NATIONAL OPEN UNIVERSITY OF NIGERIA

FACULTY OF HEALTH SCIENCES

COURSE CODE: EHS419

COURSE TITLE: SANITARY ENGINEERING

COURSE GUIDE

EHS 419
SANITARY ENGINEERING

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INTRODUCTION

EHS 419 Sanitary Engineering *is* a two (2) units course with three modules and ten (10) units. Sanitary engineering utilises application of engineering methods to improve sanitation of human communities. It provides application of mathematics, empirical evidence, scientific, social and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, and processes that lead to safe of removal and disposal of human waste as well as supply of safe potable water.

WHAT YOU WILL LEARN IN THIS COURSE

In this course, you have the course units and a course guide. The course guide will tell you what the course is all about i.e. the general overview of the course materials and how to use those materials. It also helps you to allocate the appropriate time to each unit so that you can successfully complete the course within the stipulated time limit. The course guide also helps you to know how to go about your Tutor- Marked Assignment which will form part of your overall assessment at the end of the course. Also, there will be regular tutorial classes that are related to this course, where you can interact with your facilitator and other students. Please, I encourage you to attend these tutorial classes.

COURSE AIM

The course aims to give you an understanding of sanitation as driven by engineering methods.

COURSE OBJECTIVES

By the end of this course, you will be able to:

- achieve the aim set above, there are objectives each unit has a set of objectives presented at the beginning of the unit these objectives will direct you on what to concentrate / focus on while studying the unit.
- define sanitary engineering
- explain the concept of sanitary engineering
- evaluate environmental problems of urbanization
- describe the health effects of environmental degradation
- write briefly on the elementary hydrology
- discuss what hydrological cycle is all about
- identify and elucidate the physical, chemical and biological properties of water
- explain water surveillance and sampling techniques

- discuss method for water sample collection
- list the basic methods for water analysis
- explain stages in water treatment
- describe water service/storage reservoirs
- explain the pipe system
- explain types of distribution systems
- describe pipes and fittings
- define sewage treatment
- explain physical treatment method of sewage
- explain chemical treatment of sewage
- explain biological treatment of sewage
- explain the principle of activated sludge
- explain the principle of trickling filter
- define aeration
- explain secondary clarification
- explain principle of stabilization pond
- explain the principle of aerated lagoon
- explain the principle of conservancy system of excretal disposal
- explain the principle of water carriage system of excretal disposal.

WORKING THROUGH THIS COURSE

To successfully complete this course, you are required to read each study unit, read the textbooks materials provided by the National Open University of Nigeria. Reading the referenced materials can also be of great assistance. Each unit has self-assessment exercises which you are advised to do and at certain periods during the course you will be required to submit your assignment for the purpose of assessment.

There will be a final examination at the end of the course. The course can take you about 17 weeks to complete. This course guide will provide you with all the components of the course, how to go about studying and hours you should allocate to each unit so as to finish on time and successfully.

COURSE MATERIALS

The main components of the course are:

- The Study Guide
- Study Units
- Reference / Further Reading
- Assignments
- Presentation Schedule

STUDY UNITS

The study units in this course are given below:

Module 1 Concept of Sanitary Engineering and Elementary Hydrology

Unit 1 Definitions, Concepts and Theories of Sanitary Engineering
Unit 2 Environmental Problems of Urbanisation and Natural Cycle of Water
Unit 3 Elementary Hydrology, Hydrological Cycle, Physical, Chemical and Biological Properties of Water

Module 2 Water and Waste Treatment

Unit 1 Basic Water Treatment Processes
Unit 2 Methods of Storage And Distribution of Treated Water
Unit 3 Processes of Sewage Treatment
Unit 4 Methods of Sewage/Waste Water Treatment

Module 3 Waste Disposal and Management

Unit 1 Methods of Excreta Disposal
Unit 2 Urban and Community Storm Water Management
Unit 3 Hazardous Waste Management

There are activities related to the lecture in each unit which will help your progress and comprehension of the unit. You are required to work on these exercises which together with the TMAs will enable you to achieve the objectives of each unit.

ASSIGNMENT FILE

There are two types of assessments in this course. First are the Tutor-Marked Assessments (TMAs), secondly there is a written examination. In solving the questions in the assignments, you are expected to apply the information, knowledge and experience acquired during the course. The assignments must be submitted to your facilitator for formal assessment in accordance with prescribed deadlines stated in the assignment file. The work you submit to your facilitator for assessment accounts for 30% of your total course mark. At the end of the course, you will be required to sit for a final examination of 1½ hours duration at your study centre. This final examination will account for 70 % of your total course mark.

PRESENTATION SCHEDULE

There is a time-table prepared for the early and timely completion and submissions of your TMAs as well as attending the tutorial classes. You are required to submit all your assignments by the stipulated time and date. Avoid procrastination and working behind the schedule time.

ASSESSMENT

There are three aspects to the assessment of this course. The first one is the self-assessment exercises. The second is the tutor marked assignments and the third is the written examination or the examination to be taken at the end of the course. Do the exercises or activities in the unit by applying the information and knowledge you acquired during the course. The tutor-marked assignments must be submitted to your facilitator for formal assessment in accordance with the deadlines stated in the presentation schedule and the assignment file. The work submitted to your tutor for assessment will count for 30% of your total course work. At the end of this course, you have to sit for a final or end of course examination of about a three-hour duration which will count for 70% of your total course mark.

TUTOR-MARKED ASSIGNMENTS

This is the continuous assessment component of this course and it accounts for 30% of the total score. You will be given four (4) TMAs by your facilitator to answer. Three of which must be answered before you are allowed to sit for the end of course examination. These answered assignments must be returned to your facilitator. You are expected to complete the assignments by using the information and material in your readings references and study units. Reading and researching into you references will give you a wider via point and give you a deeper understanding of the subject.

1. Make sure that each assignment reaches your facilitator on or before the deadline given in the presentation schedule and assignment file. If for any reason you are not able to complete your assignment, make sure you contact your facilitator before the assignment is due to discuss the possibility of an extension. Request for extension will not be granted after the due date unless there in exceptional circumstances.

2. Make sure you revise the whole course content before sitting or the examination. The self-assessment activities and TMAs will be useful for this purposes and if you have any comment please do before the examination. The end of course examination covers information from all parts of the course.

COURSE MARKING SCHEME

Assignments	**Marks**
Assignments 1 – 4	Four assignments, best three marks of the four count at 10% each = 30% of course marks.
End of course examination	70% of overall course marks
Total	**100% of course materials**

Table 2: Course Organisation

Unit	**Title of Work**	**Weeks Activity**	**Assessment (End of Unit)**
	Couse Guide	**Week**	
1	Definitions, concepts and theories of sanitary engineering	Week 1	Assignment 1
2	Environmental problems of urbanization and natural cycle of water	Week 2	Assignment 2
3	Elementary hydrology, hydrological cycle, physical, chemical and biological properties of water	Week 3	Assignment 3
4	Basic Water Treatment Processes	Week 4	Assignment 4
5	Methods of Storage and Distribution of Treated Water	Week 5	Assignment 5
6	Processes of Sewage Treatment	Week 6	Assignment 6
7	Methods of Sewage/Waste Water Treatment	Week 7	Assignment 7
8	Methods of Excreta Disposal	Week 8	Assignment 8
9	Urban and Community Storm Water Management	Week 9	Assignment 9
10	Hazardous Waste Management	Week 10	Assignment 10

HOW TO GET THE MOST OUT OF THIS COURSE

In distance learning, the study units replace the university lecturer. This is one of the huge advantages of distance learning mode, you can read and work through specially designed study materials at your own pace and at a time and place that suit you best. Think of it as reading from the teacher, the study guide tells you what to read, when to read and the relevant texts to consult. You are provided exercises at appropriate points, just as a lecturer might give you an in-class exercise.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next to this is a set of learning objectives. These learning objectives are meant to guide your studies. The moment a unit is finished, you must go back and check whether you have achieved the objectives. If this is made a habit, then you will significantly improve your chances of passing the course.

The main body of the units also guides you through the required readings from other sources. This will usually be either from a text book or from other sources. Self-assessment exercises are provided throughout the unit, to aid personal studies and answers are provided at the end of the unit. Working through these self-tests will help you to achieve the objectives of the unit and also prepare you for tutor marked assignments and examinations. You should attempt each self-test as you encounter them in the units.

