Environmental Health and Occupational Health & Safety

Samuel Obura Afubwa

Mutuku Alexander Mwanthi

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FORWARD

For a long time the field of Environmental Health and Occupational Health and Safety has depended on literature and books written by foreign authors with little understanding of the situation in Africa. It is notable that this book will be a guide to local practitioners in Environmental Health and Occupational Health and Safety.

With the increased opportunity for learning; many practicing health professionals are going back to school to improve their academic status and it is therefore prudent that reading material relevant to our needs be available. This book can be used by both local and foreign students. For instance, under the New Kenyan Constitution, the devolvement of the Central Authority of Governance to County Government will require practitioners who are well informed and able to address increased responsibility. This book will therefore provide additional and better understanding of Environmental issues.

In most of African nations; urbanization is fast, and many rural areas are experiencing challenges such as pollution and environmental degradation which calls for balance and sustainable development taking into consideration environmental factors and impacts.

Occupational Health and Safety has not also received adequate attention since only urban centers have had services from trained officers. With the increased agricultural and industrial development, Environmental Health Officers should be able to provide this service effectively using this book as a guide. Challenges of pesticides inhalation and infectious as well as other healthy factors will be addressed.

It is my sincere hope that the academicians who have contributed to this book on Environmental Health and Occupational Health and Safety will not stop here but will make efforts to ensure more books in different fields of Environmental Health and Occupational Health will be written.

PART I

ENVIRONMENTAL HEALTH

Chapter 1 Introduction to Fundamentals of Environmental Health

Samuel O. Afubwa and Simon K. Kimani.

1.1 Introduction

Prevention is better and much cheaper than cure. This slogan is familiar to those who believe in taking measures to make health of the community to be productive and to minimize bed occupancy in hospitals. Prevention of an illness gives one an opportunity to move forward and promote health that eventually prolongs life, hence long life expectancy.

Human beings need a healthy and productive life and should be able to makr them live in harmony with nature. Rapid population growth and increasing poverty are two major factors affecting environment. Development and health in the world exert heavy pressures on natural resources.

In developing countries, the major environmental health concerns are still those environmental factors which contribute to the spread of infectious diseases, all of which require provision of safe water, basic sanitation and adequate shelter, availability of food and food handling practices controlling disease vectors, and agricultural hazards.

In 1989, WHO defined environmental health: as comprising of those aspects of human health and disease that are determined by factors in the environment. It also refers to theory and practice of assessing and controlling factors in the environment that can potentially affect health.

'Our target is human being whose environment is all around him except himself '(Einstein). The living environment consists of air, land, water, buildings and food. These fall under interface of environmental health which is a combination of the home environment, work environment and recreational environment. The Almighty seems to have divided a day into three spheres, each comprising eight hours, which make twenty-four a day. When well balanced, the health of man is guaranteed. Stay at home for eight hours, work for eight hours and rest/recreate for eight hours. All these spheres need to be healthy to man.

Hazards or stressors and risks, which need to be managed, are categorized as biological, chemical, physical, social, psychosocial and one could include climatic. Climatic hazards is divided in macro-climate, which covers general surrounding particularly outside a building and micro-climate, which covers confined spaces with its varying temperatures, humidity, air-changes and radiant heat.

Players in environmental health include public health doctors, occupational health and safety staff, and technical specialists. They are led by Environmental Health Officers who some countries still refer to as Public Health Officers.

1.2 History of environmental health

History of environmental health has a bearing to the genesis of public health. Religion played a big role in health. The laws given to the Israelites during the exodus had both physical and metaphysical implication to health. An example was that of prohibiting the consumption of pigs/swine. Pigs are generally dirty animals and host *Cysticercus celluloses* which when consumed, in the cause of eating pig meat which is raw or not well cooked, causes *Taenia solium* – a tapeworm. The blood vessels in Pigs are small in size and they prevent adequate bleeding of the swine. The presence of blood makes the Pig meat be attacked by disease causing organism which prefer blood as food.

Muslims, in their teachings, are commanded to wash their hands, feet and face before prayers. This is done five times a day. When those parts are washed well, they give the Muslims an added advantage of having clean hands, hence, minimizing waterborne infections. Muslims, as well as Christians, encourage the burying of the dead, this assists in promoting public health by having a hygienic disposal of the dead. They also are encouraged to wear long cloths (Kanzu for men) and ladies wear vail which covers the body, limiting the access of mosquito bite, hence reducing malaria and other vector related diseases.

Bhagavad Gita XVI has information cited by the 'Holy one'. Cleanliness is one of them. This is simply hygiene, which is a key player in environmental health.

Metaphysics focus on four elements of life, which are air, water, earth and fire. They have vital functions in man's existence and when one is removed, man would not exist. Most of the world's primitive people have practiced cleanliness and personal hygiene, often for religious reasons, including, apparently, a wish to be pure in the eyes of their gods. For thousands of years primitive societies looked upon epidemics as divine judgments on the wickedness of mankind.

The idea that pestilence is due to natural causes, such as climate and physical environment, however, gradually developed. This great advance in thought took place in Greece during the 5th and 4th centuries BC and represented the first attempt at a rational, scientific theory of disease causation.

By Roman times, it was well understood that proper diversion of human waste was a necessary tenet of public health in urban areas.

The Chinese developed the practice of variolation following a smallpox epidemic around 1000 AD.

An individual without the disease could gain some measure of immunity against it by inhaling the dried crusts that formed around lesions of infected individuals or inoculating a scratch on their forearms with the pus from a lesion. This practice was not documented in the West until the early-1700s, and was used on a very limited basis.

During the 14th century Black Death in Europe, the development of the principles of isolation and quarantine helped mitigate the effects of this and other infectious diseases. Jenner theorized that the pus in the blisters which milkmaids (who didn't get smallpox) received from cowpox (a disease similar to smallpox, but much less virulent) protected the milkmaids from smallpox. Louis Pasteur further developed the technique during the

1820s by treating infectious agents and rendering them non-infectious and extending its use to protecting against bacterial anthrax and viral rabies.

In East Africa, there was a time when sounds could be heard as moving wind with voices. People were encouraged to beat drums, items, doors. This was believed could chase away or divert the sounds a way. Christians used to rebuke the sounds in Jesus name. It was believed that if the sounds settle in one's house, then Smallpox would manifest. This could be considered a remote way of preventing Smallpox. Isolation of children with measles was key. So houses with an infected child would be marked. Some could hang a cloth at the door to warn others not to enter, hence quarantine, which is a Public Health measure.

During the changes that occurred in Europe, there was a need to have a person responsible for hygiene. An Inspector of Nuisance was appointed. This was followed by Sanitary Inspector, then Public Health Inspector and now Environmental Health Officer.

Sir Edwin Chadwick, who is the father of environmental health, was born on 24 January 1800 in Longsight, near Manchester. His lifelong campaign against squalor and disease laid the foundations for the modern environmental health movement

Environmental Health (EH) is the assessment and management of environmental influences (e.g. chemical, physical, biological, social and psychosocial factors) on human health (Figure 1. 1). This entails the study of food safety and hygiene (including production, distribution and fitness for human consumption), occupational health and safety (including investigation and control of work-related ill health), community health (communicable and non-communicable disease control and prevention, disaster management, health promotion and education), the built environment (including homes, workplaces and public spaces) and pollution control (including the control of the air, land and water). EH is about taking a preventative approach to tackling disease and ill-health rather than a curative approach.

(Adopted from Africa Academy for Environmental Health)

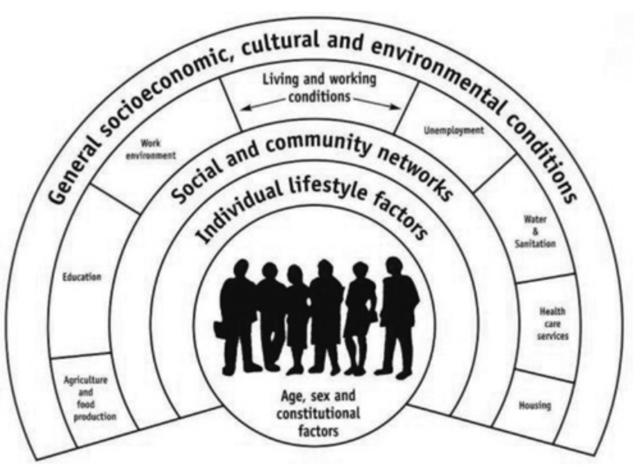

Figure 1.1 The Main Determinants of Health
(Adapted from Dahlgren & Whitehead, 1991)

Progress towards the key Millennium Development Goals (MDGs) can be accelerated through improved environmental health conditions, in particular the MDGs for child health, access to water and sanitation and environmental sustainability.

1.3 The principles of environmental health

The development of the environmental health approach has grown organically rather than by design. However it has demonstrated that it can bring rhetoric to life and adds considerable value to the process of improving human health and quality of life.

In a world that is subject to constant and turbulent change it is surely important to retain some sense of core values or principles as touchstones for our work. Environmental health and the mechanisms to deliver it are founded upon such fundamental principles. They do not apply simply to environmental health at the community level, where the main focus is local government. These principles apply to all levels of government and all sectors that contribute to environmental health. They relate to many government issues and depend upon the way in which governments at all levels relate and interact among themselves and with communities. This is a major challenge as many governments still fail to understand the true nature of environmental health and therefore the significance and value of its approach.

Environmental health is relevant in three time phases. It must work to repair past damage to control present risk and to prevent future problems. The emphasis given to each phase is determined by a complex formula of factors depending largely on an assessment of the risks and resources available. It is of course important and correct to address the most pressing issues relating to environmental health urgently, but emphasis should also be given to addressing, and so avoiding, future problems/challenges. This is the basis of precautionary principle, which is becoming widely accepted in all policies and programs and ensures that environmental health action remain as the leading edge of improving the quality of life.

Principle 1

The maintenance and improvement of the human condition is at the centre of all environment health action. The principle is in recognition that the main target of environmental action is the well being of the human race and those factors in the environment, however wide, that may affect.

Principle 2

The disadvantaged group within the society is often those that must live in the worst housing with poor environment conditions, work in the most dangerous occupations, and that have limited access to a wholesome and varied food supply.

The poor bear a disproportionate share of the global burden of ill-health and suffering. They often live in unsafe and overcrowded housing, in underserved rural areas or periurban slums. They are more likely than the well-off to be exposed to pollution and other health risks at home, at work and in their communities. They are also more likely to consume insufficient food, and food of poor quality, to smoke tobacco, and to be exposed to other risks harmful to health. This undermines their ability to lead socially and economically productive lives.

The disadvantaged do not form a single homogeneous group: different people are at a disadvantage in different contexts. For example, low income households in northern Europeans countries may be at risks of poor health because of dump and cold housing conditions, fuel poverty and/or inadequate nutrition. This phenomenon has been clearly recognized by WHO, which acknowledges that access to the appropriate medical technology cannot in itself offset the adverse effects of environmental derogation and that good health will remain unobtainable unless the environment in which people live are health promoting. A reduction in inequality requires equal access to environmental health services and an uptake of services that relate to need. The provision of high technology services should not be restricted to certain sections of the population because of social or economic disadvantage in the others, and services should be sensitive to the needs of minority groups. To achieve this, the disadvantaged within the population will require special assistance and attention. Equity is therefore a core and primary element that underpins any action on environmental health.

Principle3

A range of governance issues that can be described as the conditions for civic engagement must be in place. The adoption of the democratic principle of the government is the cornerstone to the effective management of environmental health. For example, the European Charter of environment and health sets out the basic entitlements of the individuals including the rights of full information, active consultation and genuine participation in environmental health decisions.

Environmental health protection is based on a model of democracy in which experts and elected politicians make decisions on behalf of the general public. This sometimes paternalistic and frequently closed style of decision-making is a legacy of the democratic system developed in the eighteenth and nineteenth centuries and strengthened throughout most of the twentieth. But times are changing and demands are increased for greater public participation in all aspects of society. Democratic principles also require a two-way exchange and involvement of non-governmental organizations and an informed public in the decision-making process is both necessary and practicable. It is therefore important that decision-makers are not only held accountable, but that they owe their accountability to the public.

Modernization of local services requires that people are not merely represented but actively participate in the development and delivery of local policies, services and projects and in doing so they can ensure that these meet their priorities and needs. This power sharing agenda can feel challenging and there are a variety of skills that people working in environmental health need to develop to ensure that abroad cross-section of the community are engaged and not only the ‘usual suspects’. This approach to work can take more time and will not happen overnight and it must be remembered that it will also be undertaken within other services areas. It is therefore important to join up and to communicate with others within a locality and ensure the partner agencies work together to plan for and focus on community engagement.

Many of the problems that currently face environmental health will only be solved by communities acting as a whole, rather than as individuals. This is one of the key areas to challenge our traditional approach to solving environmental health problems, and it is certainly an area that requires research.

Principle 4

Co-operation and partnership. Isolated decisions and actions cannot normally solve problems in environmental health: an intersectoral approach is needed. The practice of co-operation and partnership in pursuit of the improvements of the environmental health, not only between the health and environment sectors, but also with economic sectors and with social partners, is a crucial element, the origins of which can be traced back to the days of Edwin Chadwick. This is the principle that lies at the heart of effective environmental health management.

Intersectoral activity is at the core of good environmental health practice. Its usefulness, however, depends on how broadly it is interpreted and implemented. When intersectoral co-operation is understood to pertain only to the support of the programme of a particular sector, it fails. If properly interpreted and applied, intersectoral and co-operation and co-ordination means that:

The problems tackled are common ones in which all participants have a stake:

- Not only governmental agencies but also all the public and private sector organizations and interests active in the sector are involved.
- Policy-makers, technical and service staff and volunteers at both national and local levels have actual or potential functions to perform.
- Various participants may play leading and supporting roles with respect to specific issues.
- Co-operation consists not only of ratifying proposals, but also participation in defining issues, prioritizing needs, collecting and interpreting information, shaping and evaluating alternatives and building capacities necessary for implementation.
- Stable co-operative mechanisms are established, nurtured and revised according to experience.

Principle 5

Sustainable development or sustainability. In a similar way to the term environmental health, this concept does not just encompass certain issues, but also requires particular ways of managing them. In the policy-making process relating to environmental health there are three particularly important threads that serve to confirm the almost overlapping nature of environmental health and sustainable development. They are:

- **Policy integration:** the bringing of environmental health considerations into all other areas of policy and the tying together of different policy fields and different levels of government.
- **Partnership:** consultation with and participation by all groups in society in the planning and implementation of sustainable development policies.
- **Appropriate scale:** the handling of the policy at the level of the government (from local to international) at which environmental health issue itself occurs, with a bias or emphasis towards the subsidiary principle.

Principle 6

Environmental health issues are truly international in their character. International communication and travel is making the world an ever smaller place. Environmental health professionals have long recognized the fragility and proportions of the planet, and that the contaminants in our environment do not respect national boundaries.

The world of environmental health is also small. The worldwide community of professionals who dedicate their working lives to improving and protecting the places we live in for the common good are but a speck compared to those who work to exploit and deplete the world's resources in pursuit of wealth creation. However, the diminutive character of the world's environmental health community brings great advantages. We can and must communicate with ease. Although our languages may be different and our heritage and culture place us in different systems, our problems and approaches are mutual.

Our commonwealth of knowledge can provide us with an irresistible resource for solving many of the perplexing dichotomies we are faced with in our daily work. International co-operation and collaboration is therefore a key principle for environmental health and is one that should not be overlooked, despite the distraction of our immediate surroundings and problems/challenges.

1.4 Agendas for change

Chartered Institute of Environmental Health (CIEH) which was established in 1996 recognized that the famous names of public health – the Chadwicks, the Pastors and the Rowntrees – all reacted to the conditions of industrial revolution; it created physical and social changes in our environment.

The CIEH also looked towards the production of a National Environmental Health Action Plan (NEHAP) as a means of reforming environmental health services.

CIEH formed a commission in 2000 with the following terms of reference:

- To consider the principle of environmental health and their application to the health of individuals and the pursuit of sustainable development of communities.
- To examine the relationship between environmental health and relevant socioeconomic factors.
- To recommend a framework for action in the United Kingdom (UK) to reinforce and take forward the principles of environmental health with the involvement of the whole community.

The new call of environmental health moves away from regulation and control towards co-operation partnership and management. According to participants at the Second Symposium on Environmental Health and Economics, held on 14–15 October 2013 in Bonn, Germany 'Visualizing,' both the health and economic gains can help persuade policy-makers to improve environmental health and obtain government support. Economic evidence needs to be more widely used in environmental health decision-making. This includes better, more transparent and harmonized use of existing economic tools, a clear explanation of assumptions and the limitations of results, the production of reliable data and success stories at the national and local levels, and the timely engagement of finance, planning, transport and trade ministries, along with those for health and the environment. {Source: *Report – Environmental health and economics: use of economic tools and methods in environmental health WHO/Europe, 2013, European process on environment and health}*.

