animal faeces. Because of this inability to distinguish human from animal faecal contamination, resource managers and regulators have opted to treat all faecal contamination as equally hazardous to human health. This approach frequently results in the closure of beaches and shellfish harvesting areas that are affected by storm water runoff that carries faecal indicator bacteria. The risks related to exposure to these waters contaminated by animals is unknown. Studies that have attempted to define the risks associated with swimming in animal-contaminated water have not given a clear indication that there is an excess illness rate related to this type of exposure. These equivocal results do not lead to the conclusion that all faecal contaminated waters should be treated alike. We need to study the risks posed by animal faecal wastes to users of water resources and to find proper indicator systems that identify animal contamination of surface waters. The availability of more research data that would meet the latter two information needs would significantly improve our ability to manage water resources.

2.1.7. Illnesses due to drinking water

In northern, western and southern Europe, the drinking water supply is normally safe and regularly controlled. But if a break of the water main, a leak in waste water collecting pipe, an interruption or a problem at the water treatment plant occurs, a serious drinking water contamination problem will result and has to be faced promptly. Here again, when an emergency in relation to water occurs, it is important to rapidly contact a physician and the local public health authorities/the regional epidemiologist.

2.1.8. Helpful tips for drinking water outbreak response

2.1.8.1. General

Establish key contacts at partner institutions such as local public health authorities, laboratories, the media, daycare centers, etc.

Check resources and contingency plans. Start elaborating a plan of what types of equipment and other resources may be needed. Some resources might come from the public health authorities.

Share information with other regional/provincial/departmental/national public health authorities and facilities. This can speed up the investigation process and help health departments fill knowledge gaps.

At the beginning of an outbreak, it is very important to identify as many confirmed cases as possible to help find the source of the outbreak. This can be done through mass mailings, newspaper ads, etc.

If possible, establish a hotline for outbreak-related calls.

2.1.8.2. Laboratories

Before beginning the examinations, get a realistic idea of the turnaround time on laboratory tests.

Consider using private labs/hospitals, as well as government facilities.

2.1.8.3. Communications with other health departments or agencies

Make periodic, regularly scheduled conference calls with established key contacts. Keep everyone informed, plan next steps, share information, etc.

Decide what information is to be shared and how to share it.

Decide on a mechanism to use in sharing information, such as e-mail or fax. Make sure all channels of communication are in working order.

2.1.8.4. Checklists

Keep repertories of phone calls regarding the outbreak.

Document the number of man-hours spent on the outbreak for future budgetary/resource reference.

2.1.8.5. Media relations

Establish contact points with media sources.

If necessary, form a working group to establish good relationships with the media.

Give them fact sheets on the pathogen.

Send out frequent updates to keep the media correctly informed.

2.1.8.6. Press release

When putting together a press release on the pathogen, include any information from existing pathogen-specific fact sheets.

2.2. Biocorrosion and Sanitation

2.2.1. Biocorrosion

A lot of different terms were used to describe corrosion caused or induced by microbes. The most popular are: biocorrosion, microbial corrosion, and microbiologically influenced/induced corrosion (MIC) which possess different connotations. Biocorrosion and microbial corrosion indicate that the microbes are the main cause of the corrosion, but MIC suggests whether the microbes are involved or not involved directly. This phenomenon is caused by or enhanced by bacteria or other microorganisms and is a result of the action of microorganisms on an underlying substratum, which is metal or metal alloy like stainless steel. Biocorrosion is a major reason for electrochemical/mechanical damage of water supply and distribution devices (Kent and Evans, 2009). These damages result in leaking and impose water contamination risk since they represent an entry portal for microbial and chemical contamination. Thus, biocorrosion is an object of study in water sanitation aspect. An electron-transfer hypothesis of biocorrosion claims that it is a process in which metabolic activities of microorganisms associated with metallic materials, supply insoluble products which are able to accept electrons from the base metal (Figure 2.2).

Fig. 2.2. Biocorrosion in water-conducting pipe

2.2.1.1. Causative agents of biocorrosion

Classification of microorganisms generally depends on their affinity to oxygen. Living aerobic species require free oxygen for their functions, while anaerobic species do not live in the presence of free oxygen. Anaerobic bacteria can grow in environments with as little as 50 parts per billion (ppb) dissolved oxygen. Facultative anaerobic microbes can grow in either environment. Microaerophilic species require low concentration of oxygen. Aerobic and anaerobic organisms have often been found to co-exist in the same location. This is because aerobic forms deplete the oxygen creating an ideal environment for anaerobes.

Microorganisms have the ability for fast reproduction – some doubling in as fast as several minutes. When left untreated, they can rapidly colonize in stagnant aqueous environments introducing highly active corrosion associated with products of microbial metabolic activities like enzymes, exopolymers, organic and inorganic acids, as well as volatile compounds such as ammonia or hydrogen sulphide.

The microorganisms causing MIC include bacteria, fungi, and algae. They are presented either as individual species or can form biofilms, composed by synergistic communities (consortia). In the latter, the electrochemical processes comprising corrosion mechanisms are due to the co-operative metabolism of those consortia members rather than the enzymatic activities of the individual species.