The following are practical strategies for working through this course

1. Read the Course Guide thoroughly.
2. Organize a study schedule. Refer to the course overview for more details. Note the time you are expected to spend on each unit and how the assignment relates to the units. Important details, e.g. details of your tutorials and the date of the first day of the semester are available. You need to gather together all these information in one place such as a diary, a wall chart calendar or an organizer. Whatever method you choose, you should decide on and write in your own dates for working on each unit.
3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course works. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.
4. Turn to Unit 1 and read the introduction and the objectives for the unit.
5. Assemble the study materials. Information about what you need for a unit is given in the table of contents at the beginning of each unit. You will almost always need both the study unit you are working on and one of the materials recommended for further readings, on your desk at the same time.
6. Work through the unit, the content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit, you will be encouraged to read from your set books.
7. Keep in mind that you will learn a lot by doing all your assignments carefully. They have been designed to help you meet the objectives of the course and will help you pass the examination.
8. Review the objectives of each study unit to confirm that you have achieved them. If you are not certain about any of the objectives, review the study material and consult your tutor.
9. When you are confident that you have achieved a unit’s objectives, you can start on the next unit. Proceed unit by unit through the course and try to pace your study so that you can keep yourself on schedule.
10. When you have submitted an assignment to your tutor for marking, do not wait for its return before starting on the next unit. Keep to your

schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment form and also that written on the assignment. Consult you tutor as soon as possible if you have any questions or problems.

11. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this course guide).

FACILITATORS/TUTORS AND TUTORIALS

Sixteen (16) hours are provided for tutorials for this course. You will be notified of the dates, times and location for these tutorial classes. As soon as you are allocated a tutorial group, the name and phone number of your facilitator will be given to you. These are the duties of your facilitator: He or she will mark and comment on your assignment. He will monitor your progress and provide any necessary assistance you need. He or she will mark your TMAs and return to you as soon as possible. You are expected to mail your tutored assignment to your facilitator at least two days before the schedule date. Do not delay to contact your facilitator by telephone or e-mail for necessary assistance if you do not understand any part of the study in the course material. You have difficulty with the self-assessment activities.

You have a problem or question with an assignment or with the grading of the assignment. It is important and necessary you acted the tutorial classes because this is the only chance to have face to face content with your facilitator and to ask questions which will be answered instantly. It is also period where you can say any problem encountered in the course of your study.

FINAL EXAMINATION AND GRADING

The final examination for EHS 202: Introduction to Ecology and Environmental Science will be of 1½ hours duration. This accounts for 70 % of the total course grade. The examination will consist of questions which reflect the practice, exercises and the tutor-marked assignments you have already attempted in the past. Note that all areas of the course will be assessed. To revise the entire course, you must start from the first unit to the twelfth unit in order to get prepared for the examination. It may be useful to go over your TMAs and probably discuss with your course mates or group if need be. This will make you to be more prepared, since the examination covers information from all aspects of the course.

SUMMARY

Sanitary Engineering is a course that introduces you to how engineering methods are applied to improve sanitation of human communities. It is concerned with application of mathematics, empirical evidence, scientific, social and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, and processes that lead to safe of removal and disposal of human waste as well as supply of safe potable water. On completion of this course, you will have an understanding of basic concept of sanitary engineering, water and waste treatment methods, waste disposal and management. In addition you will be able to answer the following questions:

- Define the concept of Sanitary Engineering.
- State environmental problems of urbanisation and natural water cycle.
- Enumerate properties of water.
- Describe water treatment, storage and distribution.
- Describe the process of sewage/waste water treatment, disposal and management.
- What are the divisions of Environment?

The list of questions are expected to answer is not limited to the above list. Finally, you are expected to apply the knowledge you have acquired during this course to your practical life.
I wish you success in this course!

MAIN COURSE

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MODULE 1 CONCEPT OF SANITARY ENGINEERING AND ELEMENTARY HYDROLOGY

Unit 1 Definitions, Concepts and Theories of Sanitary Engineering
Unit 2 Environmental Problems of Urbanisation and Natural Cycle of Water
Unit 3 Elementary Hydrology, Hydrological Cycle, Physical, Chemical and Biological Properties of Water

UNIT 1 DEFINITIONS, CONCEPTS AND THEORIES OF SANITARY ENGINEERING

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1.0 Introduction
2.0 Objectives
3.0 Main Content
 3.1 Overview of Sanitary Engineering
 3.2 The Concept of Sanitary Engineering
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

It is important that you understand the meaning of sanitation and engineering separately before you can begin to think of the meaning of sanitary engineering. Sanitation can be defined as the hygienic means of promoting health through prevention of human contact with the hazards of wastes as well as the treatment and proper disposal of sewage or wastewater while engineering is the application of mathematics, empirical evidence and scientific, economic, social, and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, and processes. As we continue you will get to know the concept and theory of sanitary engineering.

OBJECTIVES

By the end of this unit, you will be able to:

- understand the definition of sanitary engineering
- explain the concept of sanitary engineering.

3.0 MAIN CONTENT

3.1 Overview of Sanitary Engineering

Now you can merge the definition of sanitation and engineering that we have defined in the introduction together to define sanitary engineering as the application of engineering methods to improve sanitation of human communities, primarily by providing the removal and disposal of human waste, and in addition to the supply of safe potable water. Sanitation and water supply have a strong effect on living conditions.

3.2 Concept of Sanitary Engineering

You need to know that in developing countries' major sources of pollution are from untreated or partially treated domestic sewage, industrial effluent, domestic and industrial garbage. Infact, many cities wastewater are discharged directly into the rivers, coastal water and water bodies often without any treatment at all. You should be aware that the polluted water can travel long distances underground when conditions allow it. Also improperly sited wells and unprotected springs are vulnerable to contamination from pit latrines, septic tanks, and other waste disposal sites. Septic tanks and other sewage systems if not properly constructed, located, and maintained, can easily pollute the ground and surface water. Insufficiently treated or untreated industrial and municipal wastes discharged into water bodies pollute water supplies and pose risks to human health. All the aforementioned problems are what the knowledge of sanitary engineering will help us to solve. As we continue you will learn how to eliminate all these environmental problems using the principles of sanitary engineering.

4.0 CONCLUSION

Now I know you can define sanitation, engineering and of course sanitary engineering. I also know that by now you should know why it is important to have the basic knowledge of sanitary engineering and its concept.

5.0 SUMMARY

This introduction of sanitary engineering is important to stimulate your interest in what this course is all about, you may be wondering since you are not an engineer, how this does concerns you. It concerns you because you are an environmentalist and you are to play crucial role in solving any environmental problems. The next Unit will teach you more of this.

6.0 TUTOR-MARKED ASSESSMENT

1. What is sanitary engineering?
2. Explain the concept of sanitary engineering with relevant examples.

7.0 REFERENCES /FURTHER READING

R.C. Dubey. (nd). *Environmental Sanitation*.

Department of Botany & Microbiology. Guruku Kangri

University. Hardiocs 2494OU (Uttranchas)

Baxeeranis, A.D. (2004). *A Guide to Ecological Sanitation*. John Wiley & Son. Incv.

UNIT 2 ENVIRONMENTAL PROBLEMS OF URBANISATION AND NATURAL CYCLE OF WATER

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3.0 Main Content
 3.1 Environmental Effects of Urbanisation
 3.2 Health Effects of Environmental Degradation
 3.3 Natural Cycle of Water
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

Human beings have become an increasingly powerful environmental force over the last 10,000 years. And with the industrial revolution, you and i have ability to affect our atmosphere. The recent increase in the world's population has magnified the effects of our activities, but the growth in world population has masked what may be an even more important human-environmental interaction. Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- evaluate environmental problems of urbanisation
- describe the health effects of environmental degradation.

3.0 MAIN CONTENT

3.1 Environmental Effects of Urbanisation

Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population. Urbanisation has some effects that it poses on the environment.