The need for change

Here the focus is on:

- A healthy environment – we cannot isolate ourselves from our surroundings – the air we breathe, the water we drink, the food we eat, the buildings and the landscapes we inhabit. They directly or indirectly affect our health and well-being.
- The holistic approach – this demands a flexibility of response that may run counter to specialism.
- The commission's approach – considers examining the agreed schedule of environmental health interests; or examining illnesses related to environmental health, and the complicated interactions between environment, behaviour and biology, make the whole topic extremely complex.

The five major principles the commission put forward are:

1. Precautionary approach
2. Intersectoral collaboration
3. Addressing inequalities and inequities
4. Community participation
5. Sustainable development.

The environment health approach is based on common principles and processes that lead to a collective objective. They are:

- Equity: a belief that there are some things which people should have, that there are basic needs that should be fulfilled, that burdens and rewards should not be spread too divergently across the community, and that policy should be directed with impartiality, fairness and justice towards these ends.
- Sustainability: aims to meet human needs in the present while preserving the environment so that these needs can also be met in the indefinite future.
- Health promotion: aims to empower a person to take charge of his/her own health.

- Intersectoral action: refers to actions affecting health outcomes undertaken by sectors outside the health sector, possibly, but not necessarily, in collaboration with the health sector.
- Community involvement and engagement: the process by which community based organisations and individuals build ongoing, permanent relationships for the purpose of applying a collective vision for the benefit of a community. The steps involved are: determine the goals of the plan, plan out who to engage, develop engagement strategies for those individuals you already know, develop engagement strategies of those individuals you do not already know, prioritize those activities, create an implementation plan, monitor your progress and maintain those relationships.
- Local political support and ownership of decisions made.
- International action: take to the streets, demonstrate and demand improvements in the policies and practices of decision makers.
- Consensus building: an opinion or position reached by a group as a whole. Consensus decision making is the process used to generate widespread agreement within a group.
- Precautionary principle: if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientfic consensus that the action or policy is harmful, the burden of proof that it is *not* harmful falls on those taking an act.
- Partnership and participation: making decisions, planning strategies and implementing them to achieve better health. At the heart of this process is the empowerment of communities, their ownership and control of their own endeavours and destinies.
- Global responsibility: the world that characterizes the process of globalization compels us to interlink local, national, and transnational phenomena, such as environmental risks.
- Integrated approach: An approach that combines all aspects that are relevant to tackle the problems.
- Supportive environment: Creating environments where health choices become easier to make. It offers people protection from the factors that can threaten good health, participation in health and enable people to expand their capabilities and health self-reliance. And is critical for a person-centred approach to health.

1.5 The International Federation of Environmental Health

The Internaional Federation of Environmental Health(IFEH) was inaugurated in 1985 and was incorporated as a UK company in 1986. It has a wide spectrum of objectives; which include encouraging the co-operation of environmental health organizations, the exchange of information and experience, and the promotion of contact between individual members of constituent bodies.

IFEH endeavours to influence international environmental health policies. In fact world environmental health associations affiliated to IFEH and the executive officials are council members.

IFEH aims to make effective links with international organizations such as WHO, the United Nations (UN), the European Union (EU), and the International Labour Office (ILO), and to represent a global view on environment health issues.

Tasks of environmental health practitioner

1. Manage environmental health risks within natural, socio-economic, build and working environments within the scope of profession
    - Identify current and potential health risks
    - Compile a comprehensive risk management plan
    - Apply various strategies to address current and potential risks
    - Monitor and review the effectiveness of the comprehensive risk management plan
    - Conduct public participation at all stages of the development and implementation of the risk.
    - Management plan
    - Present a report in an acceptable format
    - Communicate outcomes to the relevant stakeholders.
2. Manage environmental health promotion programs
    - Conduct a situation analysis in a community
    - Design sustainable health promotion programs
    - Develop implementation strategies
    - Implement the health promotion program
    - Monitor and evaluate the program
    - Participate in multi-disciplinary promotion programs.
3. Manage environmental health services
    - Apply administrative skills in context.
    - Apply relevant policies and legislation for the provision of environmental health services.
    - Develop policies and legislation for environmental health services.
    - Apply set criteria for development control.
    - Apply skills and techniques to manage human resource in an environmental health context.
    - Manage financial matters and physical resources of an environmental health service.
    - Demonstrate computer literacy skills.
    - Apply project management principles.
4. Conduct and participate in environmental health research
    - Identify research need/ theme/ problem
    - Apply research principles in design and conduct of investigation

- Manage research data in line with prescribed guidelines
- Develop intervention measures
- Implement and evaluate intervention measures
- Communicate results in appropriate format.

5. Demonstrate interpersonal relations and professional behaviour in terms of the ethical code
   - Develop and manage communication strategies to improve environmental health services.
   - Communicate verbally, in writing and electronically according to requirements to all stakeholders.
   - Facilitate resolution of conflicts within the work environment.
   - Manage communication and marketing strategies that are related to environmental health.
   - Interpret and apply code of ethics in implementing the code of practice for environmental health practitioners.

Chapter 2: Water and Health

Prof. Mwanthi and Mr. Paul Gichia

2.1 Introduction

Water is a liquid at standard ambient temperature and pressure, but it often co-exists on earth in its solid, ice, and gaseous state (water vapour or steam). Water also exists in a liquid crystal state near hydrophilic surfaces. Water covers 71% of the Earth's surface, and is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Only 2.5% of the Earth's water is fresh water, and 98.8% of that water is in ice and groundwater.

Table 2.1 Global distribution of waters

Type of water	(%)	Volume Miles³
Fresh	2.5	
Ice, permanent snow, ocean	97.5	
Fresh water lakes	0.009	30,000
Saline lakes and inland seas	0.008	25,000
Stream channels	0.0001	300
Sub-surface: Water in unsaturated aerated zone (soil moisture)	0.005	16,000
Ground water within ½ mile depth	0.31	1,000,000
Ground water, deep-lying	0.31	1,000,000
Others: Ice carps and glaciers	2.15	7,000,000
Atmosphere (at sea level)	0.001	3,100
World ocean	97.2	317,000,000
Total	100	326,000,000

Water Source	Volume (1000 km2)	% of Total Water	% of Fresh Water
Oceans. seas and bays	1,338,000	96,5	—
Ice caps. glaciers and perm. snow	24,064	1.74	68.7

Groundwater	23,400	1.7	—
Fresh	(10,530)	(1.76)	30.1
Saline	(12,870)	(0.94)	—
Soil moisture	16.5	0.001	0.05
Ground ice and permafrost	300	0.022	0.86
Lakes	176.4	0.013	—
Fresh	(91.0)	(0.007)	.26
saline	(85.4)	(0.006)	—
Atmosphere	12.9	0.001	0.04
Swamp water	11.47	0.0008	0.03
Rivers	2.12	0.0002	0.006
Biological water	1.12	0.0001	0.003
Total	1,385,984	100.0	100.0
Source: Gleick P.H., 1996: Water resources In Encyclopedia of Climate and Weather. ed. by S.H. Schneider, Oxford University Press, New York, Vol. 2, pp. 817-823.			

Figure 2.1 Volume, % of total water and % of fresh water for: oceans, seas (teachengineering.org)

Access to water_is of paramount concern and other factors, such as the population served, the reliability, the supply, and the cost to the consumer must therefore be taken into account.

An important share of the total burden of disease worldwide, around 10%—could be prevented by improvements related to drinking-water, sanitation, and hygiene and water resource management.

At the United Nations conference at Mar del Plata in 1997, which launched the international Drinking Water Supply and Sanitation Decade, the philosophy was adopted;- '*all peoples, whatever their stage of development and social and economic condition, have the right to have access to drinking water in quantities and of a quality equal to their basic needs.*'

Access to water may be restricted in several ways:

- By prohibitive charges.
- Daily or seasonal fluctuations in availability or lack of supplies to remote areas.
- Distance: Where water is scarce and has to be transported over long distances by road or on foot, the cost of drinking water may absorb a significant proportion of the average daily income.
- Seasonal, geographical, and hydrological factors: - during dry seasons, spring sources may diminish, reservoirs may become exhausted and excessive demands by one group of people may limit supplies to their neighbours.

If the performance of a community water supply system is to be properly evaluated, a number of factors must be considered. Some countries have adopted quantitative service indicators for application at community, regional and national levels. These usually include:

- **Quality**: the proportion of samples or supplies that comply with guideline values for drinking-water quality and minimum criteria for treatment and source protection.
- **Coverage:** the percentage of the population that has a recognizable (usually public) water-supply system.
- **Quantity**: the average volume of water used by consumers for domestic purposes (expressed as litres per capita per day).
- **Continuity**: the percentage of time during which water is available (daily, weekly, or seasonally).
- **Cost**: the tariff paid by domestic consumers.

Together, these service indicators provide the basis for setting targets for community water supplies. They serve as a quantitative guide to the comparative efficiency of water-supply agencies and provide consumers with an objective measure of the quality of the overall service and thus the degree of public health protection.

2.2 Water pollution

EEC definition:

Water pollution means: '*the discharge by man of substances into the aquatic environment the results of which are such as to cause hazards to human health, harm to living resources and aquatic ecosystems, damage to amenities or interfere with other legitimate uses of water.*'

Types of water pollutants

Most of water pollutants are of organic, inorganic and micro biological origin.

Organic pollutants

Most of the organic pollutants are either of

- Animal or plant origin e.g. vegetable or dead animals, algae growth.
- Use of organic chemicals in agriculture or vector control e.g. pesticides, which find their way into water supplies.

Inorganic pollutants

Most of the inorganic pollutants are chemicals which are found in the soil and pollute ground water as it seeps through the soil strata e.g. fluorides, nitrates, and salts responsible for water hardness.

Industrial wastes containing heavy metals may contaminate ground and surface water supplies e.g. lead mercury, cobolt, arsernic, barium etc.

Water installation works e.g. lead from piping materials, copper sulphate from algae/ weed control and water treatment process.

Most of the time, water for the users mentioned earlier are not available due to poor quality. All users need water of specific quality. One major cause of poor water quality is pollution. Pollution is the removal or addition of more energy and/or matter into the environment than the system can sustain. It normally causes chain reactions in the ecosystems where it occurs; these are all the processes that the system uses to try to establish a new dynamic equilibrium if it receives a foreign body. Environmental pollution involves anthropogenic release and/or consumption of physical (heat / energy), chemical (matter) and biologically active agents (organisms such as pathogens, preys and predators) into the atmosphere. All these directly or indirectly affect man.

Pollution largely entails degradation of water, soil, air etc. from where man derives his livelihood. Thus, the process itself is unsustainable due to the disequilibrating effect. When dangerous chemicals and radiations are released into the environment, they have serious repercussions on health of both the biotic and abiotic systems. These chemicals include: heavy metals; pesticides and their residues; dioxins; polychlorinated hydrocarbons (PCHs); nutrients; acidic gases, ozone etc. The dangerous radiations are largely the short wave, energy packed ultra- violet.

Pollution types

These include point source and non-point source pollution. Point source pollution is from a recognizable point e.g. effluent from an industry reaching a river via a pipe or stream. Non-point source pollution is that with diffuse, unidentifiable source, e.g. agricultural pollution.

Some water pollutants:

1. **Heavy metals** include Lead, cadmium, Manganese, zinc, copper, mercury etc. They have serious health hazards resulting directly from their cumulative effects. They have a tendency to be deposited on surfaces of some soft and bone tissues and organs such as liver, kidney, lungs, bones and heart.
2. **Persistent organic pollutants**, including poly-chloro- biphenyls (PCBs) and organic pesticides such as chlorinated hydrocarbons such as dieldrin, DDT etc are known to be serious environmental pollutants that impact negatively on health. They are cumulative in nature and, upon interacting with the lower members of the trophic chain such as producers and primary consumers (herbivores), they accumulate there over time. As these are eaten up by their predators, the latter experience even a higher build- up and accumulation of these chemicals in their bodies.
3. **Pathogens:** In water pollution, a combination of biological, chemical and physical qualities are compromised. In biological pollution, *Escherichia coli* (*E. coli*) counts exceed the normal World Health Organization (WHO) range. Other active biological agents that compromise drinking water quality include *streptococci, Clostridia, Coliforms, and Pseudomonas* etc. Other chemicals such as nitrates, heavy metals and organic compounds reduce wholesomeness of water.
4. **Decomposable organic matter:** Food remains and food processing effluents, rich in carbohydrates, proteins etc, which are used by other organisms as food. These have an oxygen demand. As they decompose, they use dissolved oxygen from the

water, causing a deficit for other aquatic organisms and processes. Creates an oxygen demand.

5. **Thermal pollutants**: Introduction of hot or cold effluents into a system causes changes in composition of aquatic organisms, especially micro organisms. Thermophils will dominate if there are elevated temperatures; mesophils will dominate under normal temperatures.
6. **Suspended matter**: Clay silts from soil erosion, cause turbidity, reduce depth of sunlight penetration, and thus affect photosynthesis.
7. **Acids and bases:** Change the pH of the water body, thereby shifting the species composition within the system.
8. **Oil pollution:** Block the air-water interaction, thereby interfering with gaseous exchange, reducing the amount of dissolved oxygen, and liable to cause composition of organisms in the ecosystem.
9. **Nutrients:** Include nitrates and phosphates which cause Eutrophication.
   Nitrates and phosphates are common nutrients washed into water bodies from farmlands. They are then taken in by man and other aquatic-dependent organisms in the form of drinking water and foods. In man for instance, nitrates in drinking water is converted into nitrites in the infant stomach, thereby resulting in the formation of mutagenetic nitrosamines and nitrosamides. In adult human beings, nitrites can cause early onset of hypertension and related cardiac disorders. While in water, nitrates and phosphates together cause eutrophication, which also causes algal blooms and ecological imbalance.
10. **Helminths / Worms:** The infective stages of many parasitic round worms and flat worms can be transmitted to man through drinking water. A single mature larva or fertilised egg can cause infection and it is clear that such infective stages should be absent from drinking water. However, if the water route is relatively unimportant except in the case of Dracunculus medicinsis (the guinea – worm) and the human schistosomiasis which are hazards primarily encountered in unpiped water supplies. While there are methods for detecting these parasites they are unsuited for routine monitoring.

    Dracunculus may be a cause of severe morbidity in rural populations and is transmitted by fresh water copepods, such as Cyclops, which represent an obligatory intermediate stage larva reach the copepods when a blister on the lumb of an infected person bursts and the larvae are washed into open wells and ponds; the parasites infect man when the copepod is ingested. In order to determine whatever a risk of infection exists, copepods may be collected in plomptom nets and examined for parasitic larvae under the microscope; the prevalence of the disease in man should also be investigated.

Detoxification of heavy metals: Chelation

Chelating or sequestering agents remove metallic ions from solution. These form inorganic and organo-metallic complexes that are often less toxic, and more rapidly excreted than the metallic ions. In the formation of the covalent bond, each atom contributes one electron to the shared pair in the common molecular orbital.

In addition, through co-ordinate covalent bonding, metals may have auxiliary valences and form complexes of co-ordination compounds with electronegative atoms. A co-ordinate covalent bond is formed when both shared electrons are contributed by one atom. When the ligand contains at least two donor atoms, chelate formation may occur. This involves the formation of ordinary covalent or co-ordinate-covalent bond between an electrophilic atom of a metal and a hydrophilic atom of a ligand.

Common chelating agents are:

1. Ethylene diamine triacetic acid (EDTA): EDTA in a solution of the disodium salt of EDTA, the sodium and hydrogen ions are chemically and biologically available.
EDTA in solutions of calcium disodium edetate. Here, calcium is bonded by coordination covalent bonds with nitrogen as well as by the usual ionic bonds. Calcium ions are effectively removed from solution.

The poly carboxylic acid can form salts utilizing covalent or ionic bonds. As the disodium salt-calcium salt is formed, additional binding is possible. Calcium has unfilled orbital that can absorb electron pairs from the nitrogen. The calcium is held firmly in the heterocyclic organo-metallic rings that result and can no longer provide calcium ions. In fact if the tetrasodium salt is added to blood or other material, calcium ions are sequestered by the claw-like hold of the chelate and clotting is prevented. The lead EDTA is even more stable; it is formed preferentially even in the presence of calcium ion. In EDTA, all six of the ligands of EDTA have contributed to the formation of partially fused 5-membered rings. Thus the ca-EDTA can be used to reduce lead toxicity.

