WATER, SANITATION AND HYGIENE (WASH) TRAINING MODULE

For Water Technology College Instructors

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### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>CLTSH</td>
<td>Community Led Total Sanitation and Hygiene</td>
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<td>CSO</td>
<td>Civil Society Organizations</td>
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<td>CWA</td>
<td>Consolidated WASH Account</td>
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<td>EDHS</td>
<td>Ethiopian Demographic and Health Survey</td>
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<td>JMP</td>
<td>Joint Monitoring Plan</td>
</tr>
<tr>
<td>ODF</td>
<td>Open Defecation Free</td>
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<td>OWNP</td>
<td>One WASH National Program</td>
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<td>MGD</td>
<td>Millennium Development Goal</td>
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<td>MOU</td>
<td>Memorandum of Understanding</td>
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<td>NHSS</td>
<td>National Hygiene and Sanitation Strategy</td>
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<td>NWI</td>
<td>National WASH Inventory</td>
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<tr>
<td>PHAST</td>
<td>Participatory Hygiene and Sanitation Transformation</td>
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<td>SDG</td>
<td>Sustainable Development Goal</td>
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<tr>
<td>SLTSH</td>
<td>School Led Total Sanitation and Hygiene</td>
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<tr>
<td>TVET</td>
<td>Technical and Vocational Education and Training</td>
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<tr>
<td>VIPL</td>
<td>Ventilated Improved Pit Latrine</td>
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<td>WASH</td>
<td>Water, Sanitation and Hygiene</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>WIF</td>
<td>WASH Implementation Framework</td>
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<td>WSSS</td>
<td>Water Supply and Sanitation Strategy</td>
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<td>WVE</td>
<td>World Vision Ethiopia</td>
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Course Syllabus

Course Description
This 5 days' course is designed to prepare water sector professionals to promote and apply the role of optimal water, sanitation and hygiene practices for the improvement of the health and nutritional status of women, children and vulnerable community groups.

Course Objective
To provide participants with the knowledge and skills of promoting optimal water, sanitation and hygiene practices that contributes to the improvement of nutritional status of women and children.

Supporting Objectives
At the completion of this training, participants will be able to:
- Describe Components of WASH and, the relationship between WASH and Nutrition
- Identify Water related diseases, ways to develop safe water supply systems
- Conduct Homemade water treatment, Sampling, Water quality Analysis and Water storage tank disinfection
- Analyze the impact of Hygiene and Sanitation interventions on health and Nutrition of children and women
- Illustrate the different sanitation strategies such as CLTSH to promote hygienic practices
- Apply hygiene and Sanitation promotion Strategies

Course Logistics
This is a five-day training conducted on-site. Presentation PPTs, reference manual and materials, laboratory equipment’s, and audiovisuals are required for the training. A transportation facility and laboratory facility also required for practical sessions of the training.

Training Methodology
- Interactive presentations
- Large group discussion
- Small group’s activities
- Brainstorming
- Case study and role play
- Laboratory practical sessions
- Community level practical sessions

Learning Materials
- Reference manual and materials (Selected references)
- National nutrition programs and strategy documents
• Computer presentation slides, and video clips
• White board, flip charts and markers

**Assignment**
• Individual and group reading assignments on selected reference and one WASH national program and strategy documents

**Participant Assessment**
- Formative assessment
  - Question and answer during facilitation
  - Informal evaluation on group presentation
- Summative Assessment
  - Pre and Post-test question

**Course Assessment**
• Daily and end-of-course evaluation

**Attendance**
• Participants are expected to attend all course contents
## TRAINING SCHEDULE FOR A 5 DAYS TECHNICAL UPDATE TRAINING ON WASH AND NUTRITION FOR WATER TECHNOLOGY COLLEGES

<table>
<thead>
<tr>
<th>Venue:</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
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<tr>
<td><strong>Morning(AM):</strong></td>
<td>Registration</td>
<td>Agenda, recap and warm-up (10 min)</td>
<td>Agenda, recap and warm-up (10 min)</td>
<td>Agenda, recap and warm-up (10 min)</td>
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<td></td>
<td>Welcome and introduction</td>
<td><strong>Session 4 (Module 2):</strong> Develop water supply sources</td>
<td><strong>Session 7 (Module 2):</strong> Water Treatment and storage</td>
<td><strong>Session 11 (Module 3):</strong> Sanitation facilities to manage human excreta</td>
<td><strong>Session 15 (Module 4):</strong> Hygienic Practices (Food hygiene, Personal Hygiene, Handwashing)</td>
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<td></td>
<td>Participant expectations</td>
<td>Interactive Presentation (30 minutes)</td>
<td>Interactive presentation (40 minutes)</td>
<td>Interactive presentation (40 minutes)</td>
<td>Interactive presentation (40 minutes)</td>
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<td></td>
<td>Course overview (Goals, Objectives, Schedule)</td>
<td>Group Activity (90 Minutes)</td>
<td>Group activity (80 minutes)</td>
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<td>Group Norms</td>
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<td>Pre-Course Assessment</td>
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<td>Review course materials</td>
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### Session 1 (Module 1):
**Introduction to WASH and Nutrition** (Key concepts, Impacts of WASH on Nutrition, National WASH Strategies)
Interactive presentation (50 minutes)
Group Activity (50 minutes)

### Session 2 (Module 2):
**Water Supply**

### Session 3 (Module 2):
**Session 5 (Module 2):** Water quality concerns and contaminants of water
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 4 (Module 2):
**Session 6 (Module 2):** Water Treatment and storage
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 5 (Module 2):
**Session 7 (Module 2):** Water Treatment and storage
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 6 (Module 2):
**Session 8 (Module 2):** Operation and Maintenance of water supply systems, water safety plans Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 7 (Module 2):
**Session 9 (Module 3):** Sanitation Promotion
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 8 (Module 3):
**Session 10 (Module 3):** Sanitation Marketing and CLTSH Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 9 (Module 3):
**Session 11 (Module 3):** Sanitation Marketing and CLTSH Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 10 (Module 3):
**Session 12 (Module 3):** Sanitation Marketing and CLTSH Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 11 (Module 3):
**Session 13 (Module 4):** Hygiene Promotion
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 12 (Module 4):
**Session 14 (Module 4):** Hygiene Promotion
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 13 (Module 4):
**Session 15 (Module 4):** Hygienic Practices (Food hygiene, Personal Hygiene, Handwashing)
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 14 (Module 5):
**Session 16 (Module 5):** WASH and Nutrition
Interactive Presentation (50 Minutes)
Group Activity (60 Minutes)

### Session 15 (Module 5):
**Session 17 (Module 5):** Nutrition and the life
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)

### Session 16 (Module 5):
**Session 17 (Module 5):** Nutrition and the life
Interactive Presentation (40 Minutes)
Group Activity (60 Minutes)
<table>
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<tr>
<th>Afternoon (PM)</th>
<th>Water related Diseases and Water supply standards</th>
<th>Burdens from poor sanitation; Sanitation and waste management</th>
<th>(Hygiene promotion, Burdens from poor hygienic practices, The “F” Diagram) Interactive Presentation (30 minutes) Group Activity (60 minutes)</th>
<th>cycle; Malnutrition and Diarrhea Interactive presentation (50 minutes) Group activity (40 minutes)</th>
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<td>Group Activity (70 minutes)</td>
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<td>Session 3</td>
<td>Develop Water supply sources</td>
<td>Sampling and Analysis of drinking water…cont.</td>
<td>Sampling and Analysis of drinking water…cont.</td>
<td>Warm-up (10 min)</td>
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<td>(Module 2)</td>
<td>(Determine water Demand) Interactive presentation (20 min) Group Activity (50 minutes)</td>
<td>Practice</td>
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<td><strong>Session 10</strong></td>
<td>(Module 3) Standards and strategies for hygiene promotion</td>
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<td><strong>Session 14</strong></td>
<td>(Module 4) Standards; Key Principles in Hygiene Promotion Interactive presentation (20 minutes) Group activity (50 minutes)</td>
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Preface

Primary prevention of diarrhoea through water, sanitation and hygiene interventions is based on reducing the faecal-oral transmission of pathogens, and includes the provision of an improved water supply, water safety planning, household water treatment and safe storage, improved sanitation facilities, and hygiene education. Ethiopia has embarked on a process of reforming its TVET-System. Within the policies and strategies of the Ethiopian Government, technology transformation – by using international standards and international best practices as the basis, and, adopting, adapting and verifying them in the Ethiopian context – is a pivotal element. TVET is given an important role with regard to technology transfer.

This manual is developed as a supporting document in the new occupational standard for Technical and Vocational Education Training focusing on water supply, sanitation and hygiene in relation with nutrition for water technology occupation.

Undertaking the operation and maintenance functions and actions effectively and efficiently requires the strengthening of the technical, operational and managerial capabilities of the water supply and sanitation staff. The module mainly focuses on concepts of water, sanitation and hygiene (WASH).

The main objectives of this module is to help trainers in water technology departments of TVET colleges provide courses related to Water supply, sanitation and hygiene effectively based on the following specific objectives:

- Describe Components of WASH and, the relationship between WASH and Nutrition
- Identify Water related diseases, ways to develop safe water supply systems
- Conduct Homemade water treatment, Sampling, Water quality Analysis and Water storage tank disinfection
- Analyse the impact of Hygiene and Sanitation interventions on health and Nutrition of children and women
- Illustrate the different sanitation strategies such as CLTSH to promote hygienic practices Apply hygiene and Sanitation promotion Strategies

At the end of each chapter key points are outlined and summarized with self-check questions.
Module 1: Introduction to Water, Sanitation and Hygiene

Introduction
This module focuses on the general concepts of water sanitation and hygiene (WASH), components of WASH and definition of terms. It also includes the benefits from water, sanitation and hygienic practices and the burdens from water, sanitation and hygiene related problems. National WASH strategies including the one WASH national programme will be addressed in this module. Global and national statuses of WASH, the relation between WASH and nutrition are also addressed in this module.

Learning Objectives for this Module
After you have studied this Module you will be able to:
- Describe key concepts of WASH, its components, safe and unsafe water supplies, improved and unimproved sanitation
- Describe the national WASH strategies including the one WASH national programme
- Explain the impacts of unimproved WASH on health and nutrition

I.1. General Concepts of Water, Sanitation and Hygiene

I.1.1. Definition of key terms

**Water Sanitation and Hygiene (WASH)**
The provision of safe water for drinking, washing and domestic activities, the safe removal of waste (toilets and waste disposal) and health promotion activities to encourage protective healthy behavioral practices amongst the affected population which allow people to live with good health, dignity, comfort and security.

**Water supply**
The provision of water by public utilities, commercial organizations, communities or individuals. Public supply is usually via a system of pipes and pumps. In order to sustain human life satisfactorily, a water supply should be safe, adequate and accessible to all.

**Safe water supply**
The supply of water is free from any form of disease-causing agents. The main criteria are: biological aspects: the water supply should be free from disease-causing microbes and parasites; chemical aspects: the water supply should be free from dissolved chemicals at the level that would damage health; radiological aspects: the water supply should be free from any naturally occurring radioactive substances.

**Sanitation:**
World Health Organization (WHO) defines sanitation as group of methods to collect human excreta and urine as well as community waste waters in a hygienic way, where
human and community health is not altered. Sanitation methods aim to decrease spreading
of diseases by adequate waste water, excreta and other waste treatment, proper handling
of water and food and by restricting the occurrence of causes of diseases.

**Basic sanitation:**
As defined by the United Nations Millennium Project Task Force on Water and Sanitation,
basic sanitation is the “lowest-cost option for securing sustainable access to safe, hygienic
and convenient facilities and services for excreta and sullage disposal that provide privacy
and dignity while at the same time ensuring a clean and healthful living environment both
at home and in the neighborhood of users.”

**Hygiene:**
The word hygiene originates from the name of the Greek goddess of health, Hygieia. It is
commonly defined as a set of practices performed for the preservation of health and
healthy living. It refers to practices associated with ensuring good health and cleanliness.

**Improved hygiene and sanitation:**
As defined by the 2005 National Hygiene and Sanitation Strategy, improved hygiene and
sanitation is the process where people demand, develop and sustain a hygienic and
healthy environment for themselves by erecting barriers to prevent the transmission of
diseases, primarily from faecal contamination.

1.1.2. Burdens from Water, Sanitation and Hygiene related problems
Every year, millions of the world’s poorest people die from preventable diseases caused by
inadequate water supply and sanitation (WS&S) services. Hundreds of millions more suffer from
regular bouts of diarrhea or parasitic worm infections that ruin their lives.

An estimated 844 million people, the majority in developing countries, are not using improved
sources of drinking water, while 2.6 billion people are not using improved sanitation. This
situation results in the avoidable deaths of an estimated 1.5 million children every year, many
victims to diarrheal diseases. (WHO, 2014)

Women and children are the main victims. Burdened by the need to carry water containers
long distances every day, they must also endure the indignity, shame, and sickness that result
from a lack of hygienic sanitation. The impact of deficient water and sanitation services falls
primarily on the poor. Unreached by public services, people in rural and peri-urban areas of
developing countries make their own inadequate arrangements or pay excessively high prices to
water vendors for meagre water supplies. Their poverty is aggravated and their productivity
impaired, while their sickness puts severe strains on health services and hospitals.
In Ethiopia, only 24% of the population use latrines that meet basic standards, and worse still, about 37% of the population practices open defecation (JMP, 2014a). This lack of adequate sanitation obviously makes faecal contamination of the environment and the spread of disease more likely.

According to the 2016 EDHS report about two-thirds of households in Ethiopia (65 percent) obtain their drinking water from an improved source. More than 44% of households obtain drinking water in a round trip taking more than 30 minutes and about in 68% of households’ adult women and female child under 15 years old are responsible for fetching water. Only 6.5% of households treat water prior to drinking. About 6.3% use improved not shared facility, 8.5% shared facility and 85.2% use unimproved facility.

A 2014 study (WVE, 2014) summarized the impact on young children as follows: Diarrhea is the leading cause of under-5 children in Ethiopia, causing 23% of all under-5 deaths (73,341 children per year). Around 44% of under-5 children in Ethiopia are stunted (i.e. their height is less than expected for their age), which can be linked to the childhood incidence of diarrhea and to the lack of WASH services. Important nutrients that the child requires for growth are wiped out through diarrhea; intestinal parasites take up remaining nutrients and when this scenario continues for some time, the child becomes stunted.

### 1.1.3. Benefits of water, sanitation and hygiene

**Health Dimension**

Diarrhea, worm infections and respiratory infections are widespread health concerns and that can be improved through implementing WASH improvements. Diarrhea is the most preventable cause of death for children under five. Worms are spread through unhygienic environments (such as contaminated soil or water) and unhygienic behavior. Annually, more than 2 billion people worldwide suffer from worm infections, 300 million people become severely sick and 155,000 people die. Worm infection is ranked as the main cause of disease in children aged 5-14.

Ensuring access to safe water, sanitation, and hygiene (WASH) services plays an important role in safeguarding the health, well-being, and resilience of individuals and communities. WASH has the potential to prevent 6.3% of deaths and 9.1% of the disease burden in developing countries.

Each year, approximately 801,000 children under 5 years of age die from diarrheal diseases that result from poor-quality WASH. An estimated 50% of under nutrition is not due to lack of food, but to diarrheal disease and worm infections caused by inadequate WASH.
Fewer than half of health facilities in the developing world have access to safe drinking water, improved sanitation, and hygiene on the premises. This contributes directly to the spread of diseases, including diarrhea, pneumonia, and even Ebola, as well as to life-threatening infections, such as sepsis, which accounts for 11% of global maternal mortality and 7% of neonatal mortality and is frequently acquired when women are forced to give birth in WASH-unsafe environments. 50% of undernutrition is not due to lack of food, but to diarrheal disease and worm infections caused by inadequate wash.

**The Educational Dimension**

Due to health problems and the lack of available toilets or water collection duties, children are more likely to miss school. Although diarrhea seldom kills children above the age of five, it remains an important issue for school-age children: it is the major source of morbidity and therefore factors into why children are absent from school. Chronic early childhood diarrhea can result in decreased blood flow to the brain or failure to absorb sufficient dietary nutrients. Repeated episodes may have permanent effects on brain development. This may have an impact on a child's learning ability and their health during school years.

**The Gender Equity and Inclusion Dimension**

Women spend a disproportionately large amount of time on water-centered activities and bear significant physical burdens. This harms their health and limits their entry into the cash economy. In many societies water is at the core of women’s traditional responsibilities: collecting and storing water, caring for children, cooking, cleaning, and maintaining sanitation within the home or community. These tasks often represent an entire day’s worth of work as women can spend as much as five hours a day collecting wood for fuel and getting water, and up to four hours preparing food. Providing access to clean water close to the home can dramatically reduce women’s workloads and free up time for other economic activities. Lack of sanitation hampers dignity and social development. Women play a key role in educating children about water. It is important to grab their interest about water awareness, since they look after the household, and it is due to contaminated water or lack of good hygiene practices that lead to children contracting diseases and getting sick.

If adolescent girls attend schools during menstruation the availability of girls’ toilets and water supply is essential to comfortably change and dispose of sanitary pads. When not available, adolescent girls may have discomfort during class. Although it has not been proven through scientific research, the lack of sanitary protection during menstruation is often mentioned by adolescent girls as a barrier to their regular attendance in school. Access to WASH facilities for women, does not only mean focusing on economic improvements but may also involve modifying long-established religious or cultural practices.
The Economic Dimension
High proportion of budget used on water. Reduced income-earning potential because of poor health, time spent collecting water, or lack of business opportunities requiring water inputs. The costs and benefits of improvements to water supply and sanitation are difficult to calculate because many benefits are not direct in terms of material changes to economic costs and outputs. In an attempt to calculate the cost benefits, a recent WHO study found that every dollar spent on improving sanitation generates an economic benefit of $3 to $6027.

Other benefits include increases in ecosystem goods, services and other non-use values resulting from improvements in ecosystem health and options from increased water access, such as the productive use of domestic water in income-generating activities and the cost savings from buying water from more expensive sources.

The Environmental Dimension
Unhygienic sanitation pollutes the environment. Improved disposal of human waste protects the quality of drinking water sources. At present, more than 200 million tons of human excreta, as well as big quantities of waste water and solid waste, go uncollected and untreated each year. This waste pollutes the environment and exposes millions of people to disease and dirt.

The Food Security Dimension
Food security initiatives therefore incorporate elements of enhanced food availability (e.g. agriculture production, imports, aid), access to food (e.g. elements of increased income, physical access, distribution of food within the household), utilization of food (e.g. behavior change, health, water and sanitation programs to reduce disease and malnutrition) and reduction in vulnerability and risk to future insecurity. Water, sanitation, and hygiene initiatives that address issues of health, education, gender, and economic development all are connected to a comprehensive approach for reducing food insecurity. The figure on the next page details some of these relationships.

1.2. Global water, Sanitation and Hygiene Challenges
The Scale of the Need
The sheer scale of the issue is a challenge in itself. It will be no small feat for half the world’s population to gain sustained access to safe water, basic sanitation and good hygiene practices (and to do so in 15 years). Even critical institutions like health care facilities and schools lack water and sanitation. A study in 54 low- and middle-income countries found that 38% of health care facilities lack access to an improved water source, 19% lack sanitation and 35% do not have water and soap for handwashing (World Health Organization & United Nations’ Children’s Fund, 2015). The scale of the need will increase, particularly as populations grow, available freshwater is used and contaminated at increasing rates, and the climate changes.
Variability of the Problem and Therefore the Solutions
Water and sanitation issues are highly variable from location to location, from season to season and community to community; and people who lack WASH are often living in the most challenging geography and climate. One-size-fits-all solutions have not worked and cannot be the strategy to scale-up reach. For example, water quality, rainfall and hydrology are site-specific and have important implications on technology selection and siting. Incorrect choices can exacerbate an already poor condition (e.g. digging a simple pit latrine that further contaminates groundwater). Customized water and sanitation services are needed that capitalize on existing local knowledge of conditions; and local people need to have the capability to make informed choices and be able to respond effectively to changing conditions.

Sustaining Water, Sanitation and Hygiene Services for the Long-Term
Focus over the past decades has been on water and sanitation infrastructure. This approach is costly in up-front capital, operations and ongoing maintenance. It requires a highly educated, skilled workforce and often doesn’t reach the most marginalized communities, nor address specific contextual challenges. Sustained operation and maintenance of this infrastructure has been challenging. For example, 30% of water hand-pumps in Africa are not working (RWSN, 2009). The failure of community water and sanitation systems is often a failure of operation and maintenance, rather than a failure of the basic technology.

Addressing this failure requires learning from the successes of those infrastructure that have been used and maintained for many years. At its core, we need to (i) increase skills and knowledge of people to use and maintain the technology and/or service and (ii) select water and sanitation products and services – including household-level solutions – which are affordable to implement, operate and maintain and appropriate to the context.

Reaching People Most in Need
Overwhelmingly, it is the poorest who lack better water and sanitation. Virtually the entire poorest 25% of the world’s population does not have piped water and the inequality in coverage between rich and poor is even greater for sanitation than for water (JMP, 2014).

Addressing this challenge requires both supporting those who serve the people most in need and providing water and sanitation solutions that marginalized households can afford over the long-term.

Integrating Water, Sanitation and Hygiene (WASH) for Health
Many of the water and sanitation approaches employed to date in international development focus on providing either improved water or improved sanitation or improved hygiene. Global monitoring programs, such as the Joint Monitoring Program of UNICEF and the WHO count access to each of the three separately. Alternatively, organizations have the vision to implement all three and struggle to do so when faced with the realities on the ground. All three – water,
sanitation and hygiene – are intertwined and all three are needed for sustained impact. Water, sanitation and hygiene are fundamental for healthy homes and broader systemic change.

1.3. Water, sanitation and Hygiene strategies in Ethiopia

1.3.1. National WASH strategies

Ethiopia has adopted ambitious water, sanitation and hygiene targets through its “Universal Access Plan”, which seeks to reach 98.5 per cent and 100 per cent access to safe water and sanitation respectively by 2015.

The water, sanitation and hygiene sector in Ethiopia is guided by the One WASH National Program (OWNP), National Hygiene and Environmental Health Strategy and Integrated Urban Sanitation and Hygiene Strategy and School WaSH strategy. (2013- 2020). The strategy prioritizes the elimination of open defecation by 2023 and achieving universal access to safe water services by 2030 and 82% improved sanitation by 2020.

In 2015, Ethiopia achieved the MDG Target coverage of 57.2% for water and 28% for sanitation. This was partly sufficient to achieve the MDG targets for water and significant progress on sanitation. The more ambitious WASH targets and standards under the SDGs significantly raises the bar for what is required. The main challenges are limited multi-year funding to reach the ambitious target, poor quality services for the poor in urban and rural areas, mainly in the area of sanitation and hygiene. Coverage and quality of services are lower among vulnerable groups including the underserved areas.

The critical bottlenecks to overcome include: Inadequate implementation capacity for hygiene and environmental health weak sector governance and integrity, particularly the lack of separation of oversight from service provision; a heavy reliance on public financing and absorption challenges; human resource constraints; lack of a review mechanism to assess progress on a regular basis; and limited multi-year funding agreements from partners which limits predictability of planning. If these are not resolved, progress will remain slow and the SDGs will be missed.

The national hand washing strategy objectives includes:

- Increased proportion of household utilization of improved sanitation facilities from an estimated 31 per cent to 84 per cent,
- Increased proportion of schools with < 100 children per latrine stand with hand washing facilities,
- Increased proportion of households practicing hand washing with soap (or a substitute) at critical times from an estimated 7 per cent to 77 per cent,
- Increased proportion of Open Defecation Free (ODF) Kebeles from an estimated 15 per cent to 80 per cent and
Increase the proportion of households practicing home water treatment and safe storage from an estimated 8 per cent to 77 per cent.

To enhance multi-sectoral coordination, the Ministries of Education, Health and Water resources signed a Memorandum of Understanding (MOU) in 2006 to enhance multi-sectoral coordination. The purpose of this MOU is to get the main partners of WASH sector involved in joint planning, implementation and monitoring of water supply, sanitation and hygiene education (WASH) in communities, schools and health institutions.

1.3.2. One WASH national programme

The One WASH National Program (OWNP) was launched on September 13/2013 to operationalize the Memorandum of Understanding (MoU) and the WASH Implementation Framework (WIF) signed by the Ministries of Water and Energy, Health, Education and Finance and Economic Development in November 2012 and March 2013, respectively.

The one WASH National Programme (OWNP) is a consolidated national Programme designed to improve WASH services for the Ethiopian people. The overall objective of the OWNP is:

…..to improve the health and well-being of communities in rural and urban areas in an equitable and sustainable manner by increasing access to water supply and sanitation and adoption of good hygiene practices (POM, 2014).

The programme is designed to be implemented in two phases. The first phase was from July 2013 to June 2015 and the second phase from July 2015 to June 2020. OWNP has four components of:

- Rural WASH
- Pastoral WASH
- Urban WASH
- Institutional WASH

OWNP has core guiding principles that is governing implementation of OWNP are summarized as below:

**Integration**: This principle aims at integrating safe water use with good sanitation and hygiene practices at the household level, in schools and health facilities (Institutional WaSh) through synergy built among the four sectoral offices: water, health, education and finance. This includes coordinated and collaborative planning, implementation, monitoring, reporting and evaluation of program results.

**Alignment**: The main goal of this principle is to ensure that OWNP will align with the policies, priorities, strategies and plans of the pertinent Ministries, Sectoral Development Plans and with
the administrative systems, standards and procedures of the Federal and Regional Governments of Ethiopia.

**Harmonization:** This principle leads to One WaSH Plan, One WaSH Budget, and One WaSH Report; implying to OWNP. Harmonization also assumes that One Consolidated WaSH Account (CWA) will be opened where all Development Partners contributions are deposited from which WaSH activities and investments would be supported.

**Partnership:** The OWNP recognizes Civil Society Organizations (CSOs) and the Private Sector as significant partners playing an essential part in attaining OWNP target along with the four sector Ministries and Development Partners. This leads to strong commitment to engage more the Civil Society Organizations (CSOs) and the Private Sectors.

### 1.3.3. Status of WASH in Ethiopia

According to WHO/UNICEF Joint Monitoring Programme 2014 report, the country has improved water supply by 57% (97% in urban areas and 42% in rural areas), thus achieving the Millennium Development Goal (MDG) 7 target 7C. Although the sanitation target has not yet been achieved, there has been tremendous progress during the past decade in improving sanitation and ending open defecation. The progress has been largely due to the establishment of a Government-led WASH coordination mechanism (ONE WASH programme) involving Ministry of Water, Health, Education and Finance and Economic Development, as well as development partners.

Despite the progress seen in Ethiopia, 43% of the population does not have access to an improved water source and 28% practice open defecation. The National WASH Inventory (NWI) report of 2012 also indicates that the majority of health facilities in Ethiopia lack access to clean water and only about 32% have access to safe water. Moreover, 17% of childhood deaths are associated with diarrhea (EDHS 2011) which remains the third leading cause of under-five mortality attributed to poor water, sanitation and hygiene.

In the area of water and sanitation (WASH), WHO support has focused on capacity building activities. The WHO initiative Water Safety Plan was introduced through capacity building training in collaboration with the Ethiopian Government and partners including German Agro Action, Drop of Water, Relief Society of Tigray, JICA, Norwegian Church Aid and Finland’s COWASH Program. More than 500 professionals and students attended various trainings organized in 2013, 2014 and 2015. WHO is currently providing technical assistance to the ‘Building adaptation to climate change in health in least developed countries through resilient WASH’ project with support from the UK Department for International Development (DFID), as well as to the Ministry of Water, Irrigation and Energy (MoWIE) to implement the ‘Climate resilient Water Safety Plans’ through development of a national strategic framework.
1.3.4. Improvements in water and sanitation
The goal of water and sanitation projects in Ethiopia and throughout the world is to bring benefits to the lives of people by improving the supply of safe water and access to sanitation. Assessing the status of water and sanitation provision and measuring improvement requires a standardized set of definitions of the different types and levels of service. The Joint WHO/UNICEF Monitoring Programme (JMP) is mandated to give globally recognized definitions to the terms. Figure below clarifies the terms and presents them as ladders of improvements in water and sanitation.

![WHO/UNICEF joint monitoring programme (JMP) water supply and sanitation categories; ladder](image)

What does the concept of a ‘ladder’ mean to you and why do you think it is used in this way? A ladder is equipment for climbing from one level to a higher level by a sequence of rungs or steps. The use of ‘ladder’ in describing water supply and sanitation indicates that there is a progression from the basic unimproved provision in a sequence of steps up to improved services at the top of the ladder. The idea of the ladder provides a useful measure of progress. Imagine you were employed as a community WASH worker with responsibility for promoting WASH improvements in your community.
1.4. WASH and Nutrition

Under nutrition remains a significant public health threat that requires both WASH and nutrition interventions. Under nutrition is an underlying cause of 45 percent of child deaths globally, and the lives of nearly 7.4 percent of the world’s children are at immediate risk due to severe wasting (low weight for height). Wasting is managed by specialized medical care combined with therapeutic feeding (Black et al., 2013).

In less developed countries, 26 percent of children under 2 years old are stunted and will suffer permanent physical and cognitive effects.

WASH interventions are an important component of programs that target stunting. Simple actions can help prevent diarrhea and under nutrition, even in hygiene-challenged environments. WASH mediates nutritional status in three ways:

1. WASH reduces the incidence of diarrheal disease. A recent study using the latest burden of disease data estimates that almost 60 percent of diarrhea is caused by unsafe water, lack of sanitation, and poor hygiene behaviors, and is thus preventable (Prüss-Üstün et al., 2014). The World Health Organization (WHO) estimates 1.7 billion cases of diarrheal disease annually which leads to 9 percent of child deaths (CHERG, 2013).

2. A second effect of poor WASH conditions is intestinal worm infection. Severe whipworm and roundworm infections are negatively associated with growth, and intestinal worms may result in poor absorption of nutrients, thus affecting nutritional status.

3. Finally, WASH interventions are able to reduce the pathogen load observed in environments with poor WASH conditions. Some causes of under nutrition are not directly associated with diarrhea, but instead are associated with high pathogen environments and poor WASH conditions.
1.4.1. Impact of WASH practices on Nutrition
WASH practices have been proven to reduce diarrheal rates by 30-40 percent (Cairncross et al., 2010). This level of reduction can be achieved through a comprehensive approach – promoting improvements in key WASH practices (e.g., handwashing, treatment and safe storage of drinking water, safe disposal of feces, and food hygiene); improving access to safe water and sanitation technologies and products; and facilitating or supporting an enabling environment (e.g., improved policies, community organization, institutional strengthening, and public-private partnerships). Furthermore, a clean environment for children is also important to reduce exposure to the pathogenic surroundings.

1. **Optimal Hand washing**
   - Hand washing prevents diarrhea effectively when done properly and at critical times (before preparing food, eating, or feeding; after defecating, cleaning a baby, or changing a diaper). Proper technique includes using soap, or an effective substitute such as ash, rubbing hands together at least three times, rinsing hands in flowing water, and drying them on a clean cloth or by air.
   - A meta-analysis of hand washing studies conducted in developing countries concluded that hand washing can reduce the risk of diarrhea in the general population by 42 percent. [http://www.globalhandwashing.org](http://www.globalhandwashing.org).
2. **Treatment of Safe Drinking Water in the Household**
   - Treatment and safe storage of drinking water in the household have been shown to reduce the risk of diarrheal disease by 30-40 percent.
   - Simple, low-cost strategies can greatly reduce the microbial content of water and result in diarrheal disease morbidity reductions comparable to those achieved by hand washing and sanitation. [http://www.who.int/household_water/en/](http://www.who.int/household_water/en/).

3. **Sanitation**
   - Improved sanitation is a proven intervention to reduce diarrheal disease rates by as much as one-third. However, sanitation remains a low priority for governments and donors due to the lack of political will and the high cost of improvement.
   - Strategic sanitation investments should encourage at-scale national or sub-national sanitation interventions and should be context-specific. They might include community-based approaches such as Community-led Total Sanitation (CLTS) and Sanitation Marketing (SanMark) and also facilitate communities to adopt improved sanitation.

**Key Food Safety Actions**
- WHO published a document called 5 Keys to Safer Food that describes actions families should take in the kitchen to maintain safe food. These actions are especially important during child weaning. Furthermore, high quality food hygiene may contribute to a healthier intestinal microbiome and positively affect gut function.
  - Detailed information can be found at [http://www.who.int/foodsafety/consumer/5keys/en/](http://www.who.int/foodsafety/consumer/5keys/en/).
  - Keep food preparation areas clean, including hands, surfaces, and utensils
  - Separate raw and cooked food
  - Cook food thoroughly
  - Keep foods at safe temperatures
  - Use safe water and raw materials

**I.4.2. Essential Nutrition Actions**
The key “Essential Nutrition Actions” within the framework of WASH-nutrition integration include the following:
- Promotion of optimal breastfeeding during the first six months
- Promotion of optimal complementary feeding starting at six months with continued breastfeeding to 2 years old and beyond
- Promotion of optimal nutrition for women
- Promotion of optimal nutritional care of sick and severely malnourished children
- Promotion of adequate intake of iron and folic acid and prevention and control of anemia for women and children
- Promotion of adequate intake of iodine by all members of the household
Prevention of vitamin A deficiency in women and children

**Summary of module 1**

- WASH is the provision of safe water for drinking, washing and domestic activities, the safe removal of waste (toilets and waste disposal) and health promotion activities to encourage protective healthy behavioral practices amongst the affected population which allow people to live with good health, dignity, comfort and security.
- Diarrhea is the leading cause of under-5 children in Ethiopia, causing 23% of all under-5 deaths (73,341 children per year). Around 44% of under-5 children in Ethiopia are stunted (i.e. their height is less than expected for their age), which can be linked to the childhood incidence of diarrhea and to the lack of WASH services. Important nutrients that the child requires for growth are wiped out through diarrhoea; intestinal parasites take up remaining nutrients and when this scenario continues for some time, the child becomes stunted.
- Water, sanitation and hygiene have many benefits in terms of health, education, gender and inclusion, economy, environment and food security.
- The big challenges in water, sanitation and hygiene are the scale of the need, variability of the problem, sustainability of services, reaching people most in need and integrating water, sanitation and hygiene for health.
- The water, sanitation and hygiene sector in Ethiopia is guided by the One WASH National Program (OWNP), National Hygiene and Environmental Health Strategy and Integrated Urban Sanitation and Hygiene Strategy and School WaSH strategy. (2013-2020). The strategy prioritizes the elimination of open defecation by 2023 and achieving universal access to safe water services by 2030 and 82% improved sanitation by 2020.
- The one WASH National Programme (OWNP) is a consolidated national Programme designed to improve WASH services for the Ethiopian people.
- WASH interventions are an important component of programs that target stunting. Simple actions can help prevent diarrhea and undernutrition, even in hygiene-challenged environments.
Module 2: Water Supply

Introduction
This module focuses on the ways safe water can be supplied to the community. Water related diseases due to contamination, shortage and related reasons could be addressed. The international water supply standards for survival and a healthy life; the water pollutants of concern with their potential sources are be addressed. The characteristics of water, demand for water, forecasting methods for the future and the mechanisms to develop water sources to address the demand with the appropriate centralized and decentralized homemade treatment options are also addressed in this module. The microbial and physicochemical analytical methods for water samples with the appropriate sampling methods from different sources are also be addressed in this module.