Let us look at some of the effects of urbanisation:

1. Urban consumption of energy helps create heat islands that can change local weather patterns and weather downwind from the heat islands. The heat island phenomenon is created because cities radiate heat back into the atmosphere at a rate of 15 percent to 30 percent less than rural areas.
2. The combination of the increased energy consumption and difference in albedo (radiation) means that cities are warmer than rural areas. And these heat islands become traps for atmospheric pollutants.
3. Cloudiness and fog occur with greater frequency. Precipitation is five percent to 10 percent higher in cities; thunderstorms and hailstorms are much more frequent, but snow days in cities are less common.
4. Urbanisation also affects the broader regional environments.
5. Regions downwind from large industrial complexes also see increases in the amount of precipitation, air pollution, and the number of days with thunderstorms.
6. Urban areas affect not only the weather patterns, but also the runoff patterns for water.
7. Urban areas generally generate more rain, but they reduce the infiltration of water and lower the water tables.
8. This means that runoff occurs more rapidly with greater peak flows. Flood volumes increase, as do floods and water pollution downstream.
9. The effect of urbanisation on nature. The most emerging issues are climate changes, freshwater scarcity, deforestation, fresh water pollution and population growth.
10. In many cities the air is already so polluted that it has been causing illnesses and premature deaths among elderly people and children.
11. Air pollutants are also harmful for water and environment, for example, by causing acid precipitation and acidity of waters.
12. Most of the ambient air-pollution in urban areas comes from the fossil fuels industry, motor vehicles, heating and electricity generation.
13. In some cities the main air polluter is the domestic heating. Many people heat their houses with firewood and cheap coal.

3.2 Health Effects of Environmental Degradation

Here are some of the health effects of environmental degradation:

1. The urban environment is an important factor in determining the quality of life in urban areas and the impact of the urban area on the broader environment.
2. Some urban environmental problems include inadequate water and sanitation, lack of rubbish disposal, and industrial pollution.
3. Unfortunately, reducing the problems and ameliorating their effects on the urban population are expensive.
4. The health implications of these environmental problems include respiratory infections and other infectious and parasitic diseases.
5. Some research suggests that indicators of health problems, such as rates of infant mortality, are higher in cities that are growing rapidly than in those where growth is slower.

4.0 CONCLUSION

By now you should be able to explain how urbanisation can affect you and your environment. Similarly, you have also learnt about how urbanisation affects the nature.

5.0 SUMMARY

From this unit you have learnt about urbanisation and how it can affect the environment and human health. You will see that despite the fact that urbanisation is good in terms of development it also has some problems that can greatly affect the environment at large.

6.0 TUTOR-MARKED ASSESSMENT

1. Highlight the effects that urbanisation can have on the environment and man.
2. Human beings have become an increasingly powerful environmental force over the last 10,000 years. Discuss.

7.0 REFERENCES/ FURTHER READING

Anderson D.D and Burnhem I (1992). Towards sustainable waste manageme nt; Issues in Science & Technology 9(1); 65-72

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Kovacs W.I. 1993 "Solid Waste Management; Historical and future perspecti ves Resources, conservation and recycling 8: 113 – 130.

UNIT 3 ELEMENARY HYDROLOGY, HYDROLOGICALCYCLE, PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF WATER

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
 3.1 Elementary Hydrology
 3.2 Hydrological Cycle
 3.3 Physical, Chemical and Biological Properties of Water
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment

1.0 INTRODUCTION

You need to understand that water is a chemical compound of oxygen and hydrogen and in the gaseous state can be represented by the molecular formula H_2O. The isotopes of hydrogen and three isotopes of oxygen exist in nature, and if these are taken into account, 3 states of water are possible. The physical properties of liquid water are unique in a number of respects, and these departure from what might be considered as normal for such a compound are of the greatest importance with respect to both the existence of life on earth and the operation of many geochemical processes.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- to describe the elementary hydrology
- to write briefly on what hydrological cycle is all about
- to be able to identify and elucidate the physical, chemical and biological properties of water.

3.0 MAIN CONTENT

3.1 Elementary Hydrology

The boiling point and freezing point of water are both far higher than would be the theoretically expected, considering the low molecular weight of the compound, and the range of temperature over which water as a liquid is wider than might be expected. The reason for these and other departures from "normal" behaviour can be gained by more detailed consideration of the molecular structure of the compound. The spheres representing the ions coalesce to some extent, and the molecule might be thought of as a sphere having two rather prominent bubbles of "blisters" attached to it. The bonds connecting the hydrogen's to oxygen describe an angle of 105^o, so that the two hydrogen are relatively close together on one side of the molecule.

Although this representation of the molecule is somewhat empirical it helps to explain some of the abnormal features of the behaviour of water. The molecule has dipolar properties because the positive charge associated with the hydrogen are connected on one side of the molecule, leaving a degree of negativity on the opposite side. Forces of attraction thus exist between hydrogens of one molecule and the oxygen bonds. They hold molecule together in a fixed pattern in the solid state. In contrast to the orderly arrangement of molecules in crystal of ice, the molecules of liquid water are in a chaotic condition of disorder. Hydrogen bonds still remain an important force but their arrangement is continually shifting.

The cohesive forces represented by the hydrogen bonds impact to liquid water is high heat of vaporization. The forces also tend to prevent the passage to electric currents and impart to the fluid its high dielectric constant. The attraction between molecules of a liquid is shown at a liquid surface by the phenomenon called Surface tension. The surface of water is 75.6 dynes per centimeter at 0^oC and 71.8 dynes per centimeter at 25^oC, which are very high values compared with the many other liquids.

3.2 Hydrological Cycle

The water cycle—technically known as the hydrologic cycle—is the continuous circulation of water within the Earth's hydrosphere, and is driven by solar radiation. The hydrosphere includes the atmosphere, land, surface water, and groundwater. As water moves through the cycle, it changes state between liquid, solid, and gas phases. Water moves through different reservoirs, including ocean, atmosphere, groundwater, rivers, and glaciers, by the physical processes of evaporation (including plant transpiration), sublimation, precipitation, infiltration, runoff, and subsurface flow. Precipitation, which is the falling of water in any form to earth; while infiltration is the process in which water is absorbed into the soil (it may also flow off the surface called surface run off); evaporation or transpiration, which occurs either when water is heated and turns into water vapor or when plants use the water and give it off as water vapor, respectively; and condensation, which occurs when water vapor cools and forms clouds. This process is then repeated over again as seen in the diagram below:

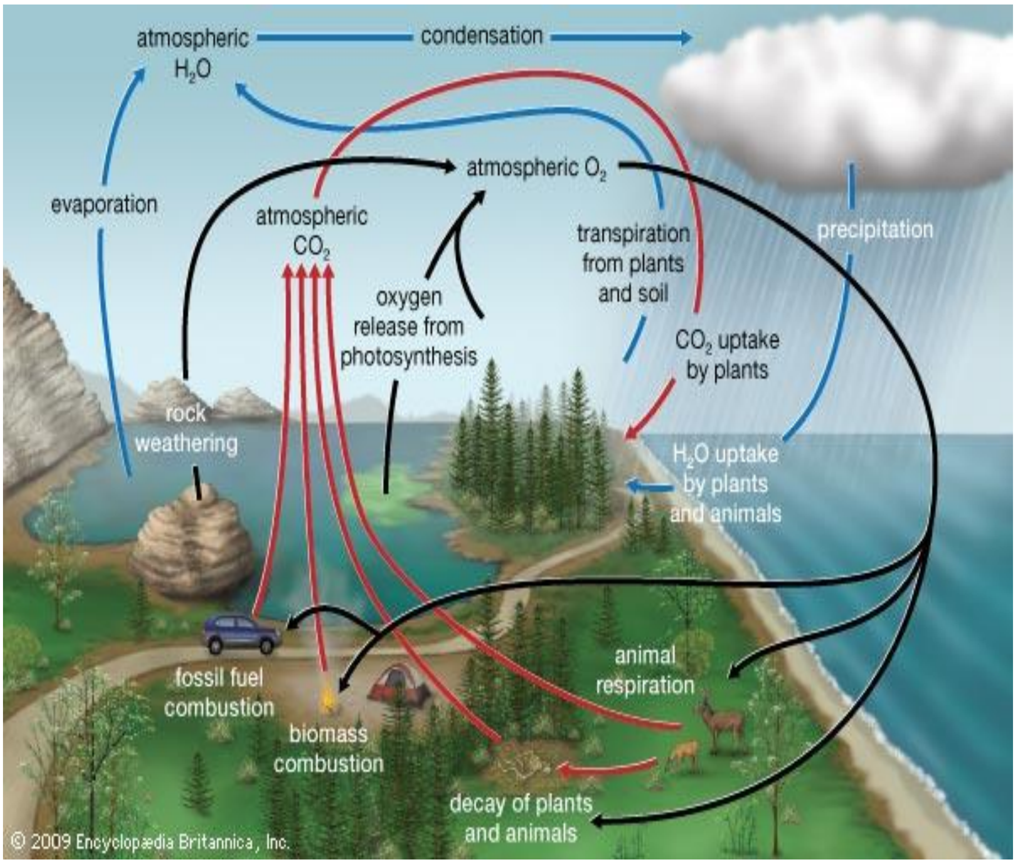

Fig. 1: Hydrological cycle

3.3 Physical and Chemical Properties of Water

Since water is not found in its pure in nature, it is important to determine its combined physical and chemical characteristics. This is done through monitoring of water for its quality. The physical and chemical parameter analysed in natural environments; Atmosphere (rainfall), hydrosphere (river, lakes, and oceans) and Lithosphere (Groundwater) are similar-

a. **Temperature:** the measurement of temperature is relevant for

- Aquatic life
- Control of waste treatment plants
- Cooling purposes for industries
- Calculation of solubility of dissolved gases
- Identification of water source
- Agriculture Irrigation
- Domestic uses (Drinking, bathing).