Stability of metal chelates

The stability of metal chelates depends upon properties of the metal chelating agents. Compounds can therefore be selected to bind certain metals with a degree of specificity sufficient to make them therapeutically useful in the treatment of intoxicants. The stability of the chelate is greatest when the ligand molecules contain more than one electron donating atom. This case is described as polydentate.

Stability is also increased if the metal becomes part of the several fused rings when the chelate is formed. It is this type of bonding that makes the hemoglobin to be very stable. The chelate formed has chemical and biological properties different from either of the precursors. The metal is no longer present in an ionized form, and is not biologically available. The chelates formed in the course of therapy must be non- toxic and very water-soluble. They are more readily excreted than the offending metal. All chelating agents remove or inactivate some of the trace metals (heavy metals) present in the organism, and it has been suggested that some drugs may exert their pharmacological action through this mechanism.

2. Metal specific chelating agents

In most cases, chelating agents are metal- specific (e.g. deferoxamine and iron). However, several possible pairs are involved.

- **Dimercaprol**

  Arsenical vesicants were developed in the First World War to supplement sulphur mustard gases. In the 2nd World war, it became apparent that the nitrogen mustards would replace the arsenical vesicants should chemical warfare be attempted. The British developed an antagonist to the toxic effect of arsenic. It was called the British Ariti-Lewisite (BAL).

  Arsenic reacts with sulphydryl groups especially those in keratin of the skin, nails and hair. The thiol group was the arsenic receptor. Generally 1 equivalent of arsenic reacted with 2 equivalents of sulphydryl groups. They introduced dimercaprol as a sample dithiol to react similarly with arsenic, thereby neutralizing its toxic effects and hastening its excretion. It is still used in treatment of arsenic and mercury poisoning.

  Dimercaprol has an offensive odor similar to that of other mercaptans or thiols. It is not soluble in water and is dispersed as a solution in peanut oil. Dimercaprol can reactivate SH-containing enzymes that have been inactivated by heavy metals. However, this may inactivate other metals that might have been active earlier (Manahan, 1992).

- **Calcium disodium edetate (Ethylene diamine tetra acetic acid) (EDTA).**

  The tetra-acetic acid is the active form of EDTA. It may be added to blood to prevent clotting. When used as drugs, salts of EDTA are known as edetates e.g. disodium and trisodium edetates. These bind calcium in large quantities, and help lower serum calcium. When in even larger quantities, especially in chronic cases, the calcium chelate formed may be damaging to the kidneys. Calcium disodium edetate will exchange calcium for lead and a few other heavy metals. It is still used in combination with dimercaprol in the treatment of lead poisoning.

- **Penicillamine:**

  This amino acid occurs only as a product of the hydrolysis of penicillin. It can be considered a dimethyl cysteine or a thiovaline. Its isomer is less toxic and is used as a drug. It is used to remove copper from lead and prevent accumulation of copper in tissues. It may be effective as a chelator of lead and probably mercury. It also combines chemically with cysteine (an amino acid) to form cysteine-penicillamine disulphide. This is much more soluble than cystine (cysteine-Cysteine disulphide). It may, however, interfere with the synthesis of DNA, collagen and mucopolysaccharides.

- **Deferoxamine (Desferl)**

This is used in treatment of nickel and thallium poisoning.

Metals and their uses:

Concerns about chemical toxicity, especially metal poisoning, are very real. This is because most of these metals are handled on daily basis by man, and therefore increase chances of exposure. The discussion below gives some uses and possible sites of exposure of man to the metals.

Lithium (Li): used in medicine for treating depression as well as in the production of glass and ceramics, batteries, plastics, detergents and alloys. It is added to some rocket fuel and lubricants, and is used as a catalyst and as the hypo chlorite salt. It may be used to disinfect water in swimming pools.

Sodium (Na): used as a household (table salt) in many branches of industry such as in the manufacture of chemicals, glass, paper, food & Medicare. Na compounds are used in the production of pigments, dyes, detergents, glass wool etc. Rock salt is used for snow and ice clearance on roads during winters. NaOH, $NaHCO_3$, and Na_2CO_3 are used in water purification process. Others such as NaF may be added to water for dental protection.

Daily consumption of sodium by humans is between 4 and 24 g per person; whereas the amount necessary for maintenance of health is about 3-4g daily.

Potassium (K): This is used as fertilizer; in production of explosives, matches, and glassware; in medicine and in photography. A radioactive isotope of 40K exists naturally which gives weak radioactivity of 0.118%.

Copper (Cu): This is mainly used in the production of alloys of zinc, nickel and tin, as a catalyst in the chemical industry; in electrochemical industry where it is used in generators, transformers and heat transchangers; and in the production of piping for water supply. Cu salts are used as pigments and fungicides and as biocides for controlling slime and algae in water supply. Naturally occurring complexes of copper are amino acids, polypeptides and humic acids. Humic substances comprise 90% of cu in fresh water but only 20% in seawater. The latter is because there is a high concentration of ca/mg in seawater, thus blocking the binding of cu and humic substances. But Cu ion (Cu2+) tends to be adsorbed on to particulate matter and deposited in the sediment as hydroxides and carbonates.

Silver (Ag): used in production of alloys in the electronics' industry and in jewelry manufacture. Ag compounds may be used in many fields such as electroplating, photography, foods and beverage processing & production of coins. It has the highest known electrical and thermal conductivity. It has bactericidal properties that render it useful as a disinfectant of swimming pool water.

Mercury (Hg):

Mercury poisoning and effects on the body:

Cadmium, Lead, Arsenic and other heavy metals and their compounds are also highly toxic to life. They also act in a similar way to mercury. There is evidence that Napoleon, Ixan the terrible and Charles II may have died from heavy metal poisoning.

Traces of Hg in organic compounds containing Hg^{2+} have always been present in nature. Therefore, all life contains some traces of Hg. Over millions of years, humans and other living creatures have become tolerant to this small concentration of Mercury.

It is also likely that other forms of life may now be dependent on mercury and other poisonous metals as trace elements for their survival. It was the use of Hg II hydrate in felt making that led to the condition called Hatters' disease, Shakers' disease or hatters' madness in the felt trade. Perhaps mercury II Nitrate ($Hg(NO_3)_2$) was responsible for the Hatters' madness in Alice in wonderland.

Biochemical interpretation of Mercury (Hg) poisoning.

Hg has a strong affinity for Sulphur, for Sulphydryl group (SH) and cysteine units in proteins. Alkyl-mercury compounds such as methyl mercury ethanoate are particularly dangerous because they can form strong covalent bonds with the Sulphur atoms in these SH groups. The alkyl mercury compounds replace H atoms in the SH group with alkyl mercury compounds and maintain their destructive activity for many periods.

The attachment of a mercury atom to the protein can seriously alter or hinder its properties. Proteins play an important part in cell enzymes that catalyze bioprocess, and form constituents of cell membrane. Thus, the binding or attraction of Hg to S in proteins can invert the activity of an enzyme and interfere with the movement of materials across a cell membrane.

Mercury poisoning: The tragedy of Mina Mata

During 1953, the inhabitants of Mina Mata, a heavily industrialized town in Japan, noticed a bizarre illness affecting their cats especially those owned by families of fishermen. The cats would first stagger around, unable to support themselves & muscles weakened paralyses, coma and death followed. In December1953, the first human death of this mysterious illness was recorded. Between 1953 and 1963, 43 other humans died of the same disease and more than 60 others were permanently disabled. Unable to find the cause of the mysterious disease, the health authorities sought help from Medical department of Kumamoto University.

In 1956, investigations focused on heavy metals. By this time domestic animals, seabirds and the fish in mina Mata bay were diagnosed of disease similar to that in humans. When cats, fish & selfish were examined for toxic matter, their samples were found to contain 20-60 times as much mercury as would normally accumulate from the minute traces naturally present in sea water. All the fishing in mina Mata was banned and it became obvious that fish, the main source of food in the area, were responsible for passing the toxic mercury on to humans.

The search for the source of mercury began immediately and was traced to a large industrial plant that produced plastics, including PVC and industrial organic chemicals. Chlorine for making PVC was produced by electrolysis of concentrated brine using a flowing mercury cathode. Several organic chemicals were prepared from ethanol that was synthesized using mercury II sulphate catalyst.

A further significant fact was that large-scale production of PVC commenced in 1952 shortly before the outbreak of the disease. The effluent from these plants flowed into settling ponds and then via a canal into Mina Mata Bay. The mud from these settling ponds was found to contain as much as 700 ppm wet weight of organic mercury compounds, mainly Mercury II chloride & Mercury II sulphide. Small concentrations of organic mercury compounds were present in the water effluent. The table below gives the number of deaths recorded per year in the Mina Mata bay area.

Table 2.2 The Mina Mata deaths (1952-1960)

Year	Dead	Tons vinyl
1952		200
53	1	300
54	12	400
55	15	500
56	50	600
57	6	1400
58	5	1400
59	18	1500
60	4	1700

Microbiological pollutants

Most of the microbiological pollutants of water supplies e.g. bacteria, viruses, protozoa, and helminthes eggs are of animal origin. These microbiological organisms find their way into water supplies through faecal contact with water. For example, infectious hepatitis is carried in blood and faeces by a virus that is highly resistant to ordinary methods of water treatment.

Sources of water pollution

It is easier to prevent water from getting polluted in the first place than cleaning it. It is therefore necessary to consider the possible sources of water pollution between the time the water falls as rain and the time it is used.

Sources of pollution include the following.

Rain water collecting surfaces may have leaves, insects, birds, dust and animal faeces on them.

Acid rain caused by industrial discharge of sulphur dioxide (by burning high sulphur fossil fuels)

When water runs over the earth's surface, it may be polluted with human or animal excreta, refuse, fertilizers, and industrial wastes. This contamination is less high up on mountains and greater nearer towns.

- Shallow wells may be contaminated by excreta and refuse being dumped into them if they are not covered. If latrines are located nearby, the water may be contaminated by diffusion.
- Wells may also be contaminated by use of dirty containers used for drawing water or by oil from a pump.
- Rivers, lakes or dams may be polluted by bathing, urinating, or defaecating or disposing solid wastes in the water.
- Even piped water may be polluted from leaks in the pipes especially when these pipes pass near foul water or dirty drains.
- Water from any source may become polluted if it is drunk from dirty or communal drinking vessels.
- Thermal pollutants: heat arises from discharge of hot water in water bodies. Even a relatively small temperature increase can have adverse effects on aquatic life. For example,
  - Salmon and trout cannot live in water much above 25°C.
  - At higher temperatures the rate of metabolism increases, creating greater oxygen demand
  - Less oxygen is available since its solubility decreases with increasing temperature.
- Industrial discharge of chemical wastes and by-products.
- Discharge of poorly treated or untreated sewage.
- Oil spills.

Table 2.3 Classification of water pollutants.

No	*Type*	*Example*
1	Oxygen-demanding wastes	Human, animal waste decaying vegetation
2	Infectious agents	Bacteria and viruses
3	Organic molecules	Detergents, insecticides, oil
4	Plant nutrients	Nitrates, phosphorous
5	Inorganic chemicals	Mercury, lead
6	Thermal pollution	Water used for cooling in industries
7	Suspended material	Silt from land erosion
8	Radioactive substances	Radioactive waste e.g. uranium

Some effects of water pollutants (hazards) on health:

1. Bioaccumulation
2. Bioamplification.
3. Characteristic Toxicity sysmptoms and conditions associated with pesticides and heavy metals
   - Mutations

- Teratogenicity (birth defect):
  - Children born with 2 heads or more
  - Children born with one or more parts of bodies missing
  - Children born with clear deformities such as more than the normal number of body parts etc.
- Nervous incoordination
- Cancers.

Due to these pollution / water quality concerns, water treatment is a requirement if it is to be safe

Health implications of water supplies

The provision of an adequate supply of safe water was one of the eight components of Primary Health Care (PHC) identified by the International conference on Primary Health Care in Alma Ata in 1978. In most countries the principal risks to human health associated with the consumption of polluted water are microbiological in nature.

An estimated 80 % of all diseases and over 1/3 of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one tenth of each person's productive time is sacrificed to water-related diseases.

Diarrhoea is caused mainly by the ingestion of pathogens, especially in unsafe drinking water, in contaminated food or from unclean hands. Inadequate sanitation and insufficient hygiene promote the transmission of these pathogens. Eighty-eight per cent of cases of diarrhoea worldwide are attributable to unsafe water, inadequate sanitation or insufficient hygiene. These cases result in 1.5 million deaths each year, most being the deaths of children.

Uses of water and factors affecting them.

The various uses of water may be grouped under the following categories:

1. Domestic purposes: drinking, cooking, bathing, washing, gardening, domestic animals, private vehicles and household sanitary purposes.
2. Hospitals, nursing homes, clinics, public toilets, sanitation of market areas, fire fighting, and recreational activities like swimming pools.
3. Industrial purposes: Manufacturing and processing of almost all goods in factories, medicines, power stations, etc.
4. Commercial purposes: Hotels, restaurants, dairies, laundries, agricultural activities, motor garages, etc.

   As can be seen from the aforesaid, water is the most important material/resource for civilization. It is however closely related to health and this relationship has been recognized since the time of Hippocrates if not earlier.

   The first person to show relationship of disease to water was Snow in 1885 in his studies of cholera. Soon after, he was followed by Budd who demonstrated the spread of typhoid fever through water supplies. In 1887, Manson showed the relationship of filariasis with mosquito and water. Ross showed the relationship between the spread of malaria and water.

2.3 Water requirements

Water usage varies from place to place depending on several factors. However, in general, the figure below gives a guide on water needs.

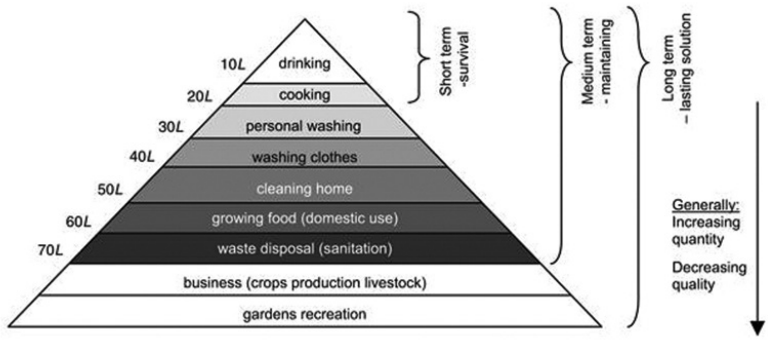

Figure 2.2 Hierarchy of water needs

Factors affecting water usage

The total water consumption per capita per day is determined by a great number of factors such as:

1. Availability of water
   If water is scarce or its source is a long way off, then the usage is limited sometimes to only the most basic needs that is cooking and drinking.
2. Water Service Levels
   Water Service Levels refer to the level at which water is accessible to a household. There are three basic levels:
   - Household connection
   - Yard connection
   - Non-piped water supply.

   Where water is connected into houses, the consumer uses more water than when it is being fetched from a standpipe outside or from a nearby spring.
3. Its cost
   Cost may be an important factor influencing access to water, and is especially important in peri-urban areas where water is purchased from vendors. Where such water is the only water available for personal and domestic hygiene purposes, the adverse effects of high costs on public health are proportionally greater. In these circumstances, it is quite common for the amount paid by individual families for water to be sufficient, if combined, to finance the construction or expansion of

a piped water supply adequate to supply public health needs. Information on the cost per family is therefore important for national and regional planning purposes.

4. Standard of living of families
   The more affluent and richer a family is, the more water will be required. It has also been observed that people in urban areas tend to use more water than in rural areas possibly due to sophistication.
5. Cultural habits of the community

Water quantity requirements

Estimates of the volume of water needed for health purposes vary widely. Daily per capita consumption must take into account the following:

- Drinking water
- Water needed for personal and
- Domestic hygiene.

- All these are important for the maintenance and improvement of public health.
- Where water is easily available, its requirement will range from 50 litres to 500 litres per person per day.
- In rural areas, daily consumption for these purposes varies widely, in urban areas, with piped supplies to house connections; it may exceed 100 litres per capita per day.
- Some authorities use a guideline value of 50 litres per capita per day, but this is based on the assumption that personal washing and laundry are carried out in the home. Where this is not the case, lower figures may be acceptable.
- Measurement of the volume of water collected or supplied for domestic purposes may be used as a basic hygiene indicator.

In developing countries it has been observed that the following amount of water is consumed depending on the method of distribution:

Table 2.4 Type of water supply and amount of water used

	Type of Supply	Litres/Person/day	Average
1	with house connection	Up to 200	50
2.	with only a stand pipe	10 to 50	30
3.	with no pipe water	5 to 25	15

Table 2.5 The average of water required for an urban residential house.