Learning Objectives for this Module
After you have studied this Module you should be able to:

- Categorize water related diseases and their impact on child growth
- Recognize minimum water supply standards for a community and at different level for both quantity and quality
- Describe the different characteristics of water, water demand and methods for calculating water demand
- Categorize and explain different sources for water supply
- Describe the methods to develop water supply sources for a town/village/community
- Demonstrate water sampling methods from different sources
- Conduct water quality analysis of important parameters (Coliforms, PH, T, TDS, EC, F, residual chlorine, SS)
- Describe the different water treatment operations and processes
- Demonstrate the different methods of homemade water treatment by following the appropriate steps and safety measures
- Practice disinfecting water storage tanks by following the appropriate steps and safety measures

2.1. Water Related Diseases and standards on water supply

2.1.1. Water Related Diseases
Water related disease encompasses illness resulting from both direct and indirect exposure to water, whether by consumption or by skin exposure during bathing or recreational water use. It includes disease due to waterborne or water-associated pathogens and toxic substances.

A broader definition includes illness related to water shortage or water contamination during adverse climate events, such as floods and droughts, diseases related to vectors with part of their life cycle in water habitats; and disease related to inhalation of contaminated water
aerosols. Water-associated/related disease can be defined as a disease related with water (supply) and sanitation. There are four water-associated diseases categories.

- Water borne diseases
- Water-washed disease
- Water-based disease
- Water related vector borne diseases

**Waterborne diseases:** Several infections enteric or intestinal diseases of man are transmitted through water contamination by fecal matter. Pathogens excreted in water by an infected person include all major categories such as bacteria, viruses, protozoa and parasitic worms. Water acts only as a passive vehicle for the infectious agent. Water borne diseases may also be transmitted by any of the faeco-oral routes: dirty hands, dirty food, dirty water, etc. The following are typical examples of water borne diseases.

<table>
<thead>
<tr>
<th>SN</th>
<th>TYPES OF DISEASES</th>
<th>WATER BORNE DISEASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bacterial</td>
<td>Typhoid and Paratyphoid fever, Cholera, Salmonellosis, Bacillary dysentery(Shigellosis)</td>
</tr>
<tr>
<td>2</td>
<td>Viral</td>
<td>Hepatitis A</td>
</tr>
<tr>
<td>3</td>
<td>Protozoa</td>
<td>Amoebiasis, Giardia, Balantidiasis</td>
</tr>
<tr>
<td>4</td>
<td>Helminthes</td>
<td>Ascaris and Trichinas</td>
</tr>
</tbody>
</table>

To prevent the occurrence of waterborne diseases, safe disposal of human excreta through provision of toilet facilities and water treatment is very essential.

**Water-washed diseases:** These comprise diseases linked to a lack/shortage of water for personal hygiene. Examples of water -washed diseases are:

- Dermatological disease such as scabies
- Ophthalmic disease such as trachoma and conjunctivitis
- Louse-borne diseases such as louse borne typhus and relapsing fever

To prevent water washed diseases, provision of an ample amount of safe water and promoting personal hygiene are very essential.

**Water-based diseases:** These are diseases caused by infectious agents that are spread by contact with water. The essential part of the life cycle of the infecting agent takes place from an aquatic animal. Typical examples:

- Schistosomiasis (Bilharziasis) and Dracunculiasis (Guinea worm)

**Prevention:** Avoid contaminating water with faces or urine, avoid contact with snail infected water (e.g. swimming), store water for about 48 hours to let cercaria died, for Guinea worm filter water (e.g. clothe filtration).
Water related vector-borne diseases: These are diseases transmitted by insects that live close to water. Infections are spread by mosquitoes, flies and other insects that breed in water or near it.

- Malaria, Sick sleeping sickness, Yellow fever, Onchocerciasis (river blindness), Leishmaniosis, etc.

To prevent this type of diseases, it is essential to make the water unsuitable for breeding of insects (vectors).

2.1.2. Water Supply Standards

Water supply standard 1: Access and water quantity

All people have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to households to enable use of the minimum water requirement.

Key indicators

- Average water use for drinking, cooking and personal hygiene in any household is at least 15 litres per person per day.
- The maximum distance from any household to the nearest water point is 500 meters. Queueing time at a water source is no more than 30 minutes.

Water sources selection: The following factors should be considered in water source selection:

- Availability, proximity and sustainability of sufficient quantity of water;
- Whether treatment is needed; and
- Its feasibility, including the existence of any social, political or legal factors concerning the source. Generally, groundwater sources and/or gravity-flow supplies from springs are preferable, as they require less treatment and no pumping.

Table 2 Basic survival Water Needs

<table>
<thead>
<tr>
<th>Survival needs: Water intake (Drinking and food)</th>
<th>2.5-3 litres per day</th>
<th>Depends on: the climate and individual physiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Hygiene Practices</td>
<td>2-6 litres per day</td>
<td>Depends on: Social and Cultural Norms</td>
</tr>
<tr>
<td>Basic cooking needs</td>
<td>3-6 litres per day</td>
<td>Depends on: food type, social as well as cultural norms</td>
</tr>
<tr>
<td>Total basic water needs</td>
<td>7.5-15 litres per day</td>
<td></td>
</tr>
</tbody>
</table>
**Maximum numbers of people per water source:** The number of people per source depends on the yield and availability of water at each source. The approximate guidelines are:

<table>
<thead>
<tr>
<th>People per Source</th>
<th>Based on Flow (liters/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 people per tap</td>
<td>7.5</td>
</tr>
<tr>
<td>500 people per hand pump</td>
<td>16.6</td>
</tr>
<tr>
<td>400 people per single-user open well</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Table 3 A Recommended basic water requirement for human domestic needs (Gleick, 1996; 1998)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Recommended Commitment (liter per person per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking Water</td>
<td>5</td>
</tr>
<tr>
<td>Sanitation Services</td>
<td>20</td>
</tr>
<tr>
<td>Bathing</td>
<td>15</td>
</tr>
<tr>
<td>Food Preparation</td>
<td>10</td>
</tr>
<tr>
<td><strong>Drinking Water:</strong> This is a true minimum to sustain life in a moderate climate conditions and average activity level</td>
<td></td>
</tr>
</tbody>
</table>

**Water supply standard 2: Water quality**

Water is palatable and of sufficient quality to be drunk and used for cooking and personal and domestic hygiene without causing risk to health.

**Key indicators**

- There are no faecal coliforms per 100ml of water at the point of delivery and use
- Any household-level water treatment options used are effective in improving microbiological water quality and are accompanied by appropriate training, promotion and monitoring
- There is no negative effect on health due to short-term use of water contaminated by chemicals (including carry-over of treatment chemicals) or radiological sources, and assessment shows no significant probability of such an
- All affected people drink water from a protected or treated source in preference to other readily available water sources
- There is no outbreak of water-borne or water-related diseases

**Water supply standard 3: Water facilities**

People have adequate facilities to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene, and to ensure that drinking water remains safe until it is consumed.

**Key indicators**

- Each household has at least two clean water collecting containers of 10–20 litres, one for storage and one for transportation
Water collection and storage containers have narrow necks and/or covers for buckets or other safe means of storage, for safe drawing and handling, and are demonstrably used. There is at least one washing basin per 100 people and private laundering and bathing areas available for women. Enough water is made available for bathing and laundry. Water at household level is free from contamination at all times.

All people are satisfied with the adequate facilities they have for water collection, storage, bathing, hand washing and laundry.

Regular maintenance of the installed systems and facilities is ensured and users are involved in this where possible.

2.2. Develop water supply sources

2.2.1. Determine Water demand

Water demand is a water requirement for different purposes (drinking, cooking, hygiene, etc) at different levels. Water demand can be classified to the following groups.

**Domestic Water Demand:** The amount of water necessary in the residences for drinking, bathing, cooking, washing etc is known as domestic water demand and primarily depends on the habits, social status, weather and traditions of the people.

**Industrial Demand:** The water needed in the industries mostly relies on the kind of industries that are established within the town. About 20 – 25% of total water demand is normally considered as industrial water demand.

**Institution and Commercial Demand:** This type of water demand includes the water requirement for the public buildings other than residences. **Commercial buildings, Malls, Colleges, Hotels, Bus depots and other similar public buildings** comes within this category.

**Water demand for Public Use:** Volume of water necessary for public utility needs like for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc comes under public demand. Usually 5 % of total water demand for city is considered for public use while designing water supply scheme.

**Agricultural water demand:** Use for crops, livestock, horticulture, greenhouses, dairies and farmlands.

**Fire Demand:** Water requirement for firefighting purpose fall under this head. The volume of water necessary for firefighting is usually computed by making use of various empirical formula. For Indian conditions Kuching’s formula provides acceptable results.

\[ Q = 3182 \sqrt{()} \]
Where, \( Q = \) volume of water required in Lits / Hour \( P = \) population of city in thousands

**Wastage and losses:** - there are always losses and wastage occurs in pipeline while water distribution. The main reasons for this are listed below Damage pipe line and or faulty accessories like valves, fittings etc. Water tabs kept open in public or residences causing water wastage Due to illegal and unauthorized connections While calculating the total amount of water of a town; allowance of 12- 15% of total quantity of water is designed to make up for losses, thefts and wastage of water.

**Water Quantity Estimation**
The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

1. Water consumption rate (Per Capita Demand in litres per day per head)
2. Population to be served.

\[
\text{Quantity} = \text{Per capita demand} \times \text{Population}
\]

**Factors affecting per capita demand:**

- **Size of the city:** Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.
- **Presence of industries.**
- **Climatic conditions.**
- **Habits of people and their economic status.**
- **Quality of water:** If water is aesthetically and medically safe, the consumption will increase as people will not resort to private wells, etc.
- **Pressure in the distribution system.**
- **Efficiency of water works administration:** Leaks in water mains and services; and unauthorized use of water can be kept to a minimum by surveys.
- **Cost of water.**
- **Policy of metering and charging method:** Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.

**Fluctuations in Rate of Demand**

Average Daily Per Capita Demand = Quantity Required in 12 Months/ (365 x Population)

If this average demand is supplied at all the times, it will not be sufficient to meet the fluctuations.

- **Seasonal variation:** The demand peaks during summer. Firebreak outs are generally more in summer, increasing demand. So, there is seasonal variation.
- **Daily variation** depends on the activity. People draw out more water on Sundays and Festival days, thus increasing demand on these days.
**Hourly variations** are very important as they have a wide range. During active household working hours i.e. from six to ten in the morning and four to eight in the evening, the bulk of the daily requirement is taken. During other hours the requirement is negligible. Moreover, if a fire breaks out, a huge quantity of water is required to be supplied during short duration, necessitating the need for a maximum rate of hourly supply.

**Design Periods & Population Forecast**

Design period is estimated based on the following:

- Useful life of the component, considering obsolescence, wear, tear, etc.
- Expandability aspect.
- Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
- Available resources.
- Performance of the system during initial period.

The various methods adopted for estimating future populations are given below. The particular method to be adopted for a particular case or for a particular city depends largely on the factors discussed in the methods, and the selection is left to the discretion and intelligence of the designer.

- Arithmetic Increase Method
- Geometric Increase Method
- Incremental Increase Method
- Decreasing Rate of Growth Method
- Simple Graphical Method
- Comparative Graphical Method
- Ratio Method
- Logistic Curve Method

**2.2.2. Identify Water Supply Sources**

Water resources are under major stress around the world. Rivers, lakes, and underground aquifers supply fresh water for irrigation, drinking, and sanitation, while the oceans provide habitat for a large share of the planet's food supply. Today, however, expansion of agriculture, damming, diversion, over-use, and pollution threaten these irreplaceable resources in many parts of the globe.

The Global Water Cycle Water covers about three-quarters of Earth’s surface and is a necessary element for life. During their constant cycling between land, the oceans, and the atmosphere, water molecules pass repeatedly through solid, liquid, and gaseous phases (ice, liquid water, and water vapor), but the total supply remains fairly constant. A water molecule
can travel to many parts of the globe as it cycles. There are three basic steps in the global water cycle: water precipitates from the atmosphere, travels on the surface and through groundwater to the oceans, and evaporates or transpires back to the atmosphere from land or evaporates from the oceans. Figure 2 illustrates yearly flow volumes in thousands of cubic kilometers.

Supplies of freshwater (water without a significant salt content) exist because precipitation is greater than evaporation on land. Most of the precipitation that is not transpired by plants or evaporated, infiltrates through soils and becomes groundwater, which flows through rocks and sediments and discharges into rivers. Rivers are primarily supplied by groundwater, and in turn provide most of the freshwater discharge to the sea. Over the oceans evaporation is greater than precipitation, so the net effect is a transfer of water back to the atmosphere. In this way freshwater resources are continually renewed by counterbalancing differences between evaporation and precipitation on land and at sea, and the transport of water vapor in the atmosphere from the sea to the land.

Nearly 97 percent of the world's water supply by volume is held in the oceans. The other large reserves are groundwater (4 percent) and icecaps and glaciers (2 percent), with all other water bodies' together accounting for a fraction of 1 percent. Residence times vary from several thousand years in the oceans to a few days in the atmosphere (Table below).
Sources of fresh water can be broadly classified as surface water sources such as rivers, lakes and reservoirs and groundwater sources like wells, springs, and infiltration galleries.

**Surface Water Sources**

Surface water is the term used to describe water on the land surface. The water may be flowing, as in streams and rivers, or quiescent, as in lakes, reservoirs, and ponds. Surface water is produced by runoff of precipitation and natural groundwater seepage. Surface water is defined as all water open to the atmosphere and subject to surface runoff. That definition distinguishes surface water from both groundwater and ocean water.

<table>
<thead>
<tr>
<th>Surface Water Sources</th>
<th>Surface area (million km)</th>
<th>Volume (million km)</th>
<th>Volume (%)</th>
<th>Equivalent depth (m)</th>
<th>Residence time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans and seas</td>
<td>361</td>
<td>1.370</td>
<td>94</td>
<td>2.500</td>
<td>~4,000 years</td>
</tr>
<tr>
<td>Lakes and reservoirs</td>
<td>1.55</td>
<td>0.13</td>
<td>&lt;0.01</td>
<td>0.25</td>
<td>~10 years</td>
</tr>
<tr>
<td>Swamps</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.007</td>
<td>1-10 years</td>
</tr>
<tr>
<td>River channels</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.003</td>
<td>~2 weeks</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>130</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>0.13</td>
<td>2 weeks to 50 years</td>
</tr>
<tr>
<td>Groundwater</td>
<td>130</td>
<td>60</td>
<td>4</td>
<td>120</td>
<td>2 weeks to 100,000 years</td>
</tr>
<tr>
<td>Icecaps and glaciers</td>
<td>17.8</td>
<td>30</td>
<td>2</td>
<td>60</td>
<td>10 to 1,000 years</td>
</tr>
<tr>
<td>Atmospheric water</td>
<td>504</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.025</td>
<td>~10 days</td>
</tr>
<tr>
<td>Biospheric water</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.001</td>
<td>~1 week</td>
</tr>
</tbody>
</table>

**Advantages of surface water**

- Easy to abstract water by direct pumping
- Water can be treated after use and put back into a river
- Dams and reservoirs can be used for hydroelectric power
- Reservoirs can be used for recreation

**Disadvantages of Surface water**

- Water will need treatment
- Seasonal
- Construction of expensive and environmentally damaging dams, may trigger earthquakes
- Flooding of land for reservoirs
- Reservoirs will eventually silt up
- Requires sufficient rainfall and large river catchment
Ground Water Sources

Groundwater is an important source of water supply throughout the world. Its use in irrigation, industries, municipalities, and rural schemes continues to increase. Groundwater occurs in many types of geologic formations known as aquifers. An aquifer is a formation that contains sufficient quantities of saturated permeable material to yield significant quantities of water. Groundwater system includes wells, springs, and infiltration galleries.

<table>
<thead>
<tr>
<th>Advantages of ground water</th>
<th>Disadvantages of ground water</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is likely to be free of pathogenic bacteria;</td>
<td>Ground water is often high in mineral content;</td>
</tr>
<tr>
<td>Generally, it may be used without further treatment;</td>
<td>It usually requires pumping.</td>
</tr>
<tr>
<td>In many instances it can be found in the close</td>
<td></td>
</tr>
<tr>
<td>vicinity of rural communities;</td>
<td></td>
</tr>
<tr>
<td>It is often most practical and economical to</td>
<td></td>
</tr>
<tr>
<td>obtain and distribute;</td>
<td></td>
</tr>
<tr>
<td>The water-bearing stratum from which it is</td>
<td></td>
</tr>
<tr>
<td>drawn usually provides a natural storage at the</td>
<td></td>
</tr>
<tr>
<td>point of intake.</td>
<td></td>
</tr>
</tbody>
</table>

The quality of groundwater is uniform and is free from turbidity and color. Generally, groundwater contains cations such as calcium, magnesium, iron and manganese as well as anions like bicarbonate, carbonate, and chloride.

Spring water is a groundwater that outcrops from ground due to impervious base that prevents percolation. Spring water is usually fed from sand or gravel water bearings ground formation (aquifer) or fissured rocks. Best places to look for springs are the slopes of hilly sides and river valley sand areas with green vegetation in dry season. If properly protected and well managed, spring water proves to be good for small community water supplies.

Generally, springs are of the gravity or artesian types.

<table>
<thead>
<tr>
<th>Gravity springs</th>
<th>Artesian springs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater flows over an impervious stratum onto the</td>
<td>High quality water due to confinement</td>
</tr>
<tr>
<td>ground surface</td>
<td>High discharge due to high pressure in the confinement</td>
</tr>
<tr>
<td>The yield varies with the position of the water table</td>
<td>Yield is likely uniform and nearly constant over</td>
</tr>
<tr>
<td>May dry up during or immediately after a dry season</td>
<td>the seasons of the year</td>
</tr>
</tbody>
</table>
Infiltration galleries are horizontal wells that collect water over practically their entire lengths. When the stream beds or lake shores are sandy and gravelly, the possibilities of finding a gravel pocket along a bank are excellent. The infiltration gallery is a simple means of obtaining naturally filtered water, and, for this purpose, it should be located 15 m or more from the bank of the river or lake. It is constructed by digging a trench into water-bearing sand, then collecting the water in a perforated pipe or gallery which leads to a central casing from which the water is pumped out.

**Other Alternative water sources**

Alternative water sources are sustainable sources of water, not supplied from fresh surface water or groundwater, that offset the demand for freshwater. Examples of alternative water sources include:

- Harvested rainwater from roofs
- Onsite storm water
- Graywater
- Discharged water from water purification processes
- On-site reclaimed wastewater
- Captured condensate from air handling units.

Alternative water is often treated to non-potable standards, meaning it is not safe for human consumption. Common uses of alternative water include landscape irrigation, ornamental pond and fountain filling, cooling tower make-up, and toilet and urinal flushing.

**Storm water as alternative source:** Stormwater is precipitation runoff over ground-level surfaces that does not soak into the ground but has not entered a waterway such as a stream or lake. Stormwater can be harvested and reused for irrigation, wash applications, cooling tower make-up or process water, dust suppression, backup fire protection, vehicle washing, and other non-potable uses. Stormwater harvesting differs from rainwater harvesting in that runoff is collected from ground-level hard surfaces rather than from roofs. Groundwater that is pumped away from a building foundation is considered alternative water and can be reused similar to stormwater. Benefits of stormwater harvesting include reduction of pollutants and potential flooding from large water events that flow to surface water. Other benefits include reduction of stream bank erosion, sewer overflows, and infrastructure damage.

Stormwater is generally collected onsite from hard surfaces such as sidewalks, streets, and parking lots before it enters a waterway. After being diverted, it is stored temporarily in dams or tanks awaiting use in non-potable applications. The characteristics of stormwater harvesting and reuse systems vary considerably by project, but most include collection, storage, treatment, and distribution.
Reclaimed Wastewater as alternative source: Reclaimed wastewater is water that is discharged from buildings and processes, treated at a wastewater treatment facility, and then reused in applications such as irrigation and industrial processes. Municipality sites that treat wastewater onsite can potentially reclaim wastewater, and it is becoming more common for local municipalities to reclaim wastewater and sell it to customers to help lower the community's demand for freshwater. This water is often available at a significantly lower cost than potable water. Reclaimed wastewater likely needs secondary treatment such as additional filtration and disinfection to further remove contaminants and particulates to ensure the water is safe for non-potable applications. An efficient and successful reclaimed water project requires a reliable source of wastewater of adequate quantity and quality to meet non-potable water needs.

Graywater as alternative source: Graywater (also known as gray water, greywater, grey water) is lightly contaminated water that is generated by bathroom sinks, showers, and clothes washing machines. Graywater does not include wastewater from toilets, urinals, or kitchens. Graywater can be used to flush toilets and urinals, irrigate landscape, and supply water for ornamental ponds, and as make-up water in cooling towers. In a graywater recycling system, water that would normally be discharged for municipal sewage treatment is collected, treated, and distributed for reuse, usually within the same building. Graywater often contains detergents and dissolved and suspended solids, and can contain pathogens.

Basic graywater treatment consists of removing suspended solids from the water, while sophisticated treatment may consist of biological treatment with membrane filtration, activated carbon, and ultraviolet light or ozone disinfection to destroy pathogens.

Major components of a graywater recycling system
- Dual plumbing that collects graywater from sinks, showers, and laundry
- Water storage tanks, which should be closed to minimize contact
- Color-coding to identify piping as a graywater source
- A treatment system to filter and disinfect water if required
- Pumps to move the water Controls.

Rainwater Harvesting: Rainwater harvesting is the collection of rainwater from rooftops that is then diverted and stored for later use. Captured rainwater is commonly used for non-potable applications and is often used to irrigate landscaping because the water is free of salts and other harmful minerals and typically requires minimal treatment. Other uses include ornamental pond and fountain filling, cooling tower make-up, and toilet and urinal flushing.
Rainwater harvesting can help to manage storm water by reducing the amount of runoff, which eases flooding and erosion by slowing runoff and allowing it to soak into the ground, turning storm water problems into water supply assets. Less runoff also means less contamination of surface water from sediment, fertilizers, pesticides, and other pollutants that might be transported in rainfall runoff. The major components of a rainwater harvesting system include:

- Roof surface
- Gutters and downspouts to carry the water to storage
- Leaf screens to remove debris
- First-flush diverter that prevents the system from collecting the initial flow of rainwater
- Cisterns/storage tanks to store the harvested rainwater
- Conveyances to deliver the stored water either by gravity or pump
- Water treatment system to settle, filter, and disinfect the water, if required.

**Water Source Selection**

Source selection for water supply purposes requires considerations of factors such as hydrology, water quality, reliability, cost, and environmental and social impacts. Particularly, the following considerations should be included in the study of water supply sources.
### Surface water sources

- Safe water yield during the drought years to meet the projected demands
- Urbanization and land development in the watershed
- Proposed impoundments on tributaries
- Water quality
- Assessment of reliability in terms of possible disruptions due to natural and manmade hazards
- Requirements for construction of water supply system components
- Economics of the project
- Environmental impacts of the project
- Water rights

### Groundwater

- Aquifer characteristics
- Safe aquifer yield
- Permissible drawdown
- Water quality
- Sources of contamination
- Saltwater intrusion
- Type and extent of recharge area
- Rate of recharge
- Water rights

---

### 2.2.3. Spring Development and Protection

Springs occur wherever groundwater flows out from the earth’s surface. Springs typically occur along hillsides, low-lying areas, or at the base of slopes. A spring is formed when natural pressure forces groundwater above the land surface. This can occur at a distinct point or over a large seepage area. Springs are sometimes used as water supplies and can be a reliable and relatively inexpensive source of drinking water if they are developed and maintained properly.

#### Spring Development Considerations

When considering using a spring as your source of drinking water, it is important to ensure that the rate of flow is reliable during all seasons of the year. Spring flow that fluctuates greatly throughout the year is an indication that the source is unreliable or may have the potential for contamination. It may be possible to learn about historical spring flow from the previous owner or a neighbor.

Water quality is also important to consider before using a spring as a water supply. Before developing the spring, collect a sample of water and have it analyzed at a local water testing laboratory to ensure that it can be efficiently and economically treated to make it safe for human consumption. Springs are highly susceptible to contamination since they are fed by shallow groundwater, which usually flows through the ground for only a short period of time and may interact with surface water. For this reason, most springs will need some treatment before the water is considered a safe source of drinking water. Testing will help determine exactly how much treatment will be necessary and may help determine if other sources of water would be more economical.
Spring Development
A spring can be developed into a drinking water supply by collecting the discharged water using tile or pipe and running the water into some type of sanitary storage tank. Protecting the spring from surface contamination is essential during all phases of spring development. Springs can be developed in two different ways and the method you choose will depend on whether it is a concentrated spring or a seepage spring. The general procedures for spring development are outlined in the following pages.

Spring Development Procedures: Concentrated Springs
- Excavate the land upslope from the spring discharge until three feet of water is flowing.
- Install a rock bed to form an interception reservoir.
- Build a collecting wall of concrete or plastic down slope from the spring discharge. Install a pipe low in the collecting wall to direct the water from the interception reservoir to a concrete or plastic spring box. (Note: problems with spring flow can occur if water is permitted to back up behind the wall.)
- Remove potential sources of contamination and divert surface water away from the spring box or collection area.
- Alternative types of interception reservoirs and collecting walls can be constructed

Spring Development Procedures: Seepage Springs
- Dig test holes upslope from the seep until you locate the point where the impervious layer is 3 feet underground.
- Create a trench approximately 18 to 24 inches wide across the slope. Trench should be extended 6 inches into the impervious layer (below the water-bearing layer) and should extend 4 to 6 feet beyond the seepage area. Install 4 inches of collection tile and surround the tile with gravel.
- Installation of a collecting wall will help prevent water from escaping the collection tile.
- This collecting wall should be constructed of 4 to 6 inches of concrete.
- Collection tile should be connected to 4-inch pipe that leads to the spring box. Box inlet must be below the elevation of the collector tile.
- Remove potential sources of contamination and divert surface water away from spring box or collection area.

Spring Development Procedures: Spring Box Considerations
- Most spring boxes are made of concrete.
- A properly constructed spring box will have a watertight cover that fits like a shoebox lid.
- This will prevent insects, animals, and surface water from entering the spring.
- Create both an overflow pipe and an outlet pipe. Drain installation will allow the box to be cleaned periodically.
2.3. Water Quality Concerns and contaminants of water

2.3.1. Water quality Concerns
To describe the quality of water many parameters have evolved that qualitatively describe the characteristics of the water. In this chapter we will discuss the parameters used to assess the physical, chemical, and biological characteristics of water.

Physical characteristics of water
Physical parameters define those characteristics of water that respond to the senses of sight, touch, taste or smell. Suspended solids, turbidity, color, taste and odor and temperature fall into this category.

Suspended Solids: Solids suspended in water may consist of inorganic or organic particles or of immiscible liquids. Inorganic solids such as clay, silt, and other soil constituents are common in surface water. Organic material such as plant fibers and biological solids (agal cells, bacteria, etc) are also common constituents of surface water. These materials are often natural contaminants resulting from the erosive action of water flowing over surfaces. Biologically active suspended solids may include disease-causing organisms as well as organisms such as toxin-producing strains of algae.

Turbidity: Turbidity is a measure of the extent of which light is either absorbed or scattered by suspended material in water. Because absorption and scattering are influenced by both size and surface characteristics of the suspended material, turbidity is not a direct quantitative measurement of suspended solids. Most turbidity in surface waters result from the erosion of colloidal material such as clay, silt, rock fragments, and metal oxides from the soil. Vegetable fibers and microorganisms may also contribute to turbidity.

Turbidity is measured photometrically by determining the percentage of light of a given intensity that is either absorbed or scattered. (Jackson turbidimeter (JTU), formazin turbidity units, or FTUs, nephelometry turbidity unit (NTU))

Natural waters may have turbidities ranging from a few FTUs to several hundred. EPA drinking water standards specify a maximum of 1 FTU.

Color: Pure water is colorless, but water in nature is often colored by foreign substances. Water whose color is partly due to suspended matter is said to have apparent color. Color contributed by dissolved solids that remains after removal of suspended matter is known as true color.

Taste and Odor: The terms taste and odor are themselves definitive of this parameter, and are closely related. Substances that produce an odor in water will almost invariably impact a taste as well. The converse in not true, as there are many mineral substances that produce
taste but no odor. Substances that impart perceptible taste and odor include minerals, metals, and salts from the soil, end products from biological reactions, and constituents of wastewater. Inorganic substances are more likely to produce tastes unaccompanied by odor. Alkaline material imparts a bitter taste to water, while metallic salts may give a salty or bitter taste. Organic material, on the other hand, is likely to produce both taste and odor.

**Temperature:** Temperature is not used to evaluate directly either potable water or wastewater. It is however, one of the most important parameters in natural surface-water systems. The temperature of surface waters governs to a large extent the biological species present and their rates of activity. Temperature has an effect on most chemical reactions that occur in natural water systems. Temperature also has a pronounced effect on the solubility of gases in water.

Temperature also affects other physical properties of water. The viscosity of water increases with decreasing temperature. The maximum density of water occurs at 4ºC, and density decreases on either side of that temperature.

**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, given by

\[
\text{conductivity} = K \times \left( \frac{\text{TDS}}{1000} \right)
\]

Knowing the appropriate value of K for a particular water, the measurement of conductivity provides a rapid indication of TDS content.

**Chemical characteristics of water**

Water has been called the universal solvent, and chemical parameters are related to the solvent capabilities of water. Total dissolved solids, alkalinity, hardness, fluorides, metals, organics, and nutrients are chemical parameters of concern in water-quality management.

**Total Dissolved Solids:** Dissolved material results from the solvent action of water on solids, liquids, and gases. Dissolved substances may be organic or inorganic in nature. Dissolved minerals, gases, and organic constituents may produce aesthetically displeasing color, taste, and odors. Some chemicals may toxic or carcinogenic. Quite often, two or more dissolved substances especially organic substances and members of the halogen group will combine to form a compound whose characteristics are more objectionable than those of either of the original materials. Not all dissolved substances are undesirable in water.
An approximate analysis for TDS is often made by determining the electrical conductivity of the water. The ability of water to conduct electricity, known as the specific conductance, is a function of its ionic strength.

**Alkalinity:** Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to neutralize acids. Constituents of alkalinity in natural water systems include CO₃²⁻, HCO₃⁻, OH⁻, HSiO₃⁻, H₂BO₃⁻, HPO₄²⁻, H₂PO₄⁻, HS⁻, and NH₃⁰. These compounds result from the dissolution of mineral substances in the soil and atmosphere.

In large quantities alkalinity imparts a bitter taste to water. The main problem with alkaline water is its reaction with certain cations present in water which may result a precipitate that can foul pipes and other water-systems appurtenances. Alkalinity measurements are made by titrating the water with an acid and determining the hydrogen equivalent.

**Hardness:** Hardness is defined as the concentration of multivalent metallic cations in solution. At supersaturated conditions, the hardness cations will react with anions in the water to form a solid precipitate. Two types of hardness can be identified- carbonate and non-carbonate hardness.

<table>
<thead>
<tr>
<th>Carbonate hardness compounds</th>
<th>Non-carbonate hardness compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate (CaCO₃)</td>
<td>Calcium sulfate (CaSO₄)</td>
</tr>
<tr>
<td>Magnesium carbonate (MgCO₃)</td>
<td>Magnesium sulfate (MgSO₄)</td>
</tr>
<tr>
<td>Calcium bicarbonate (Ca(HCO₃)₂)</td>
<td>Calcium chloride (CaCl₂)</td>
</tr>
<tr>
<td>Magnesium bicarbonate (Mg(HCO₃)₂)</td>
<td>Magnesium chloride (MgCl₂)</td>
</tr>
<tr>
<td>Calcium hydroxide (Ca(OH)₂)</td>
<td></td>
</tr>
<tr>
<td>Magnesium hydroxide (Mg(OH)₂)</td>
<td></td>
</tr>
</tbody>
</table>

Carbonate hardness is sometimes called temporary hardness because it can be removed by boiling water. Non-carbonate hardness cannot be broken down by boiling the water, so it is also known as permanent hardness. In general, it is important to distinguish between the two types of hardness because the removal method differs for the two.

<table>
<thead>
<tr>
<th>Mg/L as CaCO₃</th>
<th>Degree of hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-75</td>
<td>Soft</td>
</tr>
<tr>
<td>75-150</td>
<td>Moderately hard</td>
</tr>
<tr>
<td>150-300</td>
<td>Hard</td>
</tr>
<tr>
<td>&gt; 300</td>
<td>Very hard</td>
</tr>
</tbody>
</table>
The public Health Service standards recommend a maximum of 500 mg/L of hardness in drinking water.

**Fluoride:** Fluoride is associated in nature with a few types of sedimentary or igneous rocks. It is toxic to humans and other animals in large quantities, while small concentrations can be beneficial. Concentrations of approximately 1.0 mg/L in drinking water help to prevent dental cavities in children. If the fluoride concentrations in water exceed 2.0 mg/L, it can result in discoloration of teeth, called *mottling*. Concentrations which exceed 5 mg/L can also result in bone fluorosis and other skeletal abnormalities.

**Metals:** All metals are soluble to some extent in water. While excessive amounts of any metal may present health hazards, only those metals that are harmful in relatively small amount are commonly labeled toxic; other metals fall into the nontoxic group. Sources of metals in natural waters include dissolution from natural deposits and discharges of domestic, industrial, or agricultural wastewaters. Measurement of metals in water is usually made by atomic absorption spectrophotometer.

**Nontoxic Metals:** commonly found in water include sodium, iron, magnesium, aluminum, copper and zinc. Excessive concentration of sodium can cause a bitter taste in water and are health hazard to cardiac and kidney patients. Sodium is also corrosive to metal surfaces and, in large concentrations, is toxic to plants. Iron and manganese in very small quantities 0.3 mg/L and 0.05 mg/L, respectively, may cause color problems.

**Toxic Metals:** These include arsenic, barium, cadmium, lead, mercury, and silver. These metals are concentrated by food chain, thereby posing the greatest danger to organisms near the top of the chain.

**Organics:** Many organic materials are soluble in water. Organic in natural water systems may come from natural sources or may result from human activities. Dissolved organics in water are usually divided into two broad categories: Biodegradable and nonbiodegradable (refractory).

**Biodegradable Organics:** Biodegradable material consists of organics that can be utilized for food by naturally occurring microorganisms within a reasonable length of time. In dissolved form, these materials usually consist of starches, fats, proteins, alcohols, acids, aldehydes, and esters.

Microbial utilization of dissolved organics can be accompanied by oxidation or by reduction. When oxygen is available oxidation process becomes more efficient and predominant than reduction. In aerobic (oxygen-present) environment, the organics are broken down into simpler compounds, such as CO2 and H2O, and the microns use the energy released for
growth and reproduction. The amount of oxygen consumed during microbial utilization of organics is called the biological oxygen demand (BOD). BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. BOD can also be used to evaluate the efficiency of treatment processes, and is an indirect measure of biodegradable organic compounds in water.