You can use thermometer to measure the temperature

b. **pH:** Controlled by $CO_2/HCO_3^-/CO_3^{2-}$ Equilibria in natural water. Its values lie between 4.5 and 8.5. It is important for:

- Chemical and biological properties of liquid
- Analytical work

Measurement is done in the field. Most common method of determination is the electrometric method, involving a pH-meter. It is important to calibrate the meter with standard pH buffer solutions before use.

c. Dissolved Oxygen: Water in contact with the atmosphere has measurable dissolved oxygen concentration. Measurement is important in

- o Evaluation of surface water quality
- o Waste-treatment processes control
- o Corrosivity of water
- o Septicity
- o Photosynthetic activity of natural water.

3.4 Biological Property of Water

The presence or absence of living organisms in water can be one of the most useful indicators of its quality. In the streams, river, and lakes (think of those in your community), the diversity of fish and insect species provide a measure of the biological balance or health of the aquatic environment. A wide variety of different species of organisms usually indicates that the stream or lake is polluted. The disappearance of certain species and overabundance of other groups of organisms is generally one of the effects of pollution.

Examples

- Bacteria
- Algae
- Protozoa
- Viruses
- Coliform

4.0 CONCLUSION

From this unit you can now differentiate between physical, chemical and biological characteristics of water. Without any doubt you can now explain the compositions of water and how to measure them. Similarly, you have also learnt about how our water moves naturally in cycle and the processes involve.

5.0 SUMMARY

From this unit you have learnt the importance of water chemistry most especially in terms of water properties and water hydrology. In this unit you can list specific examples of water properties and how to quantify them. Drawing of water cycle should not be a problem for you by now. Let us go on.

6.0 TUTOR-MARKED ASSESSMENT

1. Differentiate between physicochemical and biological properties of water.
2. Explain in details what you understand by hydrological cycle.

7.0 REFERENCES/ FURTHER READING

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MODULE 2 WATER AND WASTE TREATMENT

Unit 1 Basic Water Treatment Processes
Unit 2 Methods of Storage and Distribution of Treated Water
Unit 3 Processes of Sewage Treatment

UNIT 1 BASIC WATER TREATMENT PROCESSES

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
3.1 Water Surveillance and Sampling Techniques
3.2 Method for Water Sample Collection
3.3 Basic Methods for Water Analysis
3.4 Stages in Water Treatment
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment

1.0 INTRODUCTION

Municipal services or city services refer to basic services that residents of a city expect the city government to provide in exchange for the taxes which citizens pay. Basic city services may include sanitation (both sewer and refuse), water, streets, the public library, schools, food inspection, fire department, police, ambulance, and other health department issues and transportation. In order for water to be considered safe or portable for domestic uses, it must be scrutinised with a multi-science approach involving bacteriology, chemistry, physics, engineering and public health, preventive medicine, and control and evaluation management. Portable or „drinking" water can be defined as the water delivered to the consumer that can be safely used for drinking, cooking and washing. The public health aspects are of such importance and complexity that the health authority having jurisdiction in the community now reviews, inspects, samples, monitors and evaluates on a continuing basis the water supplied to the community, using constantly updated drinking water standards. Such public health control helps to guarantee a continuous supply of water maintained within safe limits. Water analysis alone is not sufficient to maintain quality but must be combined with the periodic review and acceptance of the facilities involved.

Hence, it could be summarised that portable water must meet the physical, chemical, bacteriological, and radionuclide parameters when supplied by an approved source, delivered to a treatment and disinfection facility of proper design, construction, and operation, and in turn delivered to the consumer through a protected distribution system in sufficient quantity and pressure.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain water surveillance and sampling techniques
- discuss method for water sample collection
- elucidate the basic methods for water analysis
- explain stages in water treatment.

3.0 MAIN CONTENT

3.1 Water Surveillance and Sampling Techniques

Sampling is in fact the most important part of any analysis, since no matter how accurate the analysis is if the sample on which it is carried out is not representative; the result will be misleading. A single grab sample is only suitable for a source of constant quality and quantity, something which is not common in practice. Water bodies are continually changing in character and surface waters may exhibit sudden changes in flow and quality due to rainfall. In these cases a true sample can only be obtained by compositing individual samples obtained at frequent time intervals when the flow is made by mixing 24 separate hourly samples in proportion to the flow at the time of sampling. In certain circumstances it may be advisable to sample continually for such characteristics as Temperature, pH, Dissolved Oxygen, Conductivity, Suspended Solid, Ct etc. Ideally all analyses should be carried out on the sample immediately after collection and certainly the quicker the analysis can be done the more likely it is that the results will be a fair representation of the actual liquid insitu.

3.2 Sampling Procedure

3.2.1 Surface Sources

i. Clean and rinse all apparatus with deionised water before setting out. Calibrate all instruments in the laboratory.
ii. At the site, choose a convenient location to layout apparatus and instrument. Check all instruments again.
iii. Collect sample from the main body of the water below its surface.
iv. Put the water sample in a clean beaker and determine the temperature, pH, conductivity, turbidity etc. and record the result in your note book. Observe and note the colour and odor.
v. Collect samples for laboratory analysis by filling plastic sample bottles completely to the basin, expelling air, and immediately close

tightly and label appropriately (time of collection, type of sample, temperature, location etc) and delivery immediately to laboratory for analysis and storage (samples are stored in the refrigerator, but it is brought back to room temperature before analysis).

NOTE: that when trying to determine the total spectrum of the water quality of a body of water as it passes through a complete settlement e.g. a river, or a large lake several sampling.

3.2. 2 Water from Underground Source

Sampling for underground water samples for boreholes and artisan wells water should be collected at well head after allowing the water to flow for at least 10mins in the case of a source that is used 30 – 40 minutes every day, if not constantly used. Collect samples from shallow plastic collector below the surface of the well. Take the sample of water and determine temperature, PH, conductivity turbidity etc.

3.3 Method of Water Analysis

Water quality control analyses are based on analytical principles. This quantitative analysis may be carried out gravimetric, volumetric or colorimetric method. Determinations are usually carried out by a standard method.

3.3. 1 Gravimetric Analysis

This depends on weighing solids obtained from the sample by evaporation, filtration or precipitation. This procedure is time- consuming because of the need for careful drying to drive off moisture before weighing, both from the solids and the dish or container in which they are placed. The main uses of gravimetric analysis are for the analysis of total and volatile solids as well as suspended solids and sulphate.

3.3.2 Volumetric Analysis

Rapid and accurate determinations in water quality control can be carried out by volumetric analysis. This depends on the measurement of volumes of liquid reagent of known strength.

The requirements for volumetric analysis are relatively simple.

(a) Equipment to measure the sample accurately e.g. pipette.
(b) A standard solution of suitable strength
(c) An indicator to show when the end point has been reached.

(d) A graduated burette for accurate measurement of the volume of standard solution necessary to reach the end point.

3.3.3 Colorimetric Analysis

This is particularly useful when dealing with dilute solutions. To be of quantitative use a colorimetric must be based on the formation of a compound or complex with definite colour characteristics and the density of the colour must be proportional to the concentration of the substance under determination.

3.3.4 Electrode

This is used for the measurement of parameter such as pH.