Drinking	1.5 litres
Cooking	3.5 litres
Clothes Washing	15 litres

General	25 litres
Personal Ablutions	40 litres
Water closets	25 litres
Total	**110 litres**

Table 2.6 Suggested quantities of water sufficient for various communities

For rural community	50-75 litres
For Urban and residential areas	125 – 150 litres
For industries	175-200 litres

Source :{ www.who.int/water_sanitation_health/diseases/WSH0302}

2.4 Sources of water

Sources of water can be classified into three main categories:

1. Rain water
2. Surface water
3. Underground water.

Rain water

This is a major source of water all over the world. If rain falls through a clean atmosphere, collected by clean surfaces and stored in clean covered and non-corrosive containers it remains the purest of all natural waters.

Rain water harvesting for domestic use should be encouraged. Rain water is naturally soft, well aerated and free from pathogenic organisms. As it passes through the atmosphere it hits other impurities for example CO_2, SO_2 NH_3 and other floating impurities such as dust.

Collection of rain water is usually done by house roofs and in a few areas by exposed rock i.e. rock catchment.

Roof Catchment: This is the commonest method used. The materials recommended for the roof used for collecting water are: galvanized iron, tiles and concrete.

Thatch and lead sheets are not at all recommended since thatch is highly absorbent and lead is potentially dangerous due to cumulative effect in the body.

N.B. Very soft water dissolves lead. Lead reacts very slowly with soft water containing oxygen to form lead hydroxide which may lead to poisoning.

Asbestos roofing is also not recommended for harvesting drinking water as it may lead to asbestos related illness.

It is important to ascertain the amount of water expected to be obtained before deciding on the use of rain water as the only means of supply. To calculate this, two factors have to be considered:

- Rain distribution throughout the year (monthly rainfall pattern)

- Average rainfall in one year.

It is important to have sufficient storage capacity to cater for even the dry months. A guide to calculating rain water collection from the roofs:

- I inch of rain on a 1000 sq ft roof yields 623 gallons of water or
- 1mm of rain on a 1 sq meter surface yields 1 litre of water.

Disadvantages of rain water

- It is very difficult to collect from thatched roofs.
- Gutters and large tanks are required to store sufficient rain water to last into the dry seasons.
- The water is 'soft' and does not contain any essential mineral salts. It may not taste very good.

Surface water

When rain falls, it collects on the surface in streams, rivers, ponds, lakes, swamps and dams. Some of it gradually soaks down into the ground until it meets a layer of very hard earth or rock which it cannot penetrate. Such a layer, which may be quite near the surface or quite deep down, is called an impermeable layer. All water above this layer is surface water. This water overflows down the valley and connects with other springs to form rivers and streams. Surface water may be classified into two:

- Water that falls on high hills (upland surface water).

The water that collects into streams above where people live is often plentiful and clean and makes very good drinking water. Catchment area for this water is normally in the mountains.

If it can be piped to people living lower down the hills, it flows by gravity and no pumping is required.

Disadvantages: The source must be protected from human and animal pollution in case of settlement in the catchment area.

- Water in all other areas (e.g. plains and the coastal belt).

This is water collected below the level where people live.

Advantages

- Surface water, whether in ponds, lakes, shallow springs, streams or rivers, dams etc is the commonest source of water for most people.
- It's easily accessible – can be obtained by hand or by simple pumps.
- The larger lakes and rivers are permanent all the year round.

Disadvantages

- Easily and frequently polluted as it runs over the ground through urination and defecation by humans and animals.
- Pollution by chemicals used in agriculture & industries.

Ponds/dams

They have been a major source of water for many communities.

Disadvantages

- Commonly contaminated by faeces and other suspended matter e.g. silt and clay which make the water brownish. To some people brown water is not palatable especially when there are alternatives.
- Diseases transmission e.g. cholera which can affect a whole village.
- Many ponds are seasonal.

Lake

- It is much larger than the pond.
- It is seriously contaminated by agricultural, domestic and industrial wastes.
- Mostly fresh water which however requires treatment due to pollution.
- A threat is posed to sustainability of water supply and safety of the water. The more the treatment, the higher the cost and the less the demand. Consumers may therefore resort to alternative water sources e.g. rivers, raw water from the lake etc.

River

It has an open surface and flows most of the time by gravity. It has many characteristics as those of the lake.

- It has suspended particles, biological and chemical pollutants thrown in its way through point source and non-point source pollution.
- It's a less appealing water source for domestic use compared to the lake or the pond.
- Could be having pollutants upstream.
- Compared to the lake and pond, river water is turbulent. Therefore no settling of the suspended matter.
- The river is an easy dumping site for effluents by industries and municipalities since affluent is carried away immediately and only careful investigations can point to the source.

Underground water sources

As the water soaks through the ground and travels underground it is filtered by the soil. Underground water is therefore usually clean and often plentiful and permanent. It may come from a long way off and is not so dependent on local rain. Many rural areas and small towns use this type of water.

Wells

Are largely small water sources mostly manually dug with a wide surface and therefore exposed to any surface contamination.

- Relatively shallow and the surface left open expose it to faecal contamination, surface run off and air-borne litter.
- In some cases wood planks are placed on top of a well on which people step to draw water by bucket and string method.

Disadvantages

- Its laborious to make and use
- Expose people to diseases due to contamination
- In many cases wells are seasonal due to shallowness.
- A Water well is an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers. The well water is drawn by a pump, or using containers, such as buckets, that are raised mechanically or by hand.
- Wells can vary greatly in depth, water volume, and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water.

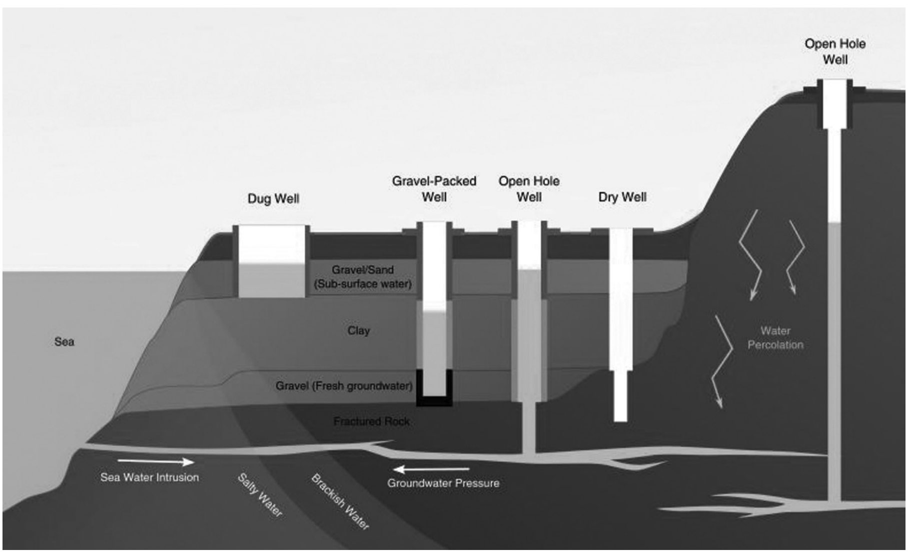

Figure 2.3 Types of wells

Bore hole (deep Well)

- The borehole has a narrow bore, very deep, mechanically dug (drilled) and lined.
- This means it is deeper and provides reliable water supply of good quality
- However a machine (pump) must be used to draw the water.

- It's an expensive source due to drilling and pumping costs. Boreholes have failed due to operation and maintenance costs which are never incooperated in the planning e.g. spare parts for the pump.

Springs

- Occur where the water table meets the ground surface.
- Most of them are considered as false underground sources because they could have disappeared underground to reappear elsewhere.
- A true spring emerges from a natural source (impervious layer). Such a spring is generally chemically and biologically pure and reliable.
- It may need protection at the source.
- To maximize the use of a spring, flow rate may be enhanced by:
  - Protecting the spring
  - Establishing the spring box.

Factors to consider when determining a suitable water supply source

1. Quality: This will determine the need for treatment and the cost of treating the water.
2. Quantity: The amount of water available is also very important, for it will be a waste of funds and time to construct a supply that will be dry most of the time.
3. Distance: - Distance should be considered due to cost of piping and traveling. It is therefore important to weigh the cost of piping against that of treating a near polluted source.

2.5 Water quality

Properties of water

1. Water is a chemical compound consisting of 2 gases i.e. Hydrogen and Oxygen in the ratio of 2:1 and hence the chemical formula H_2O.
2. Pure water should be:
   - Colourless
   - Odourless
   - Tasteless
   - Neutral pH (pH 7) i.e. Neither acidic nor alkaline
3. Water freezes at $O^{O}C$. or 32^0 F and boils at 100°C or 212^0 F.
4. Density of water is 1gm/cc at 40^0 C or 39.1^0F (maximum density of water).
5. Water is the greatest solvent known to science and due to this it is never found pure in nature. Solubility of water is dependent on:
   - Temperature - The higher the temperature of water, the more it will dissolve.
   - Softness - the softer the water is, the more soluble it becomes.
   - Pressure of water.

- Nature of the matter being dissolved since the softer it is the faster it dissolves.

6. As water passes through the atmosphere, it absorbs CO_2 forming carbonic acid which increases the solubility and enables water to dissolve lime and magnesium to form bicarbonates. This kind of water is referred to as hard.
7. Water is found in three forms in nature.
   - Solid – when frozen.
   - Liquid – when in aqueous form.
   - Gaseous – when in vapor form.

Characteristics of good drinking water

- Water should be colourless in small quantities and assumes a bluish colour when seen in large quantity.
- Should be free from smell, be sparkling and pleasant to taste.
- It should be clear and free from turbidity or suspended matter, pathogenic organisms or any other pollutant.
- It should be moderately hard, well aerated and of suitable temperature.
- It should be neutral to ^{PH}.
- The above conditions will make drinking water:
  - Palatable – that is pleasant to drink and
  - Wholesome – i.e. safe to drink.

Parameters of water that affect its quality

All natural waters contain varying amounts of other minerals in concentrations ranging from a few mg per litre in rain to about 35,000 mg/l in seawater. **Definition of parameters**: a set of measurable factors that define a system or set the conditions for its operation. For water quality, we are considering the limits for various factors or characteristics that define the quality of water.

Characteristics of water may be divided into:

Physical characteristics

Physical properties are:

1. Temperature

Pure water freezes atomic 0°C and boils atomic 100°C under 1 atm pressure. *{ BRAJESH SHUKLA - Copyright © 2012 PreserveArticles.com}*

2. Taste and odour

These are due to dissolved impurities, often organic in nature, e.g. phenols, and chloraphenols. They are subjective properties which are difficult to measurer; they depend on the individual's sharpness of the sensory cells.

3. Colour

Even pure water is not colourless; it has a pale green-blue tint in large volumes, it is necessary to differentiate between true color due to material in solution and apparent colour due to the suspended matter. For example, natural yellow colour in water from upland catchments is due to organic acids which are not in any way harmful, and are similar to organic acid from tea. Nevertheless many consumers object to a highly colored water on aesthetic grounds.

Coloured waters may also be unacceptable for certain industrial uses e.g. production of high-grade art papers.

4. Turbidity

The presence of colloidal solids gives water a cloudy appearance which is aesthetically unattractive and may be harmful. Turbidity in water may be due to clay and silt particles/ discharges of sewage or industrial wastes, or due to the presence of large numbers of microorganisms.

5. Solids

These may be present in suspension and/or in solution and are divided into the following

- Organic matter
- Inorganic matter
- Total Dissolved Solids (TDS) are due to soluble materials.
- Suspended Solids (SS) - are discrete particles which can be measured by filtering a sample thro' a fine paper.
- Settleable solids are those removed in a standard settling procedure. They are determined from the difference between SS in the supernatant and the original SS in the sample.
- Colloidal material- very fine homogeneous material with very low settling.

6. Electrical conductivity

The conductivity of a solution depends on the quantity of dissolved salts present and for dilute solutions it is approximately proportional to the TDS content. This provides a rapid indication of TDS content.

Chemical characteristics

1. ***pH***: this measures the hydrogen ion concentration in water. It ranges in a scale of 0-14 with 7 being neutral. Many chemical and biochemical reactions are controlled by pH e.g.
   - Biological activities are usually restricted to a fairly narrow pH range of 6-8.
   - Highly acidic or alkaline water causes corrosion hazards and possible difficulties in treatment.
   - The efficiency of chlorination and other chemicals is highly dependent on pH.

2. **Hardness**: this is the property of water being unable to form lather easily with soap and produces scale in hot water systems. This is due to having dissolved salts of calcium or magnesium in form of carbonates or sulfates. Hardness may not be hazardous but is economically disadvantageous due to the usage of much soap and blockage sometimes causing bursting of hot water systems.
3. **Dissolved Oxygen (DO)**: This is the most important element in water quality control. Its presence is essential to maintain the higher forms of biological life. The effect of waste discharge on a water body is determined by the oxygen balance of the system.
4. **Oxygen demand**: Organic compounds are generally unstable and may be oxidized biologically or chemically to stable, inert end products e.g. CO_2, NO_3, H_2O etc. An indication of organic content in water is obtained by measuring the amount of O_2 required by the bacteria which will stabilize that matter.
5. **Biochemical (biological) oxygen demand (BOD)**: is the measure of O_2 required by micro-organisms to break down (oxidize) organic matter in a given sample of water. The amount of oxygen consumed during a fixed time period is related to the amount of organic matter present in the original sample. Normal period is 5 days and the result is expressed as $BOD_{5.}$
6. **Chemical oxygen demand (COD)**: sometimes chemical oxidizing agents are added to samples in an attempt to oxidize chemically the material contained in the samples. Such a measurement is quicker and is less prone to the biological problems associated with BOD_5 test. COD usually refers to the value obtained from chemical oxidation while using boiling potassium dichromate.
   Permanganate value (PV): This is value obtained from chemical oxidation while using potassium permanganate solution.
7. **Total organic carbon (TOC)**: this is equivalent to the total organic matter content in water. Determination of TOC relies upon combustion of the sample and measurement of the carbon dioxide produced from the carbon present in the sample.
8. **Total oxygen demand (TOD)**: this is the amount of oxygen required to oxidize fully a sample of water. The determination of TOD involves combustion of the sample in an oxygen-enriched stream. The subsequent reduction in the concentration of oxygen in the gas stream is measured and interpreted as the TOD.
9. **Nitrogen**: this is an important element in biological systems for it has to be present for biological treatment of wastes to proceed. There are different forms of nitrogen as follows:
   - Organic Nitrogen - This is nitrogen in form of proteins, amino acids and urea. It is also referred to as Albuminoid Nitrogen.
   - Ammonia Nitrogen - is nitrogen as ammonium salts or as free ammonia.
   - Nitrite Nitrogen – This is an intermediate oxidation stage of nitrogen.
   - Nitrate Nitrogen -this is the final oxidation product of nitrogen.

- Oxidation of nitrogen compounds is referred to as nitrification and proceeds as follows:-
  Organic N + O_2 ___ Ammonia. N + O_2 _____ NO_2 _____ NO_3
  Reduction of nitrogen is refered to as denitrification and proceeds as follows: -
  NH_3 NO_3 _____ NO_2 _____ N_2 Different forms of nitrogen in water indicate the nature and strength of the sample and also the period elapsed since pollution took place.

10. **Chlorides:** They make water blackish and are an indication of sewage pollution because of the chloride content of urine.

Water hardness

Hard water is one which does not easily give lather with soap; while a soft water is one which lathers easily with soap.

Hard water fails to give lather with soap because the salts dissolved in the water react with the soap to give a precipitate or scum.

When rain falls Co2 is dissolved from the air forming carbonic acid (H_2CO_3). When water now comes into contact with calcium carbonate ($CaCo_3$) in the form of limestone or chalk it dissolves forming calcium bicarbonate in solution {$Ca(HCO_3)_2$}.

Similarly it dissolves $MgCO_3$ which occurs naturally as magnesite and deromite.

$CaCo_3 + H_2Co_3 \rightarrow Ca\ (HCO_3)_2$ Calcium bicarbonate

$MgCO_3 + H_2CO_3 \rightarrow Mg\ (HCO_3)_2$ Magnesium bicarbonate

Water dissolves many other compounds from rocks with which it comes into contact. The most important are the sulphates nitrates of magnesium, chlorides and calcium. These together with the bicarbonates are the most important impurities in natural water.

Other impurities which are found are:

- The salts of sodium: These are not objectionable unless they are present in large amounts.
- Small amounts of Silicia (SO_2) may also be present; this can be a nuisance if water is to be used as a boiler feed.
- Iron may also be present as ferrous bicarbonate Fe ($HCO_{3)2}$ and this must be removed.
- Sometimes water may become acidic by coming into contact with organic acids from decaying matter. These acids will need to be neutralized in order to prevent corrosion of lead and iron and make it suitable for industrial use and domestic consumption.