**Non-biodegradable Organics:** Common organic materials in natural water systems which are resistant to biological degradation include tannic and lignic acids, cellulose, and phenols. Molecules with exceptionally strong bonds (some of the polysaccharides) and ringed structures (benzene) are essentially non-biodegradable.

Some organics are non-biodegradable because they are toxic to organisms. These include the organic pesticides, some industrial chemicals, and hydrocarbon compounds that have combined with chlorine. Organic insecticides are usually chlorinated hydrocarbons, while herbicides are usually chlorinated phenoxyis. Many of the pesticides are cumulative toxins and cause severe problems at higher end of the food chain. An example is the near-extinction of the brown pelican that feeds on fish and other macro aquatic species by the insecticide DDT.

Measurement of non-biodegradable organics is usually by the chemical oxygen demand (COD) test. Non-biodegradable organics may also be estimated from a total organic carbon (TOC) analysis. Both COD and TOC measure the biodegradable fraction of the organics, so the BODu must be subtracted from the COD or TOC to quantify the non-biodegradable organics. Specific organic compounds can be identified and quantified through analysis by gas chromatography.

**Nutrients:** Nutrients are elements essential to the growth and reproduction of plants and animals and aquatic species on the surrounding water to provide their nutrients. Nutrients that are required in most abundance by aquatic species are carbon, nitrogen, and phosphorus.

**Nitrogen:** Nitrogen gas (N2) is the primary component of the earth’s atmosphere and is extremely stable. Nitrogen is a constituent of proteins, chlorophyll, and many other biological compounds. Upon the death of plants or animal, complex organic matter is broken down to simple forms by bacterial decomposition. Other sources of nitrogen in aquatic systems include wastes, chemical (particularly chemical fertilizers), and wastewater discharges.

**Phosphorus:** Phosphorus appears exclusively as phosphate (PO₄³⁻) in aquatic environments. Phosphate is a constituent of soils and is used extensively in fertilizer to replace and /or supplement natural quantities on agricultural lands. Runoff from agricultural areas is a major contributor to phosphate in surface waters. Municipal wastewater is another major source of phosphate in surface water. Condensed phosphates are used extensively as builders in detergents, and organic phosphates are constituents of body waste and food residue. Other
sources include industrial waste in which phosphate compounds are used for such purposes as boiler-water conditioning.

**Biological Characteristics of Water**
The presence or absence of living organisms in water can be one of the most useful indicators of its quality. A wide variety of different species of organisms usually indicates that the stream of lake is unpolluted. Microscopic plants and animals are also important in assessing the quality of water, particularly drinking water and sewage.

**Pathogens:** Pathogens are organisms capable of infecting, or of transmitting diseases to, humans. These organisms are not native to aquatic systems and usually require an animal host for growth and reproduction. These waterborne pathogens include species of bacteria, viruses, protozoa, and helminthes (parasitic worms).

**Bacteria:** Bacterial are single-cell microorganisms, usually colorless, and are the lowest forms of life capable of synthesizing protoplasm from the surrounding environment. They occur in three basic cell shapes: rod shape (*bacillus*), sphere shaped (*coccus*), and spiral shaped (*spirellus*). Gastrointestinal disorders are common symptoms of most diseases transmitted by waterborne pathogenic bacteria. Cholera and typhoid are the most violent of waterborne bacterial diseases.

**Viruses:** Viruses are the smallest biological structures known to contain all the genetic information necessary for their own reproduction. Viruses are obligate parasites that require a host in which to live. Symptoms associated with waterborne viral infections usually involve disorders of the nervous system rather than of the gastrointestinal tract. Waterborne viral pathogens are known to cause poliomyelitis and infectious hepatitis, and several other viruses are known to be, or suspected of being waterborne.

**Protozoa:** The lowest forms of animal life, protozoa are unicellular organisms more complex in their functional activity than bacteria or viruses. They are complete, self-contained organisms that can be free-living or parasitic, pathogenic or nonpathogenic, microscopic or macroscopic.

Protozoal infections are usually characterized by gastrointestinal disorders of a milder order than those associated with the bacterial infections. *Giardia lamblia* and *Entamoebae Histolica* are the common protozoa which cause infections.

**Pathogen Indicators:** Testing water for the presence of know pathogens would be a very time-consuming and expensive proposition. Tests for specific pathogens are usually made only when there is a reason to suspect that those particular organisms are present. At other times, the purity of water is checked using indicator organisms. An indicator organism is one whose
presence presumes (signals) that contamination has occurred and suggests the nature and extent of the contaminant(s).

**Coliforms:** The most important biological indicator of water quality and pollution used in public health technology is the group of bacteria called *coliforms*. This grouping includes two genera: *Eschericia Coli* and *Aerobacteraerogenes* while *E. Coli* are nonpathogenic common inhabitants of the intestinal tract, *Aerobactor* are common in the soil, on leaves, and on grain. The test for these microorganisms, called *Total Coliform Test*, was selected for the following reasons:

1. They normally inhabit the intestinal tracts of humans and other mammals. Thus, the presence of coliforms is an indication of fecal contamination of the water.
2. Even in acutely ill individuals, the number of coliform organisms excreted in the feces outnumbers the disease-producing organism by several orders of magnitude. The larger numbers of coliforms make them easier to culture than disease-producing organisms.
3. The coliform group of organism survives in natural waters for relatively long periods of time, but does not produce effectively in this environment. Thus the presence of coliforms in water implies fecal contamination rather than growth of the organism because of favorable environmental conditions. These organisms also survive better in water than most of the bacterial pathogens. This means that the absence of coliforms is a reasonably safe indicator that pathogens are not present.
4. The coliform group of organisms is relatively east to culture. Thus, laboratory technicians can perform the test without expensive equipment.

2.3.2. Sources and causes for Contamination of water

Water is an easy solvent, enabling most pollutants to dissolve in it easily and contaminate it. The most basic effect of water pollution is directly suffered by the organisms and vegetation that survive in water, including amphibians. On a human level, several people die each day due to consumption of polluted and infected water.

There are various classifications of water pollution. The two chief sources of water pollution can be seen as **Point and Non Point**.

Point refer to the pollutants that belong to a single source. An example of this would be emissions from factories into the water.

Non Point on the other hand means pollutants emitted from multiple sources. Contaminated water after rains that has traveled through several regions may also be considered as a Non-point source of pollution.
Causes of Water Pollution

- **Industrial waste:** Industries produce huge amount of waste which contains toxic chemicals and pollutants which can cause air pollution and damage to us and our environment. They contain pollutants such as lead, mercury, Sulphur, asbestos, nitrates and many other harmful chemicals. Many industries do not have proper waste management system and drain the waste in the fresh water which goes into rivers, canals and later into sea. The toxic chemicals have the capability to change the color of water, increase the amount of minerals, also known as Eutrophication, change the temperature of water and pose serious hazard to water organisms.

- **Sewage and waste water:** The sewage and waste water that is produced by each household is chemically treated and released into sea with fresh water. The sewage water carries harmful bacteria and chemicals that can cause serious health problems. Pathogens are known as a common water pollutant; the sewers of cities house several pathogens and thereby diseases. Microorganisms in water are known to be causes of some very deadly diseases and become the breeding grounds for other creatures that act like carriers. These carriers inflict these diseases via various forms of contact onto an individual. A very common example of this process would be Malaria.

- **Mining activities:** Mining is the process of crushing the rock and extracting coal and other minerals from underground. These elements when extracted in the raw form contains harmful chemicals and can increase the amount of toxic elements when mixed up with water which may result in health problems. Mining activities emit several metal waste and sulphides from the rocks and is harmful for the water.

- **Marine dumping:** The garbage produce by each household in the form of paper, aluminum, rubber, glass, plastic, food if collected and deposited into the sea in some countries. These items take from 2 weeks to 200 years to decompose. When such items enter the sea, they not only cause water pollution but also harm animals in the sea.

- **Accidental Oil leakage:** Oil spill pose a huge concern as large amount of oil enters into the sea and does not dissolve with water; there by opens problem for local marine wildlife such as fish, birds and sea otters. For e.g.: a ship carrying large quantity of oil may spill oil if met with an accident and can cause varying damage to species in the ocean depending on the quantity of oil spill, size of ocean, toxicity of pollutant.

- **Burning of fossil fuels:** Fossil fuels like coal and oil when burnt produce substantial amount of ash in the atmosphere. The particles which contain toxic chemicals when mixed with water vapor result in acid rain. Also, carbon dioxide is released from burning of fossil fuels which result in global warming.

- **Chemical fertilizers and pesticides:** Chemical fertilizers and pesticides are used by farmers to protect crops from insects and bacterias. They are useful for the plants growth. However, when these chemicals are mixed up with water produce harmful for
plants and animals. Also, when it rains, the chemicals mix up with rainwater and flow down into rivers and canals which pose serious damages for aquatic animals.

- **Leakage from sewer lines:** A small leakage from the sewer lines can contaminate the underground water and make it unfit for the people to drink. Also, when not repaired on time, the leaking water can come on to the surface and become a breeding ground for insects and mosquitoes.

- **Global warming:** An increase in earth’s temperature due to greenhouse effect results in global warming. It increases the water temperature and result in death of aquatic animals and marine species which later results in water pollution.

- **Radioactive waste:** Nuclear energy is produced using nuclear fission or fusion. The element that is used in production of nuclear energy is Uranium which is highly toxic chemical. The nuclear waste that is produced by radioactive material needs to be disposed off to prevent any nuclear accident. Nuclear waste can have serious environmental hazards if not disposed off properly. Few major accidents have already taken place in Russia and Japan.

- **Urban development:** As population has grown, so has the demand for housing, food and cloth. As more cities and towns are developed, they have resulted in increased use of fertilizers to produce more food, soil erosion due to deforestation, increase in construction activities, inadequate sewer collection and treatment, landfills as more garbage is produced, increase in chemicals from industries to produce more materials.

- **Leakage from the landfills:** Landfills are nothing but huge pile of garbage that produces awful smell and can be seen across the city. When it rains, the landfills may leak and the leaking landfills can pollute the underground water with large variety of contaminants.

- **Animal waste:** The waste produce by animals is washed away into the rivers when it rains. It gets mixed up with other harmful chemicals and causes various water borne diseases like cholera, diarrhea, jaundice, dysentery and typhoid.

- **Underground storage leakage:** Transportation of coal and other petroleum products through underground pipes is well known. Accidentals leakage may happen anytime and may cause damage to environment and result in soil erosion.

**Water pollutants also include both organic and inorganic factors.** Organic factors include volatile organic compounds, fuels, waste from trees, plants etc. Inorganic factors include ammonia, chemical waste from factories, discarded cosmetics etc. The water that travels via fields is usually contaminated with all forms of waste inclusive of fertilizers that it swept along the way. This infected water makes its way to our water bodies and sometimes to the seas endangering the flora, fauna and humans that use it along its path.
2.4. Sampling and Analysis of Water

2.4.1. Sampling of water for quality analysis

The analytical results of a sample are only as accurate as the quality of the sample taken. If your technique for collecting samples is poor, then no matter how accurate your lab procedures are, the results will be poor. By sampling according to set procedures, you reduce the chance of error and increase the accuracy of your sample results. This draft will cover the proper methods of sampling, sample preparation, documentation and sampler cleaning.

Types of Samples

There are mainly three types of Water/Wastewater samples:

Grab samples: Grab sample shows the characteristics of the water at the time of sampling only and should not exceed a sampling time of 15 minutes. Grab sampling is done for such procedures as batch discharge, constant waste stream characteristics and when the parameter tested deteriorates rapidly such as cyanides, volatile organic compounds and phenols.

Composite Samples: These are individual samples taken and deposited in the same collection bottle. There are two methods that are most common to collecting composite samples.

i. Time paced is when samples are collected at set increments of time.

ii. Flow paced samples: which are taken when a measured volume of water flows over the sensor of a flow meter, which is more preferred; since it gives the most representative sample. Metals, Base/Neutral/Acid Organics, BOD and TSS samples may be collected by this method.
**Integrated samples:** Those are combination of grab samples collected at the same time but at different locations. Integrated samples are required when the knowledge of the volume, movement, and composition of the various parts of the water being sampled usually is required. Collecting integrated samples is a complicated and specialized process that must be described adequately in a sampling plan for each test.

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### Sampling Locations

1. **Surface water** is what is seen on the Earth’s surface. It can be either flowing water, like oceans, rivers and streams, or stored in natural depressions, like lakes and water holes. Surface water can be:
   - Permanent: flowing or held in natural depressions throughout the year
   - Semi–permanent: flowing or held for only part of the year
   - Constructed: held in structures ranging from dams to a water tank that catches rain.

2. **Groundwater** is water stored in–between the particles of soil underground. The soil acts like a sponge eventually forming a groundwater reservoir, called an aquifer. There are two main forms of groundwater.
   - Superficial: usually between 3 to 20 meters down. It is the most accessible because it is near the surface.
   - Confined: deep down below the surface of the Earth. Special equipment is needed to access this water.

   Groundwater always becomes surface water sooner or later.

3. **Water distribution systems:** are ways of controlling the flow and direction of both surface water and groundwater. They are the link between the water supply source and the consumer. They include:
   - Irrigation systems – used in agriculture
   - bore lines – used to deliver bore water
   - Scheme water systems – used to deliver water to households.
4. **Water treatment system**: Water is used for many purposes. Water treatment systems function to make untreated water suitable for a particular purpose. For example, as drinking water or for industrial processes.

**Sampling equipment**

Typical sampling equipment when taking water samples, it's important to:

- Use the correct sampling equipment
- Use the correct personal protective equipment (PPE)
- Record the necessary information correctly
- Check all equipment before carrying out sampling.

There are many different types of equipment used for sampling water. Groundwater sampling is conducted using groundwater bores and low flow pumps. Using this kind of equipment requires advanced knowledge. You may have an opportunity to observe this sort of water sampling.

Equipment typically used when sampling surface water includes:

1. New, prepared plastic and glass sampling bottles, clearly labelled with a marker pen.
2. Sterile disposable gloves to avoid contamination.
3. A cooler for storing and transporting filled sample bottles.
4. Ice or dry ice to maintain samples at the correct temperature.
5. Any equipment needed for taking on-site tests (for example: thermometer, conductivity meter, pH meter)
6. Communication equipment (for example: mobile phone, walkie-talkie)
7. Any maps needed

**Collection Sample Container Cleaning**

1. **Plastic (polyethylene)**
   - Wash with hot water (detergent optional).
   - Rinse with acid (nitric for metals).
   - Rinse with tap water, then three times with Distilled water.

2. **Glass**
   - Wash with hot water (detergent optional).
   - Rinse with acid (nitric for metals).
Rinse with tap water, then three times with Distilled water.
Dry in contamination-free area.
Rinse glass containers with an interference-free, redistilled solvent (e.g., acetone, isopropanol or methylene chloride) for extractable organics.
Rinse glassware for volatile organics with isopropanol.
Rinse with tap water, and then at least three times with deionize water.
Dry in contaminant-free area.

3) Ice Chests

Sample Labelling
Correct labelling of samples is essential. They need to be easily identified at all times. Without proper labelling, all samples can look alike and mistakes can happen.
Water sample labels must include:
   a) A unique identifying code for cross-referencing
   b) Date of sampling.
   c) They can also include:
      d) The location and name of the sampling site
      e) The name of the sampler
      f) The time of sampling
      g) The type of sample
      h) Any observations that might affect test results.

You must always keep a record of your activity when sampling water. This is done using field sheets.
Field sheets are forms used to record data relating to each sample.

Chain of Custody (COC)
If the samples you take need to be sent to a laboratory for testing or if they need to be stored, a Chain of Custody (COC) must also be used.
A Chain of Custody (COC) is a form that outlines:
   1. The location a sample was taken
   2. The date and time of the sampling
   3. The sampling equipment used
   4. The type of laboratory testing required
5. An analysis of the samples taken.
A Chain of Custody is a legal document used to trace who has been in control of the samples from the time of collection through analysis, reporting and disposal. When you submit your samples to a laboratory you must give them a COC. The lab will make a copy of the COC to give you and the results will be faxed or emailed to a manager, usually within two weeks.

Table 7: Sampling Event Report Form

<table>
<thead>
<tr>
<th>Collection Information</th>
<th>Date:</th>
<th>Site Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Owner/Collector:</td>
<td>Signature:</td>
<td></td>
</tr>
<tr>
<td>Level of PPE Used:</td>
<td>Weather Conditions:</td>
<td></td>
</tr>
<tr>
<td>Additional Agencies Involved:</td>
<td>Agency Contact Information:</td>
<td></td>
</tr>
</tbody>
</table>

Signature of Agency Representative(s):

**Site and Sample Description**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sample Location</th>
<th>Time</th>
<th>Sample Amount (volume or weight)</th>
<th>Sample Type (Matrix)</th>
</tr>
</thead>
</table>


**Incident Details**

Describe the number of people exposed and the types of symptoms they are experiencing:

General conditions of exposed flora and fauna (if available):

Describe the event and reason for sample collection:

**Chain of Custody Form**

<table>
<thead>
<tr>
<th>Site Name:</th>
<th>Sample Owner/Collector:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID</td>
<td>Collection Date/Time (24 h)</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
</tr>
</tbody>
</table>


Relinquished By: | Received by: | Date/Time: |
| Relinquished By: | Received by: | Date/Time: |
| Relinquished By: | Received by: | Date/Time: |
| Relinquished By: | Received by: | Date/Time: |

Dispatched by: | Date/Time: | Received by: | Date/Time: |

**Method of Sample Transport**

Shipper: | Phone No.: | Tracking No.: |
Sampling Plan

All equipment needs to be properly checked before sampling takes place. This includes communication equipment and transport.

All sampling plans include basic information about who is doing the sampling, when it is done and a job number.

1. **Job brief:** clearly describe why sampling needs to be done. What evidence is there to justify the project?

2. **Types of sample:** note whether you will be taking grab or composite samples, or both. What kind of containers will you need?

3. **Location and access:** include where the sampling will take place and what you will need to access it. What will you need to access this location?

4. **Sampling equipment:** decide what equipment you will need to carry out the sampling. List everything you need including Personal Protective Equipment (PPE) and records sheets.

5. **Transport needs:** decide what you will need to take to transport any samples needed for analysis.

6. **Types of test:** list what tests you will be sampling for. Include any tests you will be doing on site, as well as any tests that will be done in a laboratory.

7. **Testing equipment:** list any equipment you will need to do the onsite tests.

Sampling Methods

**Manual sampling:** Manual sampling involves minimal equipment but may be unduly costly and time-consuming for routine or large-scale sampling programs. It requires trained field technicians and is often necessary for regulatory and research investigations; for which critical appraisal of field conditions and complex sample collection techniques are essential. Manually collect certain samples, such as waters containing oil and grease.

**Automatic sampling:** Automatic samplers can eliminate human errors in manual sampling, can reduce labor costs, may provide the means for more frequent sampling, and are used increasingly

Sample Volume

Collect a 1-L sample for most physical and chemical analyses. For certain determinations, larger samples may be necessary. It is strongly recommended that the laboratory that will conduct the analyses also be consulted to verify the analytical needs of sampling procedures.

Do not use samples from the same container for multiple testing requirements (e.g., organic, inorganic, radiological, bacteriological, and microscopic examinations) because methods of collecting and handling are different for each type of test.
Sample Storage and Preservation
Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is a practical impossibility because complete stability for every constituent never can be achieved. At best, preservation techniques only retard chemical and biological changes that inevitably continue after sample collection.

Sample Storage before Analysis
- Nature of sample changes: Some determinations are more affected by sample storage than others.
- Certain cations are subject to loss by adsorption on, or ion exchange with, the walls of glass containers. These include aluminum, cadmium, chromium, copper, iron, lead, manganese, silver, and zinc, which are best collected in a separate clean bottle and acidified with nitric acid to a pH below 2.0; to minimize precipitation and adsorption on container walls.
- Temperature changes quickly; pH may change significantly in a matter of minutes; dissolved gases (oxygen, carbon dioxide) may be lost. Because changes in such basic water quality properties may occur so quickly, determine temperature, reduction-oxidation potential, and dissolved gases in situ and pH, specific conductance, turbidity, and alkalinity immediately after sample collection. Many organic compounds are sensitive to changes in pH and/or temperature resulting in reduced concentrations during storage.
- Changes in the pH-alkalinity-carbon dioxide balance may cause calcium carbonate to precipitate, decreasing the values for calcium and total hardness. Microbiological activity may affect the BOD concentration. Color, odor, and turbidity may increase, decrease, or change in quality.
- Zero head-space is important in preservation of samples with volatile organic compounds and radon. After capping or sealing bottle, check for air bubbles by inverting and gently tapping it; if one or more air bubbles are observed then, if practical, discard the sample and repeat refilling bottle with new sample until no air bubbles are observed (this cannot be done if bottle contained preservatives before it was filled).

Preservation Techniques
To minimize the potential for volatilization or biodegradation between sampling and analysis, keep samples as cool as possible without freezing. Preferably pack samples in crushed or cubed ice or commercial ice substitutes before shipment.
- Avoid using dry ice because it will freeze samples and may cause glass containers to break.
- Dry ice also may effect a pH change in samples.
Keep composite samples cool with ice or a refrigeration system set at 4°C during compositing.

Analyze samples as quickly as possible on arrival at the laboratory. If immediate analysis is not possible, preferably store at 4°C.

No single method of preservation is entirely satisfactory; choose the preservative with due regard to the determinations to be made.

Use chemical preservatives only when they do not interfere with the analysis being made. Preservation methods are limited to pH control, chemical addition, the use of amber and opaque bottles, refrigeration, filtration, and freezing. Table below lists preservation methods by constituent.

**Time required:** An hour or less depending on the number of samples grabbed.

**Equipment and Reagents:** Ice box, sampling bottles, portable meters

**Significant Experimental Hazards:** Student should be aware of hazards associated with the sampling waste water that contains many sorts of pathogens, personal protective equipment should be used.

### 2.4.2. Sampling Procedures

The sampling methods in this section are described in the order sample types are required to be taken. Failure to adhere to these methods could result in sample results being inaccurate, requiring further sampling and investigation at unnecessary expense to the consumer.

N.B. where timed actions are required, time should be measured using a suitable digital instrument. Time durations must not be estimated. All personnel required to take samples of private water suppliers must be trained and authorized to sample (a suggested “authorization to sample” proforma is appended to this manual).

1) **Plumbing metals (lead, copper, zinc, nickel):** Fill the bottle before any cleaning or flushing of the tap. Do not rinse the bottle first.

2) **Tap preparation and on site measurements:** Ensure that the tap type and condition is likely to provide a sample that is representative of the supply:
   - Record any observations where its representativeness might be compromised, e.g. unhygienic surroundings, attachments/anti-splash devices in use.
   - Check for any on line filters, point of use devices or softeners Remove anti-splash devices or rubber hoses etc.
- Clean the outside of the tap with 70% isopropyl alcohol wipe to remove any debris, grease or other potential sample contaminants.
- Turn the tap on and adjust the flow to a steady stream, ensuring that the water flows directly into the bottle, without it over-spilling the rim of the vessel. Run for a minimum of 3 minutes.
- Run further until the temperature stabilizes.
- Take any on site test measurements (see appendices (2) for methods), including chlorine residual where the supply has been chlorinated.

3) **General chemistry samples:** These samples include those for pH, color, conductivity, and turbidity. If using a 1L clear plastic bottle type:

4) **Microbiological sampling:** Following tap preparation and all relevant chemistry samples, carry out the following procedures: NB. For purposes of best practice this method employs a double disinfection procedure:
   - Inject or spray a pre-prepared chlorine solution over and into the tap nozzle using a suitable vessel/container (the make shall be named in the equipment list appended in this manual). Leave the solution for a contact time of 1 minute. (N.B. the make and model of the vessel or container used must be listed in the equipment list provided in the appendix of this document and added to the local version of this manual). Turn on the tap and adjust the flow to a steady stream.
   - Run for 1 minute.
   - Re-apply the disinfectant and leave for 1 minute
   - Turn on the tap and adjust flow to steady stream
   - Run the tap for a minimum of 2 minutes.
   - Where the supply has been treated with a chlorine disinfectant, take a free chlorine residual reading to ensure they match the readings obtained taken at the stage. If the reading is higher flush the tap for a further 2 minutes and repeat the test.

5) **Bacteriological sampling procedure:** Usually a pre-prepared 500ml sterilized clear plastic bottle with added sodium thiosulphate):
   - Using the bacterial bottle type shown in the appendix of this manual, hold it near its base and unscrew cap.
   - Do not put the cap down. Hold it open end downwards.
   - Do NOT rinse the bottle.
   - Fill the bottle by holding it under the water stream a slight angle ensuring the top of the bottle does not come into contact with the tap.
   - Avoid splashing and fill to the line where the cap meets the bottle so as to leave an air space to allow for expansion during transportation.
   - Replace the cap taking care not to touch the inside of the cap or it to come into contact with anything.
   - Tighten the cap and invert.
Transfer to and transport in a refrigerated unit or cool box.

6) **Procedure for sampling raw water from an open water source:** This procedure is applicable for taking investigational samples from any open water facility. This includes from rivers and streams, chambers, channels and storage reservoirs (and tanks) where sampling can only be achieved by standing over open water from height. This method is not appropriate for bacteriological sampling as it poses contamination risks and health and safety hazards. When sampling from height, all appropriate local health and safety procedures must be adhered to. Disposable gloves must be worn when taking microbiological samples (e.g. large volume samples). Where a risk of falling into open water is a risk always wear a life jacket. Raw water is defined as water that has not been treated for human consumption and other domestic purposes and includes any point that is prior to the regulatory sampling point.

- When working from height, direct filling of sample bottles, other than samples for pathogens and viruses is not to be used. It requires the use of a dipping jug – a jug on a chain or rope.
- First find a suitably safe place to take the sample without causing risk of injury. This may be a bridge, platform or jetty.
- Check that the jug is clean and dry. Disinfection of the jug at this stage shall be considered where appropriate. Methods of disinfection should observe all necessary health and safety procedures.
- Throw the jug out and allow it to sink well below the surface. Do not allow the jug to hit the bottom of the tank, channel etc.
- Draw the jug back using the attached rope.
- Fill sample bottles by pouring from the jug, observing any specific requirements of the bottle type.

7) **Procedure for pathogens and viruses by direct dipping of raw water:** Samples shall be collected in the appropriate bottle shown in the appendix of this manual. The volume required for pathogen and virus samples will usually be 5 or 10 litres. Either way samples should be collected in in the relevant container. N.B. disposable gloves should be worn for the collection of these samples.

- Lower the container carefully into the water, observing all health and safety precautions and procedures. If the water is flowing, then ensure that the opening of the container faces downstream.
- Allow the container to fill.
- Retrieve the container and replace the cap.
- Dry the container and avoid exposure to sunlight as much as possible.
- Dispose of gloves in a suitable receptacle in the vehicle or back at base and wash hands. Transfer to and transport in a refrigerated unit or cool box ensuring the samples are separated from all clean and treated water samples.
2.4.3. Conduct Water Quality Analysis

2.4.3.1. Jar Test

The jar test is a method of measuring the effect of coagulation, flocculation, and sedimentation on turbidity. Although the procedure is not outlined in Standard Methods, it is used in most water treatment plants to find the best coagulant dosages under varying conditions.

Coagulation/flocculation is the process of binding small particles in the water together into larger, heavier clumps which settle out relatively quickly. The larger particles are known as floc. Properly formed floc will settle out of water quickly in the sedimentation basin, removing the majority of the water's turbidity.

In many plants, changing water characteristics require the operator to adjust coagulant dosages at intervals to achieve optimal coagulation. Different dosages of coagulants are tested using a jar test, which mimics the conditions found in the treatment plant. The first step of the jar test involves adding coagulant to the source water and mixing the water rapidly (as it would be mixed in the flash mix chamber) to completely dissolve the coagulant in the water. Then the water is mixed more slowly for a longer time period, mimicking the flocculation basin conditions and allowing the forming floc particles to cluster together. Finally, the mixer is stopped and the floc is allowed to settle out, as it would in the sedimentation basin.

The type of source water will have a large impact on how often jar tests are performed. Plants which treat groundwater may have very little turbidity to remove are unlikely to be affected by weather-related changes in water conditions. As a result, groundwater plants may perform jar tests seldom, if at all, although they can have problems with removing the more difficult small
suspended particles typically found in groundwater. Surface water plants, in contrast, tend to treat water with a high turbidity which is susceptible to sudden changes in water quality. Operators at these plants will perform jar tests frequently, especially after rains, to adjust the coagulant dosage and deal with the changing source water turbidity.

**Time required:** Two hour or less depending on the number of samples determined.

- Equipment and Reagents
- Volumetric flask (1,000 ml)
- Analytical balance
- Magnetic stirrer (optional)
- Beakers (1,000 ml)
- Pipets (10 ml)
- Watch or clock
- Turbidimeter and sample tubes
- A stirring machine with six paddles capable of variable speeds from 0 to 100 revolutions per minute (RPM)
- Coagulants and coagulant aids

**Procedure**

1) Decide on six dosages of the chemical(s).
2) If pre-lime has to be fed, it is usually best to hold the amount of lime constant and vary the coagulant dosage.
3) You will need to prepare a stock solution for each type of chemical used. The strength of the stock solution will depend on the chemical dosages which you decided to use in step 1.

The table below shows what strength stock solution you should prepare in each circumstance.

<table>
<thead>
<tr>
<th>Approximate dosage required, mg/L</th>
<th>Stock solution concentration, mg/L</th>
<th>1 ml added to 1 L sample equals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 mg/L</td>
<td>1,000 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>10-50 mg/L</td>
<td>10,000 mg/L</td>
<td>10 mg/L</td>
</tr>
<tr>
<td>50-500 mg/L</td>
<td>100,000 mg/L</td>
<td>100 mg/L</td>
</tr>
</tbody>
</table>

For example, if all of your dosages are between 1 and 10 mg/L, then you should prepare a stock solution with a concentration of 1,000 mg/L. This means that you could prepare the stock solution by dissolving 1,000 mg of the chemical in 1 L of distilled water. However, this would produce a much larger quantity of stock solution than you need and would waste chemicals. You will probably choose instead to dissolve 250 mg of the chemical in 250 ml of distilled water.

4) Weigh out the proper quantity of the chemical using the analytical balance.
5) Measure out the proper quantity of distilled water in the volumetric flask.
6) Add the chemical to the distilled water. Mix well.
7) If lime is used, it is best to use a magnetic stirrer since lime is not completely soluble in water.
8) Measure 1,000 mL of raw water and place in a beaker. Repeat for the remaining beakers.
9) Place beakers in the stirring machine.
10) With a measuring pipet, add the correct dosage of lime and then of coagulant solution to each beaker as rapidly as possible.
11) The third column of the table in step 2 shows the amount of stock solution to add to your beaker.
12) With the stirring paddles lowered into the beakers, start the stirring machine and operate it for one minute at a speed of 80 RPM. While the stirrer operates, record the appearance of the water in each beaker. Note the presence or absence of floc, the cloudy or clear appearance of water, and the color of the water and floc.

13) Reduce the stirring speed to 20 RPM and continue stirring for 30 minutes. Record a description of the floc in each beaker 5, 10, 15, 20, 25, and 30 minutes after addition of the chemicals.
14) Stop the stirring apparatus and allow the samples in the beakers to settle for 30 minutes. Record a description of the floc in each beaker after 15 minutes of settling and again after 30 minutes of settling.

15) Determine which coagulant dosage has the best flocculation time and the most floc settled out. This is the optimal coagulant dosage.
A hazy sample indicates poor coagulation. Properly coagulated water contains floc particles that are well-formed and dense, with the liquid between the particles clear.

16) Test the turbidity of the water in each beaker using a turbidometer. Pipet water out of the top of the first beaker and place it in a sample tube, making sure that no air bubbles are present in the sample. (Air bubbles will rinse while turbidity will sink.) Carefully wipe the outside of the sample tube clean. Place the sample tube in a calibrated turbidometer and read the turbidity. Repeat for the water from the other beakers. The least turbid sample should correspond to the optimal coagulant dosage chosen in step 10.

17) If lime or a coagulant aid is fed in addition to the primary coagulant, you should repeat the jar test to determine the optimum dosage of lime or coagulant aid. Use the concentration of coagulant chosen in steps 10 and 11 and alter the dosage of lime or coagulant aid.

Issues to consider for your practical report

- What are the potential sources of error in this experiment? How could they be overcome?
- Are there alternative methods for determining the optimum dosage of coagulant? If so, how do they compare to this method?
- What are typical water turbidity values in sea, rivers, streams, lakes and drinking water? How do your data compare with these values?
- What are the potential human health and environmental effects (if any) of excess coagulant dosage?
- Based on the type of coagulant used, write the chemical equations that occurred during the experiment.
Table 8: Jar Test Experimental result Reporting Form

### Experiment (6): Jar Test
Experimental Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>ID No.</th>
<th>Group</th>
</tr>
</thead>
</table>

Coagulant Type:
Variable dosing coagulant at constant pH

Temperature:

<table>
<thead>
<tr>
<th>Beaker ID</th>
<th>Initial Water Quality</th>
<th>Final Water Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coagulant conc. mg/l</td>
<td>Turbidity (NTU) pH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coagulant (mg/l) Turbidity (NTU) pH Observation</td>
</tr>
</tbody>
</table>

Coagulant Type:
Constant dosing at variable pH

Temperature:

<table>
<thead>
<tr>
<th>Beaker ID</th>
<th>Initial Water Quality</th>
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<tr>
<td></td>
<td></td>
<td>Coagulant (mg/l) Turbidity (NTU) pH Observation</td>
</tr>
</tbody>
</table>
2.4.3.2. Physical parameters

**Temperature:** Temperature must be measured in situ because a water sample will gradually reach the same temperature as the surrounding air. If it is not possible to measure the temperature in situ, a sample must be taken from the correct location and depth of the sampling station and its temperature measured immediately it is brought to the surface. Temperature is measured with a glass thermometer, either alcohol/toluene-filled or mercury filled, with 0.1 °C graduations, or an electronic thermometer of the type that is usually an integral part of a dissolved oxygen meter or a conductivity meter.

**Procedure**

1. When a glass thermometer is used and the testing point can be reached, immerse the thermometer in the water until the liquid column in the thermometer stops moving (approximately 1 minute, or longer if necessary). For a pumping well, immerse the thermometer in a container with water flowing through until the temperature stabilises. Record the reading to the nearest 0.1 °C.

2. When either a glass thermometer or an electronic thermometer is used and the measurement point is inaccessible, obtain a water sample of at least 1 litre. Rinse the thermometer (or the probe) with a portion of the sample and discard the rinse water. Immerse the thermometer (or the probe) in the sample. Hold it there for approximately 1 minute (longer if the temperature reading has not become constant). Record the reading to the nearest 0.1 °C.

3. When an electronic thermometer having a probe with long leads is used, lower the probe to the required depth. Hold it at that depth until the reading on the meter is constant. Record the temperature to the nearest 0.1 °C and the depth to the nearest 10cm. Lower (or raise) the probe to the next measurement point for the next reading.