3.4 Stages in Water Treatment

- Aeration: is used to alter the concentration of dissolved gases, to strip volatile organics, and to reduce tastes and odors, it also involves removal of dissolved gases ($C0_2$ and H_2S).
- Screening: To ensure efficient and reliable operation, the main units in a treatment plant is necessary to remove the large floating and suspended solids such as branches, rags and other debris which could obstruct flow in the plant. This preliminary treatment usually involves a simple screening or straining. The flow is passed through a screen of 520mm aperture mesh. This is placed extending above and below and covering sides of the water intake pipe.
- Pre-Chlorination: This is the addition of chlorine immediately after screening. This is done for the following reasons:
  a) To reduce turbidity, colour and odour by killing suspended microorganisms or reduce their growth when the water is excessively contaminated by them.

b) To improve the coagulating effect of the coagulant by bringing soluble ion into colloidal particle size that can be precipitated.

c) To oxidise organic matter, sulphide and other odourous gases, ferrous ions, manganese and other oxidisable matter when present in large amounts in order to improve taste and odour.

3.4.1 Sedimentation

This is the process where water is allowed to flow slowly through a basin so that suspended sediments will settle down. The amount of suspended matter removed during sedimentation depends on the size of the sedimentation basin, the particle size, the detention time and the amount of water involved.

3.4.2 Coagulation

This is the use of certain chemical called coagulants. This is used because many impurities in water are present as colloidal solids which will not settle. Thus chemicals (Alum, lime, etc) convert fine sediments that can never settle into bigger sizes called flocs. These flocs are further aggregated together to from bigger amounts of suspended matter that can be precipitated. Large amounts of suspended and dissolved matter are removed in this process resulting in the removal of most of the taste, colour and odour. In modern times, iron compounds are used as coagulants typical called ferri flocs, silica, soda-lime.

3.4.3 Flocculation

The removal of colloidal particles can be achieved by promoting agglomerative of such particles by flocculation. This is the agitation of water by hydraulic or mechanical mixing which causes the collision between particles to produce settle able solids from a high concentration of colloidal particles. With low concentration of colloids a coagulant is added to produce bulky floc particles which enmesh the colloidal solids. Before flocculation can take place it is essential to disperse the coagulant, usually required in doses of 30-100mg/l, throughout the body of water in rapid mixing chamber.

3.4.4 Clarification and Stabilisation

Clarification is divided into three parts:

(a) Rapid mix
(b) Flocculation and
(c) Settling. Here the water is stirred gently by the flocculators so that sludge from coagulation can be removed completely and dispersed. This unit is called clarifier.

In stabilisation, the hardness is checked, pH is checked. Sludge are finally removed by mechanical or chemical means.

3.4.5 Filtration

This is the process in which water is allowed to flow through granular material such as sand in order to remove colloidal impurities. Such impurities are those not removed during coagulation and sedimentation process. During filtration, a wide range of impurities and water contaminants are removed. It removes bacteria effectively, odour, taste, colour, iron and manganese. There are various types of filters in use, but early common ones are; the slow sand fitter and the rapid sand filter. Other filters are pressure filters, multiple media filters, up flow filters etc.

3.4.6 Disinfection

Due to the small size of bacteria it is not possible to ensure their complete removal from water by physical and chemical means alone and for potable water suppliers it is necessary to ensure the death of harmful micro-organisms by disinfection. It is important to note the difference between Sterilisation (the killing of all organisms) and disinfection (the killing of harmful organisms) which is the normal aim in water treatment.

3.4.6.1 Methods of Disinfection

a) Chlorination

Chlorine (and its compound) is widely used for the disinfection of water because of the following advantages.

- It is readily available, as gas, liquid or power -
- It is cheap
- It is easy to apply to its high solubility.
- It is very toxic to micro organisms
- It leaves a residual in solution, which while not harmful to man provides protection to distribution system.
- It has several secondary uses. e.g. oxidation of iron manganese and H_2S, destruction taste and odor.

It has some disadvantages

- It is a poisonous gas and must be carefully handled.
- It can give rise to taste and odor problems particularly in the presence of phenols.
- Suspended materials may shield bacterial from the action of the chlorine.
- Chlorine is a powerful oxidizing agent and will attack a wide range of compounds thereby making it less available to attack microorganisms.
- Its effectiveness is pH – dependent. pH values of 7.2 are adequate.

4.0 CONCLUSION

In this unit you have learnt about water surveillance and sampling techniques, method for water sample collection and various stages involve in water treatment. You can now differentiate between wholesome and unwholesome water.

5.0 SUMMARY

This unit has equipped you with the basic knowledge that you must put into practice to be able to supply wholesome water to the community for their use. As we are moving to unit 5 our focus will be on the methods of storage and distribution of treated water.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain water surveillance and sampling techniques
2. Discuss method for water sample collection
3. Elucidate the basic methods for water analysis
4. Explain the stages in water treatment

7.0 REFERENCES/FURTHER READING

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UNIT 2 METHODS OF STORAGE AND DISTRIBUTION OF TREATED WATER

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
 3.1 Water Service/Storage Reservoirs
 3.2 The Pipe System
 3.3 Types of Distribution Systems
 3.4 Pipes and Fittings
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

Metering of water supplied to individual users has been shown to reduce consumption substantially, perhaps by as much as 50%. In the absence of meters, users have no incentive to conserve water and waste in much more common. Metering is also desirable in that it permits analysis of use patterns of different classes of users, thereby providing data which is useful in planning expansion of facilities and in assessing the magnitude of loss due to leaks in the distribution system.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- water service/storage reservoirs
- the pipe system
- types of distribution systems
- pipes and fittings.

3.0 MAIN CONTENT

3.1 Water Service/Storage Reservoirs

Impounding reservoirs have two functions; to impound water for beneficial use, and to retard flood flows. Water may also be stored to equalise pumping rates in the short term, to equalise supply and demand in the long term, and to furnish water during emergencies such as fires and loss of pumping capacity. Elevated storage may be provided by earthen, steel or concrete reservoirs located on high ground or tanks desired above the ground surface. Water is pumped at a more or loss uniform rate, with flow in excess of consumption being stored in elevated storage tanks distributed throughout the system. During periods of high demand, the stored water augments the pumped flow, thus helping to equalise the pumping rate and to maintain uniform pressure in the system. It may be economical to pump during off peak hours. It should be noted that leakage can occur from the service connections as well as the points.

3.2 The Pipe System

a) The Primary Feeders (Mains)
These are sometimes called the arterial main, they form the skeleton of the distribution system. They are so located that they will carry quantities of water from the pumping plant, to and from the storage tanks and to the various parts of the area to be served. In small cities they should form a loop about 1000m or two – thirds of distance from the centre of the town to the outskirts. They should have valves not over 1.5km apart and mains connecting to them should also be valued so that interruptions of service in them will not require shutting down the feeder main. In large towns the primary feeders should be constructed as several interlocking coops with the main not over 1000m apart. Looping allow continuous service through the rest of the primary mains even though one portion in shut down temporarily for repairs. Under normal condition looping also allows supply from two directions for large fire flows. Large and long feeders should be equipped with blow offer (was hunt) at low points and air relief relieves at high points.

b) The Secondary Feeders (Services Pipes)
They carry large quantities of water from the primary feeder to the various areas to care for normal supply and fire fighting. They form smaller loops within the loops of the primary mains by running from one primary feeder to another. They should be only a few blocks apart and thus serve to allow concentration of large amounts of water for fire fighting without excessive head loss and resulting, low pressure.

c) The Small Distribution Mains
They form a grid over the area to be served and supply water to the fire hydrants and service pipes of the residence and other buildings. Their sizes will usually be determined by fire flow requirements. In residential areas however, particularly where there are heavy water uses for lawn sprinkling, it may be necessary to determine the maximum customer demand.

3.3 Types of Distribution Systems for Buildings

i) The direct feed type
This is used when the pressure in the municipal main is adequate to supply all the futures inside the building with water for 24 hours each day.

ii) The indirect feed type
This is used when the pressure in the municipal water main in insufficient to supply water to the fixtures at all times of the day water is supplied to fixtures, inside the building by elevated tank on the top of the building (roof listen).

3.4 Pipes and Fittings

There are three requirements for a pipeline

i) It must convey the quantity of water required.
ii) It must resist all external and internal faces coming upon it.
iii) It must be durable and have long life.