Bacteria involved in the process of metal biocorrosion such as those associated with iron, copper and aluminum and their corresponding alloys, are a large and physiologically quite diverse group. The predominant types of bacteria implicated with MIC are sulphate-reducing bacteria (SRB), sulphur/sulphide oxidizing bacteria (SOB), metal-reducing bacteria (MRB), metal-depositing Bacteria (MDB), acid producing bacteria (APB) and bacteria excreting exopolymers or slime.

Sulphate-reducing bacteria (SRB) can grow in low oxygen environments and require sufficient organic nutrients. They can grow in anaerobic conditions and are involved in numerous MIC problems affecting a variety of systems and alloys. SRB can survive also in an aerobic environment for a period of time until finding a compatible environment. These microorganisms reduce sulphates to sulphides producing hydrogen sulphide (H_2S) or iron sulphide (Fe_2S). They can be detected through the surface deposits, as well as by the characteristic hydrogen sulphide smell.

Sulphur/sulphide oxidizing bacteria (SOB) are aerobic species which oxidize sulphide or elemental sulphur into sulphates. Some of them can oxidize sulphur into sulphuric acid (H_2SO_4) thus creating highly acidic (pH ≤ 1) ambient. This high acidity is linked with the degradation of coating materials in a number of applications. These bacteria are common in wastewater systems and are often found in conjunction with SRB.

Presence of such (aerobic) bacteria is important to understand the basic mechanism of corrosion and the resultant degradation in the different types of metals that may be affected.

Metal-depositing bacteria (MDB) take part in the biotransformation of metal oxides. The iron and manganese oxidizing bacteria – *uron/manganese-related bacteria* **(***IRB)* are of particular interest in respect to biocorrosion. These bacteria can convert soluble iron ions (ferrous) to insoluble iron ions (ferric). The ferric iron is deposited on the piping or system surfaces to create deposits that are host sites where other bacteria can grow. IRB can grow in a wide variety of conditions as they may be aerobic or anaerobic.

These iron and manganese oxidizing bacteria are connected with MIC, typically located in corrosion pits on steels. Some species can accumulate iron or manganese compounds as a result of the process of oxidation. High concentrations of manganese in biofilms have been attributed to the corrosion of ferrous alloys, including pitting of stainless steels in treated water systems. The oxidation process causes often appearance of the so-called iron tubercles.

Iron-oxidizing bacteria, such as *Gallionella, Sphaerotilus, Leptothrix*, and *Crenothrix*, are the leading sources of MIC.

*Slime-producing bacteria (also called low nutrient bacteria – LNB). These b*acteria grow in potable water where the nutrients concentration is very low. They form slimes and deposits, thus ensuring host sites colonized by other MIC bacteria. Slime-producing microorganisms isolated from sites of corrosion include *Clostridium* spp., *Flavobacterium* spp., *Bacillus* spp., *Desulfovibrio* spp., *Desulfotomaculum* spp., and *Pseudomonas* spp.

Acid-producing bacteria are able to synthesize large amount of either inorganic or organic acids as metabolic by-products. The inorganic acids produced by these microorganisms include: nitric (HNO_3), nitrous (HNO_2), sulphurous (H_2SO_4), sulphuric (H_2SO_3), and carbonic (H_2CO_3). In general, H_2SO_3 and H_2SO_4 are end products of oxidation performed by the above mentioned *Sulphur/Sulphide Oxidizing Bacteria*. The other one – HNO_2 and HNO_3 – are mainly produced by bacteria belonging to the ammonia- and nitrite-oxidizing group. The corrosion effect of the N- and S-containing inorganic acids is facilitated by their water soluble salts. The corrosion effect is complicated by their action and the extremely low pH values.

Organic acid-producing bacteria were described as the group positively correlating with corrosion. They were suggested as the primary cause in carbon steel corrosion in an electric power station. Acetic, formic and lactic acids are common metabolic by-products of these bacteria implicated in the corrosion of iron and its alloys.

Some anaerobic organisms that produce organic acids can be found in closed gas or water systems.

Thus, the following environmental conditions must be favorable for microbes to grow and cause microbiologically influenced corrosion: metals (host location), nutrients, water, and oxygen (although certain types of bacteria need very small amounts of oxygen). In case all these environmental conditions are available, microbial growth will occur. When the nutrients in the system are consumed, the microbes may become dormant. When the environmental conditions, i.e., nutrients, are replenished, the microbial growth starts again.

Fungi are also part of the group of microorganisms that cause corrosion. They are eukaryotic microorganisms and grow forming filamentous (mycelium) structures. They reproduce by spores and can form vegetative mycelia which can reach macroscopic dimensions. Fungi are most often found in soils, although some species are capable of living in water environments. They are well-known to metabolize organic matter, producing organic acids, thus contributing to MIC. Representatives of genera *Cladosporium, Aspergillus, Penicillium* and *Fusarium* are most commonly associated with MIC. The corrosion effect in respect to the iron and aluminum alloys is attributed to the organic (citric) acid produced by them. The iron-reducing fungi have been isolated from tubercles in a water distribution system, suggesting corrosion accelerated by this group of microorganisms. Similar to some bacterial forms, they can create environments suitable for anaerobic species.

Algae can be found in almost any aquatic environments ranging from freshwater to saltwater. They produce oxygen in the presence of light (photosynthesis). The availability of oxygen has been found to be a major factor in corrosion of metals in saltwater environments.