**PH:** Determination of the pH of water should, if possible, be made in situ. If this is not possible, for example with well water or when access to a lake or river is very difficult, the measurement should be made immediately after the sample has been obtained. There are three different methods of pH measurement: pH indicator paper, liquid colorimetric indicators and electronic meters. The use of pH indicator paper is simple and inexpensive, but the method is not very accurate and requires a subjective assessment of color by the user.

**Measurement of pH using color indicators**

A comparator and color discs are required for this method of measuring PH. The instrument made by one manufacturer uses color discs for the pH ranges and indicators listed below.

**Procedure**

1. Fill three comparator cells to the 10-ml mark with portions of the water sample and place one of the cells in the left-hand compartment of the comparator.
2. Add 1 ml of universal indicator to one of the cells and mix well; place the cell in the right hand compartment. Compare the color in the right-hand cell with the glass standards of the universal disc.

3. From the above list, choose an indicator that has the mid-point of its range near to the approximate pH determined with the universal indicator. Add 0.5 ml of this indicator to the third comparator cell, mix, and place the cell in the right-hand compartment of the comparator.

4. Put the appropriate standard disc in the comparator and compare the colour of the sample with the glass standards on the disc. Record the result to the closest 0.2pH unit.

**Measurement of pH using a pH meter**

There are many models of pH meter and it is beyond the scope of this manual to describe them all. The common features are a sensing electrode and a reference electrode connected to an electronic circuit that amplifies the voltages produced when the electrodes are immersed in a solution or water sample.

**Procedure: Standardizing the meter**

1. Remove the protective rubber cap and slide the rubber sleeve up to expose the hole in the side of the reference electrode.
2. Rinse both electrodes with distilled water and blot them dry with soft absorbent paper.
3. Pour sufficient buffer solution into a beaker to allow the tips of the electrodes to be immersed to a depth of about 2 cm. The electrodes should be at least 1 cm away from the sides and the bottom of the beaker.
4. Measure the temperature of the buffer solution with a thermometer and set this on the temperature adjustment dial of the meter (if the meter is so equipped). Some meters have an automatic temperature adjustment feature.
5. Turn on the pH meter.
6. Adjust the needle on the pH dial to the known pH of the buffer. If the needle keeps jumping, check that the leads from the electrodes are firmly connected to the meter. When the needle stops moving, make the fine adjustment.
7. Turn the instrument to stand-by (if it is equipped for this).
8. Raise the electrodes clear of the buffer solution. Remove the buffer and rinse the electrodes with distilled water.
9. Proceed to determination of pH of the sample. If the sample is not ready, place the electrodes in distilled water.
Determining of pH of sample

1. The electrodes are either immersed in, or have been rinsed with, distilled water. Remove them from the water and blot dry.
2. Rinse the electrodes and a small beaker with a portion of the sample.
3. Pour sufficient of the sample into the small beaker to allow the tips of the electrodes to be immersed to a depth of about 2 cm. The electrodes should be at least 1 cm away from the sides and the bottom of the beaker.
4. Measure the temperature of the water sample and set the temperature adjustment dial accordingly (if the instrument does not have automatic temperature compensation).
5. Turn on the pH meter.
6. Read the pH of the water sample on the dial of the meter. Make sure that the needle has stopped moving before the pH is recorded.
7. Turn the pH meter to stand-by and raise the electrodes out of the sample. Remove the sample and discard it. Rinse the electrodes and the beaker with distilled water, and blot the electrodes with soft tissue.
8. If other samples are to be tested, repeat steps 2 to 7.
9. If no other samples are to be tested, slide the rubber sleeve down to cover the hole in the side of the reference electrode and replace the protective rubber cap on the tip.
10. Switch the meter off and pack it in its carrying case for transport.

Conductivity

The ability of water to conduct an electric current is known as conductivity or specific conductance and depends on the concentration of ions in solution. Conductivity is measured in millisiemens per metre (1 mS m⁻¹ = 10 µS cm⁻¹ = 10 µmhos cm⁻¹). The measurement should be made in situ, or in the field immediately after a water sample has been obtained, because conductivity changes with storage time. Conductivity is also temperature-dependent; thus, if the meter used for measuring conductivity is not equipped with automatic temperature correction, the temperature of the sample should be measured and recorded.

Reagents

- Distilled water for preparing standard potassium chloride solution should have a very low conductivity. It must not contain CO₂. Use redistilled water and boil it immediately before use. Allow to cool in a hard-glass bottle fitted with a CO₂ trap.
- Standard potassium chloride solution, 0.0100 mol l⁻¹, for the calibration of electrodes and determination of the cell constant. Dissolve 0.7456 g of anhydrous KCl (dried at 105°C and cooled in a desiccator) in CO₂-free distilled water. Make up to 1,000 ml at 20°C. Store in a hard-glass bottle fitted with a CO₂ trap. The conductivity of this solution is 127.8 mS m⁻¹ at 20 °C.
**Procedure:** Determination of cell constant

1. Rinse out the conductivity cell with at least three portions of standard KCl solution.
2. Adjust the temperature of a fourth portion of the solution to 20 ± 0.1 °C (or as near as possible to that temperature).
3. Immerse the conductivity cell in a sufficient volume of the KCl solution for the liquid level to be above the vent holes in the cell. There should be no air bubbles clinging to the electrodes and the cell should not be closer than 2 cm to the sides and bottom of the container.
4. Observe and record the temperature of the KCl solution to the nearest 0.1 °C. Some meters have built in thermometers and/or automatic temperature compensation.
5. Turn the meter on. Follow the manufacturer’s operating instructions and record the meter reading.
6. Calculate the cell constant. The formula includes a factor that compensates for the difference in temperature if the reading was taken at a temperature other than 20.0°C. The value of the temperature correction factor \([0.019(t - 20) + 1]\) can be determined from the graph in figure below.

**Measurement of sample conductivity**

1. Rinse the conductivity cell with at least three portions of the sample.
2. Adjust the temperature of a portion of the sample to 20 ± 0.1 °C (or as close as possible to that temperature).
3. Immerse the conductivity cell containing the electrodes in a sufficient volume of the sample for the liquid level to be above the vent holes in the cell. There should be no air bubbles clinging to the electrodes and the cell should not be closer than 2 cm to the sides and bottom of the container.
4. Observe and record the temperature of the sample to the nearest 0.1 °C. Some meters have built in thermometers and/or automatic temperature compensation.
5. Turn the meter on. Follow the manufacturer’s operating instructions and record the meter reading.
6. Turn the meter off and pack it and the electrode in the carrying case for transport.

**Dissolved Oxygen:** The dissolved oxygen concentration depends on the physical, chemical and biochemical activities in the water body, and its measurement provides a good indication of water quality. Changes in dissolved oxygen concentrations can be an early indication of changing conditions in the water body.

Two main methods are available for the determination of dissolved oxygen: The Winkler method and the electrometric method using membrane electrodes.
Use of the Winkler method requires the addition of three chemical reagents to the sample very soon after it is obtained. The dissolved oxygen concentration (in mg l⁻¹) is then determined by titration with sodium thiosulphate solution, which may be done in the field or up to 6 hours later in a laboratory. The electrometric method is suitable for the field determination of dissolved oxygen and is simple to perform. It requires an electrically powered meter and an appropriate electrode. The result it gives requires the application of correction factors to compensate for salinity and temperature; some meters have built in temperature compensation.

**Winkler method**

**Apparatus**
- BOD bottle, capacity 250 to 300 ml
- Graduated cylinder
- Flask
- Burette (or other device for dispensing and measuring liquid)
- Pipettes (or similar means of adding reagents)

**Reagents**
- Distilled water in a rinse bottle.
- Manganous sulphate solution. Dissolve 500 g manganous sulphate pentahydrate, MnSO₄·5H₂O, in distilled water. Filter if there is any undissolved salt, and make up to 1 litre.
- Alkaline-iodide-azide solution. Dissolve 500 g sodium hydroxide, NaOH (or 700 g potassium hydroxide, KOH), and 135 g sodium iodide, NaI (or 150 g potassium iodide, KI), in distilled water and dilute to 1 litre. Sodium and potassium salts may be used interchangeably. Dissolve 10 g sodium azide, NaN₃, in 40 ml distilled water and add to the NaOH/NaI mixture. This reagent should not give a colour with starch when diluted 1:25 and acidified.
- Concentrated sulphuric acid.
- Starch indicator solution. Make a smooth paste by blending 1 g of soluble starch with a little cold distilled water in a beaker of capacity at least 200 ml. Add 200 ml of boiling distilled water while stirring constantly. Boil for 1 minute and allow to cool. Store in a refrigerator or at a cool temperature. Alternatively, thiodene powder may be used as an indicator.
- Sodium thiosulphate solution (0.025 mol l⁻¹ for 200 ml sample). Dissolve 6.3 g sodium thiosulphate pentahydrate, Na₂S₂O₃·5H₂O, in distilled water and make up to 1 litre. Standardize against KI. Add either 1 ml chloroform or 10 mg mercuric iodide to stabilize the solution. Store in a brown bottle.
Procedure

The procedure described here assumes that the sample has already been properly collected in a dissolved oxygen sampler and is contained in a BOD bottle.

1. Remove the BOD bottle containing the sample from the dissolved oxygen sampler and insert the matching ground-glass stopper in the neck of the bottle. Be sure that no air bubbles have been trapped under the stopper and maintain a water seal around the stopper until ready for the next step of the procedure.

2. Pour off the water seal and remove the ground glass stopper. Add 1 ml of MnSO4 solution, then 1 ml of alkaline-iodide-azide solution. For both additions, hold the tip of the pipette against the inside of the bottle neck to prevent splashing.

3. Replace the ground-glass stopper, being careful to avoid trapping air bubbles under it.

4. Mix the contents by inverting the bottle several times. Keep a finger over the stopper during mixing to make sure that it does not fall out. A brown floc will form in the bottle before and during the mixing. If there was no dissolved oxygen in the sample, the floc will be white. When the bottle is set down the floc will settle, leaving a clear liquid above it.

5. Allow the floc to settle between a half and two-thirds of the way down the bottle, then mix again as in step 4 (above). Allow to settle once more, until all of the floc is in the lower third of the bottle.

6. Remove the stopper, add 1 ml of H2SO4 without splashing, replace the stopper and mix the contents of the bottle by inverting it several times. The floc will disappear and the liquid in the bottle will be a yellowish-brown colour. If there was no dissolved oxygen in the sample the liquid will be colourless. Note: The dissolved oxygen in the sample is now “fixed”. The amount of iodine that has been released from the reagent (causing the yellow-brown colour) is proportional to the amount of oxygen that was in the sample. If the bottle is kept tightly stoppered it may be stored for up to 6 hours before step 8, titration with sodium thiosulphate solution.

7. Transfer a volume, Vt, corresponding to 200 ml of the original sample to the flask. Adjustment should be made to compensate for the amount by which the sample was diluted when 1 ml of MnSO4 and 1 ml of the alkaline-iodide-azide solution were added. If, for example, a 300-ml BOD bottle is used, the volume would be:

\[ V_t = 200 \times \frac{300}{300 - 2} = 201.3 \text{ ml} \]

8. Titrate with sodium thiosulphate solution (0.025 mol l⁻¹), stirring the contents of the flask until the yellow-brown colour fades to a pale straw colour. Add a few drops of starch solution and a blue colour will develop. Continue titrating a drop at a time until the blue colour disappears.
Calculation
For titration of 201.3 ml (200 ml of sample plus 1.3 ml allowance for reagents) with 0.025mol l-1 sodium thiosulphate:

1 ml Na2S2O3 solution = 1 mg l-1 dissolved oxygen

If sodium thiosulphate is used at a strength other than 0.025 mol l-1, and if the sample volume titrated is other than 200 ml (excluding the volume added to compensate for the chemical reagents as described in step 7), the dissolved oxygen in the sample may be calculated from the following formula:

\[
\text{Dissolved oxygen} = \frac{\text{ml titrant} \times \text{mol l}^{-1} \times \text{titrant} \times 8,000}{\text{volume of sample titrated}} \text{mg l}^{-1}
\]

Electrometric method
Apparatus
- Battery-powered meter. This is a meter designed specifically for dissolved oxygen measurement. Other meters, such as a specific ion meter or an expanded scale pH meter, may also be used.
- Oxygen-sensitive membrane electrode.

Procedure
1. Follow exactly the calibration procedure described in the manufacturer’s operating instructions. Generally, electrodes are calibrated by reading against air or against a sample of known dissolved oxygen content. This “known” sample could be one for which dissolved oxygen concentration has been determined by the Winkler method or one that has been saturated with oxygen by bubbling air through it. The zero end of a calibration curve can be determined by reading against a sample containing no dissolved oxygen, prepared by adding excess sodium sulphite, Na2SO3, and a trace of cobalt chloride, CoCl2, to the sample.
2. Rinse the electrode in a portion of the sample which is to be analyzed for dissolved oxygen.
3. Immerse the electrode in the water, ensuring a continuous flow of water past the membrane to obtain a steady response on the meter.
4. Record the meter reading and the temperature, and the make and model of the meter.
5. Switch the meter off and pack it and the electrode in the carrying case for transport.

Turbidity: Turbidity is caused by suspended and colloidal matter such as clay, silt, organic and inorganic matter and microscopic organisms. Many methods are available for the measurement of turbidity including turbidimeter and optical probes. Turbidity is measured by determining the amount of scatter when a light is passed through a sample.
Instrument Calibration and Verification

Many brands of instruments are commercially available for the measurement of turbidity incorporating a wide variety of technologies. The manufacturer's instruction manual should be consulted for specific procedures regarding their calibration, maintenance and use. Calibration of any measurement instrument must be conducted and/or verified prior to each use or on a daily basis, whichever is most appropriate. Depending on the instrument, the verification and calibration can differ slightly. If the instrument readings do not agree within ± 10 % of the calibration standards, the unit must be recalibrated, repaired or replaced. The following are basic guidelines for calibration/verification of meters and are provided as an example:

Meter Calibration and Verification

Portable turbidimeter are calibrated with Formazin Primary Standards. The manufacturer recommends calibration with a primary standard such as StablCal® Stabilized Standards or with formazin standards every three months.

Generally, only a calibration verification measurement is required in the field; however, if a calibration is needed, record a post calibration reading for each calibration standard used.

Meter Verification:
1. Push Verify Cal to enter the Verify menu.
2. Gently invert the liquid standard several times prior to insertion into meter. Insert the 10.0 NTU (or other defined value) Verification Standard and close the Lid.
3. Push Read. The display shows “Stabilizing” and then shows the result and tolerance range.
4. Push Done to return to the reading display. Repeat the calibration verification if the verification failed. If a meter is unable to pass verification, then that meter will need to be calibrated.

Meter Calibration:
1. Push the CALIBRATION key to enter the Calibration mode. Follow the instructions on the display. Note: Gently invert each standard several times before inserting the standard and use a non-abrasive, lint-free paper or cloth to wipe off the standards.
2. Insert the 20 NTU StablCal Standard and close the lid. Push Read. The display shows “Stabilizing” and then shows the result. Record the result.
3. Repeat Step 2 with the 100 NTU and 800 NTU StablCal Standard. Record both results.
4. Push Done to review the calibration details.
5. Push Store to save the results. After a calibration is complete, the meter automatically goes into the Verify Cal mode.
Probe Calibration and Verification

1. Turn the meter “ON” and allow it to stabilize
2. Immerse the probe in the first standard solution and calibrate the probe against the solution.
3. Rinse the probe with de-ionized water, remove excess rinse water and calibrate the probe using additional standards as appropriate.
4. Record the standard values used to calibrate the meter.

Procedures

Depending on the meter, the sample measurement procedure can differ slightly.

Grab Sample Measurement

These procedures should be followed when conducting turbidity measurements of grab samples:

1. Collect a representative sample and pour off enough to fill the cell to the fill line (about 15 mL) and replace the cap on the cell.
2. Wipe off excess water and any streaks with a soft, lint-free cloth (lens paper).
3. Turn instrument on. Place the meter on a flat, sturdy surface. Do not hold the instrument while making measurements.
4. Insert the sample cell in the instrument so the diamond or orientation mark aligns with the raised orientation mark in the front of the cell compartment. Close the lid.
5. If appropriate, select manual or automatic range selection by pressing the range key.
6. If appropriate, select signal averaging mode by pressing the Signal Average key. Use signal average mode if the sample causes a noisy signal (display changes constantly).
7. Press Read. The display will show ---- NTU. Then the turbidity is displayed in NTU. Record the result after the lamp symbol turns off.
8. Rinse the cell with de-ionized water or rinse out with sample water prior to the next reading.

In-Situ Measurement

These procedures should be followed when conducting in-situ turbidity measurements:

1. Place the probe into the media to be measured and allow the turbidity reading to stabilize. Once the reading has stabilized, record the measurement in the logbook.
2. When deploying meters for extended periods of time, ensure the measurement location is representative of average media conditions.

Units

Turbidity measurements are reported in nephelometric turbidity units (NTUs). It is important to note that if the turbidity measurements are for NPDES reporting purposes, all values above
40 NTU must be diluted with turbidity free-water and calculated by multiplying by a dilution factor.

2.4.3.3. Chemical Parameters

Residual Chlorine- Using Comparator: After chlorinating a water source or container one of the simplest ways to test if the right chlorine dose is given is to measure the Free Residual Chlorine (FRC). The presence of FRC in water proves that enough chlorine has been added to treat the water or in other terms to react on all matter present in the water, including microorganisms, and leaving some extra chlorine (residual) in the water to deal with possible recontamination (such as during handling etc.) The measurement of Free Residual Chlorine is most easily done using a comparator also commonly called a « Pool tester » and tablets (called DPD1) that will be added to the water in the comparator, and that will react and change the colour of the water if residual chlorine is present.

Procedures

1. Rinse the Pool tester 3 times with the water to be tested, including the cover. If a syringe is used to fill the pool tester, it should be rinsed inside and outside thoroughly with the water to be tested.
2. Fill the 3 compartments to the top with the water to be tested.
3. Put one DPD 1 tablet in the right hand or pink coloured compartment (measurement of Free Residual Chlorine) Prevent touching the tablet with dirty hands!
4. Replace the cover tightly (it is normal that some liquid is pressed out) with the arrows pointing towards the coloured reference scale.
5. Shake until the tablets are completely dissolved (about 20 seconds).
6. Read the results in natural day light, comparing the colours in the outside compartments (sample) with those in the central compartment (reference). The residual chlorine level is the level at which the sample colour is similar to the central compartment. A darker pink indicates a higher residual chlorine level no colour change indicates the water is not chlorinated or not sufficiently chlorinated to have a residual chlorine level
7. After testing empty pool tester and rinse again
**Important**

- Chlorine takes time to kill all the organisms so the chlorine should be in contact with the water for at least 30 minutes.
- For step 1 and 2 always make sure that you the quality of the water you’d like to test does not change: let water flow for a few moments before taking it from a tap. Be careful when pouring water out of a container: let it flow before taking your sample. If using jerry cans, fitted with a tap, do not use the tap to fill the pool tester, as the taps being placed next to the ground are often soiled (leading to false results).
- Never touch the tablets with, the inside of the pool tester or the inside part of the cover with dirty your fingers: this could affect the results. Never use tablets that have fallen on the ground.
- DPD3 cannot be used to determine free residual chlorine.
- Only whole DPD1 tablet must be used. Do not use broken tablets (while opening packaging or because of bad storage).
- Tablets have a shelf life of 5 years. The expiry date is written on the outside of the 500 tablets cardboard boxes.

### Required residual chlorine level

<table>
<thead>
<tr>
<th>Condition of water</th>
<th>Contact time</th>
<th>Recommended Free Residual Chlorine</th>
<th>Acceptable chlorine level</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &lt; 8</td>
<td>30 minutes</td>
<td>0.5 mg/l</td>
<td>0.2-1.5 mg/l</td>
</tr>
<tr>
<td>pH &gt; 8</td>
<td>60 minutes</td>
<td>1.0 mg/l</td>
<td>0.5-1.5 mg/l</td>
</tr>
</tbody>
</table>

**Important**

- In most waters the required free residual chlorine should be 0.5mg/l. In water with a pH of more than 8, chlorine is less efficient and a residual chlorine level of 1.0 mg/l is recommended.
- If chlorine level in the water is source is below 0.2mg/l it is recommended to increase the chlorine doses at the water source.
- If chlorine levels are too high one has to reduce the chlorine doses at the water source when treating again the same water source. Water with a high chlorine dose (eg 2mg/l) is still safe for consumption but the taste will be affected.
- Residual chlorine levels in water will reduce over time retreatment might be needed when water is stored over longer periods (eg in a bladder).
- To find the right chlorine doses to treat water one has to do bucket testing (see separate guidance sheet).
**Residual Chlorine Using Photometer:** The Palintest Chlorine/Chloramines test uses the DPD method. This method is internationally recognised as the standard method of testing for chlorine and other residuals. In the Palintest method the reagents are provided in tablet form for maximum convenience and simplicity of use.

**Reagents and Equipment**
Palintest DPD No 1 Tablets
Palintest DPD No 2 Tablets
Palintest DPD No 3 Tablets
Palintest Automatic Wavelength Selection Photometer
Round Test Tubes, 10 ml glass (PT 595)

**Separation of Chlorine Residuals:** The photometer is programmed for free chlorine and for the chloramine stages. Use program Phot 71 Free Chlorine then select ‘Follow On’ from screen options to continue test for program 72 Monochloramine and again for program 73 Dichloramine.

**Procedures**
1. Rinse test tube with sample leaving a few drops in the tube.
2. Add and then crush the DPD No 1 tablet in the few drops of the water sample until the tablet is thoroughly crushed.
3. Add the 10 ml test solution, mix and seal the tube with the cap.
4. Gently invert the tube to remove any bubbles from the inner walls of the tube.
5. Select Phot 7 on photometer.
6. Take photometer reading in usual manner - see photometer instructions.
7. The result represents the free chlorine residual as mg/l CI₂.
8. To measure monochloramine, continue the test on the same test sample. Select ‘Follow On’ from screen options to continue the test program.
9. Add one DPD No 2 tablet, crush and mix to dissolve.
10. Gently invert the tube to remove any bubbles from the inner walls of the tube.
11. Take the photometer reading. The result displayed is the mono-chloramine concentration as mg/l CI₂.
12. To measure dichloramine, continue the test on the same test portion. Select ‘Follow On’ option from screen options to continue the test program.
13. Add one DPD No 3 tablet, crush and mix to dissolve. Stand for two minutes to allow full colour development.
14. Take the photometer reading. The photometer displays the dichloramine concentration as mg/l CI₂.
**Alkalinity:** The YSI Alka phot test is based on a unique colorimetric method and uses a single tablet reagent. The test is simply carried out by adding a tablet to a sample of the water. Under the conditions of the test, a distinctive range of colors from yellow, through green, to blue is produced over the alkalinity range 0 - 500 mg/l CaCO₃. The color produced in the test is indicative of the alkalinity of the water and is measured using a YSI Photometer.

**Reagents and Equipment**
YSI Alkaphot Tablets
YSI 9300 OR 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

**Test Procedure**
1. Fill test tube with sample to the 10 ml mark.
2. Add one Alkaphot tablet, crush and mix until all of the particles have dissolved.
3. Stand for one minute then remix.
4. Select Phot 2 on photometer.
5. Take photometer reading in usual manner (see photometer instructions). The result is displayed as mg/l CaCO₃.

**Iron:** The YSI Iron HR test is based on a single tablet reagent containing an alkaline thioglycollate. The test is carried out simply by adding a tablet to a sample of the water under test. The thioglycollate reduces ferric iron to ferrous iron and this, together with any ferrous iron already present in the sample, reacts to give a pink coloration. The intensity of the color produced is proportional to the iron concentration and is measured using a YSI Photometer.

**Reagents and Equipment**
YSI Iron HR Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

**Test Procedure**
1. Fill test tube with sample to the 10 ml mark.
2. Add one Iron HR tablet, crush and mix to dissolve.
3. Stand for one minute to allow full color development.
4. Select Phot 19 on photometer.
5. Take photometer reading in usual manner (see photometer instructions).
6. The result is displayed as mg/l Fe.

**Manganese:** Manganese may occur in water in various different valency states. In the first stage of the YSI method, manganese in lower valency states is oxidised to form permanganate by the action of an oxidising agent. In the second stage the permanganate formed is further
reacted with leucomalachite green to form an intense turquoise colored complex. Catalysts and inhibitors are incorporated into the tablet reagents to ensure that the color reaction proceeds correctly and interferences are eliminated. The intensity of color produced in the test is proportional to the total manganese concentration and is measured using a YSI Photometer.

**Reagents and Equipment**

YSI Manganese No 1 Tablets
YSI Manganese No 2 Tablets YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

**Sample Collection**

Manganese is readily absorbed onto the surfaces of sample containers. To avoid loss of manganese test sample as soon as possible after collection. It is important, because of the extreme sensitivity of this test, to ensure that glassware used for the sample collection and test procedure is scrupulously clean. For most accurate results in laboratory use it is recommended that all glassware is acid-rinsed and then thoroughly washed out with deionised water before use.

**Test Procedure**

1. Fill test tube with sample to the 10 ml mark (see Note 1).
2. Add one Manganese No 1 tablet, crush and mix to dissolve.
3. Add one Manganese No 2 tablet, crush and mix to dissolve then cap the tube.
4. Stand for 20 minutes to allow color development (see Note 2).
5. Select Phot 20 on photometer.
6. Take photometer reading in usual manner (see photometer instructions).
7. The result is displayed as mg/l Mn

### 2.4.3.4. Bacteriological parameters

<table>
<thead>
<tr>
<th>Multiple fermentation tube technique</th>
<th>Membrane filter technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slower, requires 48 hours for a positive</td>
<td>More rapid: quantitative results in or presumptive positive about 18 hours</td>
</tr>
<tr>
<td>More labour-intensive</td>
<td>Less labour-intensive</td>
</tr>
<tr>
<td>Requires more culture medium</td>
<td>Requires less culture medium</td>
</tr>
<tr>
<td>Requires more glassware</td>
<td>Requires less glassware</td>
</tr>
<tr>
<td>More sensitive</td>
<td>Less sensitive</td>
</tr>
<tr>
<td>Result obtained indirectly by statistical approximation (low precision)</td>
<td>Results obtained directly by colony count (high precision)</td>
</tr>
<tr>
<td>Not readily adaptable for use in the field</td>
<td>Readily adapted for use in the field</td>
</tr>
<tr>
<td>Applicable to all types of water</td>
<td>Not applicable to turbid waters</td>
</tr>
<tr>
<td>Consumables readily available in most countries</td>
<td>Cost of consumables is high in many countries</td>
</tr>
<tr>
<td>May give better recovery of stressed or damaged organisms in some circumstances</td>
<td></td>
</tr>
</tbody>
</table>
Membrane Filter Technique: The Membrane Filter (MF) Technique was introduced in the late 1950s as an alternative to the Most Probable Number (MPN) procedure for microbiological analysis of water samples. The MF Technique offers the advantage of isolating discrete colonies of bacteria, whereas the MPN procedure only indicates the presence or absence of an approximate number or organisms (indicated by turbidity in test tubes).

Principle: The membrane filter method gives a direct count of total coliforms and faecal coliforms present in a given sample of water. A measured volume of water is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 µm. Bacteria are retained on the surface of the membrane which is placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature. If coliforms and/or faecal coliforms are present in the water sample, characteristic colonies form that can be counted directly.

Apparatus
- Incubator(s) or water-bath(s) capable of maintaining a temperature to within ± 0.5 °C of 35 and 37 °C and to within ± 0.25 °C of 44 and 44.5 °C. Choice of temperature depends on the indicator bacteria and the medium.
- Membrane filtration apparatus, complete with vacuum source (electrically operated pump, hand-pump or aspirator) and suction flask.
- Autoclave for sterilizing prepared culture media. A pressure-cooker, heated on a hot-plate or over a Bunsen burner, may be substituted in some circumstances.
- Boiling-pan or bath (if filtration apparatus is to be disinfected in boiling water between uses).
- Laboratory balance, accurate to ± 0.05 g, and with weighing scoop. This may be omitted if media and potassium dihydrogen phosphate are available in pre-weighed packages of the correct size.
- Racks for bottles of prepared culture media and dilution water. These must fit into the autoclave or pressure-cooker.
- Distilling apparatus with storage capacity for at least 5 litres of distilled water.
- Refrigerator for storage of prepared culture media.
- Hot-air steriliser for sterilising pipettes and glass or metal Petri dishes.
- Thermometer for checking calibration of incubator or water-bath.
- Pipette cans for sterilising pipettes.
- Boxes for Petri dishes for use in hot-air steriliser.
- Reusable bottles for culture media.
- Measuring cylinders, capacity 100 ml and 250 ml.
- Reusable pipettes, glass, capacity 1 ml and 10 ml.
- Bottles to contain 9-ml volumes of buffered dilution water.
- Flasks for preparation of culture media.
- Wash-bottle.
- Blunt-edged forceps.
- Pipette bulbs.
- Spatula.
- Container for used pipettes.
- Brushes for cleaning glassware (several sizes).
- Fire extinguisher and first-aid kit.
- Miscellaneous tools.
- Waste bin.

**Consumables**

- Methanol for disinfecting filtration apparatus using formaldehyde gas (unnecessary in the laboratory, but essential if analyses are done in the field). It is essential to use methanol. Ethanol or methylated spirits cannot be substituted.
- Membrane filters, 0.45 µm pore size and of diameter appropriate for the filtration apparatus being used and complete with absorbent pads.
- Disinfectant for cleaning laboratory surfaces and a container for discarded pipettes.
- Culture media (options are listed in the section on media).
- Phosphate-buffered dilution water.
- Petri dishes, glass or aluminum (reusable) or plastic (disposable).
- Polyethylene bags for wrapping Petri dishes if dry incubator is used.
- Magnifying lens (as an aid to counting colonies after filters are incubated).
- Wax pencils for labelling Petri dishes.
- Autoclave tape.
- Detergent for cleaning glassware and equipment.

**Procedures**

1. Collect the sample and make any necessary dilutions.
2. Select the appropriate nutrient or culture medium. Dispense the broth into a sterile Petri dish, evenly saturating the absorbent pad.
3. Flame the forceps, and remove the membrane from the sterile package.
4. Place the membrane filter into the funnel assembly.
5. Flame the pouring lip of the sample container and pour the sample into the funnel.
6. Turn on the vacuum and allow the sample to draw completely through the filter.
7. Rinse funnel with sterile buffered water. Turn on vacuum and allow the liquid to draw completely through the filter.
8. Flame the forceps and remove the membrane filter from the funnel.
9. Place the membrane filter into the prepared Petri dish.
10. Incubate at the proper temperature and for the appropriate time period.

11. Count the colonies under 10 - 15 X magnification.
12. Confirm the colonies and report the results.

Note: Observe aseptic technique throughout the procedure.
2.5. Water Treatment

2.5.1. Conventional Water Treatment

Water withdrawn directly from rivers, lakes, or reservoirs is rarely clean enough for human consumption if it is not treated to purify it. Even water pumped from underground aquifers often requires some degree of treatment to render it potable, that is, suitable for drinking.

Objectives of Treatment. The object of treatment processes is to remove all undesirable impurities, to the extent where they do not cause any trouble to human health and water is available to the consumers as per health standards. Following may be the objectives.

i. To remove color, dissolved gases, and murkiness of water.

ii. To remove objectionable taste and odor from the water.

iii. To kill the troublesome bacteria.

iv. To estimate the corrosive and tuberculation properties of water. This treatment is essential from pipes and pipe fittings safety point of view.

v. To make water safe for drinking and domestic purposes, and also for various industrial purposes like brewing, dyeing, steam boilers etc.

Surface water supplies generally require more extensive treatment than groundwater supplies do. This is because most streams, rivers, and lakes are contaminated to some extent with domestic sewage and runoff. Even in areas far removed from human activity, surface water contains suspended soil particles (silt and clay) and organics and bacteria (from decaying vegetation and animal wastes.)

The amount of treatment required depends on the

(a) Quantity and quality of raw water, and
(b) Required standards of purified water

A water treatment unit process is defined as an engineered system that employs particular kinds of influences or actions to effect certain intended state changes for the water. Every unit operation aims at the removal of reduction of specific objectionable substances to the desired degree.

The most common type of treatment of surface water includes clarification and disinfection. Clarification is usually accomplished by a combination of coagulation-flocculation, sedimentation, and filtration; the most common method for disinfection used is chlorination. A typical flow diagram that shows the sequence of the individual treatment steps, or unit processes, is shown in Figure below.
Table 9 Functions of water treatment units

<table>
<thead>
<tr>
<th>Unit treatment</th>
<th>Function (removal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration, chemicals use</td>
<td>Color, odor, taste</td>
</tr>
<tr>
<td>Screening</td>
<td>Floating matter</td>
</tr>
<tr>
<td>Chemical methods</td>
<td>Iron, Manganese etc</td>
</tr>
<tr>
<td>Softening</td>
<td>Hardness</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Suspended matter</td>
</tr>
<tr>
<td>Coagulation</td>
<td>Suspended matter, a part of colloidal matter and bacteria</td>
</tr>
<tr>
<td>Filtration</td>
<td>Remaining colloidal dissolved matter, bacteria</td>
</tr>
<tr>
<td>disinfection</td>
<td>Pathogenic bacteria, organic matter and reducing substances</td>
</tr>
</tbody>
</table>

Figure 5 A flow diagram of a typical surface water treatment plant

Screening: Retention of a substance by a screen that has a mesh size smaller than the substance to be retained.

Gravity settling: A particle falling under the influence of gravity is called sedimentation.

Coagulation: Charge neutralization of a negatively charged colloid, usually by chemical means, such as the use of alum or ferric compounds.

Flocculation: A unit process that promotes collisions between particles that attach to each other upon contact, growing in size to increase settling velocity.

Filtration: Convection of a water stream through a porous media with the intent to retain suspended particles within the media.

Gas transfer: Transport of gas between the dissolved phase in water and a gas phase.
**Ion-exchange**: The exchange of benign ions (such as Na\(^+\)) bonded to sites within an ion exchange material such as a zeolite mineral or a synthetic resin) intended to be displaced by an ion targeted for removal (such as Ca\(^{2+}\)) which has a stronger bonding force.

**Adsorption**: The attachment of a molecule to an adsorption site provided by an internal surface of an adsorbent material. Activated carbon is the best known adsorbent for an engineered system.

**Biological treatment**: A reaction between an organic molecule and a microorganism.

**Disinfection**: Inactivation of microorganisms.

**Water treatment process selection**
Water treatment process selection is a complex task. Circumstances are likely to be different for each water utility and perhaps may be different for each source used by one utility. Selection of one or more water treatment processes to be used at a given location is influenced by the necessity to meet regulatory quality goals, the desire of the utility and its customers to meet other water quality goals (such as aesthetics), and the need to provide water service at the lowest reasonable cost. Factors that should be included in decisions on water treatment processes include: Contaminant removal, Source water quality, Reliability, Existing conditions, Process flexibility, Utility capabilities, Costs, Environmental compatibility, Distribution system water quality and Issues of process scale.