Pipelines are classified into three categories:

(a) Mains" – Pipeline for the conveyance of water over long or short distances for the distribution of water through towns and in general large sized pipeline.
(b) "Service pipe" – The individual supply line to a house, block of flats, laid underground from a main to the building. The service pipes are fitted with valves and meters.
(c) Distribution pipes" (plumbing pipes) – pipe work within a building for the distribution of water to various appliances. Most water distribution pipes in buildings are made of galvanised iron pipes. They are designed to ensure adequate water supply to the fixtures.

4.0 CONCLUSION

From this unit you have learnt how treated water can stored, channel to point of use and various means of water distribution systems and different types of pipes and fittings that can be used.

5.0 SUMMARY

This unit has made it possible for you to be able to identify various means by which water can distributed using different types of pipes and fittings. Let us proceed to unit 6 our focus will be on methods and processes of sewage.

6.0 TUTOR-MARKED ASSIGNMENT

1. Write short note on water storage and services
2. Highlight and explain different types of distribution systems

7.0 REFERENCES/FURTHER READING

Douglass, A.S. (1986). *Water and Wastewater Engineering*. UK Raven: Cambridge University Press.

UNIT 3 PROCESSES OF SEWAGE TREATMENT

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Physical Treatment
    3.2 Chemical Treatment
    3.3 Biological Treatment
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment

1.0 INTRODUCTION

Sewage treatment is a process to convert sewage - which is water no longer needed or suitable for its most recent use - into an effluent that can be either returned to the water cycle with minimal environmental issues or reused. The latter is called water reclamation and implies avoidance of disposal by use of treated wastewater effluent for various purposes. Treatment means removing impurities from water being treated; and some methods of treatment are applicable to both water and wastewater. The physical infrastructure used for wastewater treatment is called a "wastewater treatment plant.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define sewage treatment
- describe physical treatment method of sewage
- explain chemical treatment of sewage
- discuss biological treatment of sewage.

3.0 MAIN CONTENT

3.1 Physical Treatment

Physical treatment methods include screening, communition, grit removal, sedimentation and filtration. Except for filtration each of these units operations will be incorporated in most modern treatment plants.

3.1.1 Screening

Coarse screens or racks with 50mm openings or large are used to remove large floating objects from wastewaters. They are installed ahead of pumps to prevent clogging. These materials consist of wood, rags, and paper which will not putrefy and may be disposed by incineration, burial, or dumping.

3.1.2 Comminution

Comminutor or (shredders) are devices that are used to grid or cut waste solids to about 6mm size. Comminutors eliminate the problem of disposal of screenings by reducing the solids to a size that can be processed elsewhere in the plant.

3.1.3 Grit Removal

Specially designed grit chambers are used to remove inorganic particles such as sand, gravel, eggshells, and bone to prevent damage to pumps and to prevent the accumulation of this material in sludge digesters. Grit may be used for fill or handled away and dumped if it does not contain too much organic material.

3.1.4 Sedimentation

Plain sedimentation basic in wastewater treatment is used to remove the larger suspended material from the incoming wastewater. The material to be removed is high in organic content (50 – 70%) and has a specific gravity of less than 1.2. A slopping bottom facilitates removal of the sludge.

3.1.5 Filters

Filters are used as final or advanced treatment following secondary or other treatment processes, such as lagoons and stabilization ponds. Wastewater is applied continuously at about 0.4m/day and the straining action of the sand is relied upon the remove most of the remaining suspended solid in the wastewater.

3.2 Chemical Treatment

The main unit processes used for wastewater treatment are chemical precipitation and chlorination. A number of treatment plants use a combination of chemical processes (usually precipitation) and physical operations to achieve complete treatment. Such processes are known as physical – chemical treatment processes.

3.2.1 Chemical Precipitation

This is used to increase the removal of suspended solids to 90%. It can also be used to remove phosphates for the control of eutrophication. Alum and ferric chloride are two commonly used coagulants. Lime is often added to improve the action of the coagulant. Chemicals are introduced and mixed by rapid mechanical agitation; this is followed by gentle agitation in a flocculating basin before the wastewater is introduced to the sedimentation basin. Suitable for large seasonal variation in wastewater flow, but is costly and with increase in sludge volume.

3.2.2 Chlorination

Chlorination may be used as a final step in the treatment of wastewater when an effluent low in bacterial content is required (Post chlorination) to reduce the BOD. Pre-chlorination before sedimentation helps to control odors may prevent flies in trickling filters; and assists in grease removal. Its relatively expensive, hence many treatment plants have no chlorination facilities.

3.3 Biological Treatment

These are basic components of almost all secondary treatment schemes; this treatment involves the conversion of the dissolved and colloidal organic matter in wastewater to biological cell tissue and to end products and subsequent removal of the cell tissue, usually by gravity settling. The biological conversion can be accomplished both aerobically (presence of O_2) and aerobically (absence of O_2) the aerobic conversion is significantly more rapid. The microorganisms responsible for the conversion can be maintained in suspension or attached to a fixed or moving medium. Such biological treatment processes are known as aerobic suspended growth or attached growth processes. The activated sludge process, which is used extensively, is the best known example of aerobic suspended-growth process. The trickling filter is the most common attached – growth process.

4.0 CONCLUSION

In this unit you have learnt about the three treatment processes and their principles. This unit has elucidated the importance of each treatment process. The first treatment process is physical treatment followed by chemical and biological treatment. In practice physical treatment is subtractive while chemical and biological treatment processes are additive. Physical treatment is subtractive because of removal of log of wood, paper, broken bottles, grit plastics etc while chemical and biological treatment processes are additive because of addition of chemical and microbes respectively.

5.0 SUMMARY

From this unit you can now differentiate between physical, chemical and treatment of wastewater. It is expedient and equally appropriate for us to look at the methods of wastewater treatment and this is what we will be considering in the next unit.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is sewage treatment?
2. Explain in details chemical treatment of sewage.
3. Succinctly discuss biological treatment of sewage.

7.0 REFERENCES / FURTHER READING

World Bank/United Nations Report 279/04 (February, 2004). "Nigeria Strategic Gas Plan." *Joint UNDP/World Bank Energy Sector Management. Assistance Programme* (ESMAP), ESM 279, Report 279/04, February, 2004. www.google.com

UNIT 4 METHODS OF SEWAGE/WASTE WATER TREATMENT

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Activated Sludge
    3.2 Trickling Filter
    3.3 Aeration
    3.4 Secondary Clarification
    3.5 Stabilisation Pond
    3.6 Aerated Lagoon
4.0 Conclusion
    3.7 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

In this unit we will be looking at the methods involved in wastewater treatment. Let's go!

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- Activated sludge
- Trickling filter
- Aeration
- Secondary clarification
- Stabilisation pond
- Aerated lagoon.

3.0 MAIN CONTENT

3.1 Activated Sludge

Experiments have indicated that blowing of air in wastewater results in the formation of flocs. Examination of these under microscope indicated the presence of a variety of microorganisms. When the blowing of air stopped, the flocs settled. This floc, when added to fresh wastewater causes its digestion and therefore is called activated sludge. This process is so named because it involves the production of an activated waste. Activated sludge processes are used for both secondary treatment and complete aerobic treatment without primary sedimentation. Wastewater is fed continuously into an aerated tank where the microorganism metabolises and biologically flocculates the organics. Microorganisms are settled from the aerated mixed liquor in the final clarifier and returned to the aeration tank. Clean supernatant from the final settling tank now becomes the plant effluent. A portion of the settled biological solid is recycled and the remaining mass is wasted. The level at which biological mass is returned depends on the quantity of wastewater and degree of treatment required. Usually this quantity varies from 20-30% of the waste water volume. Aeration units are the made unit of the activated sludge system, the main aim of which are to supply oxygen to the sewage to keep the return sludge aerobic and to mix up the return sludge with the sewage thoroughly.

3.2 Trickling Filters

This is employed in cities with low populations. These are also known as sprinkling or percolating filters in these filters sewage trickles over the filter media which are continuous in operation. These filters may be rectangular or circular in plan coarse aggregates of impervious nature are used as filter media. The size of the filter media should be between 5-7.5cm an under drainage system is provided in the filter bed to collect the effluent. As sewage passes through the filter ring media an organic film known as zoogleal film is formed around the particles of filtering media. A large number of aerobic bacteria present in this film carry out oxidation of organic matters. As the applied sewage trickles through this film final suspended solids are removed and held by the film and colloidal particles are absorbed by its.