Microbial consortia

The role of the microbial consortia in MIC is crucial as such types of communities are commonly recognized in the natural environment. The interactions between microflora in MIC are complex. The acids produced by APB are serving as nutrients for SRB and methanogeic microorganisms. At the same time, the biomass of SRB accumulates at biocorrosion sites due to the previous APB metabolic activities. Experiments have been performed to prove the enhanced effect of mixed populations of acetogenic bacteria and SRB on biocorrosion rate. It is suggested that the former supports the growth and sulphide production by SRB. Also, the corroding metal surfaces are often invaded by consortia of MDB and SRB microorganisms and that the oxygen consumption by MDB creates convenient conditions. The latter are favorable for the growth of SRB and, thus, the joint action of MDB and SRB may facilitate the breakdown of stainless steel surface.

2.2.1.2. Water distribution system and Microbiologically Influenced Corrosion (MIC)

MIC is considered a mechanism accelerating corrosion. Therefore, it could occur more often in metal alloys vulnerable to the various forms of corrosion, and in environments where biological activity takes place.

The used materials in the water distribution systems include mild steels, stainless steels, copper alloys, nickel alloys, and titanium alloys. Mild steels, stainless steels, aluminum, copper, and nickel alloys have all been shown to be susceptible to MIC, while titanium alloys have been found to be virtually resistant to MIC under ambient conditions.

MIC problems have been found in piping systems, storage tanks, cooling towers, and aquatic structures. Mild steels are widely used in these applications due to their low cost, but are among the most readily corroded metals.

The bacteria are frequently implicated in accelerated corrosion of steel and non-ferrous metals. Ductile iron, vinyl and reinforced concrete represent the bulk of pipelines currently being used in many countries to deliver safe drinking water. However, cast iron and ductile iron distribution pipes are the most susceptible to corrosion and breakage. In fact, each year thousands of water lines are removed for replacement – most suffer from severe damage caused by corrosion.

Corroding iron, usually thought of in terms of rust, may take many forms. In the case of buried iron pipe for drinking water and sewage, the corroded material is a hard, graphitic substance which temporarily maintains the shape of the pipe wall and looks like iron, but provides virtually no strength. Later, the material can form pits, which, in some cases, penetrate the wall and cause leaks. This type of corrosion contributes to water loss, pipe breakage and potential water contamination.

2.2.1.3. Mode of biocorrosion action

Bacterial corrosion often proceeds in several steps:

1. Dissolved oxygen in the water stimulates the development of aerobic microflora for production of specific metabolites, which may accelerate ongoing electrolytic corrosion. Due to this microbial growth the surrounding zone becomes oxygen deficient and anaerobic.

2. Development of one or few species of mixed population of the anaerobic bacteria during consumption of acidic metabolites. The predominant bacteria of these anaerobic species are the sulphate-reducing bacteria (SRB), which utilize the oxygen in sulphates and reduce them to sulphides. Hydrogen sulphide gas (H_2S) is also an end product of the SRB activity and promotes corrosion. It is highly toxic and flammable and is believed to accelerate hydrogen embrittlement.

3. Production of strong acids such as sulphuric acid (H_2SO_4) from sulphides by sulphur oxidising bacteria (SOB) when oxygen becomes available again. The strong acids will further accelerate the ongoing corrosion process.

The microorganisms invade the piping system through the water supply. Inside microorganisms form a biofilm on material’s surface and the microenvironment becomes dramatically different from the bulk surroundings. Changes in pH, dissolved oxygen, and organic and inorganic compounds in the microenvironment can lead to electrochemical reactions which increase corrosion rates.

Such steps are performed if the microflora in the piping system leads to biofilm formation or biofouling. Thus, bacterial community is composed of microorganisms and their products. It is present in almost every water distribution system, and when uncontrolled may present a threat to public health.

Biofilm attaches to the interior walls of water distribution pipes – mostly around corroded surfaces on pipes. Almost immediately after attaching to pipeline walls, the organisms begin building upon themselves, adding layer upon layer, forming a plaque-like coating. Such growth, together with tuberculation (corrosion encrustation), can clog water lines to the point of insufficient water pressure and depleting chlorine used to disinfect drinking water. Biofilm (microbes) is also resistant to many chemicals by their protective membrane and ability to breakdown numerous compounds (Fig. 2.3).

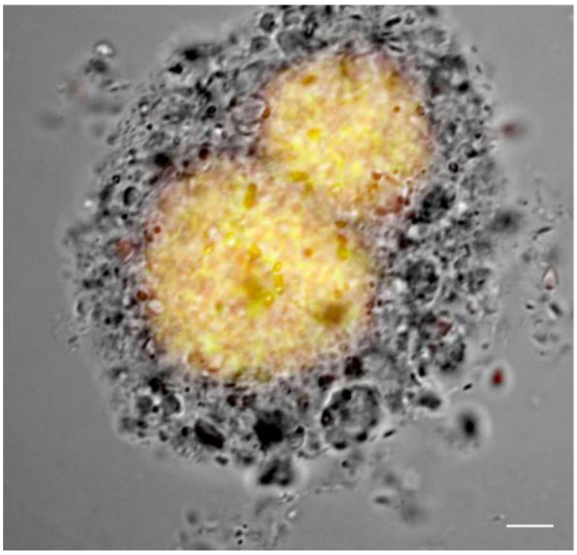

Fig. 2.3. Biofilms produced by SRB

The growth of the biofilm depends on the following factors characteristic for the water: availability of microbial nutrients; characteristics of pipe walls such as roughness, among other; microbial and chemical quality, temperature, pH, low chlorine level, and velocity.