2.5.1.1. **Preliminary treatment processes**
1. **Pumping and containment** - The majority of water must be pumped from its source or directed into pipes or holding tanks. To avoid adding contaminants to the water, this physical infrastructure must be made from appropriate materials and constructed so that accidental contamination does not occur.
2. **Screening** - The first step in purifying surface water is to remove large debris such as sticks, leaves, trash and other large particles which may interfere with subsequent purification steps. Most deep groundwater does not need screening before other purification steps.
3. **Storage** - Water from rivers may also be stored in reservoirs for periods between a few days and many months to allow natural biological purification to take place. This is especially important if treatment is by slow sand filters. Storage reservoirs also provide a buffer against short periods of drought or to allow water supply to be maintained during transitory pollution incidents in the source river.
4. **Pre-conditioning** - Many waters rich in hardness salts are treated with soda-ash (Sodium carbonate) to precipitate calcium carbonate out utilising the common ion effect.
5. **Pre-chlorination** - In many plants the incoming water was chlorinated to minimise the growth of fouling organisms on the pipe-work and tanks. Because of the potential adverse quality effects, this has largely been discontinued.

6. **PH adjustment** - Distilled water has an average pH of 7 (neither alkaline nor acidic) and sea water has an average pH of 8.3 (slightly alkaline). If the water is acidic (lower than 7), lime or soda ash is added to raise the pH. Lime is the more common of the two additives because it is cheap, but it also adds to the resulting water hardness. Making the water slightly alkaline ensures that coagulation and flocculation processes work effectively and also helps to minimize the risk of lead being dissolved from lead pipes and lead solder in pipe fittings.

2.5.1.2. **Primary water treatment processes**

**Sedimentation:** Sedimentation is removal of particulate materials suspended in water by quiescent settling due to gravity. It is a commonly used unit operation in water and wastewater treatment plants.

**Water Treatment:** Plain Sedimentation, Sedimentation after Flocculation and Sedimentation after Softening

**Wastewater Treatment:** Grit Removal, Primary Sedimentation and Biomass Sedimentation

**Types of sedimentation:** - Four types of sedimentation depending on the degree of interaction between settling particles can be identified.

1. Type I: Discrete particle settling (The most common in water treatment)
   - No interaction between particles
   - Settling velocity is constant for individual particles
   - Dilute solid’s concentration
   - Examples: presedimentation in water treatment, grit removal in wastewater

2. Type II: Flocculent settling
   - Particles collide and adhere to each other resulting in particle growth
   - Dilute solid’s concentration
   - Examples: coagulation/flocculation settling in water treatment and primary sedimentation in wastewater treatment

3. Type III: Hindered or zone settling
   - Particles are so close together movement is restricted
   - Intermediate solids concentration
   - Solids move as a block rather than individual particles
   - Fluidic interference causes a reduction in settling velocity
   - Distinguishable solids liquid interface
   - Intermediate solids concentration
Example: settling of secondary effluents

4. Type IV: Compression settling
   ➢ Particles physically in contact
   ➢ Water is squeezed out of interstitial spaces
   ➢ Volume of solids may decrease
   ➢ High concentration of solids (sludge)

Settling tanks (or) sedimentation tanks
The principle involved in these tanks is reduction of velocity of flow so that the particles settle during the detention period. Such tanks are classified into,

(i) fill and draw types tanks (batch-process),
(ii) Continuous flow tanks.

<table>
<thead>
<tr>
<th>Depending on theory shape</th>
<th>Depending on the direction of flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular, Rectangular, and Square.</td>
<td>Horizontal flow—longitudinal, radial flow</td>
</tr>
<tr>
<td></td>
<td>Vertical flow—circular (upward flow)</td>
</tr>
</tbody>
</table>

For water treatment, continuous circular or rectangular, horizontal flow type tanks are commonly used.

Detention time. This is the theoretical time that the water is detained in a settling basin. It is calculated as the volume of the tank divided by the rate of flow, and is denoted as $\theta = V/Q$.

Coagulation and Flocculation
Coagulation: the objective of coagulation (subsequently flocculation) is to turn the small particles of color, turbidity, and bacteria into larger flocs, either as precipitates of suspended particles. The term coagulation comes from the Latin word coagulare, meaning to drive together.

Coagulation is a chemical process in which charged particles (colloids) are destabilized.

Coagulants
A coagulant is the substance (chemical) that is added to the water to accomplish coagulation. There are three key properties of a coagulant:

1. Trivalent cation. most efficient cation
2. Nontoxic. For production of safe water
3. Insoluble in neutral pH range. So that coagulants added can precipitate without leaving high concentration of ions in water.

Selection of the proper coagulant depends upon: 1) the characteristics of the coagulant, 2) particulates, 3) water quality, 4) cost, and 5) dewatering characteristics of the solids that are produced. The selected coagulant should be non-toxic and relatively inexpensive. It should also be insoluble in neutral pH range and do not leave high concentrations of metals in the treated water.
Commonly used coagulants are:

- **Alum**: $\text{Al}_2(\text{SO}_4)_3.14\text{H}_2\text{O}$
- **Ferric chloride**: $\text{FeCl}_3$
- **Ferric sulfate**: $\text{FeSO}_4$
- **Polyelectrolytes (Polymers)**

**Flocculation**: This term is derived from the Latin word flocculare, meaning to 'form a floc'. *Flocculation* is stimulation by mechanical means to agglomerate destabilized particles into compact, fast settleable particles (or flocs). The objective of flocculation is to bring the particles into contact so that they will collide, stick together, and grow to a size that will readily settle. The flocculation process relies on turbulence to promote collisions. Velocity gradients are also a convenient way of measuring this turbulence. Time is an important factor, and the design parameter for flocculation is $G_t$, a dimensionless number. The velocity gradient must be controlled within a relatively narrow range in order to get good floc formation and not to shear of already formed flocs. The heavier the floc and the higher the suspended solids concentration, the more mixing is required to keep the floc in suspension.

**Filtration**: About 5 percent of the suspended solids may still remain as nonsettleable floc particles. These remaining flocs can cause noticeable turbidity and may shield microorganisms from the subsequent disinfection process. To produce a crystal clear potable water an additional treatment step following coagulation and sedimentation is needed.

Filtration involves the removal of suspended particles from the water by passing it through a layer or bed of a porous granular material, such as sand. As the water flows through the filter bed, the suspended particles become trapped within the pore spaces of the filter material, or filter media, as it is called. This is shown schematically in Figure below.

![Figure 6](image)

*Figure 6 (a) Schematic diagram of the filtration process, (b) Schematic diagram of the backwash or cleaning cycle of a rapid filter.*
Filters are classified as follows

Classification of filters:

<table>
<thead>
<tr>
<th>Based on the filter media</th>
<th>Based on the depth of filter media</th>
<th>Based on the rate of filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sand filters, e.g. natural silica sand</td>
<td>• Deep granular filters, e.g. Sand, dual-media and multi-media (combination of two or more media), granular activated carbon</td>
<td>Gravity filters</td>
</tr>
<tr>
<td>• Anthracite filters, e.g. crushed anthracitic coal</td>
<td>• Pre coat filters, e.g. diatomaceous earth, and powdered activated carbon, filters</td>
<td>(i) slow sand filters</td>
</tr>
<tr>
<td>• Diatomaceous earth filters, e.g. diatomaceous earth</td>
<td></td>
<td>(ii) rapid sand filters</td>
</tr>
<tr>
<td>• Metal fabric filters (micro strainers), e.g. stainless steel fabric filter</td>
<td></td>
<td>(iii) high-rate sand filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pressure filters.</td>
</tr>
</tbody>
</table>

Rate of filtration (loading rate) is the flow rate of water applied per unit area of the filter. It is the velocity of the water approaching the face of the filter:

\[
\text{loading rate} = \frac{Q}{A} = \frac{\text{flow rate onto filter surface}}{\text{surface area of filter}} = \frac{\text{m}^3/\text{d}}{\text{m}^2}
\]

Where \( v_A \) = face velocity, \( \text{m}/\text{d} \) = loading rate, \( \text{m}^3/\text{d.m}^2 \)

\( Q \) = flow rate onto filter surface, \( \text{m}^3/\text{d} \)

\( A \) = surface area of filter, \( \text{m}^2 \)

**Mechanism of Filtration**

Even though the theory of filtration is quite complex, it basically involves, transport mechanisms, and attachment mechanisms.

The transport mechanism brings small particles from the bulk solution to the surface of the media. It involves the processes of (a) gravitational settling, (b) diffusion, (c) interception and (d) hydrodynamics.

These are affected by physical characteristics such as size of the filter medium, filtration rate, fluid temperature, size and density of suspended solids. As the particles reach the surface of the filter media, an attachment mechanism is required to retain it. This occurs due to (i) electrostatic interactions (ii) chemical bridging or specific adsorption.

1. **Straining** – particles larger than the pore size of the filtering medium are retained or strained out mechanically. Particles smaller than the pore size are trapped by chance of contact.
2. **Inertial Impaction** – Inertial impaction occurs when the particles with high inertia follow a streamline, but when approaches the medium its trajectory departs from the fluid stream around the medium and attach to the medium.

3. **Sedimentation** – The pores of the filtering medium act as a tiny sedimentation chamber and hence particles settle.

4. **Interception** – Direct interception takes place when the particles with less inertia and almost follows the stream lines around the medium (obstacle). The particles clear the obstacle but their outer peripheries come in contact with the medium.

5. **Adhesion** – flocculant particles become attached to the surface of the filtering medium as they pass by. Some particles may be taken deep into bed due to the force of the flowing water when the particles are not firmly attached to the filtering medium.

6. **Flocculation** – conditions within the pores of a filter bed promote flocculation. Flocs thus grow in size and become trapped in the interstices.

7. **Biological growth** – The surface layer of a sand bed gets coated with a zoogloeaal film which feeds on the organic impurities (bacteria and organic matters), converting them into simple harmless compounds and thus purifying the water.

8. **Electrolytic changes** – The sand particles of filter media and the particles of suspended and dissolved matter, carry electrical charges of opposite nature. Because of having opposite charges, they attract each other and neutralize the charges of each other. This results in the change of chemical characteristics of water.

**Slow Sand Filters:** Slow sand filters were first introduced in the 1800s. In slow sand filters water is allowed at a slow rate through a bed of sand, so that coarse suspended solids are retained on or near the surface of the bed. The water is applied to the sand at a loading rate of 2.9 to 7.6 m³/d.m². As the suspended or colloidal material is applied to the sand, the particles begin to collect in the top 75 mm and to clog the pore spaces. As the pores become clogged, water will no longer pass through the sand. At this point the top layer of sand is scrapped off, cleaned, and replaced. Slow sand filters require large areas of land and are operator intensive. The raw water turbidity has be also less than 50 NTU.

The filtering action of a slow sand filter is a combination of straining, adsorption, and biological flocculation. Gelatinous slimes of bacterial growth called ‘schmutzdecke’ form on the surface and in the upper sand layer. This layer consists of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae. This layer breaks down organic particles in the water biologically, and is also very effective in straining out even very small inorganic particles from water. The underlying sand provides the support medium for this biological treatment layer. Slow sand filters slowly lose their performance as the Schmutzdecke grows and thereby reduces the rate of flow through the filter. Eventually it is necessary to refurbish the filter. Two methods are commonly used to do this. In the first, the top few millimetres of fine sand is very carefully scraped off using mechanical plant and this exposes a new layer of clean sand. Water is then decanted back into the filter and re-circulated for a few hours to allow a new Schmutzdecke to
develop. The filter is then filled to full depth and brought back into service. The second method, sometimes called wet harrowing, involves lowering the water level to just above the *Schmutzdecke*, stirring the sand and thereby suspending any solids held in that layer and then running the water to waste. The filter is then filled to full depth and brought back into service. Wet harrowing can allow the filter to be brought back into service more quickly.

![Figure 7 Typical Slow Sand Filter](image)

**Advantages** | **Disadvantages**
--- | ---
Simple to construct and supervise | Large area is required
Suitable where sand is readily available | Unsuitable for treating highly turbid waters
Effective in bacterial removal | Less flexible in operation due to seasonal variations in raw water quality
Preferable for uniform quality of treated water

**Rapid Sand Filters:** The most common type of filter for treating municipal water supplies is the rapid sand filter. Water passes downwards through the filter media and the filters are cleaned by backwashing. As the name implies, the water flows through the filter bed much faster (about 100 times as fast) than it flows through the slow sand filter.

During filtration, the water flows downward through the bed under the force of gravity. When the filter is washed, clean water is forced upward, expanding the filter bed slightly and carrying away the accumulated impurities. This process is called backwashing. Cleaning by backwash operation is a key characteristic of a rapid filter.

**Advantages** | **Disadvantages**
--- | ---
Turbid water may be treated | Requires skilled personnel for operation and maintenance
Land required is less compared to slow sand filter | Less effective in bacteria removal
Operation is continuous.
Many rapid filters currently in operation use sand as the filter media, but the sand grains (and pore spaces) are larger than those in the older, sand filters. In a rapid sand filter, the effective size of the sand is about 0.5 mm and the uniformity coefficient is about 1.5.

2.5.1.3. Secondary treatment processes

Disinfection: Disinfection is the process of killing all pathogens. Safe water means water (a) free from pathogenic bacteria, (b) aesthetically acceptable, and (c) free from excessive minerals, and poisonous matter. Pathogens die away or are destroyed in significant numbers in the course of treatment. The purpose of disinfection is to kill and pathogens remaining after conventional treatment. The substance used for disinfection is called disinfectant. When a disinfectant is added to water, it reacts chemically and products are released. They attack the cell of the pathogen and inactivate the cell. Pathogens found in water supplies include viruses, bacteria, and protozoa (including cysts). Disinfectants must effectively reduce all types of pathogens without being toxic to humans or domestic animals. Additionally, it must not drastically change the taste or color of water and it must be persistent.

Factors affecting the efficiency of disinfection

1. Nature and concentration of organisms
2. Nature and concentration of disinfectant
3. Nature of water to be disinfected (interfering substances like NH3, iron, Mn, organic matter)
4. Temperature of water
5. Time of contact

Disinfection methods include:

- Heat
- Mechanical (ultrasonic vibration, membrane filtration)
- Radiation (Gamma, Ultraviolet radiation)
- Chemical
  - Halogens (chlorine, bromine, iodine)
  - Chlorine dioxide (ClO2)
  - Chloramines (C1NH2, Cl2NH, Cl3N)
  - Ozone

The kinetics of disinfection depends on the following

1. Time of contact
2. Concentration of disinfectant
3. Concentration of organisms
4. Temperature of water
**Chlorination**

Chlorine is the most commonly used disinfectant. The chlorine dosage required is a function of the water's organic content (including the microorganisms) and the water's reduced inorganic content. Reduced inorganics include species such as Fe$^{2+}$, Mn$^{2+}$, NH$_3$, etc. which will be oxidized by chlorine.

Chlorine is added to the water supply in two ways. It is most often added as a gas, Cl$_2$(g), generated from the vaporization liquid chlorine. However, it also can be added as a salt, such as sodium hypochlorite (NaOCl) or bleach.

**Breakpoint Reaction.** When excess free chlorine is added beyond the 1:1 initial molar ratio, monochloramine is removed as follows:

\[
2\text{NH}_2\text{Cl} + \text{HOCl} \rightarrow \text{N}_2(g) + 3\text{H}^+ + 3\text{Cl}^- + \text{H}_2\text{O}
\]

The formation of chloramines and the breakpoint reaction create a unique relationship between chlorine dose and the amount and form of chlorine as illustrated below.

**Chlorine demand:** The difference between the amount of chlorine added to water and the amount of residual chlorine after a specified contact period is defined as the chlorine demand.

**Chlorination Practice**

- Required application rate is site specific.
- Need to establish a combined residual after a reasonable contact time in the plant and with no detectable indicator organism concentration.
- Common dosage range for breakpoint is 4 to 10 mg/L as Cl$_2$.
- Common contact times 10 to 20 minutes.
- Total combined residual leaving the plant 0.5 to 2.0 mg/L.
- Maintain residual sufficient to ensure 0.2 mg/L free residual available at the farthest points in the distribution system.
- Chlorine to ammonia weight ratios for chloramine formation 3:1 to 4:1. Points of chlorination
- Pre-chlorination: It is the application of chlorine to water prior to any unit treatment process.
- Post chlorination: This is the application of chlorine to treated water before it enters the distribution system.
- Re-chlorination: This occurs when the distribution system is long and complex, post-chlorination dosages are not sufficient to get required Cl₂ residuals at consumer's end. So, stage-wise application of chlorine is distribution system is carried out and is called re-chlorination.

2.5.1.4. Tertiary treatment units

**Softening:** Softening is the removal of hardness from water. It can be achieved by lime-soda softening or ion exchange. Hard water is usually defined as water which contains a high concentration of calcium and magnesium ions. Measurements of hardness are given in terms of the calcium carbonate equivalent, which is an expression of the concentration of hardness ions in water in terms of their equivalent value of calcium carbonate (Table 9).

<table>
<thead>
<tr>
<th>Mg/L as CaCO₃</th>
<th>Degree of hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-75</td>
<td>Soft</td>
</tr>
<tr>
<td>75-150</td>
<td>Moderately hard</td>
</tr>
<tr>
<td>150-300</td>
<td>Hard</td>
</tr>
<tr>
<td>&gt; 300</td>
<td>Very hard</td>
</tr>
</tbody>
</table>

Table 10 Degree of Hardness

Water softening is needed when hardness is above 150-200 mg/L; hardness 50-80 is acceptable in treated water. Hardness is a problem because it interferes with soaps and detergents and leaves a white crusty scale around faucets.

**Softening methods**
1. Boiling
2. Lime treatment
3. Lime-soda process
4. Ion-exchange method

2.5.2. Homemade Water Treatment

The water sources used for supplying water were not always clean. Household water treatment can help improve water quality at the point of consumption, especially when drinking-water sources are distant, unreliable or unsafe. However, household water treatment should be viewed primarily as a stop gap measure only; it does not replace the obligation of a service
provider to provide access to safe drinking water. It is intended for people who have no access to improved drinking-water sources, for people with access to improved sources outside of their home or premises (i.e. when contamination can occur during transport and storage), for people with unreliable piped supplies who have to store water to bridge the gaps between deliveries, and for people in emergency situations (WHO and UNICEF, 2014). The following household level water treatment systems will be addressed in this training.

- Disinfection: making sure water is free from disease causing germs. This may be done by chemicals, heat, or even sunlight.
- Sedimentation: allowing dirt to fall/settle to the bottom of a water container over time.
- Filtration: physically removing dirt by passing the water through a material such as ceramic or sand.

Is household water treatment safe?

- Specific safety concerns are included in each section. Generally speaking, the methods and products outlined in this manual are safe. However, care should be taken whenever chemicals are in use, especially with children.

Methods for household water treatment

Straining (Cloth Filtration)

Straining water is an important first step that, if done correctly, will improve the effectiveness of all the methods mentioned in this manual. Pouring muddy or dirty looking water through a piece of fine, clean cotton cloth will often remove a certain amount of the suspended solids and insect larvae contained in the water. A simple test to determine whether the cloth is adequate is to use it to filter the water.

If the dirt does not pass through the cloth, then it is working correctly. A cotton cloth works best and you should not be able to see through the cloth. On the other hand, the cloth should not be so thick that it takes a very long time to filter the water. Washing the cloth between uses will make straining more effective. Straining alone is unlikely to make water from a contaminated source completely safe to drink. But it makes household water treatment easier.

Disinfection

Disinfection can often affect the taste of water.

- Boiling will leave the water tasting flat.
- Solar will make the water hot.
- Chemicals can leave a bad taste.
All of these problems can be overcome by simple methods. It is important to talk to people who are using these methods about this to make sure they do not abandon clean water for an unsafe source or stop treating the water they collect.

**Boiling**

Boiling is a traditional method of treating water. If done properly it can provide safe water to a population that has no alternatives. Boiling has positive and negative aspects.

- Boiling will kill all germs that cause disease
- Boiling water is something people can do themselves
- It takes one kilogram of firewood to boil one litre of water for one minute. Boiling should not be promoted in areas where wood is scarce and no other heating options are available.
- Boiling will not make water less cloudy.

- Boiling has no residual effect, so improper storage can lead to re-contamination. Boiled water should be stored safely and used within a few days. Boiling is only effective if the temperature is high enough. Water that is simply steaming has not been boiled.
- For boiling to work, water must be brought to a rolling, bubbling boil.

**Solar disinfection**

Exposing water to sunlight will destroy most germs that cause disease. This is even more effective at higher temperature (although the temperature of the water does not need to rise much above 50°C). One easy method of treating the water is to expose plastic or glass bottles of water to the sun. In tropical regions, a safe exposure period is about five hours, centered on midday. The amount of time the bottle is exposed to the sun will need to be doubled (two days instead of one) when the water is cloudy. The exposure time should also be increased if there is not sunny weather (rainy season).
How do we use solar disinfection?
This method, also known as the SODIS system, uses clear plastic or glass bottles to increase the temperature of the water by placing it direct sunlight. For greater effectiveness place the bottle on a corrugated-iron roof. The water can also be held in a clean and clear plastic bag if a bottle is not available.

Solar disinfection has positive and negative aspects.
- Solar disinfection will kill most germs that cause disease if exposed to the sun long enough.
- Solar disinfection is something people can do themselves with widely available materials (clear bottles or clear plastic bags).
- Solar disinfection has no residual effect, so improper storage can lead to re-contamination. Water treated by this method should be stored safely and used within a few days.
- Solar disinfection takes more time than other methods and requires sunny weather.

Tips:
To speed the process, fill the bottle three-quarters full and vigorously shake it. Then fill the bottle and expose it to sunlight. Further sporadic shaking during exposure will also

Chemical help disinfection:
- People are unlikely to want to drink the warm, treated water. Encourage them to let it cool.
- There are many chemicals capable of disinfecting water. These chemicals often vary in their effectiveness and safety. Chlorine is the common chemical disinfectant of choice and available in different phases and concentration
- Toxic to consumers if the dose is higher
- Chlorination by products can also result in cancer if organic matter is high (turbid) Consult the environmental health offices in your district if you want to apply chlorine for disinfection.
How to treat water with chlorine tablets?

Care should always be taken when working with chemicals. Do not allow the chemicals to come into contact with the eyes. Chemicals should be stored out of reach from children in a dry place out of direct sunlight.

Chemical disinfection has positive and negative aspects

- These products are easy and safe to use.
- There is a residual effect of disinfection, which gives some protection against contamination after treatment.
- These products must be brought from outside the community; it is not something they can do with local resources.
- Chemical disinfection will not get rid of all germs that cause disease. Water should be strained prior to use of chemical disinfection in order to ensure all risks are eliminated.

Tips:

- Chemical disinfection is not as efficient when used with dirty or cloudy water. If the water looks dirty or cloudy, use a double dose of chemical.
- Chemical disinfection, especially a double dose, can leave a taste that people do not like. This could cause them to stop treating water. The problem of chemical taste can be removed by using the correct amount of chemical and by shaking the water in a bottle to increase the air content.
- Talk to people about the product. Is it easy to use? How is the taste? A different product may be needed.
Leaving a container open and exposing it to heat (direct sunlight for example) will reduce the ability of the chemical to protect against contamination. Encourage people to keep water covered and out of direct sunlight whenever possible.

**Sedimentation**
If water is muddy, giving it time to settle or adding chemicals can cause the dirt to fall to the bottom of the container and make the water clear.

Straining the water through a cloth can make this process more efficient. Note: Water that has been made clear by sedimentation is not clean. It still needs disinfection to remove germs that cause disease. But making dirty water clear will make disinfection more effective.

**Three pot method**
The three pot method reduces dirt and germs that cause disease by storing water in containers, allowing dirt to settle, and moving cleaner water to different containers over time.

Each day when new water is brought to the house:
A Drink water from pot 3.
B Slowly pour water stored in pot 2 into pot 3.
C Wash out pot 2.
D Slowly pour water stored in pot 1 into pot 2.
E Wash out pot 1.
F Pour water collected from the source (bucket 4) into pot 1. Strain through a cloth if possible. Allow the water to settle for a day and then repeat the process.

Only drink water from Pot 3. This water has been stored for at least 2 days, and the quality has improved. Periodically this pot will be washed out and may be sterilized by scalding with boiling water. Using a flexible tube to siphon water from one pot to another disturbs the water less than pouring.
**Tips:**

- This method can be improved by using a straining cloth when pouring into the pots. The three pot method is a good interim measure that can be adopted in an emergency until mass distribution of other methods is possible or the quality of the source is improved.
- In an emergency, people may not have three containers. Although it is likely to be less effective than the method described above, two containers can be utilized instead of

The three pot method has positive and negative aspects.

- The three pot system greatly reduces dirt and disease causing germs in water.
- This method is low cost, easy to use, and is something people can do themselves with local resources.
- This method reduces, but does not totally remove, disease causing germs. Boiling, chemical, or solar disinfection is still needed to completely remove all risk of disease.

**Chemical sedimentation**

Chemical sedimentation is the use of chemicals to speed up the removal of dirt from water. The two most common chemical sedimentation products used are PUR and Watermaker. These chemicals are useful, especially in floods, because they remove dirt from water AND disinfect. Both are suitable for household water treatment in emergencies.

These products contain two chemicals. One chemical acts like a glue and makes small particles stick together. This creates bigger particles, called floc, that fall to the bottom of the container faster. Then another chemical disinfects the clear water, similar to the chemical disinfection described earlier in this manual. These products are more expensive and difficult to use than other methods. If water is 1) clear or only slightly cloudy and 2) chemical disinfection is available, then do not use chemical sedimentation. One sachet of PUR treats 10 litres of water. Watermaker is available in different sized packets which treat different amounts of water. Check the instructions on the package before teaching people how to use it.
Tips:

- Chemical sedimentation has positive and negative aspects.
- These products can make muddy water safe to drink.
- There is a residual effect of disinfection, which gives protection against contamination after treatment.
- These products are more complicated to use and require more training and follow up. These products are significantly more expensive per litre of water treated than chemical disinfection products and should only be used when water is muddy or no other product is available.
- People will need more than one container to properly use these chemicals.

Filtration (Simple household filters)

There are many different types of household filter, some produced commercially and others that can be manufactured locally. Most will remove a high proportion of solids and silt. Many will also remove parasites including cysts, ova, and guinea worm larvae, but some simple filters may not remove all microorganisms from water. The various types of simple household filter are sand filters, candle filters and stone filters.
Homemade sand Filters
This not only removes large particles (ova, larvae, cysts, and Cyclops species) but also removes or kills much smaller organisms, including viruses and bacteria.

A simple water filter made from local resources primarily sand, gravel and cement/barrel remove over 90% of many common water-borne pathogens. Because bacteria and viruses are not completely removed, additional treatment such as disinfection (usually with chlorine) may be desirable after filtration.

Through community-based training several countries, including Kenya, Uganda, Zambia and Sudan, some groups have even started using the filters to generate income from sales of clean water. Therefore, it is possible to do so in Ethiopia too.

Candle filters:
Candle filters are often commercially produced. In this type of filter, contaminated water is allowed to filter slowly through a porous ceramic material. Larger microorganisms - ova, cysts, and most bacteria - are left in the outer layer of the filter material, which is periodically cleaned by gently scrubbing the filter under clean, running water. Smaller microorganisms, such as the virus that causes hepatitis A, may not be removed by candle filters. This might be higher in terms of cost but you can still suggest for households who can afford it.

Candle filters are made of ceramic. Water is poured into one container and slowly passes through the ceramic into another container. Candle filters have positive and negative aspects.
These products are easy and safe to use.

- If properly maintained, this product can be used to produce clean water for a long time. These products are expensive and often fragile.
- It can take a great deal of time to treat water, especially when the water is very dirty.
- There is no residual effect of disinfection, the clean water container must be covered to protect against contamination.
- These products need regular maintenance and require more training and follow up.

**Bio sand filters**

Although they are not commonly used, biosand filters are an effective and long lasting method of household water treatment. Biosand filters filter water through the sand AND the biological material that grows on the top of the filter.

- The filter is cleaned when it becomes clogged.
- Because the biological layer needs time to grow, the filter will not treat water properly when it is first put into use and after cleanings. Although these filters are simple to use, they require hands on training when they are distributed. Details on construction and maintenance of these filters can be found in Additional resources.
- If properly maintained, this filter can treat water for a long time
- It can take a great deal of time to treat water, especially when the water is very dirty.
- There is no residual effect of disinfection, the clean water container must be covered to protect against contamination.
- These filters need regular maintenance and require more training and follow up.
2.5.3. Disinfecting Water Storage tanks

It is necessary to prepare a proper water storage tanks and tankers at different level. This water tanks and tankers used permanently or for a short period of time should regularly be cleaned and disinfected in order to avoid any microbial contamination. There are several reasons to clean and disinfect water storage tanks regularly including: to kill or prevent the survival of waterborne pathogens (bacteria, viruses, and other microorganisms) that can cause gastrointestinal and other diseases; to prevent the accumulation of scale and slime (biofilm), which can be sources of contaminants and can also harbor pathogens; and to control the accumulation of sediments and algal growth, which degrade the taste and odor of potable water.

Step 1: Select the tanks to use

Tanks should be selected based on three considerations: normal use; ease of cleaning and water storage hygiene. Selected tanks should only have been used for holding food-grade liquids, for example, milk, cooking oils, fruit juices, wines and spirits or vinegar. Tanks previously used for holding nonfood-grade liquids such as fuel and sewage should not be used. Tanks that previously held water but have been out of use for some time must also be cleaned and disinfected as described below under Steps 2 and 3. Tanks must be easy to clean. This means they must be accessible for cleaning and have no sharp corners that may hold dirt and so prevent the removal of food deposits. Water will only remain clean if stored safely. Tanks must therefore be covered and fitted with an access point with a lockable lid.

Step 2: Cleaning Empty the tank

Open the outlet valve or tap and drain out any remaining liquid. Collect the liquids so that they can be safely disposed of (see Step 4). In the case of tankers, outlet valves are usually located at the back so parking it on a slope will help to ensure that all the liquid can be discharged (see Figure 3.2 overleaf). Permanent storage tanks are usually fitted with a washout valve that draws liquid from the base. Use this, rather than the normal outlet valve, for emptying.

Scrub the internal surfaces of the tank: Use a mixture of detergent and hot water (household laundry soap powder will do) to scrub and clean all internal surfaces of the tank. This can be done with a stiff brush or a high pressure jet. Attaching the brush to a long pole may make it possible to clean the tank without entering it. Take special care to clean corners and joints so that no small amounts of the original liquid remain. Even minute amounts of some liquids can give the water a bad taste and people will refuse to drink it. Leave the outlet valve open while cleaning and collect the liquid for safe disposal.

Wash and flush the tank: This is most easily done with a high pressure hose pipe or water jet but if they are not available the tank can be filled with (preferably hot) water and left to stand for a few hours. Drain all the water from the tank and collect for safe disposal as before. Continue flushing the tank until there are no longer traces of detergent in the water.
Step 3: Disinfection
The most common way of disinfecting a water tank is by chlorination. Chlorine is delivered in a variety of ways but the most common is high-strength calcium hypochlorite (HSCH), which, when mixed with water, liberates 60 to 80% of its volume as chlorine.

Calculate the volume of the tank the amount of chlorine needed to disinfect the water tank will depend on its volume.

Add the disinfectant: Fill the tank a quarter full with clean water. Sprinkle 80 grams of granular HSCH into the tank for every 1000 litres total capacity of the tank. Fill the tank completely with clean water, close the lid and leave to stand for 24 hours. If the tank is required for use urgently, double the quantity of chlorine added to the tank. This will reduce the time of disinfection from 24 to 8 hours.

Prepare for use: Completely empty the tank and carefully dispose of the disinfecting water as it will contain a high concentration of chlorine. Fill the tank with drinking-water, allow to stand for about 30 minutes then empty the tank again. The tank is now ready for use.

### Dosage of Unscented Household bleach

<table>
<thead>
<tr>
<th>TANK SIZE</th>
<th>HOUSEHOLD BLEACH LITRES (L)</th>
<th>HOUSEHOLD BLEACH CUPS (250mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>450</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>900</td>
<td>0.9</td>
<td>4</td>
</tr>
<tr>
<td>1150</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td>2300</td>
<td>2.3</td>
<td>10</td>
</tr>
<tr>
<td>4500</td>
<td>4.5</td>
<td>20</td>
</tr>
<tr>
<td>6800</td>
<td>6.8</td>
<td>30</td>
</tr>
<tr>
<td>9000</td>
<td>9.1</td>
<td>40</td>
</tr>
<tr>
<td>11400</td>
<td>11.5</td>
<td>50</td>
</tr>
</tbody>
</table>

(5-6% Sodium hypochlorite) for disinfecting water storage tanks
2.5.4. Household water storage

The principal health risk associated with household water storage is the ease of recontamination during transport and storage, particularly where the members of a family or community do not all follow good hygiene practice. Good hygienic measures include the following:

- Careful storage of household water and regular cleaning of all household water-storage facilities;
- Construction, proper use, and maintenance of latrines;
- Regular hand-washing, especially after defecation and before eating or preparing food; careful storage and preparation of food.

Water that is clean from the supply or has been treated in the household needs to be protected from recontamination. The following precautions and considerations are important:

Location of storage vessel: The storage vessel should be placed above ground level to restrict access by children and animals. It should preferably be placed in a shaded position to keep the water cool, and should be accessible to users and for refilling.

Design of storage vessel: The storage vessel should be designed to reduce the risk of contamination: it should have a secure, tight-fitting lid, be robust enough to withstand rough handling without cracking, and be easy to lift from the ground and carry back to the storage point after filling. Stored water may be kept cool by using earthenware jars or pots; these allow some water to evaporate, which has a cooling effect. Containers should be easy to fill and clean, so that contact with hands is minimized.

Removal of water: It should be possible to remove water from the container hygienically, with no contact between hands and the water. Water is commonly withdrawn by means of a cup. This may be acceptable where the cup is not used for any other purpose, is cleaned regularly, and is stored where contamination cannot occur. However, as it is difficult to dip the cup into the water without also putting in the hands, the risk of contamination is still high. It is better to use a ladle that is stored permanently inside the container; this reduces the risk of contamination while the ladle is not in use. However, the ladle should be used only to transfer water to a cup or other vessel. Substances such as petrol, diesel fuel, pesticides, and solvents should not be stored or used near water facilities (sources, catchments, storage tanks, etc.). Containers that have been used for the storage, transport, or handling of these substances should not subsequently be used to store water intended for human consumption, even after thorough cleaning.

The most important elements of water storage can be summarized as follows:

- Use a clean water source or treat the water, either at home or in a storage tank.
- Store water in an earthenware or plastic container with a lid.
- Store the water container at a height that puts it beyond the reach of children and animals.
- Fit a tap to the container for drawing clean water in order to prevent contamination by dirty cups, ladles, or hands.
- Fit a tap to the container for drawing clean water in order to prevent contamination by dirty cups, ladles, or hands.

**Household water treatment technology selection criteria**

There are several criteria that one should take into consideration when deciding which household water treatment technology is most suitable. Some of these include:

1. **Effectiveness**: How well does the technology perform?
2. ** Appropriateness**: How well does the technology fit into people’s daily lives?
3. **Acceptability**: What will people think of the technology?
4. **Cost**: What are the costs for the household?
5. **Implementation**: What is required to get the technology into people’s homes?