3.3 Aeration

The rate at which oxygen is consumed by the microorganism is the biological reactor is called the oxygen utilisation rate. The oxygen utilisation rate will always exceed the rate of natural replenishment, thus some artificial means of adding oxygen must be used. When depletion of oxygen occurs, the sewage becomes sick and lifeless, resulting in sludge bulking. Oxygen addition should be sufficient to match the oxygen utilisation rate and still maintain a small excess in the mixed liquor at all times to ensure aerobic metabolism Aeration techniques consists of using air diffusers to inject compressed air into the biological reactor and / or using mechanical mixers to stir the stir the contents violently enough to entrain and distribute air through the liquid.

3.4 Secondary Sedimentation/Clarification

The effluent from primary treatment still contains 40 to 50% of the original suspended solids and virtually all of the original dissolved organics and inorganics. To meet the minimum standards for discharge, the organic fraction both suspended and dissolved, must be significantly reduced. This organic removal, referred to as secondary treatment may consist of chemical-physical processes or biological process. The biomass generated by secondary treatment represents a substantial organic load and must be removed to also meet acceptable effluent standards. These solids are removed in secondary clarifiers. Clarification is the removal of solids from the liquid phase and thickening the removal of liquid from the solid or sludge phase. A high degree of clarification is required to reduce the load on the secondary biological treatment plant.

3.5 Stabilisation Pond

This consists of a large, shallow earthen basin where wastewater is retained long enough for natural purification process to provide the necessary degree of treatment. Part of the system must aerobic to produce an acceptable effluent. Some oxygen is provided by diffusion from the air, but the bulk of the oxygen in ponds is provided by photosynthesis. Shallow ponds in which dissolved oxygen is present at all depths are called Aerobic Ponds (Polishing or tertiary ponds). Deep ponds in which oxygen is absent except for a relatively thin surface layer are called Anaerobic Ponds. Under favourable conditions facultative ponds in which both aerobic and anaerobic zones exist may be used as the total treatment system for municipal wastewater.

3.6 Aerated Lagoons

These are distinguished from ponds in that oxygen for lagoons is provided by artificial aeration. Lagoons are classified by the degree of mechanical mixing provided when sufficient energy is supplied to keep the entire contents, including the sewage solids, mixed and aerated, the reactor is called an Aerobic Lagoon. The effluent from an aerobic lagoon requires solids removal in order to meet suspended – solids effluent standards. When only enough energy is supplied to mix the liquid portion of the lagoon, solid settle to the bottom in areas of low velocity gradients and proceed to degrade an aerobically. This facility is called a Facultative Lagoon; it differs from that in the facultative pond only in the method by which oxygen is supplied.

4.0 CONCLUSION

From this unit you can now vividly and comprehensively explain various methods of wastewater treatment ranging from activated sludge to aerated lagoon.

4.0 SUMMARY

We can now proceed to how to manage human excreta and this is our focus in the next unit.

5.0 TUTOR-MARKED ASSIGNMENT

Write short note on the following:

- Activated sludge
- Trickling filter
- Secondary clarification
- Stabilisation pond
- Aerated lagoon

6.0 REFERENCES / FURTHER READING

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MODULE 3 WASTE DISPOSAL AND MANAGEMENT

Unit 1 Methods of Excreta Disposal
Unit 2 Urban and Community Storm Water Management
Unit 3 Hazardous Waste Management

UNIT 1 METHODS OF EXCRETA DISPOSAL

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
  3.1 Conservancy System
  3.2 Water Carriage System
  3.3 The Need for Latrines and Toilets
4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment

1.0 INTRODUCTION

In many rural communities, human wastes are disposed of in some kinds of latrine system. The latrine system is either built for individual household use or as public latrines. Individual latrines are preferable because public latrines are subject to abuse, poor maintenance or neglect. In some communities, might soil buckets are used to dispose human wastes but the labour for this system is increasingly difficult to obtain. The location of sanitation facilities is very important as they affect the quality of drinking water sources. This problem needs special attention if the water table in the vicinity of the latrine is high sanitation facilities should not be located close to shallow wells or springs.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain Conservancy system of excretal disposal
- explain Water carriage system of excretal disposal.

3.0 MAIN CONTENT

3.1 Conservancy System

This is disposal of excreta without water. In this system the human excreta is collected in various types of privies, few of which are

i) Pit privy
ii) Aqua privy
iii) Bore hole privy
iv) Cesspools
v) Concrete vault privy
vi) Chemical toilet
vii) Removable receptacle privy
viii) V.I.P. latrine (ventilated invert pit toilet by Proof Wright).

i) Pit Privy: This is very economical with no operation. It essentially consists of manually dug pit 1.3m x 1.0m in plan and 1.5 to 2.8m deep or a hole of usually greater than 2.5m deep and of about 1.0m in diameter. At the top of this pit the squatting seat is provided in a compartment. When the pit is filled it is closed from the top and a new are in excavated by its side. Pit privy should be located at a distance not less than 200m from the position of local water sources; should be close to dwellings but not less than 5m.

ii) Bore-Hole Privy: This is similar to pit privy, the only difference is that in place of a pit it has a deep 40cm diameter borehole. The depth of the borehole should be 1.0m less than ground water table so that the waste may not pollute the underground water.

iii) Agua Privy: Most privies are of temporary nature. Aqua privy is an improved type of privy which makes it possible to provide a permanent structure. The aqua privy consists of water tight tank in which wastes are anaerobically digested, the design is shown below. The effluent produced can be disposed of in soak away pits. The accumulated solids in the tank need to be removed regularly. Wastes from the squatting hole are conveyed through drop pipe aperture, 12-15cm to the tank, for easy clearing of blockages, the pipe should not be firmly connected in position. In commercial toilets tanks of adequate size may be fitted with a number of pipes. The settlements of solids from the effluent may be improved by adopting a two-tank design.

The total capacity of the privy can be calculated from.

V = P (Q + S)

Where P = Number of users

Q = Volume of liquid discharged per person per day of -12 litres

S = Volume of sludge storage space allowed per person, a reasonable factor is 120 – 150 litres.

The minimum recommended volume for about 10 people is 1,500 litres. The privy should be dislodged when the sludge reaches within 10 -15cm of the connecting aperture between the two tanks the de-sludging can be carried out once in 5years for a property designed privy.

iv) Cesspool: This essentially consists of a pit or chamber lined with dry bricks or stones. The excremental matter flow through pipe from the water close to the pool, when the cesspool is filled up it emptied and cleaned.

v) Concrete Vault Privy: When water table is very close to the ground surface it becomes difficult to construct pit privy and bore-hole privy because the excremental matter will pollute the underground water. Under such circumstances concrete vault privy is most suitable. It essentially consists of water tight vault constructed in the ground.

vi) Chemical Toilets: This is the most satisfactory method of disposal of excreta without water. In this method, a metal tank filled with the solution of concentrated caustic soda is placed below the squatting seat. The excreta is totally liquefied when it comes in contact with caustic soda. The main advantage is that it eliminates odour.

vii) Removable Receptacle Privy: This is a cheap type of privy. It essentially consists of a metal box placed below the squatting seat. The excreta is collected daily from this removable privy by sweepers.

3.2 Water Carriage System

This is disposal of excreta with the use of water i.e use of septic tank and soaks away.

3.3 The Need for Latrines and Toilets

- Absence of basic sanitation facilities can:
- Result in an unhealthy environment contaminated by human waste. Without proper sanitation facilities, waste from infected individuals can contaminate a community's land and water, increasing the risk of infection for other individuals. Proper waste disposal can slow the infection cycle of many disease-causing agents.
- Contribute to the spread of many diseases/condition that can cause widespread illness and death. Without proper sanitation facilities, people often have no choice but to live in and drink water from an environment contaminated with waste from infected individuals,

thereby putting themselves at risk for future infection. Inadequate waste disposal drives the infection cycle of many agents that can be spread through contaminated soil, food, water, and insects such as flies.

- Proper sanitation (for example, toilets and latrines) promote health because they allow people to dispose of their waste appropriately. Throughout the developing world, many people do not have access to suitable sanitation facilities, resulting in improper waste disposal.

4.0 CONCLUSION

You now from this unit all the available types of excreta disposal system. I know by now you are thinking about the type of disposal system that you are using at home and how it can affect your water source.

5.0 SUMMARY

The unit is important to all of us because there is no one that can live without excreta but we have different problem in excreta disposal. I am sure you can now differentiate between conservancy and water carriage systems of excreta disposal.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss in details conservancy system of excretal disposal and state how it is different from water carriage system of excretal disposal.
2. Why do you think there is need for construction of toilet and latrine in our communities?