There are two types of hardness:

1. Temporary hardness
2. Permanent hardness

Temporary hardness (alkaline)

This is caused by the presence of Calcium and Magnesium bicarbonates and it can be removed by boiling the water.

Heat

$$Ca\ (HCO_3)2 \rightarrow CaCo3 + H_2O + CO_2$$
$$\quad (Ppt) \quad (l) \quad (g)$$
$$Mg\ (HCO3)2 \rightarrow MgCo_3 + H_2O + CO_2$$
$$\quad (Ppt) \quad (l) \quad (g)$$

The CO_3^{2-} are precipitated from the water and in the case of calcium salts, there is almost complete removal of the hardness. In the case of Magnesium salts, the hardness is partially removed.

Permanent hardness (non-alkaline)

This form of hardness is not removed when H_20 is boiled. It is caused by the presence of salts such as chlorides, nitrates and sulphates of calcium and magnesium which are not affected by boiling.

Both types of hardness can be removed by chemical treatment which results in the removal of calcium and magnesium salts as compounds of low solubility.

Why it is necessary to remove causes of hardness:

Problems associated with hard water

- Wastes of soap: Calcium and magnesium bicarbonate chlorides and sulphates form an insoluble scum or magnesium soap. Until all the salts have reacted, the soap is unable to do its job and is being wasted. The scum spoils the finish of the fabrics in laundries and textile works.
- It causes deposits of scale on the inside of boilers; the scale consists mainly of insoluble (Ca $(HCO_3)_2$ originally present in the water. This scale reduces the conductivity through the boiler tubes thus reducing the efficiency of the boiler.
- Dissolved salts such as calcium sulphates are not decomposed by boiling. They will accumulate in the boiler walls until they become so concentrated that they crystallize out on the boiler metal.
- Hard water can for example, interfere in such process as dyeing (by reaction with the dye) or in tanneries (by reaction with the tannery chemicals).

Biological characteristics

Bacteriological analysis of water supplies usually provides the most sensitive quality parameter. A feature of most natural waters is that they contain a wide variety of microorganisms forming a balanced ecological system. The types and numbers of the various groups of microorganisms present are related to water quality and other environmental factors.

In the treatment of organic waste waters, microorganisms play an important role and most of the species found in water and waste water are harmless to man. However, a number of microorganisms are responsible for a variety of diseases and their presence in water poses a health problem.

It is therefore necessary to develop an understanding of the basic principles of microbiology and thus gain an appreciation of the role of microbiology in water quality control.

2.6 Water –related infections

A water related disease is the one which is in some way associated with water or impurities in water. It is necessary to distinguish water related diseases from those related to some chemical property of water. Damage to the teeth and bones for instance, is associated with high fluoride levels. This is non –infectious water related disease.

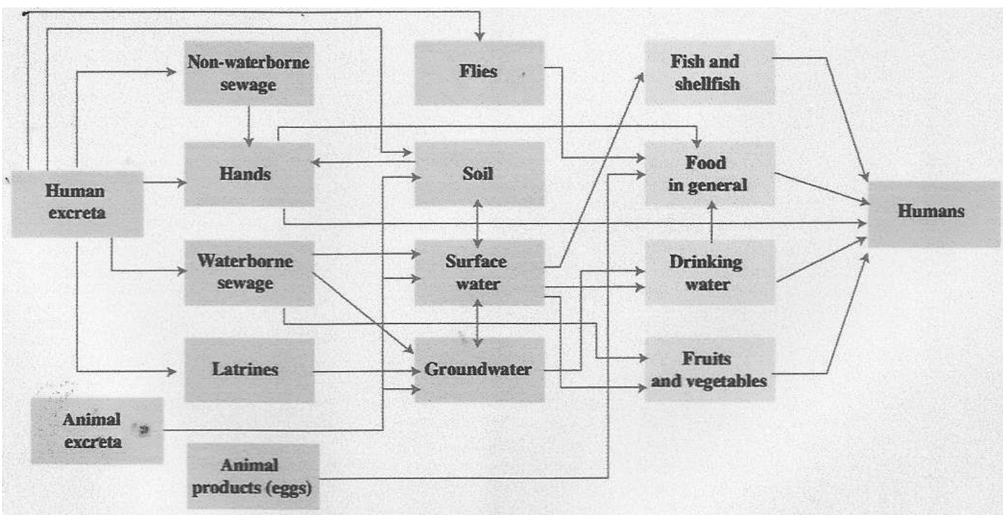

Figure 2.4 Classification of transmission mechanism Safe water, Better Health

Building the evidence on effective interventions

Guide for estimating national disease burden

Understanding the preventable burden of disease associated with risk factors such as inadequate water sanitation and hygiene provides a basis for evidence-based decision-making.

Global estimates such as those summarized here will need to be complemented with national- and even local/project-level data to inform local decision-making. WHO has developed a guide to assist in estimating the national burden of water, sanitation, and hygiene-related disease.

Water related infections are classified into four distinct water-related mechanisms by which a disease may be transmitted from one person to another:

1. Water-borne mechanism
2. Water -washed mechanism
3. Water-based mechanism
4. Water-related insect vector mechanism.

Water borne mechanism

Truly speaking water borne transmission occurs when the pathogen is in water which is drunk by a person or animal which may then become infected. Potentially water borne diseases include the classical infections notably cholera and typhoid but also include a wide range of other diseases such as infectious hepatitis, diarrhoea and dysenteries. The term water-borne disease has been and still is greatly abused with water-related disease. It is essential to know that water borne transmission is merely the special case of drinking faecal material in water and that any disease that can be water-borne can also be transmitted by any other faecal-oral route e.g poor personal hygiene of food handlers.

Water washed mechanism

There are many infections of the intestinal tract and of the skin which may be significantly reduced following improvements in personal and domestic hygiene.

A water-washed disease may be defined as one whose transmission will be reduced following an increased volume of water used for hygiene purposes. Water – washed diseases are of three types:

- Infections of the intestinal tract e.g. diarrhoeal diseases, cholera, bacillary dysentery and other diseases under water –borne or water-washed. These diseases are all faecal-oral in their transmission route and are therefore potentially either water-borne or water –washed.

  Many of the diarrhoel infections in the tropics behave as waster-washed rather than water-borne diseases.
- The second type of water-washed infection is that of the skin or eyes. Bacterial skin sepsis, scabies and fungus infection of the skin are extremely prevalent in many hot climates, while eye infections especially trachoma are also common and may lead to blindness. These diseases are related to poor hygiene and will be reduced significantly if increased volumes of water are used for personal hygiene.
- The third type of water- washed infection is also not faecal-oral and therefore cannot be water-borne. These infections carried by lice or mites which may be removed by improved personal hygiene and therefore reducing the probability of infestation of the body and clothes. Mites cause scabies and are also promoters of Asthma. Mites and lice are vectors of various forms of rickettsial typhus body lice cannot persist on people who regularly launder their clothes. Louse-borne relapsing fever may respond to improved hygiene and increases use of water for washing.

Water based mechanism

A water based disease is one in which the pathogen spends a part of its life cycle in water or in an intermediate host which lives in water.

All these diseases are due to infection by parasitic worms (Helminths) e.g. shistosomiasis in which water polluted by urine contains schistosomes which develop in snails until they are shed into the water as infective carcariae and re-infect man through the skin.

Another example is the guinea worm (common in West Africa). In this the intermediate host is cyclops, a small crustacean, human infection occurs following ingestion of water containing Cyclops. Eggs are discharged when a sufferer's ulcers burst open. If eggs are ingested by cyclop they develop into larvae which leave the ingested cyclop during digestion. They migrate through the tissues to the lower limbs and eggs are discharged nine months later. The other diseases in this category are acquired by eating insufficiently cooked fish, crabs, crayfish or aquatic vegetation. They are not related to supply but are affected by excreta disposal.

Insect vector mechanism

The final mechanism of water-related diseases is spread by insects which either breed in water or bite near water. Malaria, yellow fever, dengue fever and onchocerciasis (river blindness) are transmitted by insects which breed in water while West Africa trypanosomiasis (Gambia sleeping sickness) is spread by riverine tsetsefly which bite near river (waters).

Table 2.7 Summary of mechanisms of water related infection Transimission and preventive strategies appropriate for each mechanism.

Transmission Diseases (examples)	Preventative Strategy	Mechanism
Water-borne	Diarrhoea, Cholera, Typhoid	- improve water quality - prevent casual use of other unimproved sources
Water-washed	Roundworm (Ascariasis), Trachoma, Typhus	- improve water quantity - improve water accessibility - improve hygiene
Water-based	Malaria, River Blindness (Onchocerciasis), Sleeping Sickness (Trypanosomiasis)	- improve surface water management - destroy breeding sites of insects - decrease need to visit breeding sites - remove need for water storage in the home or improve design of storage vessels

Cairncross et al., 1981

2.7 Protection of water sources

The most effective method of protecting water from contamination/pollution would be to protect the whole water shed/catchment area. Catchment area – that section of the country side from where water for consumption is drawn before it collects into a dam, river etc. But it may be practically impossible due to sometimes the extent of the area that may be inhabited by people. The most appropriate method will, therefore depend on the source of the domestic supply.

River protection

- In case of a river it is necessary to protect the actual draw off point.
- Growth of vegetation in and around the water course should be encouraged. The vegetation provides natural screening and sedimentation of suspended particles.
- At the river intake point (draw off point) a lot can be done to prevent contamination of the water:
  1. Diversion dam can be provided across the channel. The purpose of this dam is to:
     - Provide sufficient water even in dry periods
     - Allow sedimentation due to reduced flow.
  2. If water is removed from the intake by a pump, it is necessary to protect the pump from large floating objects by providing surface screens.
  3. With suitable bed conditions water may be obtained from a river by digging tunnels parallel to the river course called infiltration gallaries. The earth between the gallery and the river water provides some form of filtration.
  4. Where activities like bathing and watering of animals are done in a river, zoning can be done to separate such activities from intake point for drinking water. The zone for drinking water intake should be located upstream.

Protection of springs

Springs, where they exist and have a reliable flow can make ideal sources of water for a community water supply. No pumping is required to extract water from them. However, springs may be easily contaminated by people collecting water and by polluted surface water and protection is therefore necessary.

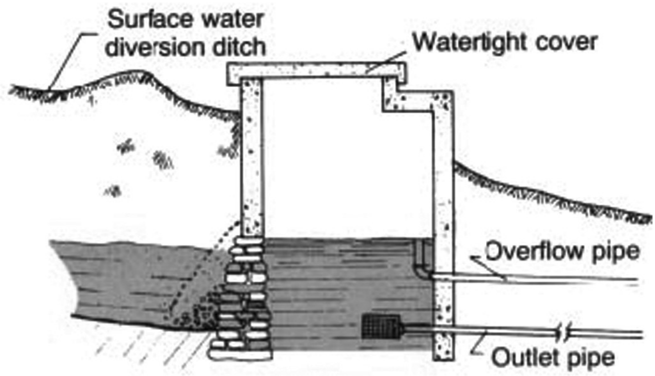

Figure 2.5 A protected spring

This is done by building a box of brick (spring box). Masonry or concrete around the spring so that water flows directly out of the box into a pipe without ever being exposed to pollution from outside. In excavating the foundations for a spring box it is important to avoid digging through the impervious layer, or the water may seep downwards so that the spring disappears or moves downhill. The 'eye' of the spring (the point where the water emerges) should be covered with carefully selected sand or gravel. If this material is too coarse, the spring water may erode the soil behind it, but should not be finer than the existing soil behind it or it may block the flow.

A spring may sometimes flow very strongly for brief periods after rain, and the whole structure must be sound enough to resist erosion. A spring box should be built so as to prevent fine sediments from settling over the eye of the spring and blocking its flow. This is done by ensuring that the overflow pipe is not above the eye flowing produces turbulence – should be in some level

The spring box should have a removable cover, so that it can be cleaned from time to time.

Puddled clay should be used to backfill being the box to seal the ground against infiltration by surface water. The top of the spring box should be at least 300mm above the ground. The access hole should have a cover which is not easily removed. A ditch may be dug on the uphill side of the spring into a bank or 'bund' to divert surface water. A fence or hedge planted on the 'bund will help keep people and animals away.

Well Protection

Well water, like spring water, may be quite clean but if care is not taken it could become contaminated very easily by:

- Surface water draining in the well
- People dropping objects into the water
- Dirty equipment used from drawing water
- Dropping earth from the unprotected walls of the well
- Nearby latrines, soakage pits etc
- People and animal falling in.

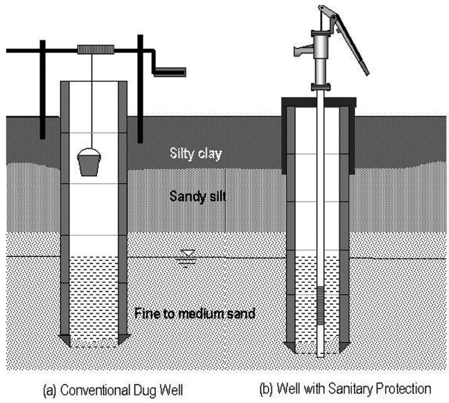

Figure 2.6 A conventional and sanitary protected well

To prevent well contamination the following measures should be put in place;

- The sides of the well should be lined with impervious material to the depth of about 3m and incase of deep wells upto the 1st impervious stratum.
- The top should be covered by a concrete apron which drains away from the entrance of the well. This helps to divert dirt from the mouth of the well.
- The apron should be provided with a water tight covered mouth which may be opened by only when the well is in use.
- A drain should be provided around the apron to drain spilled water away from the well.
- The area surrounding the well shouldn't be used as a dumping ground for refuse.
- Pit latrines or soakage pits should be sited not less than 30m from the well.
- The method of water extraction should be improved and where possible a pump should be used.

2.8 Water treatment

Purpose of water treatment

To ensure that drinking water is suitable for domestic use through:

- Removal of pathogenic organisms and toxic substances e.g. heavy metals.
- Removal of taste producing substances e.g. iron and manganese.
- Carbon dioxide which corrodes concrete and metal is removed.

Methods used in water treatment

Broadly divided into small scale (household) treatment and large scale treatment.

Small scale treatment methods

In general terms, treatment of water at household level follows the processes shown in table 2.7. However, depending on the quality of raw water, some processes may not be necessary.

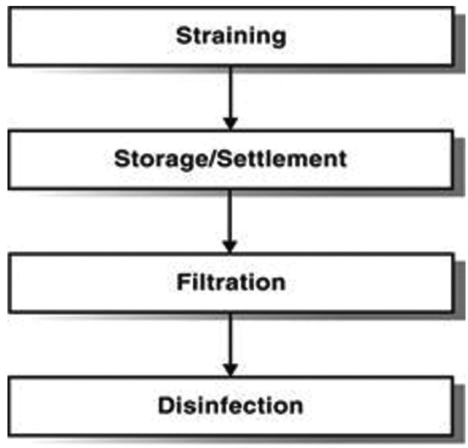

Figure 2.7 small scale treatment methods

Straining

Pouring water through a clean piece of cotton cloth will remove a certain amount of the suspended silt and solids. It is important that the cloth used is clean, as dirty cloth may introduce additional pollutants. Specifically made monofilament filter cloths may be used in areas where guinea-worm disease is prevalent.

Such cloths remove organisms known as *copepods*, which act as intermediate hosts for the guinea-worm larvae. The cloth must always be used with the same surface uppermost. The cloth may be cleaned using soap and clean water.

Settling and decanting

The simplest way to clarify muddy water is to allow the suspended material in it to settle. This process is called *sedimentation*, and takes place when water is allowed to stand in a container.

When water is stored for a day in safe conditions, more than 50% of most bacteria die. Furthermore, during storage, the suspended solids and some of the pathogens will settle at the bottom of the container. The container used for storage and settlement should have a lid to avoid recontamination, but should have a neck wide enough to facilitate periodic cleaning. For example a bucket with a lid could be used for this purpose.

Three pot system

A household can maximize the benefit of storage and settlement by using the three-pot system. As the name suggests, the system consists of three pots. Each day when new water is brought to the house:

- Water stored in Pot 2 is slowly poured into Pot 3 and Pot 2 washed out.
- Water stored in Pot 1 is slowly poured into Pot 2 and Pot 1 washed out.
- Water collected from the source (Bucket 4) is poured into Pot 1. The water may be strained through a clean cloth.

Using a flexible pipe to siphon water from one pot to another disturbs the sediment less than pouring.

Water should be drawn from the top of the container where it will be cleanest and contains less pathogens. Storage and settlement for at least 48 hours also eliminates organisms called the *cercariae*, which act as intermediate host in the life cycle of bilharziasis (*schistosomoasis*), a water-based disease prevalent in some countries. Longer periods of storage will lead to better water quality.