**Effectiveness**: Effectiveness is the ability of the technology to provide sufficient water quality and quantity. There should be enough safe drinking-water for a household to meet its basic needs. Criteria that show the technology’s effectiveness include the following:

**Water quality**: Which microbiological, physical and chemical contaminants can be removed by the technology and how much?

**Water quantity**: How much water can be provided every day? And is it sufficient to meet the household’s daily needs?

**Local water source**: Will the technology be able to treat the specific microbiological, physical and chemical contaminants of the local water source? Will it treat water from different sources to the same level?

** Appropriateness**: Some technologies will be more suitable than others depending on the needs and conditions of the community. Answering the following criteria can help to match a technology with a particular community:

**Local availability**

- Can the technology be manufactured in or near the community using local materials and labour?
- Does the technology need imported spare parts or consumables?
- Is it possible to buy spare parts or consumables locally?
- Is the supply chain reliable?
Time
- How long does it take for a household to treat enough water to meet their daily needs?
- Does it significantly add to the household’s labour burden?

Operation and maintenance
- What are the household’s responsibilities to operate and maintain the technology?
- Is it easy and convenient for women and children to use the technology?

Life span
- How long will the technology last before it needs to be fixed or replaced?

Acceptability: People’s opinion about the technology will affect its widespread adoption and consistent use. It is difficult for many people to accept a new technology until they personally experience the benefits. People’s acceptance of a technology is affected by the following criteria:

Taste, smell and colour
- How will the treated water look, taste and smell?
- Needs and motivations?
- What benefits will the technology give to people?
- Will it provide convenience, health improvement, social status, and time or money savings?

Cost: Most household water treatment options are not free. Successful cost recovery is an important part of the programme sustainability. The following costs need to be considered:

Capital costs
- Initial purchase of a durable product.
- Transportation.

Ongoing costs
- Continuing purchase of consumable products.
- Operation and maintenance.
- Potential repair and replacement parts

Willingness to pay and affordability
- Can households afford the full cost of the technology?
- Are households willing to pay for capital costs?
- Are households willing to pay for on-going operation and maintenance costs?
- How is technology impacted by household income fluctuations?
Do durable or consumable items need to be subsidized?

**Implementation costs**
- Cost to run the programme (e.g. staff, office space).
- Cost to raise awareness in the community.
- Cost to educate people about how to use the technology.
- Cost to provide ongoing support for households.

**2.6. Operation and Maintenance of Water Treatment and Supply Systems**

**2.6.1. How water utilities are structured**

Water utilities are part of the organizational structure for water supply in towns and cities. In Ethiopia each Woreda has a Council, and each town in the Woreda has its own Town Council. Under each Town Council there is a Town Water Board, and under it is the water utility, which may also be termed the Town Water Supply Enterprise. In some towns the water utility is also responsible for the collection and disposal of sewage, in which case it is referred to as the Town Water Supply and Sewerage Enterprise and reports to the Town Water Supply and Sewerage Board. The water utilities have a duty to provide the water supply (and sewerage services) promptly, at appropriate cost, and with a high quality.

The Town Water Board is a committee made up of individuals who are specialists in water treatment and supply, representatives of other sector offices such as Health and Education, and other **stakeholders** (in this context, representatives of people who would be affected by the water utility’s actions). Importantly, two members of the Board are democratically elected community representatives. At least one of these has to be a woman. The term of office of the Board members is five years. The function of the Board is to ensure the effective performance of the water utility. In particular, it is responsible for ensuring that the water delivered to the public conforms to quality standards. The Board is also responsible for determining the utility’s vision, mission, aims, objectives and values, together with approval and monitoring of the utility’s budget and work programme, recruitment of the utility’s General Manager, and approval of appointment of Heads of Department.
A water utility may have several departments (Figure below):

- The Planning Department plans for the growth in services provided.
- The Commercial and Customer Care Department handles queries and complaints from commercial and domestic customers.
- The Engineering Department is responsible for major engineering works, such as refurbishment or expansion of facilities.
- The Corporate Affairs Department takes care of public relations and communications such as publicity campaigns to encourage efficient use of water.
- The Rural Water Supply Department ensures that water supply is extended to cover the rural population.
- The Operation and Maintenance Department ensures the smooth running of the water treatment and supply system.
- The Water Quality Assurance Department monitors the quality of delivered water to ensure that it is up to standard.
- The Human Resource Management Department looks after the recruitment and training of staff.
- The Finance Department manages the water utility’s budget and makes sure that all financial transactions are recorded, and that revenue is collected for water supplied. Finally, if relevant, the Sewerage Department looks after the sewer network and sewage treatment. (Note that sewage is the water-carried faecal waste from toilets, sewers are the pipes carrying this waste and sewerage refers to the infrastructure that conveys sewage. It encompasses components such as receiving drains, manholes, pumping stations and screens.)
2.6.2. The basics of operation and maintenance

**Operation and maintenance** of a water supply system refers to all the activities needed to run the system continuously to provide the necessary service. The two words are very frequently used together and the abbreviation ‘O&M’ is widely used. The overall aim of operation and maintenance is to ensure an efficient, effective and sustainable system (Castro et al., 2009). ‘Efficient’ means being able to accomplish something with the least waste of time, effort and resources; ‘effective’ means being successful in producing the intended result; and ‘sustainable’ means able to be maintained at the best level over time – in this case, the supply of water.

**Operation**

**Operation** refers to the routine activities and procedures that are implemented to ensure that the water supply system is working efficiently. The activities that contribute to the operation of a water utility are undertaken by technicians and engineers who have responsibility for controlling the functions of the system (Figure below).

![Figure 10: Control panel in a water treatment plant.](image)

The components of the system that they look after, such as the treatment plants, process units and all the equipment and facilities (for example, offices and laboratories) are called the **assets**. For each asset there will be operating guidelines to follow. For instance, a water pump should only be operated for a limited number of hours per day and this must not be exceeded, otherwise it will be exposed to overheating and eventually to failure. The pump should also be run long enough to fill the service reservoir (which you learned about in Study Session 1). If not, there will not be enough water for distribution to customers.

**What are service reservoirs?**

They are reservoirs of water that serve to balance the fluctuating demands of users. They also serve as a back-up supply in case there is a breakdown at the water treatment plant that cuts the production of clean water.
Maintenance

Maintenance (Figure below) refers to planned technical activities or activities carried out in response to a breakdown, to ensure that assets are functioning effectively, and requires skills, tools and spare parts (Carter, 2009). There are two types of maintenance:

Corrective or breakdown maintenance: this is carried out when components fail and stop working. Breakdown is common in many utilities in Ethiopia and occurs as a result of poor preventive maintenance (explained next).

Preventive maintenance: this is a regular, planned activity that takes place so that breakdowns are avoided. Examples of preventive maintenance would include servicing of equipment, inspecting equipment for wear and tear and replacing as necessary, cleaning and greasing moving parts of equipment, and replacing items that have a limited lifespan. Preventive maintenance is important because it ensures that the asset fulfils its service life. It also prevents crises occurring and costly repairs (in terms of time and money) being needed.

Example daily tasks in running a water treatment plant

- Check water meter readings and record water production.
- Check and record water levels in storage tanks.
- Check chemical solution tanks and record amounts used.
- Inspect chemical feed pumps.
- Check and record residual chlorine at the chlorine contact tank and in the distribution system.
- Inspect inlet pumps, motors and controls.
- Record inlet pump running times and pump cycle starts.
- Complete a daily security check.

Example annual tasks in running a water treatment plant: The schedule for these tasks is spread throughout the year with some allocated for January, some for February, etc. so that workload is managed sensibly. Some of these tasks may need to be completed three or four times a year.

- Overhaul chemical feed pumps.
- Inspect and clean chemical feed lines and solution tanks.
- Calibrate chemical feed pumps.
- Operate all valves inside the treatment plant and pump-house. Maintain log continuously throughout the year.
- Review emergency response plans.
- Inspect chemical safety equipment and repair or replace as needed.
- Inspect, clean and repair control panels in pump house and treatment plant.
- Inspect storage tanks for defects and deficiencies, and clean if necessary.
- Flush the distribution system and exercise/check all fire hydrant valves.
Perform preventive maintenance on treatment plant and pump house buildings.

2.6.3. Leakage prevention, detection and control

Although leaks can occur through valves that are malfunctioning, the largest losses of water are through leaks in the water main itself, either where two sections are joined or where there is a defect in the pipe. **Proactive leakage control** (where teams take action to prevent leaks occurring) can bring several benefits. It will mean that more water is available for supply, and it will delay the need for costly expansion programmes. It will also lead to less disruption of traffic and daily life, which happens when a leakage is discovered and has to be fixed. Less infrastructure damage is caused and there is less risk of the mains water becoming contaminated. One way to minimize leaks is to ensure that the water pressure in the distribution system is not excessive. Lowering the system pressure during periods of low water demand can lead to a decrease in leakage loss, and extend the life of pipes (Thompson and Wang, 2009). Another form of proactive leakage management is to replace ageing pipes as they reach the end of their life.

**Detecting leaks in water mains:** Preventing leaks by using corrosion-resistant materials, following the correct procedures for pipe laying, and conducting regular checks and preventive maintenance is the best approach, but inevitably some leaks will still occur. The challenge is to find the leaks, which will probably be underground, and repair them as quickly as possible. This is **active leakage control**.

**Detecting leaks at home:** For homes with a piped water supply, if the water bill suddenly goes up when the circumstances in the home have not changed, it is a sign that perhaps there is a leak in the water system. A way of confirming this is to turn off all the water appliances and observe the water meter. If the dials on it are turning, there is a leak somewhere. It may be possible to hear the hissing noise of water escaping. A search for the source of the sound will reveal the leak. Water-flushed toilet systems can be checked by putting a few drops of food coloring in the water tank of the cistern, and 30 minutes later checking the water in the toilet bowl. If it has color in it, the cistern is leaking.

**Illegal connections:** There are cases in Ethiopia and many other places of people illegally tapping into a water main in order to obtain water without paying for it. The cost of the water they use is borne by others who do pay for the water produced by the utility. Apart from committing a crime (theft of water, thus depriving the water utility of revenue), people who make illegal connections to the water supply system also endanger the safety of the mains water through possible contamination.
2.6.4. Water Safety Plans

What is a Water Safety Plan?

A Water Safety Plan is a plan to ensure the safety of drinking water through a risk assessment and management process that considers all the points in water supply from the catchment to the consumer. It is a means of preventing and managing threats to a drinking water supply system, before anything goes wrong, taking into account all the stages of the supply process from the water catchment to the consumer.

A Water Safety Plan considers all the stages in the supply of water, and therefore it involves:

- Management of the catchment to prevent contamination of the source water
- Removal or elimination of contaminants during treatment of the water
- Prevention of contamination of the water after treatment (during distribution, storage and handling).

Water Safety Plans put the emphasis on controlling risks where they are likely to arise, rather than having a treatment plant deal with cases of contamination after they have occurred. Preventing a problem from occurring is much better than having it occur and then trying to minimize its impact.

![Figure 11 Elements of a water supply system](image-url)
The components of a Water Safety Plan

1. Assemble a team of experts
2. Describe the water supply system
3. Identify the hazards and hazardous events
4. Carry out a risk assessment and prioritise the risks
5. Identify the control measures needed for each risk
6. Define the monitoring system for each control measure
7. Prepare Management Procedures
8. Prepare the verification programme
9. Develop Supporting Programmes
10. Document all of the above

Figure 12 the steps in Water safety plan

Figure 13 a water supply system
Summary of Module 2

- Drinking water must be safe, of adequate quantity, accessible and affordable. Water has several uses of which the most important are for personal consumption and cleanliness, for irrigation, and for industry.
- Unsafe water can seriously harm human health. Infants, young children, older people and people debilitated by disease are the most vulnerable.
- The diseases associated with water can be classified as waterborne, water-washed, water-based and water-related. The causative agents of disease in unsafe water include bacteria, viruses, protozoa and helminths (worms).
- The main illnesses in Ethiopia include diarrhoeal diseases and malaria. Detection of faecal coliform bacteria including E. coli is used to test for the presence of faecal contamination and to indicate the likelihood of the presence of pathogenic organisms in drinking water. Chemical contamination of water can cause health problems. Turbidity, colour, taste and odour are important factors in water being acceptable to people.
- Protected water sources (often called ‘improved’ water sources) are those that have barriers against contaminants and provide water that is safe to drink. Urban areas can obtain water supplies from groundwater, surface water and rainwater. Groundwater sources such as shallow wells, deep wells (boreholes) and springs should be protected against contamination by animals and surface run-off.
- Water pollution is any contamination of water with substances that are detrimental to human, plant or animal health.
- Water pollutants can be of point or non-point source, depending on whether substances are discharged directly into a body of water or indirectly from diffuse sources. Water pollutants include sediments and suspended solids, organic matter, biological pollutants, plant nutrients and chemical pollutants. Biological pollutants include bacteria, viruses, protozoa and helminths. They mainly enter the water through faeces from infected people and animals, and are the cause of many water-related diseases.
- Large-scale water treatment often involves seven stages: Screening, Aeration, Pre-chlorination, Coagulation, flocculation, sedimentation, filtration and disinfection. Sustainability in water treatment is enhanced by using simple processes, locally available materials, regular training of staff, designing for future water demand, using robust equipment and the use of renewable energy.
- Water utilities have many different departments, each with specific responsibilities. The Operation and Maintenance Department is vital for ensuring the continuous supply of good-quality water.
- Life-cycle costing is a means of arriving at an objective decision when considering the purchase of assets.
- Standardization of equipment and spares simplifies stock management, reduces purchase costs, and reduces the range of staff skills required for repairs, thus increasing the chances of more people being able to undertake repairs and maintenance.
- Households may have to collect their own water if there is no water distribution system to take water to individual houses.
- Household water treatment is needed if the safety of the water for human consumption is in any doubt. Removal of suspended particles is the first step in household water treatment.
Module 3: Sanitation

Introduction
This module focuses on the impact of sanitation to human health and life. Excreta related diseases due to lack of sanitation facilities or improper management, Sanitation and disease transmission as well as the international sanitation standards addressed in this module. The mechanisms in which we manage liquid and solid wastes, the different sanitation facilities including sanitation marketing are addressed in different sessions of this module. An introduction to wastewater treatment methods and different sanitation strategies including the national hygiene and sanitation strategy, community led total sanitation and hygiene (CLTSH) are also included in this module.

Learning Outcomes for this Module
After you have studied this Module you should be able to:
- Describe burdens from unimproved sanitation and excreta related diseases
- Evaluate the interactions between Sanitation and disease transmission
- Describe the international standards for sanitation facilities and sanitation marketing
- Explain the different sanitation strategies
- Differentiate the different sanitation strategies to improve sanitation status of a given community
- Demonstrate the different community mobilization approaches for implementing the sanitation strategies that focuses to solve sanitation problems at community level

3.1. Burdens from poor sanitation
3.1.1. Improved and unimproved sanitation
Sanitation and hygiene are critical to health, survival, and development. Sanitation aims to prevent contamination of the environment by excreta and, therefore, to prevent transmission of pathogens that originate in faeces of an infected person.

Many countries are challenged in providing adequate sanitation for their entire populations, leaving people at risk for water, sanitation, and hygiene (WASH)-related diseases.

Access to sanitation is measured by the percentage of the population with access and using improved sanitation facilities.
3.1.2. Excreta Related Diseases

Many human infections are spread through contact with human excreta. Bacteria, viruses, protozoa and parasitic worms cause many diseases that are spread by direct contact with faeces or indirectly via contaminated food and soil. These different types of pathogens or infectious agents are described below. Diseases may also be transmitted through a carrier organism or vector. **Vectors** are organisms that do not cause diseases themselves, but carry or transmit disease-causing agents. For example, mosquitoes carry the protozoa that cause malaria and infect people with the disease through mosquito bites. Other examples of disease vectors are lice, ticks, fleas and rats.

### Main types of infectious agents

- **Bacteria** are very simple microscopic organisms. Some types of bacteria are essential to human life, playing a part in the digestive system. Others have other benefits, such as decomposing wastes. Pathogenic bacteria are responsible for many diseases, including tuberculosis and pneumonia and several waterborne diseases such as typhoid and cholera.

- **Viruses** are not living organisms themselves but are infectious agents able to invade cells and cause them to manufacture more virus material. Polio, HIV/AIDS, influenza and rotavirus are examples of diseases caused by viral infections.

- **Protozoa** are the simplest members of the animal kingdom. They are microscopic, consist of a single cell and are found in water, soil and the sea. Some types are beneficial to humans, breaking down pollutants in water, but others are parasitic, causing diseases including malaria, amoebic dysentery (Figure 2.2) and sleeping sickness.
Parasitic worms live inside the bodies of their human host, usually in the intestines. There are several different types of parasitic worm including tapeworms, flukes and roundworms. Roundworms, also known as nematodes, include Ascaris, hookworm and whipworm. Most worm infections are not fatal, but they do cause long-term debilitating illness. Parasitic worms are sometimes collectively known as helminths. Note however, that there are many types of worm that are not parasitic or harmful in any way. For example, earthworms decompose dead plant matter and improve soil structure and fertility.

Table 11: Health problems associated with poor sanitation and management of wastes.

<table>
<thead>
<tr>
<th>Disease-causing agent</th>
<th>Disease</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>Shigellosis</td>
<td>Causes abdominal pains and diarrhoea (see below).</td>
</tr>
<tr>
<td></td>
<td>Typhoid</td>
<td>Mild to severe fever lasting from a few days to several weeks.</td>
</tr>
<tr>
<td></td>
<td>Cholera</td>
<td>An infection of the intestines that can cause watery diarrhoea leading to dehydration.</td>
</tr>
<tr>
<td></td>
<td>Diarrhoeal diseases</td>
<td>Production of frequent watery faeces that can lead to dehydration. Can be fatal, particularly among young children.</td>
</tr>
<tr>
<td>(note these can also be caused by viruses)</td>
<td>Diarrhoea is a symptom of several other diseases in this table.</td>
<td></td>
</tr>
<tr>
<td>Viruses</td>
<td>Hepatitis A</td>
<td>An infection of the liver that can cause pain, diarrhoea and jaundice.</td>
</tr>
<tr>
<td></td>
<td>Polio</td>
<td>Can cause temporary or permanent muscle weakness, and sometimes death.</td>
</tr>
<tr>
<td>Protozoa</td>
<td>Amoebiasis (also known as amoebic dysentery)</td>
<td>Infection that can occur up to several years after exposure to the protozoa. Can cause mild to severe diarrhea and liver damage.</td>
</tr>
<tr>
<td></td>
<td>Giardiasis</td>
<td>Infection of the small intestine. It is usually symptomless but can have a variety of intestinal symptoms, such as chronic diarrhoea, abdominal cramps, gas production and frequent loose, pale and greasy stools.</td>
</tr>
<tr>
<td>Parasitic worms</td>
<td>Ascariasis (roundworm)</td>
<td>One in four of the world’s population has this infection, which can lead to weight loss, malnutrition and anaemia. It is very common in Ethiopia.</td>
</tr>
<tr>
<td></td>
<td>Hookworm infection</td>
<td>Two species of nematodes that inhabit the small intestine, from where they suck blood, leading to anaemia.</td>
</tr>
<tr>
<td></td>
<td>Tapeworm infection</td>
<td>A worm that normally lives in the intestines which can cause anaemia and malnutrition. This is usually spread through eating improperly cooked food that contains the worm or its eggs.</td>
</tr>
<tr>
<td></td>
<td>Bilharzina or schistosomiasis</td>
<td>A disease caused by the Schistosoma worm that can cause diarrhoea and blood in the urine and faeces. In the long term, it can lead to liver and kidney damage.</td>
</tr>
</tbody>
</table>
3.1.3. Sanitation and Disease Transmission

Most infections occur through the faecal-oral route where pathogens enter a person’s mouth through ingesting (eating or drinking) contaminated food or water, or when contaminated fingers are placed in the mouth. The different transmission routes are shown in Figure below, which is known as the ‘F diagram’. Pathogens contained in faeces enter a new host (a person’s body) through the ‘Fs’ – fluids, fingers, flies or fields/floors. Effective sanitation, clean water and good hygiene behavior provide barriers to this transmission.

**Figure 14: The F diagram showing how diseases can pass from faeces to a new host. Sanitation (using)**

The faeces (on the left of the diagram) comes from an infected person. The new host (on the right of the diagram) could be any man, woman or child who is not currently infected with the disease. Infections can be transmitted from faeces to the new host as follows:

- Infection from fluids usually involves drinking or cooking with water contaminated with faecal organisms.
- In the fingers pathway, a person ingests the organisms (usually during eating) if they have come into contact with faeces and have not washed their hands properly afterwards. This contact can occur from defecation, from cleaning a child’s bottom, from touching dirty surfaces or eating food prepared in an unhygienic manner.
- Flies and cockroaches often thrive on excreta. If they land on food they can transfer faecal matter that can be subsequently ingested by a person.
- Field (or soil) infection can occur by the ingestion of unwashed raw vegetables and fruit grown in soil contaminated with faeces. Contaminated soil may be transported by feet or shoes for long distances. Infections can also be transmitted through dirty floors, perhaps if food is dropped on the floor and then picked up and eaten.

- Name two vectors involved in faecal-oral disease transmission.
• Flies and cockroaches are two examples of vectors that can carry pathogens from faeces on to food that is then eaten.

3.2. Standards and Strategies for Sanitation

3.2.1. Sanitation Standards

Excreta disposal standard 1: access to, and numbers of, toilets

People have adequate numbers of toilets, sufficiently close to their dwellings, to allow them rapid, safe and acceptable access at all times of the day and night.

Key indicators

➢ A maximum of 20 people uses each toilet
➢ Use of toilets is arranged by household(s) and/or segregated by sex
➢ Separate toilets for women and men are available in public places (markets, distribution centers, health centers, etc.)
➢ Shared or public toilets are cleaned and maintained in such a way that they are used by all intended users
➢ Toilets are no more than 50 meters from dwellings
➢ Toilets are used in the most hygienic way and children’s faeces are disposed of immediately and hygienically

Excreta disposal standard 2: design, construction and use of toilets

Toilets are sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use.

Key indicators

➢ Users (especially women) have been consulted and approve of the siting and design of the toilet
➢ Toilets are designed, built and located to have the following features:

• They are designed in such a way that they can be used by all sections of the population, including children, older people, pregnant women and physically and mentally disabled people.

• They are sited in such a way as to minimize threats to users, especially women and girls, throughout the day and night

• They are sufficiently easy to keep clean to invite use and do not present a health hazard;

• They provide a degree of privacy in line with the norms of the users;

• They allow for the disposal of women’s sanitary protection, or provide women with the necessary privacy for washing and drying sanitary protection cloths
• They minimize fly and mosquito breeding (see guidance note 7).

  ➢ All toilets constructed that use water for flushing and/or a hygienic seal have an adequate and regular supply of water.
  ➢ Pit latrines and soakaways (for most soils) are at least 30 meters from any groundwater source and the bottom of any latrine is at least 1.5 meters above the water table.
  ➢ Drainage or spillage from defecation systems must not run towards any surface water source or shallow groundwater source.
  ➢ People wash their hands after defecation and before eating and food preparation. People are provided with tools and materials for constructing, maintaining and cleaning their own toilets if appropriate.

3.2.2. Policies, strategies and programmes

There are several national policies, strategies and programmes that are relevant to improving sanitation and hygiene in Ethiopia. Key policies are:

  ➢ The Health Policy (1993) which stresses that environmental health, occupational health and safeguarding the environment are priority issues.
  ➢ The Environmental Policy (1997) which promotes the use of renewable resources and recycling, and includes specific policies for industrial waste.
  ➢ The Water Resources Management Policy (1999) which describes the conservation, exploitation, use and protection of water resources.

These policies are reinforced by proclamations such as the Public Health Proclamation No. 200/2000, the Ethiopia Water Resources Management Proclamation No. 4/1995, and the Proclamation for the Establishment of the Ethiopian Environmental Protection Authority 2002. These proclamations provide support for regions, zones and woredas to develop a regulatory framework for their activity in the water, sanitation and hygiene sector.

  ➢ The National Hygiene and Sanitation Strategy of 2005 (MoH, 2005) sets out a ‘sanitation vision’ for Ethiopia that is: 100% adoption of improved (household and institutional) sanitation and hygiene by each community which will contribute to better health, a safer, cleaner environment, and the socioeconomic development of the country.
  ➢ The goal of 100% access to basic sanitation has been carried forward to other policies and programmes, and is one of the targets of the new One WASH National Programme. (‘WASH’ stands for ‘water, sanitation and hygiene’.)
  ➢ The One WASH National Programme (OWNP), as the name suggests, is a single programme that combines the three interlinked components. Announced in 2013, it aims to address the WASH challenges in Ethiopia by adopting a unified and collaborative approach. The overall objective of the OWNP (FDRE, 2014) is: to improve the health and well-being of communities in rural and urban areas in an equitable and sustainable manner by increasing access to water supply and sanitation and adoption of good hygiene practices. The OWNP is unlike previous WASH programmes because it takes a
sector-wide approach and involves the federal ministries of Water, Irrigation and Energy, Health, Education, and Finance and Development. The four ministries have signed a memorandum of understanding (MoU) that sets out their roles and responsibilities. It therefore cuts across the traditional separation of responsibilities between ministries and has structures and processes designed to ensure closer cooperation and collaboration between all the stakeholders.

**National Hygiene and Sanitation Strategy**

The National Hygiene and Sanitation Strategy (NHSS) was developed by the Ministry of Health and published in 2005. It was designed to complement the existing Health Policy and Water Sector Strategy. Figure below shows the image on the front cover of the document.

![Image from the cover page of the National Hygiene and Sanitation Strategy. (MoH, 2005)](image)

The three pictures represent the three elements of WASH: safe water supply, sanitation, and hygiene, and shows that all three have a direct impact on personal health.

The Strategy puts forward three strategic pillars for improved sanitation and hygiene:

**Pillar 1: An enabling environment**: this refers to such things as policies, regulation, cooperation between sectors, partnership, capacity building etc.

**Pillar 2: Sanitation and hygiene promotion**: this means efforts and activities to raise awareness of the importance of sanitation and hygiene to create demand and encourage
behavior change. **Pillar 3: Improved access to hardware**: improved availability of appropriate technology solutions for latrines, handwashing and water supply.

These three pillars were designed to support the plans for improved sanitation and hygiene which would lead to prevention of disease and ultimately contribute to the long-term aim of eradicating poverty in Ethiopia.

**National development plans**
- The Growth and Transformation Plan (GTP)
- Universal Access Plan (UAP)

### 3.3. Sanitation and Waste Management

We can think of sanitation as the prevention of human contact with wastes, or as the provision of facilities and services for the safe disposal of human faeces and urine.

Waste management is defined as the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.

The two terms – sanitation and waste management – both refer to waste, but sanitation is primarily concerned with liquid waste and waste management is primarily concerned with solid waste. **Liquid wastes** are any wastes in a liquid form such as wastewater and **sewage**. Faeces and the contents of pit latrines and septic tanks are also classed as liquid wastes. **Solid wastes** are anything in solid form that is discarded as unwanted.

**Sanitation** means preventing people from coming into contact with wastes by providing facilities and services for the treatment and disposal of human excreta and other liquid wastes produced in homes, workplaces and public buildings.

**Waste management** is the collection, treatment and disposal of solid wastes produced in the home, workplace and public buildings.

**Types of liquid waste**
- **Blackwater** – is wastewater that contains or consists of urine and faeces. It contains pathogens (disease-causing agents).
- **Greywater, or sullage**, is wastewater from human washing and bathing, kitchen sinks, clothes washing, etc. It does not contain excreta.
- **Stormwater (or surface run-off or rainwater run-off)** is wastewater that flows on the surface of the land to join streams. Note that this is considered as wastewater because it contains many different contaminants.
- **Sewage** is a combination of wastewater coming from any of the above sources and flows in underground sewers or open ditches.
- **Excreta** is a combination of urine and faeces.

### Types of solid waste

- **Residential waste**: from households and residential areas. This is sometimes called household waste. Garbage, rubbish, trash and refuse are other terms for residential waste. Commercial waste: from businesses such as food and drink establishments, shops, etc.
- **Industrial waste**: from various types of industrial processes, e.g. food processing, paper manufacture, manufacture of chemicals and metal processing.
- **Institutional waste**: from public and government institutions, e.g. offices, religious institutions, schools, universities, etc. This is similar to residential and commercial waste in composition.
- **Municipal waste** (or municipal solid waste) covers all the above wastes produced in an urban area. It is similar in composition to residential waste excluding some industrial Healthcare waste: any solid waste produced in hospitals, clinics, health posts and other health facilities.
- **Agricultural waste**: waste that comes from farming. Waste from open areas: street sweepings, contents of roadside dustbins, ditches and other public places.
- **Construction and demolition waste**: from various types of building and demolition activities in urban areas.
- **Electronic and electrical waste (e-waste)**: wastes generated from used electronic devices and household appliances.

### 3.4. Sanitation facilities to Manage Human Excreta

#### 3.4.1. Trends in latrine use in Ethiopia

It ranks sanitation provision in increasing order of desirability, as listed below:
- Open defecation (least desirable)
- Unimproved facilities
- Shared facilities
- Improved facilities (most desirable).

Figure below shows the changes in sanitation coverage in Ethiopia from 1990 to 2012 for urban and rural populations, and the total for the whole country. The columns in the diagram show the coverage according to the categories of the sanitation ladder. The sloping lines between 1990 and 2012 indicate the change over that time.
Selecting the most appropriate sanitation facility requires a thorough analysis of all factors including cost, cultural acceptability, simplicity of design and construction, operation and maintenance, and local availability of materials and skills. There are different sanitation facilities in the world where they do have their own advantages and disadvantages. The most widely rural community practice is open defecation as shown in the Figure below.

3.4.2. Unimproved latrines
Unimproved latrines, such as traditional pit latrines, do not ensure hygienic separation of human excreta from human contact.

Traditional pit latrines
A traditional pit latrine (Figure below) consists of a pit in the ground without any slab. The pit may be wholly or partially lined to prevent it collapsing. The Central Statistical Agency (2014) found in a survey that 44.4% of households in urban areas of Ethiopia use traditional pit latrines. The quality of these latrines is far below acceptable standards and, consequently, they pose great health risks to users and pollution risks to the environment. The Ministry of Water and Energy (2011), reported that the quality of latrines is generally poor, with more than 50%
structurally unsafe and 50% unhygienic. Latrines of this type frequently generate bad smells and are prone to insect infestation.

![Traditional pit latrine with no slab.](image)

**Figure 18 Traditional pit latrine with no slab.**

**Shared latrines**

Shared latrines are household latrines used by two or more households. They can be of a high standard, but there is always a risk that nobody takes responsibility for keeping them clean, meaning that they are not looked after properly. Communal latrines and public latrines (Figure below) are also classed as shared latrines. The Central Statistics Agency survey (2014) found that about 33.3% of urban residents in Ethiopia use shared latrines. Public latrines provide a much-needed service to local people and can be hygienic as long as they are properly maintained and managed. They also create employment for cleaners and attendants, who collect money from users. However, the operation and management of many shared latrines in Ethiopia needs improving.

![A clean, well-maintained public latrine in Addis Ababa](image)

**Figure 19 A clean, well-maintained public latrine in Addis Ababa**

**3.4.3. Improved Latrines**

For a latrine to be classed as ‘improved’, it should satisfy the following requirements:

- It should be safe to use (the pit may need to be lined)
- It should have a structurally sound and cleanable slab floor
- Handwashing facilities should be available
- There should be no contamination of groundwater or surface water
The squat hole should be fitted with a lid so that excreta are not accessible to flies or other creatures.

It should be free from odors or unsightly conditions.

There should be no need for people to handle the excreta.

If possible, the latrine should be 6–10 m from the home, and located downwind from the house.

It is best not to build a latrine in areas where groundwater is used as a water source, but if this has to be done, the base of the pit should be at least 2 m above the water table.

On sloping ground, it should be located below the level of any well or water source, so that any liquid seeping out of the pit flows away from the water source.

The pit should be at least 15 m away from a water source, although some authorities recommend a minimum distance of 30 or 50 m. In Ethiopia, federal guidelines state that latrines must be sited at least 30 meters from any water source to be used for human consumption and if on sloping ground be lower than the source (MoH, 2004).

The diameter of the pit should be at least 1 m, but should not exceed 1.5 m because this increases the risk of the pit collapsing.

The lifetime of a pit latrine depends on several factors, such as the depth of the pit, the number of users, the type of anal cleansing materials used (e.g. water, degradable material such as paper, leaves or sticks, or non-degradable material such as stones), and the rate of decomposition of the faecal material in the pit.
The pit should be designed for three to five years of use. The accumulation rate of sludge on average, is 40–60 litres per person per year. The depth of a pit latrine should be at least 1.5 m, but the figure can be calculated more precisely using the following formula:

\[
\text{Depth of pit} = \frac{P \times S \times N}{A} + 0.5 \text{ m}
\]

Where:
- \(P\) = average number of users
- \(S\) = sludge accumulation rate in m\(^3\) per person per year
- \(N\) = minimum useful life required in years
- \(A\) = cross-sectional area of the pit in m\(^2\)

Note that in this formula the sludge accumulation rate is required in units of cubic meters per person per year. The additional 0.5 m is so that the latrine can be covered with 0.5 m of soil at the end of its life.

Example: Using the above formula, calculate the required pit depth for a 1 m diameter latrine that has to last five years for a five-person household. Assume the sludge accumulation rate is 50 litres per person per year.

In this case:
- \(P = 5\)
- \(S = 50 \text{ litres per person per year} = 0.05 \text{ m}^3 \text{ per person per year}\)
- \(N = 5 \text{ years}\)

\[
A \text{ is given by the formula for the area of a circle } (\pi \times \frac{d^2}{4}) \text{ or } (3.142 \times \frac{1^2}{4}) = 0.79 \text{ m}^2
\]

So the depth needed is \[
\frac{5 \times 0.05 \times 5}{0.79} + 0.5 = 2.1 \text{ m}
\]

The slab for an improved pit latrine must be firm, secure and well-constructed. Slabs can be made from locally-available materials such as wooden logs, planks or concrete.
Ventilated improved pit latrine

The ventilated improved pit latrine or VIP latrine differs from a standard improved latrine due to the addition of a vent pipe (Figure 5.9). The VIP latrine was developed to overcome the problems of odor and fly breeding commonly found in unvented pit latrines.

Odor control is achieved by air coming in through the superstructure, entering the squat hole and pushing the hot, smelly air in the pit upward through the vent pipe. The pipe is typically 110–150 mm in diameter and reaches more than 300 mm above the highest point of the
superstructure. Fly control is achieved by a screen at the top of the pipe. Flies outside the latrine attracted to the odour emitted by the vent pipe are unable to pass inwards through this screen.

3.4.4. Ecological sanitation

Ecological sanitation, also known as ecosan, describes an approach to human waste management rather than a single method. In ecosan systems, human excreta is considered to be a resource, not waste. The principle is to make use of excreta by transforming it into an end product that can be used as a soil improver and fertiliser for agriculture.