Typical signs of bacterial corrosion are: clusters of pits that are several *cm* in diameter; high local corrosion rates; sulphuric smell.

2.2.1.4. MIC threats to water quality

The corrosion of iron pipes in a distribution system can cause different problems: i) lost of pipe mass due to microbial oxidization process; ii) accumulation of large amount of tubercles that increase head loss and decrease water capacity; iii) the release of soluble or particulate iron corrosion by-products into the water causing decrease of its aesthetic quality ("red water" at the tap); iv) the leaks resulted from massive biocorrosion They are potential entry routes for water contamination with microbial pathogens causing waterborne diseases and/or chemical compounds hazardous to human health.

Key water quality parameters that are expected to influence corrosion include pH, alkalinity, buffer intensity, and bacterial water contamination.

- **pH:** weight loss increases with increasing pH more than 7 as by-product release decreases.
- **Alkalinity:** increasing alkalinity generally leads to lower weight loss.
- **Buffer Intensity:** higher buffer intensity is often associated with increased alkalinity, although the two parameters are not exactly equivalent. However, their effect on iron corrosion seems to be similar.

2.2.1.5. Classification of water damages

Water damage involves a large number of possible losses caused by destructive processes such as rotting of wood, growth, rusting of steel, delaminating of materials such as plywood, among others. The damage may be imperceptibly slow and minor such as water spots that could eventually mar a surface, or it may be instantaneous and catastrophic such as flooding (URL1, URL2).

Water damage is typically classified into one of the three categories:

Category 1 Water refers to a source of water that does not pose substantial threat to humans and is classified as "**Clean Water**". Examples are broken water supply lines, tub or sink overflows or appliance malfunctions involving water supply lines.

Category 2 Water refers to a source of water that contains a significant degree of chemical, biological or physical contaminants and causes discomfort or sickness when exposed to or even consumed. It is known as "**Grey Water**". This water carries microorganisms and nutrients of microorganisms. Examples are toilet bowls with urine (no faeces), sump pump failures, seepage due to hydrostatic failure and water discharge from dishwashers or washing machines.

Category 3 Water is known as "**Black Water**" and is grossly unsanitary. This water contains unsanitary agents, harmful bacteria and fungi, causing severe discomfort or sickness. Type 3 category is contaminated water sources that affect the indoor environment. This category includes water sources from sewage, seawater, rising water from rivers or streams, ground surface water or standing water. Category 2 Water or “Grey Water” that is not promptly removed from the structure and/or have remained stagnant may be reclassified as Category 3 Water. Toilet back flows that originate from beyond the toilet trap are considered black water contamination regardless of visible content or color.

The class of water damage is determined by the probable rate of evaporation based on the type of materials affected, or wet, in the room or space that was flooded. Determining the class of water damage is an important first step, and will determine the amount and type of equipment utilized to dry-down the structure:

The Classes are:

Class 1- Slow rate of http://en.wikipedia.org/wiki/Evaporationevaporation. Affects only a portion of a room. Materials have a low permeance/porosity. Minimum moisture is absorbed by the materials.

Class 2- Fast rate of evaporation. Water affects the entire room of carpet and cushion. May have wicked up the walls.

Class 3- Fastest rate of evaporation. Water generally comes from overhead, affecting the entire area; walls, ceilings, insulation, carpet, cushion, etc.

Class 4- Specialty drying dituations. Involves materials with a very low permeance/porosity, such as hardwood floors, concrete, crawlspaces, plaster, etc. Drying generally requires very low specific humidity to accomplish drying.

The deficiency in sanitation services is higher than in water supply services. In order to reduce with 5 % the deficiency in sanitation by 2015, the investment of 2.2 billion is necessary (URL3).

2.2.1.6. MIC prevention of water distribution system

In general, the most effective ways to prevent material failure is proper and accurate design, routine and appropriate maintenance, and frequent inspection of the material for defects and abnormalities (URL4).

Proper design of a system includes a careful selection process in order to eliminate materials that could potentially be incompatible with the operating environment and to select the ones that are most appropriate for the system. In some cases, a change to an alternate material such as PVC piping has greatly reduced underground pipeline corrosion problems.

Routine maintenance will reduce the possibility of a material failure due to extreme operating conditions.

Routine inspections can help identify if a material is at the beginning stages of failure.

2.2.1.6.1. Monitoring/detection methods

If microbiologically influenced corrosion is suspected due to observation of slime, restrictions in flow, or leaks/pinhole leaks in pipes, the testing for the presence of MIC is warranted to determine:

- Whether bacteria related to MIC are present and, if so, their relative concentration.
- The extent of the corrosion present.
- The source of the corrosion.
- Limits of the MIC affected system components.

Testing is performed by collecting a number of samples at various locations in a system and sampling the makeup water. Depending on the system configuration, visual observations, and problems, sampling during one or more time intervals may also be appropriate.