Always take drinking water from pot 3. This water has been stored for at least two days, and the quality has improved. Periodically this pot will be washed out and may be sterilized by scalding with boiling water.

Filtration

Filtration is the passage of polluted water through a porous medium (such as sand). The process uses the principle of natural cleansing of the soil.

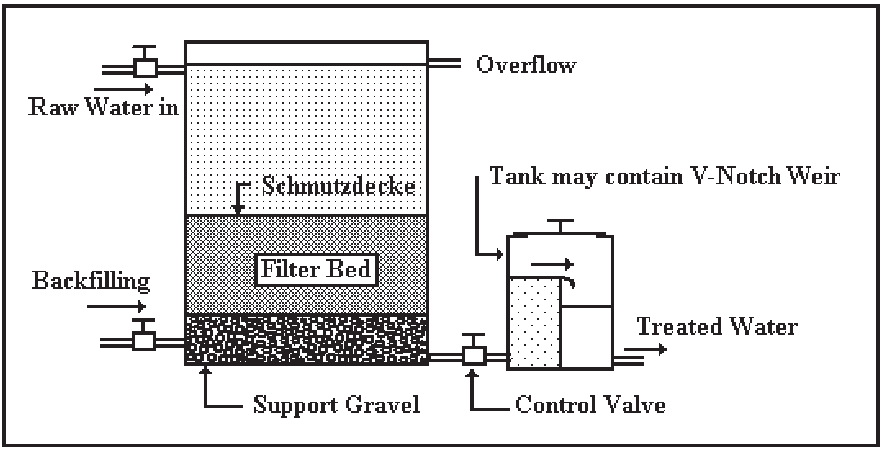

Figure 2.8 Slow sand Filter

It consists of a large tank, in which the water stands about 1m deep over a bed of carefully graded sand. The raw water filters down through the sand to a set of underdrains. The top of the outlet pipe is fixed above the level of the sand surface to avoid negative pressures in the sand bed, and thus prevent air being entrapped.

Most of the filtration takes place in the top layer. At the very top of the sand bed a dense slimy layer of retained fine material, with an active flora and fauna, develops. This biologically active zone, known as the *Schmutzdecke*, is responsible for most of the water quality improvement provided by a slow sand filter. In particular, the Schmutzdecke retains or kills the great majority of viruses, bacteria, protozoan cysts, and helminthes eggs and this makes the slow sand filter a far more efficient pathogen- removing process than the rapid sand filter.

Over a period of time, the development of Schmutzdecke increases the resistance of the filter bed to the flow of water, and it is necessary to clean it every few weeks or months. This is done by raking of 20 mm of sand from the top of the bed and discarding it. When the sand bed is only 600 mm thick, more sand is needed.

If cleaning is required more than once a week, it means either

- The sand is too fine
- The flow is too fast or
- The water too dirty.

The water may be improved before filtering by sedimentation, or by pre-filtration using coarse media, such as coconut fibres or burnt rice husks.

Ceramic filters

Water may be purified by allowing it to pass through a ceramic filter element. These are sometimes called candles. In this process, suspended particles are mechanically filtered from the water. The filtered water must be boiled or otherwise disinfected. Some filters are impregnated with silver which acts as a disinfectant and kills bacteria, removing the need for boiling the water after filtration. Ceramic filters can be manufactured locally, but are also mass-produced. They can be costly but have a long storage life and so can be purchased and stored in preparation for future emergencies. The impurities held back by the candle surface need to be brushed off under running water, at regular intervals. In order to reduce frequent clogging, the inlet water should have a low turbidity. Figure 2.7 shows a variety of ceramic candles.

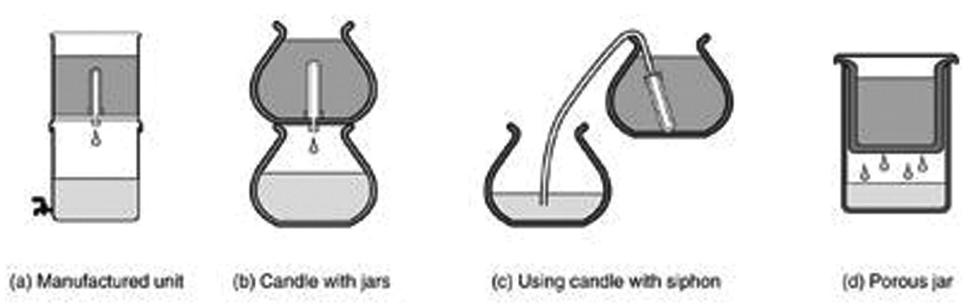

Figure 2.9 Ceramic filters

Disinfection

It is essential that drinking water be free of harmful organisms. Storage, sedimentation and filtration of water reduce the contents of harmful bacteria but none of them can guarantee the complete removal of germs. Disinfection is a treatment process that ensures drinking water is free from harmful organisms or pathogens. It is recommended that this be the final treatment stage, as many of the disinfection processes will be hampered by suspended solids and organic matter in the water. There are various methods of achieving disinfection at household level:

1. Disinfection by boiling

Boiling water is a very effective though energy consuming method to destroy pathogenic germs- bacteria, viruses, spores, cercerea, amoeba cysts, and worm eggs etc.

Presence of turbidity or other impurities has little effect on germicidal effectiveness. If boiling is the only type of treatment available, it is recommended to let the water settle before, and decant it or filter it through a fine-meshed cloth so as to remove coarse impurities and suspended particles.

The water is then brought to a strong boil which is maintained for at least five, preferably 20 minutes. For storing, it must not be transferred to a different vessel, but left in the former one and covered, so as to protect it from recontamination.

Boiling, together with the associated release of gases, especially CO2 alters the taste of water. But through stirring while boiling and by letting the water sit in the partially filled vessel for a few hours afterward, the water picks up air and regains its original taste. If done properly; boiling is a very effective and simple disinfection method. Since it requires a significant amount of energy, this method is only recommended in exceptional cases.

2. Disinfection using chlorine

Chlorine is a chemical most widely used for the disinfection of drinking water because of its ease of use, ability to measure its effectiveness, availability and relatively lower cost. When used correctly, chlorine will kill all viruses and bacteria, but some species of protozoa and helminthes are resistant.

There are several different sources of chlorine for home use; in liquid, powder and tablet form. Chlorine is commonly available to households as liquid bleach (sodium hypochlorite), usually with a chlorine concentration of 1%. Liquid bleach is sold in bottles or sachets, available on a commercial basis.

Chlorine must be added in sufficient quantities to destroy all the germs but not so much as to affect the taste adversely. The chemicals should also have sufficient contact time with the pathogens (at least 30 minutes for chlorine). Deciding on the right quantity can be difficult, as substances in the water will react with the disinfectant at different rates. Furthermore, the strength of the disinfectant may decline with time depending on how it is stored. It is therefore recommended that in emergency situations, chlorine solutions be centrally dispensed to the users by qualified personnel. Displaced people should receive standard containers for collecting/storing water, as well as simple dropper tubes or syringes. Technical staff should provide the instructions for mixing the chlorine solution, at the point of dispensing.

3. Solar disinfection

Ultra-violet rays from the sun are used to inactivate and destroy pathogens present in water. Fill transparent plastic containers with water and expose them to full sunlight for about five hours (or two consecutive days under 100% cloudy sky). Disinfection occurs by a combination of radiation and thermal treatment. If a water temperature of at least 50°C is achieved, an exposure period of one hour is sufficient. Solar disinfection requires clear water to be effective.

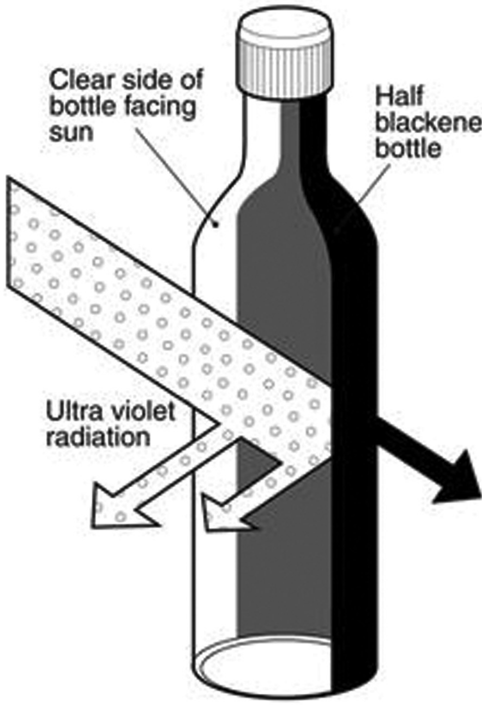

Figure 2.10 the Sodis system

An enhanced example is the Sodis system, whereby half-blackened bottles are used to increase the heat gain, with the clear side of the bottle facing the sun, as shown above.

Aeration

Aeration is a treatment process in which water is brought into close contact with air for the primary purpose of increasing the oxygen content of the water. With increased oxygen content:

- Volatile substances such as hydrogen sulphide and methane which affect taste and odour are removed.
- Carbon dioxide content of water is reduced and
- Dissolved minerals such as iron and manganese are oxidised so that they form precipitates, which can be removed by sedimentation and filtration.

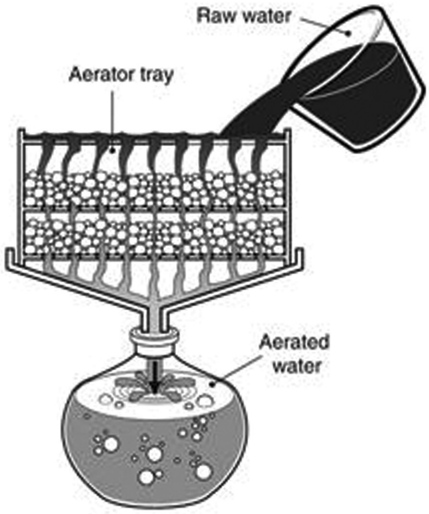

Figure 2.11 Water aeration

Aerator trays

The close contact between water and air required for aeration can be achieved in a number of ways. At a household level, rapidly shake a container part-full of water, for about five minutes and then stand the water for a further 30 minutes to allow any suspended particles to settle to the bottom.

On a larger scale, aeration may be achieved by allowing water to trickle through one or more well-ventilated, perforated trays containing small stones, as shown in Figure 2.11. The water must be collected in a container and allowed to stand for about 30 minutes to settle suspended particles.

Large scale water treatment

Conventional water treatment works

Treatment is usually necessary for town water supplies. Sufficient water for a whole town is not always available from the ground, and so polluted surface sources often have to be used. The larger scale of a town water supply makes the quality of the water more important than for a small village supply. A single source of pollution in an urban supply could cause a water-borne epidemic in the whole town, so that the consequences of poor water quality are more serious.

The following processes are used in large scale water treatment either singly or in combination:

1. **Screening**
   The screening process is done to remove floating matter such as leaves, branches, dead animals etc
2. **Plain Sedimentation**

- Denotes separation of the suspended particles (impurities) by action of the natural forces alone i.e. by gravitation and natural aggregation of the settling particles.
- It is done to remove suspended impurities e.g. silt, clay, sand etc.
- It is natural purification treatment particularly suited to streams, lakes and tidal waters.

3. **Sedimentation with coagulants**

Non-settleable solids are removed by adding a coagulant. The solids are too small to settle by gravity. They have a net negative charge and tend to repel one another keeping themselves in an almost equidistant within the water thereby keeping it uniformly turbulent.

Purpose of coagulant is to neutralize the repulsive charges so that particles can coalesce largely around the positively charged part of the coagulant. The particle becomes heavy enough to settle down and the solids therefore get deposited at the bottom of the sedimentation tank/container as flocs. Together they form the sludge leaving the clarified water on top.

Aluminum salts are among the more popular coagulants; the Al 3+ ions react with water to give a precipitate which can be represented most simply as $Al(OH)_3$.

$$Al^{3+}_{(aq)} + 3H_2O \rightarrow Al(OH)_{3\,(s)} + 3H^+_{(aq)}.$$

Millions of kilograms of hydrated aluminium sulphate, $Al_2(SO_4)_3\,18H_20$, are used annually to clarify municipal and industrial water supplies. Water which has passed through a coagulation plant is often filtered to remove any remaining suspended material.

Due to acidic conditions produced by the aluminium, a neutralizing chemical is added after coagulation processes e.g. lime water.

4. **Filtration**

Filtration is the deliberate passage of polluted water through a porous medium, thus utilizing the principal of natural cleansing of the soil. This widely used technique in water treatment is based on several simultaneously occurring phenomena:

- Mechanical straining of undissolved suspended particles (screening effect).
- Bacteriological – biological process within the filter.
- Filters may be divided into two principally different types:

  Slow sand (or biological) filtration (V=0.1 – 0.3m/h)
  Rapid filtration (V=4-15m/h).

Depending on filtration rate, different mechanisms are operative within the filter. Generally, a filter consists of the following components:

- Filter medium (inert medium; quartz sand; or chemically activated medium, burnt material)
- Support bed (gravel) and under-drain system
- Influent and effluent pipes

- Wash and drain lines
- Control and monitoring accessories.

Filtration is accomplished by allowing the water to trickle to pass through the filter medium supported on several layers of successively coarse gravel. A thin layer of precipitated material forms on the medium. Up to a point this added layer of finely divided particles improves the efficiency of the filter. When it becomes too thick it is removed by backflushing by forcing water, or air followed by water, upwards through the bed for a period of time.

5. **Disinfection**

Various chemicals are used to treat drinking water to remove microorganisms. Disinfection is also essential for water in public swimming pools, although the tolerable bacteria count there can be somewhat higher. The most common disinfectant is chlorine, which kills bacteria by inhibiting the activity of certain enzymes essential to their metabolism. Large water treatment plants use liquid chlorine from high pressure tanks as a disinfectant. Enough chlorine is added to give a residual chlorine concentration of 0.2 to 1.0 ppm. This concentration is ordinarily high enough to destroy any bacteria entering the water after it leaves the treatment plant.

Many chemicals other than chlorine can be used to disinfect water supplies e.g. Ozone(O3). Although more expensive than chlorine, it is considerably more effective, killing many germs and viruses that are not attacked by chlorine. It leaves no chemical residue and hence does not produce objectionable tastes or odors in drinking water. However, ozone does not offer any protection against microorganisms that enter the water after it has been treated.

6. **Removal of taste and odour**

No matter how safe water may be to drink, it is objectionable if it has an unpleasant taste or odour. E.g. the smell of hydrogen sulphide associated with water from hot mineral springs. One way of removing objectionable tastes and odors from water is to pass it through a filter bed containing activated charcoal, a finely divided form of carbon. The enormous surface area of this material (about $600m^2/g$) enables it to absorb large quantities of various materials. Most of these are organic compounds held physically on the surface of the carbon. In the case of chlorine, a chemical reaction occurs.

$$2Cl_2\,(aq) + C(s) + 2H_20 \rightarrow CO_2\,(aq) + 4\,H\,(aq) + 4\,Cl\,(aq).$$

Through this reaction, the taste and odor associated with chlorinated drinking H20 can be eliminated. After the filter bed has been operated for about a year, most of the carbon can be reclaimed by heating to about 1000°C to remove absorbed organic impurities.

Disinfection by use of chlorine

Chlorine demand

Chlorine is an oxidizing agent. If it is added to improve water it will immediately oxidize the impurities and no longer be available for disinfection. It is therefore essential that the chlorine dose should be greater than the required to satisfy the immediate chlorine demand of the water.

This chlorine demand will vary, depending on the quality of the water. Roughly, 1mg/l of chlorine is required to satisfy 2mg/l of BOD.

If an adequate dose is used to satisfy the chlorine demand, a 'residual' of chlorine remains which provides protection against contamination occurring during subsequent distribution of the water. Chlorine residuals are of two kinds; free and combined.

Free residuals

$$Cl_2 + H_2O \rightarrow HC1 \quad + \quad HC1O$$

$$H+ \; Cl - \quad H+ \quad + C1O -$$

The hypochlorous acid (HCl0) and chlorite ions (ClO^-) are free residuals. Hypochlorous acid is the more effective disinfectant, but most of it tends to dissociate to form chlorite ions at high (alkaline) PH values. The residual may be all HClO at PH 5, about half HClO at PH 7.5 and all ClO- at PH 9. A given chlorine dose is far more effective in destroying viruses and bacteria in water if the PH is low (Say < PH 7). Chlorine is also considerably more effective at warm temperatures.

Combined residuals

If ammonia is present in the water, the chlorine combines with it to form chloramines, known as combined residuals. These are also disinfectants but with less than $1/20^{th}$ the power of hypochlorous acid.