Ecosan systems require more space than conventional latrines, but they provide a more sustainable approach to waste management than other systems. In the group of improved sanitation facilities in the sanitation ladder, ecosan systems are represented by composting toilets.

Composting toilets convert human waste into compost (soil-like material that can be safely used as fertiliser) by the action of aerobic bacteria.

Aerobic means ‘with oxygen’ and is usually applied to microbial decomposition processes that take place where air is present. Composting toilets are just one of several latrine technologies that can be classified as ecosan systems.

3.4.4.1. Arborlo latrine

An Arborlo latrine is an eco-sanitation option. It uses one shallow pit (1-meter-deep) for composting excreta, which is then used to grow a tree when the pit is full. The superstructure, slab and footing are portable, so that when the pit is full (i.e. within 0.5 meters from the top), the structure can be moved to a new pit. The pit typically fills in about six to nine months. The full pit is topped with soil and a fruit bearing or fuel wood tree is planted in the nutrient rich soil.

![Figure 23 Arborloo – a simple ecological latrine that helps people to see human excreta as a](image-url)
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Inexpensive to construct and most parts are reusable</td>
<td>➢ Ash, lime, sawdust, earth, or vegetable matter must be added regularly</td>
</tr>
<tr>
<td>➢ No direct contact with excreta</td>
<td>➢ Space is required for planting trees after pit is full</td>
</tr>
<tr>
<td>➢ No water needed (Except for cleaning)</td>
<td>➢ Space is required to reallocate the latrine on a regular basis</td>
</tr>
<tr>
<td>➢ Can be used by washers and wipers for anal cleansing</td>
<td>➢ Frequently need to dig a new pit and reinstall superstructure</td>
</tr>
<tr>
<td>➢ Pit excavation is small and shallow</td>
<td>➢ May be culturally unacceptable</td>
</tr>
<tr>
<td>➢ Orchard or fuel wood grove is developed over time</td>
<td></td>
</tr>
</tbody>
</table>

### 3.4.4.2. Urine-diverting latrine

The **urine-diverting latrine**, also known as a urine-diverting dry toilet (UDDT) is a latrine that separates urine and faeces. Both wastes are treated separately, without damaging the environment or endangering human health, and then used in agriculture.

The urine and faeces go into different containers at the source. The urine is kept for 24 hours; after which it is mixed with three parts water to be used as a very effective fertiliser. Soil or ash is added to the latrine after each use and the faeces are composted.

After approximately 12 months, pathogenic micro-organisms will have died off and the composted faeces can be used as a soil conditioner (helping the soil to retain moisture) for household gardening or urban agriculture.
3.4.4.3. Biogas latrines

In a biogas latrine or bio-latrine (Figure 5.13), the waste enters an airtight tank situated underground, and undergoes anaerobic digestion, resulting in the production of biogas and digested sludge. Biogas is a clean and convenient fuel that contains about 60% methane. Anaerobic digestion is the process whereby bacteria and other micro-organisms break down (decompose) organic material in the absence of air, yielding biogas. The digested sludge collects in a separate tank and can be used as a soil fertiliser.

Biogas can be used for cooking and lighting, refrigeration, engine operation and electricity generation. Animal wastes can also be added to the digester. Being a relatively expensive system, this has been applied in Ethiopia only at public latrines and institutions such as schools, colleges, universities, hotels and prisons, where large numbers of people use the latrine.

![Figure 25 Basic components of a biogas latrine](image)

3.4.5. Water-flushed systems

All of the latrine technologies described so far are dry systems. These are the most appropriate systems for places where there is limited water supply. If water is piped into the premises or is otherwise easily available, then a water-flushed system can be used. Water-flushed toilets, also known as water carriage or water-borne toilets, can be connected to a pit, septic tank or sewer. A septic tank is an underground, watertight tank in which sewage is collected. Faecal solids accumulate in the tank and partially treated liquid is discharged into the ground.

3.4.5.1. Pour-flush toilets

The problems of flies and smells in latrines can be overcome by using a toilet pan with a water seal. The shape of the toilet pan is designed with a bend in the outlet pipe. Water remains in the bend at all times and creates a ‘water seal’. Pour-flush toilets use this system. After defecation, 1.5–2 litres of water is poured (using a small container) into the toilet pan to move
the wastes along. This system is popular where people traditionally use water for anal cleansing, and where water is readily available. Pour-flush toilets can be located inside the house, since the water seal prevents bad odours and insect nuisance.

![Figure 26 Basic components of a pour-flush toilet, showing the water seal.](image)

### 3.4.5.2. Cistern-flush toilet

The **cistern-flush toilet** also known as a water closet or WC, is usually made of ceramic material and consists of two parts: a bowl into which excreta are deposited and a tank (cistern) with volume of approximately 6-13 litres that supplies flush water for carrying away excreta. It needs a connection to constant running water for operation, and a discharge pipe to take the wastewater away to a sewer or septic tank. WCs are quite common in government offices, schools, hotels and health facilities. The attractive feature of the flush toilet is that it has a water seal to prevent odours from coming back up through the plumbing, but it is costly and requires a skilled plumber for installation.

![Figure 27 A cistern-flush toilet.](image)
3.4.5.3. Urinals
Urinals, used by men and boys, are only used for collecting urine. Urinals are either wall-mounted units or a drainage channel constructed on the floor in connection with the wall. Most urinals use water to flush. In public places and schools, urinals for men and boys help to keep toilets cleaner and decrease the demand for toilet seats.

3.4.6. Choice of latrine technology
Several factors have to be considered when choosing the most appropriate latrine technology. This is a complex technical process so we can only cover some of the main issues here.

- Location
- Construction materials
- Cost
- Safety and accessibility
- User preferences

3.5. Sanitation Marketing
Sanitation marketing (sometimes referred to as SanMark) is an approach to household sanitation promotion that aims to improve standards by encouraging people’s demand for sanitation products and services. This helps companies supplying these products and services to develop and prosper because they have a growing market of customers. In this way sanitation marketing addresses both supply and demand for products and services, resulting in the development of a sustainable local sanitation industry.

A key principle of sanitation marketing is that it is demand-driven, which means that individuals and households must want to install sanitation for their own use. They choose what type of facility they want to build and pay for it themselves. In the past, sanitation development was often funded by charities or subsidies, but this created dependency and if households had a low sense of ownership they did not always use their sanitation facilities properly or maintain them.

The National Sanitation Marketing Guideline (NSMG) explains the principles and gives guidance on the process (MoH, 2013). Sanitation marketing starts with research to understand consumers’ motivations and preferences and to find out about any constraints to improved latrine adoption. If communities and individuals are practicing open defecation and have limited knowledge of good hygiene behaviour then these problems will need to be addressed before the demand for new products can exist. One way to tackle this is the community-led total sanitation (CLTS) approach, also known in Ethiopia as community-led total sanitation and hygiene (CLTSH).
CLTSH is an approach to changing community behaviour that aims to achieve open-defecation free (ODF) status and ensure everyone has access to and uses a latrine. CLTSH involves specially trained people, known as facilitators, working with the community to analyse the extent of open defecation in the area. The facilitators help the community to understand the implications for faecal-oral contamination, and trigger a feeling of disgust and shame in community members that motivates them to take action. The community is empowered and encouraged to build its own latrines and aim for ODF status.

The NSMG recommends that the process should also be supported with behaviour change communication (BCC). This has a focus on changing behaviour of individuals through education and raising awareness of good hygiene practice as a means to improve health. Both CLTSH and BCC help people to recognize the value of having their own latrine which creates the demand for sanitation products.

3.5.1. Strategies for sanitation marketing
To be successful, sanitation marketing must give attention to supply as well as demand. There is no point in creating demand if the right products are not available to meet that demand. On the supply side, strategies should be structured around the traditional ‘4 Ps’ of marketing, which are product, place, promotion and price. Knowing how these four factors interact in sanitation marketing will help build and promote sustainable commercial opportunities for sanitation services in your area.

**Sanitation products**: Slabs for latrines, Solid waste collection, and construction of bio-gas diverters, sinks, water pipes and taps will be the core component of most sanitation packages. Slabs may be made of concrete, plastic, ceramic or other appropriate materials. The product strategy will be to supply households with a slab that is durable, affordable, convenient and easy to clean and maintain.

**Sanitation ‘place’**: must be easily accessible to customers (especially for heavy items such as a concrete slab). A major problem in peri-urban areas is that the place of production and sale of the slabs can be a long way from people’s homes.

**Promotion of sanitation facilities**: Promotion is the process of designing messages about sanitation products and services and communicating them to potential customers so as to create a demand for sanitation facilities. Communication strategies include printed materials like posters (Figure below) leaflets and advertising messages on television and radio.
Pricing of sanitation products and services: Price is a key factor in making a product financially sustainable, meaning it can be manufactured and sold over a long period and cover its costs without the need for subsidies or grants. The consumer wants prices to be as low as possible while the manufacturer wants prices (and their profits) to be as high as possible. If these two demands can be balanced (a low enough price for the buyer that still generates enough profit for the seller), financial stability and sustainability can be achieved.

3.5.2. Business model for sanitation marketing
Giving due consideration to the 4 Ps can lead to the development of a successful business model, like the one shown in Figure below. This model shows the steps in the supply process from manufacture to installation. Three main stakeholders are involved: the producer; the sales agent; and the customer.
3.6. Community Led Total Sanitation and Hygiene (CLTSH)

Community Led Total Sanitation (CLTS) is an innovative methodology for mobilizing communities to completely eliminate open defecation (OD). Communities are facilitated to conduct their own appraisal and analysis of open defecation (OD) and take their own action to become ODF (open defecation free).

At the heart of CLTS lies the recognition that merely providing toilets does not guarantee their use, nor result in improved sanitation and hygiene. Earlier approaches to sanitation prescribed high initial standards and offered subsidies as an incentive. But this often led to uneven adoption, problems with long-term sustainability and only partial use. It also created a culture of dependence on subsidies. Open defecation and the cycle of fecal–oral contamination continued to spread disease.

In contrast, CLTS focuses on the behavioral change needed to ensure real and sustainable improvements – investing in community mobilization instead of hardware, and shifting the focus from toilet construction for individual households to the creation of open defecation-free villages. By raising awareness that as long as even a minority continues to defecate in the open everyone is at risk of disease, CLTS triggers the community’s desire for collective change, propels people into action and encourages innovation, mutual support and appropriate local solutions, thus leading to greater ownership and sustainability.

What is ‘Total Sanitation’?

A community is a group of people who form relationships over time by interacting regularly around shared experiences, which are of interest to all of them for varying individual reasons.

Moreover; these interactions lead to the formation of relationship having strong bonds in the form of culture, norms, values, etc.

Community-led development is a development approach through which communities lead the process of identifying and analyzing issues, exploring solutions, planning action, identifying resources, implementing planned activities, reviewing progress, setting bylaws and sharing/communicating the outcomes of their actions.

Total sanitation refers to the elimination of open defecation in a community through the construction and use of latrines (and hand washing) to achieve a dramatic reduction in sanitation and hygiene related diseases.

Community-led total sanitation emphasizes changing sanitation behavior rather over making physical changes, such as latrine construction. This is done through a process of social
awakening stimulated by facilitators from within or outside the community. The approach concentrates on the behavior of the community as a whole rather than on individuals.

- Total use of hygienic latrines, i.e., no open defecation or open/hanging latrine in use
- Hygienic latrines well maintained
- Good personal hygienic practices
- Using sandals when defecating
- Effective hand washing after defecation and before taking or handling food
- Water points well managed
- Safe water use for all domestic purposes
- Food and water covered
- Garbage disposal in a fixed place and domestic animal excreta disposed of in a hygienic way
- Waste water disposal in a hygienic way
- Clean courtyards and roadsides
- No spitting in public places

3.6.1. Principles of CLTSH approach

- CLTS focuses on outcomes, not on hardware inputs;
- CLTS emphasis on collective action, mobilizing the community rather than establishing household contacts;
- CLTS suggest local choice, providing a variety of technological options and getting people to access affordable technologies.
- CLTS develop local Market, by promoting the availability of sanitary materials and allowing private suppliers to respond to the demand.
- Through CLTS approach, communities construct their own latrines or toilets with their own resources. Those people who are better off help those who are too weak or poor to help themselves.
- In CLTS, no standardized top-down designs are decided for the people. People decide for themselves.
- While implementing CLTS, facilitators do not teach or preach. Appraisal and analysis are facilitated. But after triggering, information, media campaigns and encouragement can be provided.
- Through applying CLTS approach, Natural Leaders (NLs) are emerged, when community proceeds towards Open Defecation Free (ODF) status.
- Through applying CLTS approach, local innovations of low cost toilet models using locally available materials are developed.
- In CLTS, community-innovated systems of reward, penalty, spread and scaling-up are followed.
3.6.2. The sequence of steps
The following is a rough outline of sequence of steps which could be followed, and tools that could be applied in triggering CLTS in villages. This is definitely not the only way of doing it but some essential elements will be emphasized. Please feel free to modify and change in accordance with the situation, but the DOs and DON’Ts are important.

- **Pre-triggering**
  Selecting a community. Introduction and building rapport
- **Triggering**
  Participatory sanitation profile analysis. Ignition moment
- **Post-triggering**
  Action planning by the community. Follow up
- **Scaling up and going beyond CLTS**

![Figure 30 Steps in CLTSH](image)

**Pre-triggering (first & second visits)**
Pre-triggering is the first step of CLTS. During this period, first and second visit-if needed- is made to the selected village. Only one or two aged and experienced facilitators visit the selected village, where they meet with the religious leaders and Village Chief. The core objective of this visit is to fix an appointment with the villagers for the next meeting (triggering and) build the rapport with the villagers. However, following tasks during this visit are to be performed:

- Tell the village chief that the team will come to the village on the other day, and all the villagers will help them know about the education, health, culture, cultivation etc… of the village. (better not to use the terms hygiene and sanitation during the pre-triggering as people are reluctant to listen to hygiene and sanitation propagandas). The facilitators will not promise of giving them subsidies and any physical assistance. In this visit, the facilitators will not give any full details regarding the CLTS. They should tell the villagers
that they do not understand regarding their village from many aspects i.e. education, economy, health, hygiene, water and sanitation etc.

- Fix up a day for another meeting. The facilitators will make sure that in the selected day is not overlapping with the market day, marriage day at the village and some other important days where important events like funeral, and condolences etc would take place. In the context of Afghanistan, Friday is the most convenient day if it is convenient to both villagers and facilitators as on this day, all the villagers are at their homes, and most of them can participate in the triggering events. The favorable time is from 09:00AM through 11:00AM on Friday.
- Know the size of population, number of households, history of subsidy, and locate some dirty and filthy places.
- Know the distance of the village from the NGO office.
- See whether the village is favorable or challenging for CLTS triggering.

**Triggering**

This is the most difficult visit as the community is triggered in this visit, which is a challenging and tough job. However, it depends upon the interpersonal and verbal skills of a facilitator as well as his/her triggering experience. Before going to the village, two separate teams-male and female-will be developed and the role of each team member should be pre-determined (who will be the facilitator, co facilitator…). The teams should go to village on their fixed up date, day and time. Upon arrival in the village Female team should be directed to the pre-selected house, where already informed and gathered women welcome the female team. Male team should go to the pre-selected team, a common place for guests, where the already informed and gathered villagers welcome the male team. This is the step, where facilitators trigger the villagers through applying Participatory Rural Appraisal (PRA) tool. Following are the important steps in PRA Tools:

**Introduction, strengthening rapport, and launching the triggering session**

1. Social Mapping
2. Transect Walk/Walk of Shame
3. Calculation of Feces
4. Flow Diagram
5. Triggering Stage/Ignition Point
6. Calculation of Medical Expenses
7. Water Quality Tests through Water Quality Test Kits
8. Glass Exercise

**Post triggering**

The post-triggering phase refers to awareness and momentum from the triggering translating into action plans for making the community open defecation free (ODF). The household members assess the water and sanitation situation in their community as well as the location of
open defecation sites. Through further participatory exercises, discussions and awareness raising activities, a community plan is developed to stop open defecation and promote more hygienic individual behavior, leading to the construction of latrines.

This process included visits to supervise and monitor CLTS through Home Visits; One-on-one interaction with CBHVs; Observations; Transect Walks and Interviews.

**Advantages of CLTS**
- CLTS does not rely on sanitation subsidies or service delivery from external agencies. The approach encourages people to change their hygiene behaviors without prescribing how they should do it.
- Empowering the households and enabling them to get onto the sanitation ladder at the level that they can afford.
- CLTS also empowers natural community leaders and facilitators who then move on to other communities to spread the effect or use the momentum of collective action and social cohesion to address other livelihoods issues in the community.

**Disadvantages of CLTS**
- CLTS relies on the quality of the facilitators and implementing organization.
- The selection process, their training and their motivation level are critical factors for success.
- Where previous interventions have offered subsidies or prescribed certain standards the community tends to have reservations and be spectacle about CLTS and wait for assistance.

3.7. **Wastewater Treatment**

Wastewater contains many substances that are considered impurities. Impurities are any substances that are not found in “pure” water. Fresh domestic untreated or raw wastewater has a musty odor, a pH range of 6.5 to 8.0 and is grayish brown in color. Contaminants can be broadly lumped into four basic classes: Organic contaminants; Inorganic contaminants; Pathogens; and Other contaminants. More rigorous treatment of waste-water includes the removal of specific contaminants as well as the removal and control of nutrients. Natural systems are also used for the treatment of waste-water in land-based applications. Sludge resulting from waste-water treatment operations is treated by various methods in order to reduce its water and organic content and make it suitable for final disposal and reuse.

3.7.1. **Contaminants Typically Found in Untreated Wastewater**

**Suspended solids:** can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.
**Biodegradable organics:** Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most common in terms of BOD (biochemical oxygen demand) and COD (chemical oxygen demand). If discharged untreated to the environment, their biological stabilization can lead to the depletion of natural oxygen resources and to the development of septic conditions.

**Pathogens:** Communicable diseases can be transmitted by the pathogenic organisms in wastewater. **Nutrients:** Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater. **Priority pollutants:** Organic and inorganic compounds selected on the basis of their unknown or suspected carcinogenicity, mutagenicity, or high acute toxicity. The presence of these compounds in wastewater must be minimized for public health reasons and to protect the biological treatment processes.

**Refractory organics:** These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides. Some of these may be toxic to the biological treatment processes.

**Heavy metals:** usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is discharged to a stream used as a potable water source. The presence of heavy metals may also impact the recycling of bio solids (stabilized waste sludge) on farmland.

**Dissolved inorganics:** Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is discharged to a stream used as a potable water source.

Three major components of a Wastewater System: Collection/Conveyance, Treatment and Disposal.

### 3.7.2. Waste water collection/conveyance system

There are three types of collection systems;

**Sanitary Sewer**
- Collects commercial and household wastes (sometimes industrial).
- A sanitary sewer does not include any storm water.

**Storm Sewer**
- Collects runoff from streets, land, and roofs.
- Historically discharge has been discharged to the stream without treatment.
**Combined Sewer**
- Collects sanitary and storm water.
- During storms, high flows can create short-term overloading conditions at treatment plant, impacting treatment efficiencies.
- Separating combined sewers is costly.

**Wastewater Conveyance Systems**

**Gravity Sewer**
- Used when slope is sufficient to produce velocity of 2 feet/second.

**Pumping Stations and Force Mains**
- Lift wastewater to higher point so it will again flow with gravity.
- Pumped under pressure directly to plant.

![Figure 31 Typical wastewater collection and conveyance system](image-url)

### 3.7.3. Basic wastewater treatment processes

**Preliminary Treatment**

- **Screening:** Removes rags, sticks, and other debris; protects pumping equipment
- **Grit Removal:** Removes settleable inorganic grit
- **Pre-Aeration:** Adds oxygen to the wastewater to reduce odors
- **Flow Metering and Sampling:** Measures and records flows; sample wastewater for analyses of components

**Primary Treatment**

- **Sedimentation and Flotation:** Removes settleable organic and inorganic particles and floating debris such as fats, oils, and greases
Secondary Treatment

**Biological Treatment:** Removes dissolved and remaining colloidal (also known as nonsettleable) organic matter; can convert ammonia-nitrogen to nitrate-nitrogen

**Secondary Sedimentation:** Separates biomass and chemical precipitates from treated wastewater

**Tertiary (Advanced) Treatment**

**Chemical Phosphorus:** Removal Adds chemical to form precipitate with phosphorus for removal in the secondary clarifiers

**Biological Nutrient Removal:** Removes nitrogen and phosphorus using specialized microorganisms

**Filtration:** Removes additional suspended solids (beyond that obtained by simple settling) using gravity or pressure filters

**Disinfection:** Kills pathogenic organisms

**Solids Treatment**

**Digestion:** Stabilizes remaining organic matter; results in overall net reduction in solids

**Disposal:** Moves stabilized solids from plant to farmland for recycling or to landfill

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**Figure 32 Wastewater Treatment Process**

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**Summary of Module 3**

Many countries are challenged in providing adequate sanitation for their entire populations, leaving people at risk for water, sanitation, and hygiene (WASH)-related diseases.
Many human infections are spread through contact with human excreta. Bacteria, viruses, protozoa and parasitic worms cause many diseases that are spread by direct contact with faeces or indirectly via contaminated food and soil.

Most infections occur through the **faecal-oral route** where pathogens enter a person’s mouth through ingesting (eating or drinking) contaminated food or water, or when contaminated fingers are placed in the mouth.

The **National Hygiene and Sanitation Strategy** of 2005 (MoH, 2005) sets out a ‘sanitation vision’ for Ethiopia that is: 100% adoption of improved (household and institutional) sanitation and hygiene by each community which will contribute to better health, a safer, cleaner environment, and the socioeconomic development of the country.

**Waste management** is the collection, treatment and disposal of solid wastes produced in the home, workplace and public buildings.

Selecting the most appropriate sanitation facility requires a thorough analysis of all factors including cost, cultural acceptability, simplicity of design and construction, operation and maintenance, and local availability of materials and skills.

**Sanitation marketing** (sometimes referred to as SanMark) is an approach to household sanitation promotion that aims to improve standards by encouraging people’s demand for sanitation products and services.

CLTSH is an approach to changing community behaviour that aims to achieve open-defecation free (ODF) status and ensure everyone has access to and uses a latrine. CLTSH involves specially trained people, known as facilitators, working with the community to analyse the extent of open defecation in the area.

Wastewater contains many substances that are considered impurities. Impurities are any substances that are not found in “pure” water.
Module 4: Hygiene Promotion

Introduction
This module focuses on the burdens from poor hygienic practices, the hygiene promotion strategies, hygiene promotion standards with key principles in hygiene promotion. It also discusses the hygiene promotion options and the five fallacies about hygiene promotion. The different hygienic practices including personal hygiene, food hygiene and handwashing are discussed.

Learning Objectives for this Module
After you have studied this Module you should be able to:
- Explain the health problems due to poor hygienic practices
- Describe hygiene promotion and draw the “F” diagram
- Describe hygiene promotion standards and the key principles in hygiene promotion
- Explain key hygienic practices that needs to be taken (food hygiene, personal hygiene, hand hygiene, menstrual hygiene)
- Demonstrate the appropriate hand washing practices following the appropriate steps
- Follow the appropriate procedures of key hygienic practices in handling food, washing hands

4.1. Burdens from poor hygienic practices
Hygiene poses another global health challenge. However, thus far, hygiene has not been prioritized on the international development agenda, despite the fact that hand washing with soap could save 300,000 people annually.

Safe drinking water and sanitation in the absence of hygienic behavior will not prevent faeco-oral infections. Many households, for example, have no other option than to store water before use. Even if the original source of the water is safe, the water is frequently contaminated by unhygienic conditions and practices in the home.

Across the developing world, hand washing and menstrual hygiene facilities along with toilets are often not available in schools, thereby deterring attendance, particularly for adolescent girls.

A recent study by Freeman et al., published in the Journal of Epidemiology and Infection, estimates that inadequate hand hygiene practices affects 80% of the global population. Even though hygiene’s health benefits are well documented, there is no global development target or monitoring framework to track the uptake of improved hygiene practices.

The burden of water-related diseases curtails efforts to improve public health in the developing world. Diarrhea – most often related to unsafe drinking water, poor sanitation and inadequate
hygiene – is one of the leading causes of death among children under the age of five. It kills more children than Malaria or HIV/AIDS.

The WHO estimates that exposure to inadequate drinking water, sanitation and hand hygiene was responsible for 58% of deaths from diarrhea, adding up to 840,000 deaths in low and middle-income countries, in 2012. This translates into 1.5% of the global disease burden, even 5.5% for children under five.

There is growing evidence that repeated exposure to unsafe drinking water, poor sanitation and inadequate hygiene have a significant impact on stunting. This comes about as a result of intestinal worm infections, diarrheal diseases and environmental enteropathy which lead to a poor nutritional status. Cholera is also transmitted via contaminated water. The cholera epidemic in Haiti has killed more than 8,500 people since 2010.

Taking all of the above into account, water, sanitation (including wastewater) and hygiene must be given greater priority in the health community, which presently puts too much focus on curative approaches.

4.2. Hygiene Promotion

Hygiene Promotion is the planned, systematic attempt to enable people to take action to prevent or mitigate water, sanitation, and hygiene related diseases and provides a practical way to facilitate community participation and accountability.

Hygiene Promotion also involves ensuring that optimal use is made of the water, sanitation and hygiene enabling facilities that are provided. Previous experience has shown that facilities are frequently not used in an effective and sustainable manner unless Hygiene Promotion is carried out.
Access to hardware combined with an enabling environment AND Hygiene Promotion make for hygiene improvement as shown in the model of the Hygiene Improvement Framework for Emergencies (see below left). The overall aim of hygiene improvement is to prevent or mitigate WASH related diseases.

Figure 33 Reductions of morbidity from diarrheal diseases due to WASH interventions

4.3. The F-diagram and barriers for faeco-oral transmission

The ‘F’ diagram (left) illustrates the transmission routes of most diarrhoeal diseases and how the transmission routes can be interrupted. Although the main focus of Hygiene Promotion should be the prevention or reduction of diarrhoea, the methods employed may also be used to address other public health issues such as malaria or other water and sanitation related diseases. Depending on the context, it may be more appropriate to focus on an environmental cleanup, where the key priorities are already well managed.

The diagram below represents the different components of Hygiene Promotion in an emergency situation and examples of the specific activities related to each component are then provided.
Figure 34 the improved "F" Diagram

Barriers to faecal-oral transmission
Primary barriers such as the use of a latrine and protected water sources prevent initial contact with the faeces. Secondary barriers such as hand washing and proper storage of food and water prevent faecal material from being ingested by a new person. It is particularly important to focus on the safe removal and disposal of the faeces of babies and young children, as they contain a higher proportion of disease-causing organisms than adult faeces (Ferron et al, 2007).

4.4. Planning a hygiene promotion programme
The planning stage involves setting the aims and objectives that you hope to achieve from the hygiene promotion programme. The objectives can be divided into three levels, which collectively lead to the aims of the project (Ferron et al., 2007).

- The **aim** or goal is a general statement of intent of the entire programme.
- **Purpose** objectives refer to the wider objective of the programme.
- **Outputs** are the results that the project should be able to guarantee will happen, necessary for achieving the purpose and the aim.
Activities refer to the practical actions (e.g. promotional events and materials) that will be taken to achieve the outputs, purpose and aim/goal.

Figure 35 Safe storage of water at home

Figure 36 Risky behaviors need to be identified

A plan for a hygiene promotion programme should include:

- An overall aim or goal;
- One or two purposes (e.g. targeted hygiene practices);
- Two to four outputs;
- A series of activities for achieving each of the outputs;
- Measurable indicators and means of verification for each level of the objectives;
- Identified target audiences for the hygiene promotion; and
- Action plans for achieving the objectives (e.g. weekly activities and allocation of responsibilities).

4.5. Methods of hygiene and sanitation promotion

In addition to the tools already discussed there are several well-known methods which can be adopted to promote sanitation in communities.

The Hygiene Improvement Framework

The Hygiene Improvement Framework is a tool for designing and implementing diarrhea prevention activities. A comprehensive approach to preventing diarrhea should address three key components: access to the necessary hardware or technologies, promoting healthy behaviors and support for an enabling environment to ensure wide-scale application and sustainability.
Framework Components

Improving access to hardware includes

- Continuous safe water supply systems to communities and neighborhoods
- Sanitation facilities to dispose of feces, especially the feces of young children
- Technologies and materials for improving household level hygiene, such as soap, water treatment and safe storage containers

Promoting hygiene addresses the adoption of key hygiene practices and involves

- Communication — raising awareness of the importance of improved hygiene and supporting hygiene behavior change
- Social mobilization — involving various groups and sectors in diarrhea prevention
- Social marketing — working with the public and private sector to create demand for hygiene “products” such as soap, water disinfectants and latrines
- Community participation — identifying barriers to adopting improved hygiene practices, and designing and monitoring hygiene improvement programs
- Advocacy at all levels — influencing policy and action at all levels to promote hygiene improvement and interventions that support it

Strengthening the enabling environment entails

- Policy improvement — assessing the adequacy of national policies, identifying gaps, and developing new policies
- Institutional strengthening — helping institutions define their role and mission, improve management, increase technical competence, and train their staff
- Community involvement — developing local capacity to operate and maintain local water supply, sanitation and hygiene systems
- Financing and cost-recovery activities — helping local communities devise strategies to recover costs
Cross-sector and public-private partnerships — supporting collaboration between various sectors (e.g., public health and public works) and between public and private partners (e.g., ministries of health and soap manufacturers)

**Hygiene Improvement has proven benefits and health outcomes**

- A 30–50% reduction in the burden of diarrheal diseases can be achieved through improved water supply, sanitation, and hygiene
- An analysis of 21 controlled field trials related to water disinfection and safe water storage at the household level showed a reduction of 42% in diarrheal disease compared with other groups
- A recent review of the literature found that the single hygiene practice of handwashing with soap is able to reduce diarrhea incidence by over 40%
- A 2004 WHO report shows that investing US$1 in selected interventions to improve water and sanitation services results in benefits in the range of US$5 to US$114

**4.5.1. Hygiene Promotion Standards**

*Hygiene promotion standard 1: programme design and implementation*

All facilities and resources provided reflect the vulnerabilities, needs and preferences of the affected population. Users are involved in the management and maintenance of hygiene facilities where appropriate.

**Key indicators**

- Key hygiene risks of public health importance are identified
- Programmes include an effective mechanism for representative and participatory input from all users, including in the initial design of facilities.
- All groups within the population have equitable access to the resources or facilities needed to continue or achieve the hygiene practices that are promoted.
- Hygiene promotion messages and activities address key behaviors and misconceptions and are targeted for all user groups.
- Representatives from these groups participate in planning, training, implementation, monitoring and evaluation.
- Users take responsibility for the management and maintenance of facilities as appropriate, and different groups contribute equitably

**4.5.2. Key principles in Hygiene Promotion**

Hygiene promotion is a planned approach that aims to reduce the incidence of poor hygiene practices and conditions that pose the greatest risk to the health of children, women and men. Several hygiene promotion methodologies have been developed over time to promote hygiene. Experience with these methodologies has shown that effective hygiene promotion is based on several **key principles:**
1. **Target a small number of risk practices.** Because changing habits is not easy, an assessment should be made to understand which risk practices are most widespread, and which can be changed. From the point of view of controlling diarrheal disease, the priorities for hygiene behavior change are likely to include hand washing with soap (or a local substitute) after contact with stools, and the safe disposal of adults’ and children’s stools.

2. **Target specific audiences and identify defining characteristics** that affect their approach to hygiene. For example, a specific audience may include students, but students can represent different sexes, cultural groups, and social groups.

3. **Identify the motives for changed behavior.** While the argument for washing hands with soap will be mainly health related, the motivation for the use of toilets often may have nothing to do with health. People may be persuaded to use a toilet so that their neighbors or classmates will respect them, or for other motives. By working with the target groups one can discover their views of the benefits of safer hygiene practices and use these as the basis for a motivational strategy.

4. **Keep hygiene messages positive.** Both children and adults learn best when they laugh, and will listen more attentively if they are entertained. Hygiene promotion projects that attempt to frighten their audiences will alienate them.

5. **Identify appropriate channels of communication and understand how the target audiences communicate.** For example, what proportion of each listens to the radio and attends social or religious functions? Using traditional and existing channels is easier than setting up new ones, but existing channels can only be used effectively if their nature and capacity to reach people are understood.

6. **Decide on a cost-effective mix of communication channels.** When several channels send the same messages, the messages are reinforced. Be aware of the trade-off between reach, effectiveness, and cost. Mass media reach many people cheaply, but their messages may be soon forgotten. Face-to-face communication can be highly effective in encouraging behavior change, but tends to be expensive. Therefore, a hygiene promotion program will often use a mix of different channels to get the best of all.

7. **Plan, execute, monitor, and evaluate hygiene promotion carefully.** At a minimum, collect information at regular intervals on the outputs and the population coverage achieved. Define and periodically assess indicators of the impact of hygiene promotion on the targeted behaviors and populations.

### 4.5.3. Hygiene Promotion Options

Depending on the characteristics of the target community and the budget available, several options for hygiene promotion activities are available. When aiming to instill hygiene skills in children, the more participatory and more long-term techniques will be necessary.

- **Hygiene Education**
4.5.4. Five Fallacies about Hygiene Promotion

Fallacy No. 1. Behavior change is easy. Getting people to change the habits of a lifetime is difficult, takes time and requires resources and skill.

Fallacy No. 2. Knowledge change = behavior change. It used to be thought that education about hygiene would be enough to get people to change their behavior. However, many people already know about germs, but still don’t wash their hands (Loevinsohn, 1990, Scott et al, 2005). Change may be too expensive or time-consuming, or there may be discouragement from other members of society.

Fallacy No. 3. Experts know how to change behavior. Hygiene promotion programmes can't be designed by experts in an office. They have to be designed around the real needs, wants and contexts of the actors themselves, i.e. by taking a consumer-centered approach. On the other hand, hygiene promotion programmes can't be designed by communities themselves; outside expertise is needed.

Fallacy No. 4. A whole variety of hygiene practices should be encouraged. Only a limited number of unhygienic practices are likely to be responsible for most diarrhoeal episodes. Since behavior change is difficult, efforts should not be diluted by targeting too many practices.

Fallacy No. 5. Hygiene promotion is a cheap add-on to water programmes. Serious efforts to change behavior require serious investment and professional skill. Hygiene promotion needs careful planning and the best solutions may, or may not, dovetail well with water and sanitation activities.

4.6. Hygienic Practices

Personal Hygiene

What is personal hygiene?

Personal hygiene is a concept that is commonly used in medical and public health practices. It is also widely practiced at the individual level and at home. It involves maintaining the cleanliness of our body and clothes.
**Difference between cleanliness and hygiene**

The term cleanliness should not be used in place of hygiene. Cleaning in many cases is removing dirt, wastes or unwanted things from the surface of objects using detergents and necessary equipment.

Hygiene practice focuses on the prevention of diseases through the use of cleaning as one of several inputs. For example, a janitor cleans the floor of a health center using detergent, mop and broom. They might also use chlorine solution to disinfect the floor. The cleaning process in this example is the removal of visible dirt, while the use of chlorine solution removes the invisible microorganisms.