2.2.1.6.2. Microbiological analyses

The samples should be cultured on nutrient media for the presence (indirect bacteria counts) of low nutrient bacteria, sulphate-reducing bacteria, iron-related bacteria, and aerobic bacteria. The most important factor in bacterial counts is observing changes in trends rather than in actual numbers. Bacterial number may be indicative of biofilm growth in the case of differences in counts across a system. Bacteria cultures can also be used to identify specific species present.

Direct bacteria counts can be performed using a microscope to inspect bacteria which have been placed onto a slide and may also be stained for viewing. Visual inspection should be performed on exposed surfaces where algae and fungal growth can occur and on surfaces exposed during maintenance procedures.

The presence of SRB can be detected by observing black particles in the liquid media and/or deposited on surfaces or by the distinct hydrogen sulphide odor. Fluorescent dyes can be used to enhance visual detection, as biofilm absorbs some of the dye, whereby ultraviolet light is then used to expose the microorganisms.

2.2.1.6.3. Chemical analyses

Monitoring equipment is available for measuring a number of properties of the bulk system. A common practice has been to directly monitor temperature, pH, conductivity, and total dissolved solids, while taking samples to evaluate (by portable or laboratory testing methods) dissolved gases.

Scaling or other chemical conditions in the water affect system corrosion and the interpretation of MIC sampling results; therefore, chemical testing of each sampling location and sampling interval is also useful. The results of the water chemistry testing can also be beneficial in ascertaining how far along the corrosion is due to MIC-related bacteria.

2.2.1.6.4. Engineering analyses

Where leaks are present, appropriate sampling may also include metallurgical analysis of system components. The metallurgical engineer analyses the components using electron microscopes to ascertain the nature of all corrosion and failures present: microbiologically influenced corrosion, other corrosion, causes of degradation, deterioration and failures. Understanding the causes, effects, and appropriate investigatory methods is the first step in addressing MIC related problems.

2.2.1.6.5. Mitigation methods

The best way to prevent MIC is to prevent the growth of biofilm. Once a biofilm has formed, it can rapidly grow if not completely removed. The emphasis is placed on cleanliness and incorporating established corrosion prevention and control techniques for the various metals and forms of corrosion. Monitoring and detection of microorganisms will effectively guide preventive maintenance procedures.

Maintaining the cleanliness of systems involves monitoring the quality of water, present in the system.

2.2.1.6.6. Suppressing of Microbial Growth

The suppressing of active microbial growth along the interior walls of drinking water distribution pipes concerns the water quality. Without proper maintenance, excessive biofilm build-up, which can at times only be removed by scraping, can cause all sorts of other problems.

Chlorinating the drinking water supply is the method usually used to control biofilm growth. In cases where the water is nutrient-rich and the biofilm has developed into a plaque-like coating, officials often have to flush the system with both increased chlorine levels and large amounts of water. If this treatment does not work, some officials suggest replacing or relining distribution pipes.

Vinyl Pipe Solution: Because metallic water main materials are prone to rust and scale build-up, vinyl is the most often used pipe material today. Vinyl pipes are inert to aggressive soil conditions and do not need internal protection. Vinyl water mains also provide great resistance to biofilm formation. Vinyl will not break down under attacks from microbes including MIC because it is not used as a nutrient source to bacteria in the way most alternative pipeline materials do. And also because vinyl pipe surfaces are smooth, water flows more easily than in metallic or cement-based pipes. Immune to both underground external corrosion and internal pipe corrosion, vinyl pipe can deliver water as clean and pure as it is received.

2.2.2. Water sanitary risk analysis, assessment and management

Inadequate sanitation and hygiene practices are the reason why about 5 million people annually die from waterborne diseases, which in general are preventable. The effects of sanitation have impacted people's health and lives for ages. Protection of public health and environmental quality, especially when concerning water resources quality, its prevention and assessment, is of special national and international importance (Mons et al., 2007).

Sanitary risk assessment helps to identify threats to public health. WHO has introduced sanitary surveys, which record observable sanitary hazards of water resources, including sources of pollution and technical conditions of the water supply and distribution systems. It also develops Water Safety Plans elaborated through comprehensive, systematic risk assessment and risk management approach and encompassing all steps in water supply from providers to consumers.

In general, determination of risk concerns assessment of harmful effects for human health or ecological systems resulting from exposure to environmental stressors. A stressor is any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact. Risk assessment is used to characterize the nature and magnitude of health risks to humans and ecological receptors (e.g., birds, fish, wildlife) from contaminants and other stressors that may be present in the environment(URL5).

Environmental risk assessment typically falls into one of the two areas:

- Human health
- Ecological health

Risk assessment is a scientific process. In general, risk depends on the following factors:

- How much of the pollutant is present in an environmental medium (e.g., soil, water, air).
- How much contact (exposure) a person or ecological receptor has with the contaminated environmental medium.
- The inherent toxicity of the pollutants.

Following this, the risk assessment process in water supply usually begins by collecting measurements that characterize the nature and extent of contamination in the water, as well as information needed to predict how the contaminants will behave in the future. Here are some ways to get started:

- Planning a human health risk assessment
- Planning an ecological risk assessment

Planning major risk assessments is necessary regarding the purpose, scope, and technical approaches that will be used. Based on this, the risk assessor evaluates the frequency and magnitude of human and ecological exposures that may occur as a consequence of contact with the contaminated medium.