When free-residual chlorination is first introduced, the free residual may react with deposits on the inside of water mains, possibly producing disagreeable tastes and colours in the water for the first few months. However, when the deposits have been oxidized it will be possible to maintain free-residual chlorine in the water delivered throughout the distribution system.

The breakpoint

When a dose of chlorine is added to water, initially combined residuals are found. With higher doses these are destroyed by further oxidation, until a certain point is reached, known as the breakpoint; when the oxidation process is complete and free residuals begin to predominate. Thereafter, the residual increases in direct proportion to further increases in the chlorine dose.

Free-residual chlorination thus requires a chlorine dose beyond the breakpoint, and so is sometimes called 'breakpoint chlorination.'

Chlorine dose

The chlorine dose must be sufficient to produce the desired free residual, after satisfying the chlorine demand. A minimum free residual of 0.3mg/l is recommended, with a contact period of 30 minutes. Free chlorine is less effective as a disinfectant at high PH and low temperatures. A longer contact time is required in such conditions.

The chlorine demand can be estimated by adding various large known doses to the water and measuring the free residuals they produce.

(Demand) = (dose) – (residual)

The demand and the desired residual are added arithmetically to derive the necessary dose. Even quite clean water is likely to have a chlorine demand of about 2mg/l. The chlorine demand of some waters, particularly river waters, can increase dramatically at times of heavy pollution, after rain for instance. To allow for this it may be necessary to add a safety margin to the dose. If this causes tastes and odour problems, the excess chlorine can be removed after a sufficient contact time by adding sulphur dioxide (Sulphonation).

$Cl_2 + SO_2 + 2H_20 \rightarrow H_2S0_4 + 2HCl.$

Control of the Dose

The aim of free-residual chlorination is to ensure a free residual in the water until it is supplied to the public. To check that the chlorine dose is sufficient, the residual should therefore be measured in samples taken from various points throughout the distribution system. A suitable arrangement is to check the residual in the water leaving the treatment works once every shift- twice or three times a day and to check samples from the distribution system once a week.

Strict instructions should be given that water should not be sent to the supply without an adequate residual.

Samples from the distribution system should not be taken from dead – end pipes. It is convenient to take them from institutions such as schools, fire stations and hospitals. The tap should run for several minutes before filling the sample bottle, to ensure the water is from the mains, and not the internal pipe work. The absence of a free residual in only one part of the system suggests that pollution is entering the mains nearby, and should be dealt with by repairing the mains rather than increasing the dose. The tests should be conducted at the sampling point, immediately after collecting the sample so that the residual does not have time to change before testing.

Testing for Chlorine

Simple methods are available for measuring free residuals of chlorine in water.

The two principal methods are:

1. The orthotolidine test, in which a drop of the liquid reagent is added to the water.
2. DPD test, using tablets.

The DPD test is preferable particularly, as orthotolidine is now recognized as capable of causing cancer.

The tests measure free residual chlorine separately from the combined residual. In both tests, the addition of a reagent produces a colouring in the water, which is checked against standard colours to measure the concentration; the stronger the colour, the higher the concentration.

Orthotolidine turns the water yellow; DPD tablets turn it red.

Sources of Chlorine

1. **Gas**
   In large scale water treatment plants, chlorine is obtained as liquefied gas in cylinders or drums. The pressure within these containers is approximately 5.5 atmospheres at 21°C. For small supplies, the use of chlorine gas and of the complex equipment needed to apply it may be impractical. Other sources of chlorine are therefore used.
2. **Solutions**
   Proprietary disinfectants and bleaches may be used as chlorine sources. The disinfectants (such as Milton, zonite, Javel water) typically contain about 1% of available chlorine by weight. They may be used directly, without dilution, as 1% stock solutions. The bleaches (e.g. chloros, chlorox, and domestos) usually contain 3-5% of available chlorine and must be diluted to make up a 1% stock solution. Chlorine solutions are unstable in warm climate. They should be kept in brown or green bottles, well stoppered, and stored in dark, cool places.
3. **Powder**
   Bleaching powder or chlorinated lime (calcium hypochlorite) may also be used. It contains about 30% of available chlorine when fresh but the strength rapidly diminishes when the container is opened. Even when unopened, long periods of storage can lead to reduced strength. It is best to open the container and use the entire contents immediately to make up 1% stock solution. The inert lime will settle in a few hours leaving the active chlorine in the clear solution which can then be poured off and kept as described above. High-test hypochlorite may also be used and contains up to 70% available chlorine.
4. **Tablets**
   Various proprietary brands of chlorination tablets are on the market. They are expensive and are suitable mainly for the short-term protection of small quantities of water. Tablets of calcium hypochlorite containing 60-70% available chlorine are made for use in tablet chlorinators.

The application of chlorine – points to note

- Chlorine needs at least half-an-hour in contact with water to disinfect it. It should be applied at a point where turbulence of the water will help to mix the chlorine e.g. at a sharp bend.
- The chlorinated water should not be exposed to sunlight after dosing, as that would remove the protective residual.
- Chlorine gas is not applied directly to water, but used to form a strong solution in a small quantity of water which is then injected into the main stream. This ensures that the chlorine is fully dissolved.
- Chlorine gas is highly corrosive in the presence of moisture and equipment used to handle it should be of glass, plastic or non-corroding metals.

- Chlorine gas is poisonous, and heavier than air. It should not be stored or used inside a building with a basement. It should be stored in a building with good ventilation near the floor, and with doors opening outwards.
- Chlorine is usually applied in a solution by various drip-feed devices which can be set to add chlorine solution at an approximately constant rate.

2.9 Water quality control

In a general sense, the term 'water quality control' may be used to mean all the activities that may be put in place to monitor control and improve the quality of community water supplies. For the purpose of this topic, however, we are limiting ourselves to the following activities:

- Sanitary inspection of water sources
- Water sampling and analysis
- Drinking water standards and guidelines (WHO)
- Water surveillance.
- Water monitoring programs.

Sanitary inspections of water sources

A sanitary inspection (survey) is an on-site inspection and evaluation by qualified individuals of all conditions, devices, and practices in the water supply system that pose an actual or potential danger to the health and well being of the consumer.

- It is a fact-finding activity that should identify system deficiencies; not only sources of actual contamination, but also inadequacies and lack of integrity in the system that could lead to contamination.
- Where official visits by health officers are infrequent, responsible community members should assist in making the survey.
- The two principal activities are sanitary inspection and water quality analysis.
- These are complementary activities:
  - Inspection identifies potential hazards, while
  - Analysis indicates whether contamination is occurring, and if so, its intensity.

A sanitary inspection is important for the adequate interpretation of laboratory results. In order to make the most use of analytical, bacteriological or chemical survey, it is a must to have a comprehensive knowledge of the following:

- Conditions at the water source and within the distribution system
- The adequacy of water treatment
- The qualifications and performance of the operators.

Sanitary inspection should go hand in hand with water quality analysis for the following reasons:

- Samples represent conditions at a single point in time and even when there is frequent sampling and analysis, the results are reported after contamination has occurred.

- Microbiological contamination is often sporadic and may not be revealed by occasional sampling.

Sanitary inspection reports

- A sanitary report provides a direct method of identifying all the hazards that are potential and actual causes of contamination of the supply.
- It is concerned with the physical structure of the supply, its operation, and external environmental factors.
- The hazards recorded during inspection are often tangible and observable, and may be used together with analytical data to derive a risk assessment.
- Sanitary inspections therefore provide essential information about immediate and ongoing possible hazards associated with a community water supply, even in the absence of microbiological or chemical evidence of contamination.

Sanitary inspection report forms

Sanitary inspections are best carried out by use of pre-designed forms. The forms provide a simple and rapid means of assessing and identifying hazards associated with water supply systems.

The inspection form should include at least a checklist of the components of the water supply from source to distribution and incorporate all the potential points where hazards may be introduced.

The specific functions of the sanitary inspection report are to:

- Identify potential sources and points of contamination of the water supply.
- Quantify the hazard (hazard score) attributable to sources and supply.
- Provide a clear, graphical means of explaining the hazards to the operator/user.
- Provide clear guidance as to the remedial action required to protect and improve the supply.
- Provide the data for use in systematic, strategic planning for improvement.
- The report should not be restricted to factors that may cause problems with water quality, but should also take into account other service indicators, e.g. cost, coverage, continuity and quantity.
- It should be possible to determine an overall measure of the sanitary state of the supply based on the checklist.
- This hazard or risk score may be used in deciding priorities for remedial action by the community or by whichever agency is able to intervene and make improvements.

NB

- Whenever a sanitary survey including a visual inspection indicates that a water supply is obviously subject to pollution, the remedial action must be taken, irrespective of the results of bacteriological examination.

- For unpiped rural water supplies, sanitary inspections may be the only form of examination that may be undertaken regularly.

Water sampling and analysis

Public Health objectives for analysis of water samples are mainly:

- To determine its suitability, particularly for domestic purposes.
- To ensure the maintenance of required standards of purity, notably those laid down in legislation.

In particular, the standards apply in the food industry if the wholesomeness of the finished product may be affected by the quality of the water used. Examples of situations where found or drink may be affected by water are where water is:

- Used as an ingredient
- Otherwise used in the course of preparing food
- Used for the washing of equipments or for the personal cleanliness of food handlers.

It is important to remember that results from any single sample indicate only the condition of the water at the particular time the sample was taken. It is only by regular, systematic sampling and maintenance of a database of results over a period of time that a clear picture of water quality may be seen. In particular, this allows identification of variations from the norm, enabling assessment and investigation.

Water sampling techniques

The 'appropriate requirements' must be applied when taking samples. Steps should be taken during the taking, handling, transportation, storage and analysis of water (or causing it to be analyzed) to ensure that the sample is:

- Representative of the water.
- Not contaminated when being sampled.
- Kept at such a temperature and in conditions that will ensure there is no material change in the sample.
- Analyzed as soon as possible.
- Analyzed by a laboratory with a proper, verified quality control system.

Care should be taken to prevent the water from becoming contaminated by the neck of the bottle. This is achieved by only opening the flow to a fine stream, which can be directed into the bottle without touching the neck. The ground glass stopper should be held only by the rim to avoid touching the actual surface with the fingers; before replacing immediately the bottle is full.

There are two types of sampling bottles:

1. Plain bottles for samples that will be delivered to the laboratory within 6 hours.
2. Bottles with transport medium, e.g. maCkonkey broth, for samples that will take more than 6 hours before reaching the lab.

All sample bottles for sampling chlorinated water should contain a small quantity of sodium thiosulphate, to dechlorinate the water and stabilize any coliform organisms in the sample.

Types of samples

Types of samples taken depend on what you are testing the water for. There are two main types of samples taken for analysis:

1. Bacteriological analysis sample
2. Chemical analysis sample.

Water may be examined for various reasons.

- To determine whether water is wholesome or palatable.
- To determine suitability of water for intended use e.g. water used in making of soft drinks needs to be very pure.
- To determine the type of treatment required for water from a particular source e.g. a source with characteristic fluorides.
- To determine the efficiency of treatment method.
- To establish the source of contamination.

Sampling for bacteriological analysis

For chlorinated supplies, sampling for bacteriological quality should preferably be done once a day. But this is only practical where the laboratory is within easy reach.

For drinking water the following maximum intervals between successive examinations before it enters the distribution system have been proposed by WHO standards.

Table 2.8 Maximum interval between successive tests

Population served	Samples interval
<20,000	One month
20,000-50,000	Two weeks
50,000-100,000	Four days
>100,000	One day

Source: WHO – (2010) www.who.int/water_sanitation_health/dwq/edvol3d.pdf

NB: It is the responsibility of water undertakers to arrange for the collection and examination of water samples and to keep the MOH of the district informed of the quality but it is also advantageous for the MOH to arrange for the independent collection and sampling as a countercheck.

Collection of the sample

It is important that the quality of the sample be representative of the water being examined. Scrupulous care should be taken to avoid accidental contamination during collection.

The bacterial quality will remain almost unaltered if the sample is refrigerated immediately after collection and submitted to the laboratory in that state.

Order of taking samples

Where samples for various tests are to be collected from the same point, sample for bacteriological analysis should be taken first.

Sampling directly from the source

The source may be a river, lake, spring, dam or shallow well. It is important to make sure that the sample taken is representative of the whole water supply. So the sampling print should not be at the surface, bottom or very near the banks. The sample should be collected from as near the point of domestic intake as possible. Where the point of intake is not properly defined, collect from as near the centre as possible.

In streams and rivers, areas of relative stagnation should be avoided. The procedure of sampling is that the bottle is held at the bottom; stopper removed and immediately plunged into the water. It is held like that until it fills up then stopper returned immediately.

In a dam or lake, the bottle should be lowered to about 0.5m from surface; bottle could be attached to a string then lowered down.

N.B: Water entering the bottle should never be allowed to come into contact with the fingers or anything else first.

Sampling from a well

The pump should first be allowed to pump water out for about 5 minutes. Then proceed like in the case of sampling from a tap.

Sampling for chemical analysis

In practice, sampling for chemical analysis is a relatively simple procedure and requires only a fairly large but properly representative quantity of water. Sampling equipment consists of large bottles of preferably two litres capacity.

If the analysis is to determine BOD or DO, it is essential that no air is trapped in bottle, should be smooth to prevent dissolving of more oxygen into the water.

The sample for the analysis is then supposed to be submitted to the laboratory immediately. It is important to determine DO concentration as at the time of sampling. Sampling for analysis of other chemicals is straight forward. All that is required is to rinse the sampling bottle three times with the water to be sampled.

Sampling from a tap

Precautions

- The water should first be run off; to ensure the sample is taken from the mains supply.

- The tap is then 'flamed' for a minute or so with a portable gas blow lamp, provided the tap is metal.
- Subsequently, the water should be run for a further 2 or 3 minutes before the sample is taken.
- After the string or rubber band which fixes the cover in position has been loosened the bottle should be held by the base of the hand, while the other hand removes the stopper.
- The stopper should be retained between your two fingers ensuring that the inner surface is not touched at all while the sample is being put in. It should then be replaced immediately.
- During the whole procedure the stopper and the mouth of the bottle should not be allowed to touch anything. Neither should one breathe, sneeze, cough or shout into the bottle or stopper.

Steps of sampling from a tap:

1. Cleanse the tap nozzle of any grease, dirt, e.t.c.
2. Open the tap full bore and allow H_2O to flow for 2-3 minutes then stop the flow.
3. Flame the mouth with either a blow lamp or glowing cotton dipped in spirit, until it is too hot to touch.
4. Cool the tap by allowing more water to flow for some time.
5. Fill the bottle with a sample; care being taken to avoid splashing or if using bottle with transport media, draw measured amounts and inject into the bottles as indicated on the bottles' labels.
6. Cork or seal immediately and put the bottles in the cooled container/refrigeration.
7. Fill the sample application forms giving all the required information.
8. Send the results to the lab by the quickest means.
9. Secure the analysis results and institute appropriate remedial action.

Interpretation of results

Bacteriological results

Escherichia coli (E.coli) is only found in the intestinal tract of man and animals. So the presence of even one (1) E. coli is indicative of faecal pollution. Other types of coliforms may also be present in the intestinal canal but are more abundant outside the human body. So, isolation of coliforms in general indicates pollution and the number isolated per 100ml of water give the degree of pollution. The results of bacteriological test are presented in the form of the number of coliforms and E. coli isolated per 100ml of water. The following is the interpretation of the results provided by the laboratory:

1. Any sample with NIL E.coli and NIL coliforms per 100ml of water is safe for drinking. It is therefore satisfactory and may be classified as Grade I.
2. Any sample with upto 2 coliforms and NIL E.coli per 100ml of water is said to be also just satisfactory or fair and may be classified as Grade II.

3. Any sample with upto 25 coliforms and NIL E.coli per 100ml of water is said to be suspicious and may be rated as Grade III.
4. Any sample with more than 1 E.coli irrespective of the number of coliforms is said to be unsatisfactory or dangerous and is classified as Grade IV. All treated waters should be grade I at all times. Otherwise the treatment plant is not working efficiently, unless there is a point where water is getting contaminated after treatments i.e. post treatment contamination.

Use of indicator organisms to detect pollution

It is very important that water intended for human consumption is free from faecal pollution. Although it is possible to detect presence of many pathogens in H_2O, the methods of isolation and enumeration are complex and time consuming. It is therefore not practical to monitor drinking water for every possible microbial pathogen that might occur with contamination. A more logical approach is the detection of organisms normally present in faeces of man and other warm blooded animals as indicators of faecal pollution as well as of the efficacy of water treatment and disinfection.