Hygienic practice encompasses both cleaning for the removal of physically observable matters and the use of chlorine for the removal of microorganisms.

The hygiene practice in this example aims at preventing the spread of disease-causing organisms.

Cleaning is a means to achieve this task.

**Public health importance of personal hygiene**

- Preventing faeco-orally transmitted diseases
- Aesthetic values of personal hygiene
- Social impact

**Components of personal hygiene**

**Body hygiene (skin care)**

The body has nearly two million sweat glands. Moistened and dried sweat and dead skin cells all together make dirt that sticks on to the skin and the surface of underclothes.

The action of bacteria decomposes the sweat, thereby generating bad odor and irritating the skin. This is especially observed in the groin, underarms and feet, and in clothing that has absorbed sweat. Skin infections such as scabies, pimples and ringworm are results of poor body hygiene.

Taking a bath or a shower using body soap at least weekly is very important to ensuring our body stays clean.

Bathing can be done every day or after periods of sweating or getting dirty. The genitals and the anal region need to be cleaned well because of the natural secretions of these areas.
**Oral hygiene (oral care)**

The mouth is the area of the body most prone to collecting harmful bacteria and generating infections. Our mouth mechanically breaks food into pieces.

This process leaves food particles (food debris) that stick to the surface of our gums and teeth. Our mouth cavity is full of bacteria and is a good environment for bacterial growth. Why is the mouth a good environment for bacterial growth?

- It is at the optimum temperature (37°C) and is often rich in food particles that support bacterial growth.
- The decaying process that takes place on the surface of the teeth eventually produces a build-up called plaque (a sticky deposit on which bacteria grow) that is then converted into tartar (a hard, yellowish, calcified deposit on the teeth, consisting of organic secretions and food particles). The result is tooth decay.

**Handwashing (hand care)**

The cleanliness of our hands is very important in all our daily activities. In our normal activities our hands frequently get dirty. There are many situations in which microorganisms are likely to attach to our hands along with the dirt.

There are many communicable diseases that follow the route of faeco-oral transmission. Hand hygiene plays a critically important role in preventing this transmission.

Hygienic handwashing involves the mechanical removal of microorganisms from contaminated hand surfaces using soap or detergent. Handwashing should involve more than a quick rinse under a tap (faucet) or in running water.

To know when to wash your hands at home and at work, you must first identify critical situations; that is, situations, activities or incidents that indicate the possibility that pathogenic microorganisms are present on hands, fingers and nail surfaces. Critical situations in everyday activity include:

- After using the toilet (or disposing of human or animal faeces)
- After changing a baby’s diaper (nappy) and disposing of the faeces
- Immediately after touching raw food when preparing meals (e.g. chicken or other meat)
- Before preparing and handling cooked/ready-to-eat food
- Before eating food or feeding children
- After contact with contaminated surfaces (e.g. rubbish bins, cleaning cloths, food-contaminated surfaces)
- After handling pets and domestic animals
➢ After wiping or blowing the nose or sneezing into the hands (respiratory hygiene)
➢ After handling soiled tissues (your own or others’, e.g. children).

**Menstrual hygiene (Personal hygiene for women)**
The vagina is able to clean itself; no special care is needed other than washing the external genitals. Washing the outer genital area with clean water must be a daily practice. Change tampons and sanitary napkins or pads regularly.

Always wash your hands before and after handling a tampon or pad. Clean and soft cloths can be used in place of sanitary pads. The use of dirty cloths must be discouraged. Menstrual blood-absorbing items must be properly disposed of in a burial pit or other appropriate method.

**Food Hygiene**
**Important principles in food hygiene and safety**
In previous sessions of this Module, you have been introduced to the concept of hygiene, which was defined as the set of practices associated with the preservation of health. One important aspect of this is food hygiene, which refers to the many practices needed to safeguard the quality of food from production to consumption. This is sometimes referred to as ‘from farm to fork’ or ‘from farm to table’, because it includes every stage in the process from growing on the farm, through storage and distribution, to finally eating the food. It also includes the collection and disposal of food wastes.

Throughout this chain of events there are many points where, directly or indirectly, knowingly or unknowingly, unwanted chemicals and microorganisms may contaminate the food.

The term ‘food hygiene’ refers particularly to the practices that prevent microbial contamination of food at all points along the chain from farm to table.

Food safety is a closely related but broader concept that means food is free from all possible contaminants and hazards. In practice both terms may be used interchangeably.

Food hygiene is vital for creating and maintaining hygienic and healthy conditions for the production and consumption of the food that we eat.

The overall purpose of food hygiene is to prepare and provide safe food and consequently contribute to a healthy and productive society. The specific objectives for food hygiene are to:
- Prevent food spoilage, i.e. changes that make food unfit for consumption due to microbial or chemical contamination.
- Inform and educate people about simple and practical methods of keeping food safe to protect themselves against foodborne diseases.
 Protect food from adulteration (intentional contamination).
 Ensure proper practice in the food trade to prevent the sale of food that is offensive or defective in value and quality.

Food can be described in a number of different ways. Here are some terms you will find useful:
 Perishable food: food items that have a short storage life and will become spoiled or contaminated if not preserved and handled properly, e.g. meat, eggs, milk, fruits, vegetables and the like.
 Non-perishable food: foods which are not easily spoiled or contaminated, e.g. sugar and cereals.
 Wholesome food: food which is sound, clean and free from harmful ingredients – it is suitable for human consumption.
 Food hazard: food that is contaminated with biological, chemical or physical agents and, if eaten, will cause ill health.
 Thorough handwashing before and during food preparation, especially after using the toilet, and handling raw food or waste.
 Soap/ash sanitizer and clean water should be available for handwashing at convenient locations.
 Sick food handlers should not prepare food! One sick person can cause a foodborne disease outbreak, particularly where people are in crowded or unsanitary living conditions.
 Raw and cooked foods should be separated, because raw foods are a source of microorganisms and can recontaminate prepared foods.

Transmission of foodborne diseases
In the two previous study sessions you have learned about microorganisms and food contamination. The single method of transmission of foodborne diseases to human beings is through ingestion (eating) of food in the following categories:
 Raw or undercooked meat and meat products
 Raw milk (that is, milk that has not been pasteurised or sterilised)
 Food items contaminated with human faeces (directly or indirectly)
 Raw vegetables contaminated with soil
 Food contaminated by chemicals, e.g. pesticides such as malathion
 Food prepared using contaminated water, e.g. for washing vegetables
 Food kept in an unsuitable condition for a long time after preparation
 Poisonous plants.
 Why is it unwise to eat food that has been kept for a long time after it was prepared?
Hand Hygiene: Why, How & When?

WHY?
- Thousands of people die every day around the world from infections acquired while receiving health care.
- Hands are the main pathways of germ transmission during health care.
- Hand hygiene is therefore the most important measure to avoid the transmission of harmful germs and prevent health care-associated infections.

HOW?
- Clean your hands by rubbing them with an alcohol-based formulation, as the preferred mean for routine hygienic hand antisepsis if hands are not visibly soiled. It is faster, more effective, and better tolerated by your hands than washing with soap and water.
- Wash your hands with soap and water when hands are visibly dirty or visibly soiled with blood or other body fluids or after using the toilet.
- If exposure to potential spore-forming pathogens is strongly suspected or proven, including outbreaks of Clostridium difficile, hand washing with soap and water is the preferred means.

Figure 37 Steps of Handwashing
Benefits of Handwashing
Handwashing is one of the most cost-effective investments in public health, and the economic benefit from handwashing is not unique to the prevention of diarrhea and pneumonia, but also most healthcare-associated infections (HAI), which are extremely costly to individuals, healthcare systems, and countries. Handwashing halts the spread of infection and is effective in preventing the spread of some diseases.

- Diarrheal Diseases & Acute Respiratory Infections
- Bacterial Infections
- Viral Infections (seasonal influenza and flu-like illness)
- Helminthic Infections (helminthic infections, such as hookworms, among children)
- Healthcare-Associated Infections
- Stunting
- School Absenteeism (absenteeism due to diarrhea)

Determinants of Handwashing
When environments are enabling, handwashing practice can take place with greater ease. Successful handwashing behavior change requires both the availability of facilities (i.e., a handwashing station with soap and water) and adoption of a good handwashing habit.

- Enabling Environments - people must have access to the necessary materials, including a functional handwashing station with soap in a convenient location. When handwashing stations are visible and accessible they can serve as environmental cues to remind people to wash their hands.
- Action Control & Psychosocial Factors - evaluation of one's own handwashing behavior.
- The Household & the Community - handwashing behavior is positively associated with the education level and ethnicity of the household head, the household wealth index, having an improved sanitation facility and having improved water sources.
- Healthcare Facilities - Perceived risk of infection amongst healthcare workers may influence one's decision to practice proper hand hygiene.
- Primary Caregivers of Children under the Age of 5
- Inclusive WASH - Living with a disability impacts handwashing, primarily due to physical barriers.

Handwashing Hardware & Soap Efficacy - Measurement of handwashing behavior and efficacy across studies remains a challenge.

4.7. Behavioral Change (Stages)
Stage 1: Pre-contemplation (Not Ready)
People at this stage do not intend to start the healthy behavior in the near future (within 6 months), and may be unaware of the need to change. People here learn more about healthy
behavior: they are encouraged to think about the pros of changing their behavior and to feel emotions about the effects of their negative behavior on others.

Pre-contemplators typically underestimate the pros of changing, overestimate the cons, and often are not aware of making such mistakes.

One of the most effective steps that others can help with at this stage is to encourage them to become more mindful of their decision making and more conscious of the multiple benefits of changing an unhealthy behavior.

**Stage 2: Contemplation (Getting Ready)**
At this stage, participants are intending to start the healthy behavior within the next 6 months. While they are usually now more aware of the pros of changing, their cons are about equal to their Pros. This ambivalence about changing can cause them to keep putting off taking action.

People here learn about the kind of person they could be if they changed their behavior and learn more from people who behave in healthy ways.

Others can influence and help effectively at this stage by encouraging them to work at reducing the cons of changing their behavior.

**Stage 3: Preparation (ready)**
People at this stage are ready to start taking action within the next 30 days. They take small steps that they believe can help them make the healthy behavior a part of their lives. For example, they tell their friends and family that they want to change their behavior.

People in this stage should be encouraged to seek support from friends they trust, tell people about their plan to change the way they act, and think about how they would feel if they behaved in a healthier way. Their number one concern is: when they act, will they fail? They learn that the better prepared they are, the more likely they are to keep progressing.

**Stage 4: Action (current 'action')**
People at this stage have changed their behavior within the last 6 months and need to work hard to keep moving ahead. These participants need to learn how to strengthen their commitments to change and to fight urges to slip back.

People in this stage progress by being taught techniques for keeping up their commitments such as substituting activities related to the unhealthy behavior with positive ones, rewarding themselves for taking steps toward changing, and avoiding people and situations that tempt them to behave in unhealthy ways.
Stage 5: Maintenance (monitoring)
People at this stage changed their behavior more than 6 months ago. It is important for people in this stage to be aware of situations that may tempt them to slip back into doing the unhealthy behavior—particularly stressful situations.

It is recommended that people in this stage seek support from and talk with people whom they trust, spend time with people who behave in healthy ways, and remember to engage in healthy activities to cope with stress instead of relying on unhealthy behavior.

Social and Behavior Change Communication
What is SBCC?
SBCC is the systematic application of interactive, theory based, and research-driven communication processes and strategies for change at the individual, community, and social levels.

What are the essential processes in SBCC?

Steps:
1. Understanding the context & audience -situation analysis, formative research
2. Focusing & Designing the Strategy/Approach
3. Creating Activities, Materials, tools
4. Implementing & Monitoring progress
5. Evaluation & Re-planning

What are the main differences from other approaches?

- **Health Education** – building knowledge (SBCC: knowledge is not enough to change behavior)
  - IEC: print media, expert-driven information
- **Social marketing** – audience focus (SBCC also has, but broadens beyond individual level)
- **BCC** – incorporates behavior change theory identify determinants, but still individual focus
- **SBCC** Broadened focus to encompass the whole social & enabling context and different levels of change. Evolution to “SBC”

**WHY SBCC?**

- Its systematic process ensures messages and methods are grounded in data on the social context and target audience.
- Its use of mutually reinforcing communication channels can trigger change at different levels for greater impact
- Participation and capacity building cuts across SBCC activities, to make change more sustainable.
- SBCC works!

**Key elements of SBCC**

- Applies the socio-ecological model for behavior change
- Based on research
- Focused on target audience
- Uses multiple channels of communication
- Works for change at 3 levels
- Involves partners and communities throughout the process
Summary of Module 4

Safe drinking water and sanitation in the absence of hygienic behavior will not prevent faeco-oral infections.

The WHO estimates that exposure to inadequate drinking water, sanitation and hand hygiene was responsible for 58% of deaths from diarrhea, adding up to 840,000 deaths in low and middle-income countries, in 2012. This translates into 1.5% of the global disease burden, even 5.5% for children under five.

Hygiene Promotion is the planned, systematic attempt to enable people to take action to prevent or mitigate water, sanitation, and hygiene related diseases and provides a practical way to facilitate community participation and accountability.

The ‘F’ diagram (left) illustrates the transmission routes of most diarrhoeal diseases and how the transmission routes can be interrupted.

The Hygiene Improvement Framework is a tool for designing and implementing diarrhea prevention activities.

Personal hygiene is a concept that is commonly used in medical and public health practices. It is also widely practiced at the individual level and at home. It involves maintaining the cleanliness of our body and clothes.

Handwashing is one of the most cost-effective investments in public health, and the economic benefit from handwashing is not unique to the prevention of diarrhea and pneumonia, but also most healthcare-associated infections (HAI), which are extremely costly to individuals, healthcare systems, and countries.

SBCC is the systematic application of interactive, theory based, and research-driven communication processes and strategies for change at the individual, community, and social levels.
Module 5: WASH and Nutrition

Introduction
This module focuses on the impact of nutrition on child growth and how WASH components impact the nutritional status of a child. The relationship between WASH and Nutrition with evidences for integrating both components are addressed. The global and national status of undernutrition, nutrition and the life cycle; and the interrelation between malnutrition and diarrhea; diarrhea and growth are briefly discussed.

Learning Objectives for this Module
After you have studied this Module you should be able to:
- Analyze the relationship between WASH and Nutrition
- Describe the global status of Malnutrition
- Explain Nutrition and the life cycle;
- Explain the relationship between malnutrition and Diarrhea

5.1. Key Terminologies in WASH and Nutrition
WASH typically refers to activities aimed at improving access to and use of safe drinking-water and sanitation as well as promoting good hygiene practices (e.g. handwashing with soap at critical times). Interventions are generally categorized as follows:

**Water quantity:** Provision of facilities and services that increase the amount of water available for drinking, cooking and maintaining good hygiene practices within households, health care facilities or schools; and reduce the time and effort required to collect the water.

**Water quality:** Improvement and protection of the microbiological (or chemical, such as arsenic) quality of drinking-water through water treatment and safe storage or by improving existing water sources to protect them from outside contamination. Improved water sources, as defined by the World Health Organization (WHO)/United Nations Children’s Fund (UNICEF) Joint Monitoring Programme for Water Supply and Sanitation (JMP) for the purposes of measuring progress towards the United Nations’ Millennium Development Goals (MDGs), include piped water on-site, public taps or standpipes, tubewells or boreholes, protected dug wells, protected springs and rainwater (WHO/UNICEF, 2015).

**Sanitation:** Provision and use of facilities and services that safely dispose of human urine and faeces, thereby preventing contamination of the environment. Improved sanitation facilities as defined by the aforementioned JMP are those that hygienically separate human excreta from human contact and include flush or pour-flush toilets to piped sewer systems, septic tanks or pits, ventilated improved pit latrines, pit latrines with slab, and composting toilets (WHO/UNICEF, 2015).
**Hygiene:** Practice of handwashing with soap after defecation and disposal of child faeces, prior to preparing and handling food, before eating, and, in health care facilities, before and after examining patients and conducting medical procedures. In this document, hygiene also refers to interventions such as food hygiene (safe food handling, including preparation, storage and serving) and environmental hygiene, such as safely disposing of household solid waste (Adams, Bartram & Chartier, 2008).

**Malnutrition:** Malnutrition refers to all forms of nutrition disorders caused by a complex array of factors, including dietary inadequacy (deficiencies, excesses or imbalances in macronutrients or micronutrients), and includes both undernutrition and over nutrition and diet-related non communicable diseases.

**Undernutrition:** Undernutrition occurs when the body’s requirements for nutrients are unmet as a result of under consumption or impaired absorption and use of nutrients. Undernutrition commonly refers to a deficit in energy intake from macronutrients (fats, carbohydrates and proteins) and/or to deficiencies in specific micronutrients (vitamins and minerals). It can be either acute or chronic (WHO, 2013b).

**Indicators of nutritional status:** Anthropometric indicators (height and/or weight for a given age and sex) are commonly used to measure child growth and nutritional status. Indicators of undernutrition include stunting, wasting and underweight:

**Stunting** (low height-for-age) is an indicator of chronic undernutrition and often reflects general poor health and more distal economic and social factors.

**Wasting** (low weight-for-height) is an indicator of acute undernutrition and is associated with increased mortality.

**Underweight** (low weight-for-age) reflects both chronic and acute undernutrition.

Other indicators of nutritional status are deficiencies in micronutrients (e.g. iron, vitamin A, zinc, iodine), which are measured through biomarkers, requiring blood and/or urine samples. Finally, measuring dietary intake over time provides a direct measure of nutrient intake and complementary information to the outcome indicators.

### 5.2. Evidence Base for Integrating WASH and Nutrition

Key evidence for the impact of pathogenic environments on nutritional status includes:
- A comparative study of markers for environmental enteropathy, parasite burden, and growth in 119 Bangladeshi children (<48 months of age) living in rural households with different levels of environmental cleanliness (defined by objective indicators of water quality and sanitary and handwashing infrastructure) was carried out by Lin et al. (2013).
Both lower height-for-age and the presence of enteropathic biomarkers were observed for children in “dirty” household environments. These results are consistent with the hypothesis that environmental contamination causes growth faltering (lower height for age), perhaps mediated through environmental enteropathy.

- Links between the environment and nutritional status were observed in Peace Corps volunteers in Pakistan who experienced mild diarrhea and weight loss. The volunteers were observed to have both abnormal intestinal biopsies and complex carbohydrate absorption (indicative of gut dysfunction). Several years after returning to the United States, they regained weight, normal carbohydrate absorptive function, and normal intestinal biopsies. These results suggest that the pathogenic environment temporarily affected their nutritional status and that a hygienic environment supported improved nutrition (Korpe and Petri, 2013).

- A clear association between sanitation and child height was observed by using country-level regressions across 65 developing countries, with a particular focus on India. The results suggest that much of the stunting in India is associated with poor sanitation, perhaps a proxy for a pathogenic environment (Spears, 2013).

**Global status of undernutrition**

Globally, in 2014, an estimated 159 million children under 5 years of age were stunted, and 50 million were wasted (Fig. 2). The highest rates of undernutrition are reported in Africa, Asia and Oceania (UNICEF/WHO/World Bank, 2015). Moreover, billions of people worldwide suffer from vitamin and mineral deficiencies, especially iron, iodine and vitamin A (WHO, 2013b). Undernutrition in all its forms is estimated to contribute to 3.1 million child deaths each year, accounting for 45% of all deaths of children under 5 years of age (Black et al., 2013). As illustrated in Fig. 2, stunting is widespread globally, and 44 countries have a significant proportion of children (at least 30%) younger than 5 years of age who are stunted.

![Figure 38 Map of global prevalence of stunting of children less than 5 years of age (WHO, 2015a)](image-url)
Causes of undernutrition

Undernutrition is directly related to inadequate dietary intake and infectious diseases and is influenced by three broad factors: food, health and care. Optimal nutritional status results when children and families have access to foods that are conducive to a healthy diet and meet dietary needs (e.g. sufficient, safe and nutritious); appropriate maternal and child care practices; adequate health services; and a healthy environment, including safe water, sanitation and good hygiene practices. The interaction between undernutrition and infection (particularly diarrhoeal diseases) creates a potentially vicious cycle of worsening illness and deteriorating nutritional status. The resources available in a society (human, financial, physical) and how they are used (social, economic, political and cultural) constitute the basic causes of undernutrition.

5.3. Malnutrition and Diarrhea

Malnutrition is a major issue in the world. Nevertheless, there exist other factors than food shortage that play an important part, among others infections especially in chronic malnutrition (involving stunting).

Infection can be defined as the detrimental colonization of a host organism, of a foreign species (such as bacteria, viruses, fungi, and parasites) which is generally pathogen and able to multiply. The Latin origin of the word “inficere” meaning poisoning evidences the real negative impact of the process. There are several types of infections: they can be local infections, infections specific to an organ and disseminated infections.

5.3.1. Links between diarrhea and malnutrition

Diarrhea can be considered as both the cause and the consequence of malnutrition: in fact, diarrhea prevents children from catching up for stunting and malnutrition increases the frequency and the length of diarrheic episodes, constituting a vicious circle.

Infection and nutrition status

It is necessary to make the following two main preliminary methodological comments:

- Most of the studies relate to children aged less than 5 years. Nearly all of them give the weight-for-age, which is a measurement that does not distinguish between acute malnutrition and chronic malnutrition with a previous phase of acute malnutrition.
- The word « infection » is often used instead of diarrhea.

![Figure 39 Relationships between infection and malnutrition](image-url)
The consequences of infections on the nutrition status
Infections have a negative impact on the nutrition status because they reduce appetite (or food intake) and intestinal absorption, and at the same time they increase catabolism and the imprisonment of micronutrients that are necessary to growth and tissue synthesis (Luong, 2003). From mathematical models calculating the stunting proportion attributable to diarrhea (Martorell1980; Rowland 1988; Black1984), it appeared that ¼ to 1/3 of this stunting was due to intestinal infections.

Impacts of nutrition on infections
Furthermore, malnutrition prone to infections because of its negative impact on the normal protecting barriers that the skin and mucosa are against any pathogens on the one hand, and on the reduction in immune defense on the other. A meta-analysis (Black and al., 2003) on the results of 10 longitudinal studies of children aged less than 5 years and born in various communities, evidenced that the delay in weight gain (“underweight”) increases the mortality rate further to an infection. The relative part played by the factor “weight lower than the average” is 61% for diarrhea, 57% for malaria and 53% for other infectious diseases.

5.3.2. Relationships between Diarrhea and Growth Reduction in Food Intake during Diarrheic Episodes
The reasons for reducing food intake during diarrheas episodes can be:

- Either due to the child itself: anorexia (either related or not to zinc deficiency that is very often is at the origin of diarrheic episodes) or a child too weak to feed itself.
- Or the result of forced restriction because of default caring of children (Ashcroft, 2001): up the 1980s it was common to leave children on a “starvation diet” or not breastfeeding them during diarrheic episodes (Kaur 1994); please refer Brown K., 2003 for the history of this.
- Children’s weight gain was influenced by infectious phases.
- Approximately 1/3 to 1/4 of the decrease in growth could directly relate to intestinal infections (Brown K., 2003).
- During diarrhea or fever phases, breast-feeding children reduced their energetic consumption by approximately 6%.
- A reduction of 20-30% in the consumption of substitution milk could be observed in children that were not breastfed.
- Children suffering from stunting absorbed less energy than other children (Hautvast 1999).

Reduction in Intestinal Absorption (Malabsorption)

- Stunting for 43% of children aged under 15 months was due to enteropathy. (Lunn, 2000, ID34)
During acute diarrheic episodes showed that depletion in zinc and copper occurred (please read below the importance of those micronutrients).

Furthermore, some food supplements composed of plants and administered to children after weaning could also reduce food absorption.

In addition, food could be contaminated by pathogens (Mensah, 2003) and hence bring about diarrheas.

Infections and Immune System
Malnutrition—even moderate malnutrition—has been acknowledged as being responsible for weakening the immune system. The changes occurring in the immune defense system described in the developed countries and concerning some in-patients (trauma or surgery) or elderly people (anorexia further to taking medicines) could be compared to those observed in undernourished children or adults living in developing countries.

Micronutrients and Immune Answer
The role of micronutrients in appropriate immune reactions to aggressions has been now fully accepted (Bhaskaram 2002, Erickson 2000). The meta-analysis of Stephenson (2000) made a list of the four most important types of malnutrition in the world:

- Malnutrition due to a deficiency in the level of intake.
- Iron deficiency and anemia (IDA).
- Vitamin A deficiency (VAD).
- Iodine deficiency diseases (IDD).

5.4. Nutrition and WASH through the life cycle
The most crucial period in a child’s growth and development is the 1000 days starting from conception until the child’s second birthday. Adequate nutrition during this time is essential for healthy physical growth and brain development. Nutritional deficiencies during this period not only can result in disease and death, but also can have long-term consequences on cognitive and social abilities, school performance and work productivity in adulthood.

Undernutrition can span across generations and affect all stages of the life cycle. Girls suffering from undernutrition are likely to become undernourished mothers who are, in turn, more likely to give birth to low birth weight infants. For example, severe anemia during pregnancy increases the risk of preterm delivery and low birth weight babies. Low birth weight babies are, in turn, more likely to die or become stunted. Adolescent girls are particularly vulnerable to undernutrition because they have high nutrient needs due to growth and because they are at risk for becoming pregnant (Black et al., 2013).
5.4.1. WASH throughout the Life Cycle

WASH through the life cycle involves the study of special WASH needs, and health concerns of pregnant and lactating women, infants, children, adolescents, and older adults to have healthy and productive life in an innovative approach.

While it is recognized that WASH is important throughout a person’s life, the most critical period in a person’s development are the first 1,000 days – beginning with conception, throughout a mother’s pregnancy and until the age of two. This basically means that poor WASH and undernutrition can already begin with the undernourished mother who cannot provide her child with sufficient nutrients at the fetal stage, as she herself has not benefited from optimal nutrition. Current research appears to validate the view that unsafe drinking water, poor sanitation and inadequate hygiene significantly increase the risk of undernutrition, in particular during this critical window of 1,000 days, when a child is more vulnerable to the adverse effects of Faecally Transmitted Infections (FTI). Damage done to a child’s physical growth, immune system and brain development during this period is usually irreversible.
Therefore, the following optimal WASH practiced need to be promoted in line with the life cycle approaches.

**Conception to Birth:**
- Feed the mother hygienically prepared food,
- Treat drinking water at home and, store and use it safely in clean and covered storage container.
- Drink ample drinking water.
- Have cleaning and net living environment to prevent diseases transmitting vectors.
- Manage and dispose all wastes properly.
- Serve drinking water in clean cup.
- WASH hands properly using soap after visiting toilet
- Use latrine properly and handle it hygienically.
- Do not reheat your foods, eat freshly cooked foods
- Wash thoroughly fresh food before eating
- Maintain personal hygiene of both the mother and child. Focus of breast hygiene.

**From birth to 6 month**
- Properly dispose the feces of children in latrine properly
- Maintain personal hygiene of mother (focus on breast hygiene) and child
- Clean clothes and of children periodically and dry it on sun exposure
- Wash hands properly after visiting toile, after cleansing children
- Wash hands properly before cooking food, and before eating
- Eat fresh foods after thoroughly washing, and do not overcook foods or reheat food
- Treat drinking water at home and drink ample amount

**From 6 months to 2 years**
- Prepare complementary food in hygiene cooking areas
- Do not store and reheat child food
- Help children to defecate at proper place and dispose the child faces properly in latrine
- Keep safely the playground of children
- Wash children hands properly after game before eating
- Mothers/care taker should wash their hands properly after

**2 years to 10 years**
- Wash hands properly during the four critical time
- Clean the living environment and playground to make safe from fecal contaminants
- Use latrine to dispose fecal wastes and
- Dispose all wastes properly
- Treat drinking water at home before drinking and use for food preparation
**Adolescent and Adult WASH**

- Wash hands properly during the four critical time
- Clean the living environment and playground to make safe from fecal contaminants
- Use latrine to dispose fecal wastes and specially children faeces
- Manage and dispose all wastes properly
- Treat drinking water at home before drinking and use for food preparation
- Clean fresh food thoroughly and do not reheat it
- Advance sanitation facilities from basic sanitation facilities Promote optimal WASH practices

**Life Cycle Approach to WASH Intervention** *(Customized by Kefyalew Muleta)*

![Life Cycle Approach to WASH Intervention Diagram](image)

5.5. Monitoring and Evaluation of Water Sanitation and Hygiene

How do you know that your sanitation and hygiene promotion is making a difference? Is your behavior change communication having the intended results? What can be done differently to better meet objectives? These are the sorts of question that monitoring and evaluation allow you to answer. Good intentions, effective planning, large programmes and projects, and even an abundance of financial resources are not enough to ensure that development projects will be successfully implemented. Monitoring and evaluation are essential to track whether a project is delivering against its desired outcomes. It is a process that helps us learn from past successes and make the right decisions, so that current and future initiatives are better able to improve
people’s lives. This study session will focus on monitoring and evaluation of behavior change interventions.

The importance of monitoring and evaluation
Assume that you are managing a ‘handwashing with soap after visiting latrine’ campaign in your community. How do you make sure that the activities of the campaign are on track? How do you know that the necessary products (e.g. soap) and services (e.g. water) are available during the campaign? How would you know at the end of the campaign that community members are definitely washing their hands with soap after visiting a latrine?

Monitoring and evaluation are ways of systematically measuring and assessing programme activities and results. Their purpose is to check on the progress of implementation and outputs systematically. They help to determine when a programme is going to plan and when changes may be needed. They form the basis for modification of interventions, and of assessing the quality of any activities that are being conducted. Moreover, with a positive outcome, they can be used to demonstrate that programmes have been implemented effectively and have had a measureable impact. Together, monitoring and evaluation (frequently abbreviated to M&E) provide the necessary data to guide planning, to allocate resources, to design and implement programmes and projects and, if necessary, to re-allocate resources in better ways. They are essential in providing planners, implementers, policy makers and donors with the information and understanding they need to make informed decisions about the operation of their programmes.

Although often referred to together as M&E, monitoring and evaluation are two different but linked processes that apply to many projects, programmes and other interventions.

What is monitoring?
Monitoring is systematic, timely and purposeful observation and data collection to check if project activities are being implemented as planned. More precisely, monitoring assesses project activities to establish what activities are being done, and where, with whom, when and how many have been completed.

Key terms in monitoring and evaluation
Outputs are the things produced by a project or programme. In WASH, examples include tangible products like new or rehabilitated wells and pumps, new latrines and training manuals; they could be events and activities like running a training workshop for frontline workers, or producing hygiene promotion posters.
**Outcomes** are the effects of the outputs, usually in the short- to medium-term. Examples, following those above, could be the number of people who now have access to safe water as a result of the new water schemes or attendance at the training workshop.

**Impacts** are long-term effects and consequences. Examples could be a fall in the incidence of diarrhoeal disease, improved school attendance, or pumps that last longer because they are well maintained.

An **indicator** is something that can be seen or measured or counted, which provides evidence of progress towards a target. Indicators are used to monitor or evaluate project performance. They are project-specific and defined by the objectives of the project. They can be based on either quantitative or qualitative measurements.

Monitoring is used to track changes in project performance over time against measurable indicators defined well in advance. It involves collecting data and tracking actions being taken in order to measure progress towards the goals and to identify any problems. For any particular activity, the output, the outcome and the process should all be monitored.

The purpose of monitoring is to permit managers to make informed decisions regarding the implementation and performance of projects and the efficient use of resources. Monitoring is often done internally by project managers or by dedicated project monitoring staff. It involves a continuous process of checking, analyzing and giving feedback into project activity and resource allocation plans.

One well-known example of an international monitoring programme is the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation. This is a global monitoring programme for the WASH sector that annually collects and publishes data on a range of indicators for countries all over the world (JMP, 2014). At national level in Ethiopia, the National WASH Inventory is a monitoring system that collects data on water supply in urban and rural areas, sanitation and hygiene practices of households, and the status of water supply and sanitation facilities at health institutions and schools (Pratt, 2015).

**What is evaluation?**

**Evaluation** is an objective assessment of the design, implementation and results of an ongoing or completed project. Evaluations can be conducted during or at the end of the project period, depending on the purpose of the evaluation. Unlike monitoring, which should be done frequently, evaluation involves collecting data or undertaking surveys at particular points during a project. This will include baseline data collected at the start and follow-up data collected during or at the end of the project. Baseline data provides information about the situation before the project began which can then be compared with the follow-up data collected later. This comparison means that the effects of the project activities can be measured.
Evaluation also provides information that can help decision makers when planning new initiatives. Reflections on lessons learned from past successes and failures can be very helpful when planning future interventions. Unlike monitoring, evaluation of a project is usually done by an independent individual or firm in order to provide managers and staff with an objective assessment of the project.

The aim of evaluation is to determine the efficiency, effectiveness, impact and sustainability of a project, and whether it has met its objectives. In summary, monitoring and evaluation are important management tools for providing information that can help to inform decisions, improve performance and achieve planned results.

**Developing a monitoring and evaluation plan**

Planning for M&E should be part of the design phase of a project and included at the beginning when the objectives of the project are decided. The M&E plan needs to describe how the results will be measured to determine if the project objectives have been achieved.

A result is not the completion of activities. A ‘result’ is defined as a describable or measurable development change that happens as a consequence of a cause-and-effect relationship (UNDP, 2009). Results include the outputs, outcomes and impacts of project activities. These are linked together into what is commonly referred to as a results chain. The results chain essentially tells us that completion of the stated activities will lead to the outputs; the outputs will lead to the outcomes; and the outcomes will lead to the impacts.

There are various models, or frameworks, used when planning for M&E. You may come across results frameworks or logical frameworks. These are similar and both methods can be used to ensure a systematic and comprehensive approach to M&E planning.

A logical framework, or simply log frame, links the planned activities, which have been introduced to address the objectives, with the expected results in terms of outputs, outcomes and impacts. It indicates how they will be monitored and evaluated. The log frame allows information to be analyzed and organized in a structured way. It encourages clear and specific thinking about what the project aims to do and how, and highlights the aspects upon which the success of the project depends.
Summary of Module 5

WASH typically refers to activities aimed at improving access to and use of safe drinking-water and sanitation as well as promoting good hygiene practices (e.g., handwashing with soap at critical times).

Malnutrition refers to all forms of nutrition disorders caused by a complex array of factors, including dietary inadequacy (deficiencies, excesses or imbalances in macronutrients or micronutrients), and includes both undernutrition and overweight/obesity and diet-related non-communicable diseases.

Infection can be defined as the detrimental colonization of a host organism, of a foreign species (such as bacteria, viruses, fungi, and parasites) which is generally pathogen and able to multiply.

Diarrhea can be considered as both the cause and the consequence of malnutrition: in fact, diarrhea prevents children from catching up for stunting and malnutrition increases the frequency and the length of diarrheic episodes, constituting a vicious circle.

Monitoring is systematic, timely and purposeful observation and data collection to check if project activities are being implemented as planned. More precisely, monitoring assesses project activities to establish what activities are being done, and where, with whom, when and how many have been completed.
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