This evaluation of exposure is then combined with information on the inherent toxicity of the contaminators to predict the probability, nature, and magnitude of the adverse health effects that may occur.

In principle, risk management in the process of water supply evaluates how to protect public health. Examples of risk assessment and management actions include decision how much of a substance a company may discharge into a river; decision which substances may be stored at a hazardous waste disposal facility; decision to what extent a hazardous waste site must be cleaned up; setting permit levels for discharge, storage, or transport; establishing national ambient air quality standards; and determining allowable levels of contamination in drinking water.

While risk assessment provides “information” on potential health or ecological risks, risk management is the “action” taken based on consideration of that and other information, as follows:

- Scientific factors provide the basis for the risk assessment, including information drawn from toxicology, microbiology, chemistry, epidemiology, ecology, and statistics.
- Economic factors inform on the cost of risks and the benefits of reducing them, the costs of risk mitigation or remediation options and the distributional effects.
- Laws and legal decisions are factors that define the basis for the risk assessment, management decisions, and suitable methods for risk reduction.
- Social factors, such as community values, land use, zoning, availability of healthcare, life style, may affect the susceptibility of an individual or a definable group to risks from a particular stressor.
- Technological factors include the feasibility, impact, and range of risk management options.
- Public values reflect the broad attitudes within the society concerning environmental risks and risk management.

2.2.2.1. Water quality monitoring and control

There are many ways to monitor water conditions. Monitoring includes sampling the chemical condition of water to determine levels of key parameters such as dissolved oxygen, nutrients, metals, oils, and pesticides. Physical conditions such as temperature, flow, sediments, and the erosion potential, are also monitored. Biological measurements of the presence of pathogenic microorganisms in sample water are also widely used to monitor water conditions (URL7).

Monitoring can be conducted for many purposes. Some major purposes are to:

- Characterize water and identify changes or trends in water quality over time.
- Identify specific existing or emerging water quality problems.
- Gather information to design specific pollution prevention or remediation measures.
- Determine effective pollution control actions.
- Respond to officials.

Criteria have been developed for drinking water quality that accurately reflect the latest scientific achievements and are based on effects on human health. Water quality criteria concerning human health are numeric values limiting the amount of chemicals present in drinking water. The microbial (pathogen) criteria are used to protect the public from exposure to harmful levels of pathogens in drinking water.

2.2.2.1.1. Microbiological monitoring

The principal risks to human health are of microbial origin, and traditionally monitoring relies on relatively few water quality tests to establish the safety of supplies (Schoen and Ashbolt, 2011). Some agencies refer to this strategy as “minimum monitoring”, while others use the term “critical-parameter testing”. Drinking water should not contain any microorganisms known to be pathogenic (capable of causing disease) or any bacteria indicative of faecal pollution. Drinking water samples should be examined regularly. The detection of *Escherichia coli* provides definite evidence of faecal pollution; in practice, the detection of thermotolerant (faecal) coliform bacteria is an acceptable alternative. A complementary strategy for securing the microbiological safety of drinking water supplies has been advocated by WHO and a number of other agencies (including ISO), based on the minimum treatment for certain types of water (URL9).

Main values for bacteriological quality of drinking water

The parameters recommended for the minimum monitoring of community supplies are those that best establish the hygienic state of the water and thus the risk (if any) of waterborne infection.

The critical parameters of water quality involve:

- *E. coli*;
- thermotolerant (faecal) coliforms – accepted as suitable substitutes.

Water suppliers need to carry out a wider range of analyses relevant to the operation and maintenance of water treatment and distribution systems, in addition to the health related parameters laid down in national water quality standards.

Escherichia coli

The presence of coliform bacteria has frequently been observed in water supply systems with residual concentration of disinfectant. It presents a danger to the consumer, leading to a relatively high incidence of **gastroenteric symptoms** (diarrhea and vomiting).

The growth of coliform bacteria can be encouraged by sediments and the interaction between the organic compounds in water and the surface of corroded pipework.

All water intended for drinking:

- *E. coli* or thermotolerant coliform bacteria – must not be detectable in any 100 ml sample.

Treated water entering the distribution system:

- *E. coli* or thermotolerant coliform bacteria – must not be detectable in any 100 ml sample;
- Total coliform bacteria-must not be detectable in any 100 ml sample.

Treated water in the distribution system:

- *E. coli* or thermotolerant coliform bacteria – must not be detectable in any 100 ml sample;
- Total coliform bacteria-must not be detectable in any 100 ml sample. In case of large supplies, where sufficient samples are examined, total coliform bacteria must not be present in 95 % of the samples.

Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out.

Intestinal enterococci

Enterococci are bacteria found in the gut of all warm-blooded animals. The intestinal enterococci group can be used as an indicator of faecal pollution. They should not be present in drinking water and immediate action is required to identify and remove the source of faecal contamination. These organisms are controlled through disinfection of water.

Clostridium perfringens (including spores)
Clostridium perfringens is a spore-forming bacterium which is present in the gut of all warm-blooded animals. The spores can survive disinfection.