The presence of such organisms indicates the presence of faecal material and thus that intestinal pathogens could be present. Conversely, the absence of faecal commensal organisms indicates that pathogens are probably also absent. Search for such indicators of faecal pollution provides a means of quality control.

Bacteriological control of water offers the most sensitive test for the detection of recent and therefore potentially dangerous faecal pollution. It is essential that water is examined regularly and frequently as contamination may be intermittent and may not be detected by the examination of a single sample. For this reason it is essential that drinking water is examined frequently by simple tests rather than infrequently by a more complicated test or series of tests.

Priority must always be given to ensure that routine examination is maintained whenever manpower and facilities are limited. It must be appreciated that; all bacteriological analysis can prove is that at the time of examination contamination or bacteria indicative of faecal pollution could or could not be demonstrated in a given sample of water using specified culture methods.

Results of routine bacteriological examination must be always interpreted in the light of thorough knowledge of the water supplies, including their source, treatment and distribution.

Whenever changes in condition lead to deterioration in the quality of water supplied or even if they should suggest an increased possibility of contamination; the frequency of examination should be increased so that a series of samples from well chosen locations may identify the hazard and allow remedial action to be taken.

Whenever a sanitary survey including visual inspection indicates that a water supply is obviously subject to pollution, the remedial action must be taken, irrespective of the results of bacteriological examination. For unpiped rural water supplies, sanitary surveys may be the only form of examination that may be undertaken regularly.

Organisms indicative of faecal pollution

The use of normal intestinal organisms as indicators of faecal pollution rather than the pathogens themselves is universally accepted principle for monitoring and assessing the microbial safety of water supplies. Ideally, the presence of such indicative bacteria points to possible presence of all the relevant pathogens.

Indicator organisms must:

- Be abundant in faeces but absent or present only in small numbers in H_2O sources
- Should be easily isolated, identified and enumerated
- Should be unable to grow in water
- They should also survive longer than pathogens in water and be more resistant to disinfectants such as chlorine.

In actual practice, this criteria cannot be met by any one organism, although many of them are fulfilled by coliform organisms especially *Escherichia coli (E. coli)* as the essential indicator of pollution by faecal material of human or animal origin. Other micro-organisms that satisfy some of these criteria, though not to the same extent as coliform organisms can also be used as supplementary indicators of faecal pollution.

Microbiological standards

- When considering a chlorinated and treated water supply the question of standards is a relatively straight forward one.
- The presence of even low concentration of coliforms is indicative of failure in the treatment plant or subsequent pollution of the treated water.
- The WHO (WHO 1983) suggests the following standards for treated drinking water.

1. Water entering the distribution system should contain no coliform organisms.
2. Water at the tap should contain no coliforms in 95% of samples taken in any one year and it should never contain more than 10 coliforms/100mls or any Escherichia coli in subsequent samples
    - For untreated water supplies, especially rural water supplies, the question of standards is very difficult. Untreated water sources in rural areas are usually contaminated with faecal coliforms and other indicator bacteria.
    - It is therefore necessary to determine the concentration of indicator bacteria in a sample of water than simply to demonstrate their presence.
    - Surface water sources may be expected to be more polluted in any area with significant human or animal populations while ground water sources will be of better quality.
    - It is however almost impossible to find any untreated water supply in any village in any developing country in which one would not detect faecal coliforms and other faecal bacteria.

- Therefore to apply standards as stringent as those mentioned earlier would be to condemn the supplies used by the majority of the population of most developing countries.
- Such a ruling may force people to abandon improved but lightly contaminated supplies in favour of the only alternative which may be heavily polluted. E.g. we have cases where health officers have closed down shallow wells because they were found to contain 50 faecal coliforms/100mls and have thus forced villagers to use polluted irrigation canals containing 10^4 faecal coliform/100mls.
- A useful role for bacteriological water quality testing in villages using untreated water supplies is to select between alternative sources of water.
- If a number of alternative sources are tested, it is possible to determine which source consistently provides water of the best bacteriological quality particularly after rain.

Water surveillance

Water surveillance is an investigative activity undertaken to identify and evaluate factors associated with drinking water which could pose a risk to health. It's the process of gathering systematic information on hazards in water.

1. Surveillance contributes to the protection of public health and promotes improvement of the quality, quantity, coverage cost, and continuity of water supplies.
2. It is two fold in that it is both:
   - Preventive: detects risks so that action may before public health problems.
   - Remedial: identifies the source of outbreaks of water borne diseases so that corrective action may be taken promptly.

Quality control and sanitary surveys are integral parts of surveillance

- Surveillance requires a systematic program of surveys that combine analysis, sanitary inspection, institutional and community aspects.
- It should cover the whole of the water supply system including sources, pipe networks, treatment works, storage reservoirs, and distribution systems.

Quality control on the other hand is designed to ensure that water services meet agreed national standards and institutional targets.

- Quality control is the responsibility of water suppliers and they achieve this by a combination of good operating practice and preventive maintenance. This involves:
  - Establishment of safeguards in the production and distribution of drinking water.
  - Routine testing of water quality to ensure compliance with national standards.
- Quality control is distinguished from surveillance on the basis of institutional responsibilities and the frequency of the monitoring activities conducted.

- Surveillance agency is responsible for an independent (external and periodic) audit of all aspects of safety of water.
- The water supplier is responsible at all times for regular quality control, and for monitoring and ensuring good operating practice.

Organizational structure

Organizational arrangements for the improvement of water supply services should take into account the vital and complementary roles of the agencies responsible for surveillance and quality control.

The two functions should be performed by separate and independent entities because of the conflict of interests that arises when the two are combined.

Important aspects of surveillance program

- Surveillance agency should have sole responsibility within the health authority for providing surveillance services to protect the public from water-borne diseases and other hazards associated with water supply.
- Water supply surveillance should be integrated with other environmental health measures, especially sanitation.
- Surveillance requires specialized knowledge, and the agency should therefore include personnel specially trained in sanitary engineering, community health, epidemiology etc.
- Health authorities should have centralized laboratories and other services needed for programmes of water supply surveillance.
- Reports provided to the government regarding the public health status of the country's water should be produced.

The surveillance agency

- The agency responsible for surveillance of drinking water supply is the Ministry of Health (or public health) and its departmental/ regional offices.
- Its responsibilities include:
  - Monitoring of compliance with supply service standards, (quality, coverage, quantity, continuity and cost) by water supplies
  - Approving sources of drinking water
  - Surveying the provision of drinking water to the whole population
  - Generate and summarize surveillance data
  - Promote improvement of water supply systems.
- Surveillance should be concerned with all water used for domestic purposes by the population, whether supplied by a formal water-supply agency or collected from individual sources or supplies.

- Nevertheless, due to cost limitations, priority should be given to systems that provide water to larger populations and those suspected of causing substantial risk to human health.

Designing a water monitoring program

1. **Establishing national priorities**
   - Formulation of national strategies for improvements and remedial on water supply sources/systems.
   - This might include changes in training (Field staff, PHO's. Lab Technicians etc).
2. **Establishing regional priorities**
   - Deciding which communities to work in
   - Deciding which remedial activities are priorities
   - Considering public health criteria for deciding on priorities.
3. **Establishing hygiene education**
   - Aims at addressing non-technical problems
   - Looks at problems involving private supplies, water collection and transport, household treatment and storage
   - Solutions to many of these problems require educational and promotional activities.
4. **Enforcement of standards**
   - Considers law and standards related to public water supply
   - Information generated by surveillance can be used to assess compliance with standards.
   - Corrective actions taken where necessary.
5. **Ensuring community operation & maintenance**

   Support should be provided by a designated authority to enable community members to be trained so that they are able to take responsibility for the operation and maintenance of their water supplies.
   - Introduction
   - Water cycle
   - Diseases and conditions associated with Water
   - Water sources and supply systems – engineering.
   - Water treatment
     - Standards – WHO and various countries: quantity and quality
     - Chemicals
     - Filter
     - Conventional systems.

Chapter 3 Solid Waste Management

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3.1 Introduction

Human health depends on a wide range of crucial environmental factors. This underlines the importance of environmental protection. With increasing civilization bringing about urbanization and industrialization, the question of environmental pollution becomes more and more complex.

High on the list of environmental pollution is solid waste arising. Improper or lack of management of solid waste will definitely result in health implications, environmental implications and economic implications. As for the health implications, we do experience ill-health from biological, chemical and physical factors. We also experience proliferation of disease vectors. With environmental implications, we have useful spaces occupied by waste. Yet these wastes can also be used to reclaim sites. At the economic front, we waste resources which could be recycled. Wastes also consume massive budgets of Local Authorities (up to 50%) as we strive to keep our townships clean.

The importance of Solid Waste Management can therefore not be overemphasized. This is all about formulating a suitable framework that ensures proper and efficient storage, collection, transportation, and disposal of solid wastes to safety.

Important areas in the framework of solid waste management that must be addressed include having a functional system which includes:

- An organizational framework
- The factoring of all key steps, cradle-to-grave
- Public awareness and positive attitudes
- Policy and Legislation
- Improved technology and innovations
- Capital
- Political goodwill.

All these need to be worked out within the local, regional and international framework to ensure a safe environment in order to realize progress in this field.

In order to avoid problems, it is important that waste removal keeps pace with solid waste arising.

Solid waste management as it stands today is a question of innovations, technological provisions, legal provisions as well as social transformation. It has become a community development exercise. As such, managers of the process must have the technical capacity to;

1. Carry out Situation analysis /needs-capacity assessment
2. Design suitable interventions based on the technological options
3. Execute the interventions
4. Monitor and evaluate progress
5. Redesign the interventions based on emerging issues.

All this is our wish; that we cast the refuse away from our midst into safety.

This poses a serious challenge to practically all health officers. Only those health officers in a small sleepy village will not meet the task of addressing solid waste. And only that health officer who likes dwelling on expired foodstuffs on the shelves of shops will snub solid waste management in their areas of jurisdiction. But still, how will they dispose off the expired foods?

Principles of waste management

- Minimization strategies that include reduce, re-use, recycle
- Funding of wastes management with sustainable options
- Promote public awareness
- Storage / Containment
- Effective collection system to remove NIMBY
- Promote recovery / recycling
- Appropriate use of technologies
- Workers safety & protection
- Pre-disposal treatment
- Safe disposal.

Historical background

The story of solid waste is as old as mankind. Whether you want to look at it from the perspective of evolution or creation, you will appreciate that as man went about their business of obtaining a meal, something like a bone or a nut had to be left behind. This constituted waste.

Early man however never bothered about waste because:

- The population was very small
- Wastes were too little and too simple
- The land was vast
- He never associated disease with waste.

The early wastes included dead animals, animal wastes, leaves and fossils. Natural agencies like micro-organisms, winds, rains, scavengers and rodents were left to tackle the problem. The other way people dealt with the problem was to move away from the piling wastes.

In the Middle Ages however, man started living in groups of villages. Solid waste as a problem started emerging. The sense of a clean environment started emerging. That is why in East Africa we hear of terms like 'eshituoli' amongst the Luhya, 'ngatok' amongst the Kalenjin, 'kiara' amongst the Kikuyu and 'utunda' amongst the Akamba. Animal dung had to be removed and often villages had to be swept clean.

Related to the spiritual sense, the process of sanitizing was clearly demonstrated by the saying *'Cleanliness is next to godliness,'* with the constant reminder that the unclean will be condemned in a perpetual fire. This has something to do with Jerusalem where we had a continuous fire for refuse called 'tophet' or 'sheol' the origin of the word hell.

Early organization

As civilization continued with an era of industrialization and urbanization setting in, it became increasingly difficult for people to move away from their homes. In other words, it became clear that wastes do not manage people, but rather, people ought to manage the wastes. Something had to be done about the wastes.

The Romans introduced handcarts driven by slaves. Generally, wastes were deposited in drains. In Denmark, huge disposal grounds called middens were designated. Urbanization increased and so did environmental degradation.

The first organized public cleansing services can be traced back to Great Britain during the time of Edwin Chadwick (1800 – 1890). Chadwick was a lawyer whose main concern was sanitation in the local authorities. He noticed that a majority of the workers lived under insanitary conditions and were frequently absent from work due to sicknesses. He linked ill-health to a defective environment. Doctors and nurses dismissed his claims.

In 1841, cholera and plague devastated England. Studies by scholars revealed that insanitary conditions were responsible. Chadwick thus got the kind of support he needed. Parliament later enacted Poorman's Ordinance which later became the Public Health Ordinance. This constituted rules and regulations prepared to govern sanitation.

In Kenya, the Public Health Ordinance was introduced in 1921 by the Colonial Administration. In addition, the Local Authorities were mandated to make bye-laws. The Public Health Ordinance became the Public Health Act in 1974 and as up to now, efforts are being made to strengthen the field of environmental engineering for public health. EMCA (Environmental Management and Coordination Act) was enacted by Parliament in 1999 and it has a heavy influence on solid waste management. Its *'Wastes Management Regulations of 2007,'* has very clear provisions on managing solid waste.

The relevance of the historical background

There is need to examine what other people did in the past in order to borrow from their strong points then improve on their weak points; so as to improve on our performances. In Denmark they designated middens 2000 years ago!

The magnitude of the problem

The story of solid waste is a huge one in all towns and cities around the world. In the Philippines, they talk of the 'Smoky Mountains of Manila,' while in Nairobi we have heard about, 'the city in garbage.'

NIMBY (not in my backyard please) syndrome has spread and there are posters posted around compounds and premises reading 'USITUPE TAKATAKA HAPA,'i.e (no dumping).

Countless letters are being mailed to editors of local dailies by residents and visitors to lament on the issue of 'garbage' in all our towns. Mayors of towns are being judged on their efficiency not by how much water flows or school enrolment but by how efficient their councils deal with refuse.

We do not yet seem to find the magic bullet to rid our towns of 'garbage'. Rapid development has made the problem more complex. The wastes now include foods, glass, plastics, metals, household chemicals etc. We are also caught up:

- Maintenance of goods is costly and therefore volumes of goods getting dumped gets larger.
- We have less durable goods in the market as a result highher disposal frequency.
- Changing trends of products which have given us non-biodegradable package materials.
- On the other hand, we are experiencing increasing salvaging and scavenging due to increasing poverty.

Emerging issues

- Plastic waste
- E-waste
- WEEE (Waste Electrical and Electronic Equipments).

3.2 Solid waste management program – beyond municipal waste

Solid waste management is often considered a municipal venture. However, it is imperative that even rural settings have a structure and systems to manage waste, from cradle to grave

- A programme of Community Participation where people organize to have clean up activities although this requires facilities.
- Health facilities are required to have a Waste Management Plan
- Market centers and municipal estates to organize cleansing projects.

Why we must manage solid waste

1. **Prevent and control disease**
   In general, refuse related diseases are similar to faecal related diseases. Solid wastes (SW) provide a good home as well as excellent food for bacteria, protozoa, viruses and helminthes.

Further to this, flies, vectors, and rodents breed well in SW.

- Flies bring about diarrhoeal diseases, bacillary dysentery, typhoid and paratyphoid infections, hepatitis, cholera, trachoma, polio etc.
- Cockroaches are associated with diarrhoeal diseases e.g. salmonella.

- Rodents are linked to plague, leptospirosis, trichinosis, endemic typhus and rat-bite fever.

2. **Eliminate nuisance**
SW produces offensive smell and is an aesthetic effrontery.
3. **Prevent mechanical injury**
For instance, from toxic hazardous substances, broken bottles, syringes, tins etc.
4. **Prevent fires**
Some of the ways fires have been known to cause havoc are related to the way refuse is managed / mismanaged.
5. **Prevent pollution**
Leachate (that liquid oozing out of a refuse heap) can cause water pollution. Careless burning of refuse causes air pollution and metals with other chemicals as waste can cause soil pollution.
6. **Avoid waste of resources**
Some materials in waste can be reclaimed and put into useful economic gain. E.g. Paper ➔ tissue paper, bones ➔ buttons, garbage ➔ manure, construction waste ➔ reclamation of quarries.
7. **Creation of space**
Uncontrolled refuse occupy useful space which could otherwise be used for other purposes. A visit to many police stations and other government institutions including your district hospital will reveal junkyards some dating back to 1950s. We could do with those spaces you know!
8. **Prevent blockage of drains**
A look inside the drains in the cities and city estates will give you a perfect demonstration of this point. The SW is carried to the drains; then sewer lines and culverts and the blockages resulting cause flooding on roads, with lots of inconveniences.
9. **Prevent occupational hazards**
Workers involved in cleansing operations must be protected from occupational hazards e.g. mechanical injuries, infections, worm infections URI's etc.
Generally, these objectives are broken down into:

Health implications

- Diseases
- Vectors
- Injuries.

Environmental implications

- Pollution of air, water and grounds.
- Clogging of drains
- Fire links
- Occupy useful spaces.