C. perfringens has been proposed as an indicator of protozoa in treated drinking water supplies. In addition, *C. perfringens* can serve as an indicator of faecal pollution that took place previously. The presence of spores in drinking water indicates a remote or intermittent source of contamination that requires investigation.

Excessive proliferation of the biofilm
The biofilm is made up of an aggregate of microorganisms adhering to a solid surface, embedded within a polymer gel of microbial origin. It is therefore a significant reservoir of microorganisms, which often find favorable growing conditions within it; due to its structure, it protects bacteria from the action of disinfection treatments (URL6).

Heterotrophic bacterial flora (Microbial number)
The HPC test (Heterotrophic Plate Count), which counts the number of revivable aerobic microorganisms, is universally recognized for measuring the heterotrophic bacterial population in **water intended for human consumption**. The test can only measure a fraction of the heterotrophic bacteria that is present in the water, in other words those which can be grown under chosen conditions; the percentage can be less than 1 % or even 1 ‰ of the total number of bacteria in the acridine orange count. The test is not capable of distinguishing between pathogenic and non-pathogenic bacteria. The HPC test is frequently used to monitor the **effectiveness of treatments applied to water** intended for human consumption, in particular **disinfection**, and to **monitor the quality of treated water during distribution.**

High counts of revivable aerobic microorganisms, exceeding the criteria defined in national regulations, are the most commonly observed indication of **deterioration in the microbiological quality** of distribution systems.

Atypical mycobacteria
Non-tuberculous or atypical mycobacteria are widely distributed, in free form, in water, soil, plants where they are capable of surviving and multiplying. They are isolated from **drinking water supplied after treatment**, and are usually in **biofilms.**

Over 80 species have been described, but only about twenty have been recognized as potentially pathogenic to man. They are more **strongly resistant to chlorine disinfection** and can escape the effects of disinfectants. Contamination is often reduced by temperatures above 70°C. **Infections** caused by these mycobacteria are **mainly pulmonary** but general infections can also occur. In view of their extensive distribution in the environment and the possible colonization of water supply systems, it is important to assess the risk of contamination by non-tuberculous mycobacteria.

Legionella pneumophila
Each year many people are hospitalized with Legionnaires' disease – respiratory infection resulting from exposure to contaminated water aerosols from engineered water systems. This

bacterium not only causes respiratory infections in people who use engineered water systems like piped drinking water, cooling towers, fountains and humidifiers, it may also contribute to a significant number of community-acquired pneumonia cases via domestic plumbing exposure (Buse et al., 2012).

There is currently no standard method to assess the occurrence of *Legionella* bacteria or its control within engineered water systems. Internationally, culture-based methods are standard, however, they may miss more than 90 per cent of active infectious cells present (i.e., active but not able to be grown in culture).

Scientists try to assess the diversity and human health significance of *Legionella* and mycobacteria. They also look into how *Legionella* gene activity changes when it grows within amoebae and other free-living protozoa that naturally feed on bacteria in drinking water systems. In particular, scientists try to determine how different disinfectants used to treat drinking water influence the microbial ecology that supports or suppresses *Legionella* and non-tuberculous mycobacteria growth in drinking water distribution systems.

These data are used for building of a mathematical model that helps to describe critical numbers of *Legionella* in water pipe biofilms (slimes), shower head water, and bathroom aerosols that could be inhaled. Researchers also model different ways and locations where *Legionella* can be controlled for *Legionella* control strategies.

Pseudomonas aeruginosa

Pseudomonas aeruginosa is a bacterium that is present everywhere in the environment – in freshwater, soils and plants. It is a constant in wastewater and, as a result, in surface water that receives polluted effluents, but nevertheless it can develop in the purest water such as natural mineral water. In the event of a water supply being colonized, thermal treatment by circulating water at 70°C for 30 minutes is often the only way to reduce contamination, provided no scaling, corrosion products or dead legs are present.

Pseudomonas aeruginosa is both opportunistic pathogenic bacteria (it infects lungs, urinary tract, kidneys) and an indicator of environmental contamination for water intended for human consumption in healthcare establishments.

***Aeromonas* spp.**

The group of *Aeromonas* includes mesophilic bacteria, which are sources of human infections, represented by 16 species, including *Aeromonas hydrophila*. *Aeromonas* are natural hosts in aquatic environment, mainly freshwater, reaching counts of 10^6-10^8 CFU (Colony Forming Units)/ml in waste domestic water and 10-10^3 CFU/ml in river water. The frequency and extent to which *Aeromonas* colonize water pipes varies considerably depending on the water system in question, where their presence can be confused with that of coliforms. In spite of their **relative sensitivity to chlorinated products**, they become **embedded in biofilms** where they compete with indigenous bacteria to consume the many organic compounds in water. There are two kinds of infection associated with *Aeromonas*. On the one hand, they can be responsible for **wound infections** after coming into contact with water (bathing, fishing, rowing, etc.) and, on the other hand, they are implicated in **cases of gastroenteritis** that may be due to ingested food or water.

2.2.2.1.2. Chemical monitoring

In general, approaches to the management of chemical hazards in drinking water include methods where the source water is a treat and others which are concerned with materials and chemicals used in the production and distribution of drinking water. These approaches are based on the assumption that health authorities will be aware of other specific sources of risk in each region, such as chemical contamination, and will include them in the monitoring scheme. It is much more effective to test for a narrow range of key parameters as frequently as possible (in conjunction with the sanitary inspection) than to conduct comprehensive but lengthy and largely irrelevant analyses less frequently.

The parameters recommended for the minimum monitoring of community supplies are those that best establish the hygienic state of the water and thus the risk (if any) of waterborne infection.

The guidelines specifying chemical aspects of drinking water quality are set up by WHO (URL9).

2.2.2.1.3. Physical and aesthetic monitoring

The chemical and physical quality of water may affect its acceptability to consumers. Turbidity, color, taste, and odor, whether of natural or of other origin, affect consumer perceptions.

- Turbidity in excess of 5 NTU (Nephelometric Turbidity Unit) may be objectionable to consumers.
- Color of drinking water may be due to the presence of organic matter such as humic substances, metals such as iron and manganese, or highly colored industrial wastes. Consumers may turn to alternative, perhaps unsafe, sources, when their water displays aesthetically displeasing levels of color, typically exceeding 15 TCU (True Color Units). Drinking water should ideally be colorless.
- Odor in water is due mainly to the presence of organic substances. Some odors are indicative of increased biological activity, while others may originate from industrial pollution. Sanitary surveys should include investigations of sources of odor when odor problems are identified.

The combined perception of substances detected by the senses of taste and smell is often called “taste”. Changes in the normal taste of a public water supply may signal changes in the quality of the raw water source or deficiencies in the treatment process.

Water should be free of tastes and odors that would be objectionable to the majority of consumers.

2.2.2.2. Water quality control

The main aim of the water quality control is to protect and restore water quality for public health and the environment.

It is not easy to provide generally applicable guidelines for other biological hazards, particularly parasitic protozoa and helminthes. However, WHO guidelines for drinking water quality include information regarding the above mentioned characteristics and bacteria as well as viruses and some toxic cyanobacteria.

- Many parasites have a complex geographical distribution and it may be unnecessary to take precautions against those that do not occur locally. The majority of waterborne parasites are also transmissible by other routes, such as food and direct faecal-oral spread, and these routes should also be considered in the formulation of strategies for control.
- Species of protozoa known to have been transmitted by the ingestion of contaminated drinking water include *Entamoeba histolytica* (which causes amoebiasis), *Giardia spp*., and *Cryptosporidium*. These organisms can be introduced into a water supply through human or, in some instances, animal faecal contamination.
- Viral pathogens associated with waterborne transmission are commonly those infecting the gastrointestinal tract and excreted in the faeces of infected humans (enteric viruses). Enteric viruses typically cause acute disease with a short incubation period. Water may also play a role in the transmission of other viruses with different modes of action (Adenoviruses, Astroviruses, Caliciviruses, Hepatitis A, E viruses, Rotaviruses). As a group, these viruses can cause a wide variety of infections and symptoms involving different routes of transmission, infection and excretion.
- The most distinguished characteristic of cyanobacteria regarding public health impact is that various species can produce toxins implicated in liver damage, neurotoxicity and tumor promotion. Potential health concerns arise from exposure to the toxins through ingestion of drinking water.

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QUESTIONS AND ANSWERS FOR BOOK CHAPTER 2

Q1. The waterborne diseases unify the following:

a) waterborne microbial diseases, water hygiene diseases, water contact diseases, water habitat vector-borne diseases, waterborne chemical diseases

b) waterborne bacterial diseases, water hygiene diseases, water exchange diseases, water habitat vector-borne diseases, waterborne chemical diseases

c) waterborne microbial diseases, water sanitation diseases, water contact diseases, water habitat animal-borne diseases, waterborne physical diseases

d) waterborne animal diseases, water hygiene diseases, water contact diseases, water habitat insect-borne diseases, waterborne chemical diseases

A1. a) waterborne microbial diseases, water hygiene diseases, water contact diseases, water habitat vector-borne diseases, waterborne chemical diseases

Q2. Microbiologically Influenced Corrosion (MIC) is a phenomenon resulting from the action of microorganisms in contact with a water surface

a) TRUE b) FALSE

A2. b) FALSE

Q3. Key water quality parameters that influence corrosion are:

a) pO2, decrease alkalinity, buffer intensity and microbial water contamination
b) pH, increase alkalinity, buffer intensity and mechanical water contamination
c) pH, increase alkalinity, buffer intensity and microbial water contamination
d) pO2, decrease alkalinity, buffer intensity and mechanical water contamination

A3. c)pH, alkalinity, buffer intensity and bacterial water contamination

Q4. Iron/Manganese-Related Bacteria can convert soluble iron ions (ferrous) to insoluble iron ions (ferric).

a) TRUE b) FALSE

A4. a) TRUE

Q5. MIC contributes to water supply enlargement, pipe breakage and potential water contamination.

a) TRUE b) FALSE

A5. b) FALSE

Q6. Category 2 Water refers to a:

a) source of water that does not pose substantial threat to humans and is classified as "Clean Water".

b) source of water that contains a significant degree of chemical, biological or physical contaminants and is known as "Grey Water"

c) source of water that doesn’t contain chemical and physical contaminants but is microbiologically contaminated

d) source of water that is grossly unsanitary and is known as "Black Water"

A6. b)source of water that contains a significant degree of chemical, biological or physical contaminants and is known as "Grey Water"