7.0 REFERENCES/ FURTHER READING

O'Riordan, T. (Ed.). (1995). *Environmental Science for Environmental Management*. Harlow: Longman.

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UNIT 2 URBAN AND COMMUNITY STORM WATER MANAGEMENT

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1.0 Introduction
2.0 Objectives
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1.0 INTRODUCTION

Stormwater is water that originates during precipitation events and snow/ice melts. Storm water can soak into the soil (infiltrate), be held on the surface and evaporate, or runoff and end up in nearby streams, rivers, or other water bodies (surface water). In natural landscapes such as forests, the soil absorbs much of the storm water and plants help hold stormwater close to where it falls. In developed environments, unmanaged stormwater can create two major issues: one related to the volume and timing of runoff water (flooding) and the other related to potential contaminants that the water is carrying (water pollution).

Stormwater is also a resource and important as the world's human population demand exceeds the availability of readily available water. Techniques of storm water harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain storm water and storm water filtration system
- describe integrated waste management?
- explain best storm water management practices.

3.0 MAIN CONTENT

3.1 Storm Water Pollution

Pollutants entering surface waters during precipitation events are termed polluted runoff. Daily human activities result in deposition of pollutants on roads, lawns, roofs, farm fields, etc. When it rains or there is irrigation, water runs off and ultimately makes its way to a river, lake, or the ocean. While there is some attenuation of these pollutants before entering the receiving waters, the quantity of human activity results in large enough quantities of pollutants to impair these receiving waters. In addition to the pollutants carried in stormwater runoff, urban runoff is being recognized as a cause of p+ollution in its own right. In natural catchments (watersheds) surface runoff entering waterways is a relatively rare event, occurring only a few times each year and generally after larger storm events. Before development occurred most rainfall soaked into the ground and contributed to groundwater recharge or was recycled into the atmosphere by vegetation through evapotranspiration.

Modern drainage systems which collect runoff from impervious surfaces (e.g., roofs and roads) ensure that water is efficiently conveyed to waterways through pipe networks, meaning that even small storm events result in increased waterway flows. In addition to delivering higher pollutants from the urban catchment, increased stormwater flow can lead to stream erosion, encourage weed invasion, and alter natural flow regimes. Native species often rely on such flow regimes for spawning, juvenile development, and migration.

3.2 Urban Flooding

Stormwater is a major cause of urban flooding. Urban flooding is the inundation of land or property in a built-up environment caused by stormwater overwhelming the capacity of drainage systems, such as storm sewers. Although triggered by single events such as flash flooding or snow melt, urban flooding is a condition, characterized by its repetitive, costly and systemic impacts on communities. In areas susceptible to urban flooding, backwater valves and other infrastructure may be installed to mitigate losses.

3.3 Storm Water Filtration System for Urban Runoff

Managing the quantity and quality of stormwater is termed, "Stormwater Management." The term *Best Management Practice* (BMP) or stormwater control measure (SCM) is often used to refer to both structural or engineered control devices and systems (e.g. retention ponds) to treat or store polluted stormwater, as well as operational or procedural practices (e.g. street sweeping).

Stormwater management includes both technical and institutional aspects, including:

- control of flooding and erosion;
- control of hazardous materials to prevent release of pollutants into the environment (source control);
- planning and construction of stormwater systems so contaminants are removed before they pollute surface waters or groundwater resources;
- acquisition and protection of natural waterways or rehabilitation;
- building "soft" structures such as ponds, swales, wetlands or green infrastructure solutions to work with existing or "hard" drainage structures, such as pipes and concrete channels
- development of funding approaches to stormwater programs potentially including stormwater user fees and the creation of a stormwater utility;
- development of long-term asset management programs to repair and replace aging infrastructure;
- revision of current stormwater regulations to address comprehensive stormwater needs;
- enhancement and enforcement of existing ordinances to make sure property owners consider the effects of stormwater before, during and after development of their land;
- education of a community about how its actions affect water quality, and about what it can do to improve water quality; and
- planning carefully to create solutions before problems become too great.

3.4 Integrated Water Management

Integrated water management (IWM) of stormwater has the potential to address many of the issues affecting the health of waterways and water supply challenges facing the modern urban city.

Also known as low impact development (LID in the United States, or Water Sensitive Urban Design (WSUD) in Australia, IWM has the potential to improve runoff quality, reduce the risk and impact of flooding and deliver an additional water resource to augment potable supply.

4.0 CONCLUSION

In this unit you have acquired enough knowledge that can help you to explain storm, storm management, urban flooding, Storm water filtration system, management of urban storm water and integrated waste management.

5.0 SUMMARY

This unit might have acquinted you with pollution of the environment due to storm water, urban flooding and also the *Best Management Practice* (BMP) or stormwater control measure (SCM) to treat or store polluted stormwater, as well as operational or procedural practices such as street sweeping.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is urban flooding?
2. List five (5) Best management practices of storm water.

7.0 REFERENCES/FURTHER READING

O'Riordan, T. (Ed.). (1995). *Environmental Science for Environmental* Management. Harlow: Longman.

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UNIT 3 HAZARDOUS WASTE MANAGEMENT

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 3.2 Characteristic Hazardous Waste
 3.3 Disposing of Hazardous Waste
 3.4 Transport of Hazardous Waste
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 3.8 Final Disposal of Hazardous Waste
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1.0 INTRODUCTION

Hazardous waste is a waste that poses substantial or potential threat to public health or the environment human health or the environment. Hazardous wastes can be liquids, solids, contained gases, or hazardous waste is a waste with properties that make it dangerous or potentially harmful to human e. g sludge's. They can be by-products of manufacturing processes or simply discarded commercial products, like cleaning fluids or pesticides, hazardous waste is a waste that exhibits at least one of four characteristics-ignitability, corrosivity, reactivity, or toxicity. Therefore, hazardous waste management can be defined as the skill/process of handling dangerous waste in such a manner that will prevent it from affecting the public health and the ecosystem of the environment adversely. Hazardous waste generally may be in form of a solid, liquid or gases.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain types of hazardous waste.
- list the characteristics of hazardous waste
- describe the disposing and transport of hazardous waste
- explain the methods of treating of hazardous waste.

3.0 MAIN CONTENT

3.1 Types of Hazardous Waste

- **Hazardous solid waste**: - refers to any dangerous, non-liquid or gaseous materials from humans activities in a community that is no longer desired which is thrown away. It includes mercury containing wastes, thermometers, fluorescence lightening, bulb Electrical and electronics, computers, cell phones, television Aerosols / Propane cylinders Caustics / Cleaning agents refrigerant containing appliances Some specialty batteries (e.g. lithium, nickel cadmium, or button cell batteries).

- **Liquid hazardous waste** Are those dangerous waste that are inform of liquid or those carried by water such as used water in the community, detergent, from kitchen, bathroom, domestic, cleaning, recreational, swimming pool, abattoir, hospitals, industrial processes. Motor oil, paint, and solvent.

- **Gaseous hazardous waste management** Are skill/process of handling coordinating, monitoring and control of those dangerous waste that are inform of gases such as aerosol, smoke, insecticide, fungicide, herbicides and other toxic gases.

3.2 Characteristic hazardous wastes

- **Ignitability** – Ignitable wastes can create fires under certain conditions, undergo spontaneous combustion, or have a flash point less than 60°C (140°F). Examples include waste oil and used solvents. The characteristic of ignitability is defined in the hazardous waste regulations.
- **Corrosively** – Corrosive wastes are materials, including solids, that are acids or bases, or that produce acidic or alkaline solutions. Aqueous wastes with a pH less than or equal to 2.0 or greater than or equal to 12.5 are corrosive. A liquid waste may also be corrosive if it is able to corrode metal containers, such as storage tanks, drums, and barrels. Spent battery acid is an example
- **Reactivity** – Reactive wastes are unstable under normal conditions. They can cause explosions or release toxic fumes, gases, or vapors when heated, compressed, or mixed with water. Examples include lithium-sulfur batteries and unused explosives.
- **Toxicity** – Toxic wastes are harmful or fatal when ingested or absorbed (e.g., wastes containing mercury, lead, DDT, PCBs, etc.). When toxic wastes are disposed, the toxic constituents may leach from the waste and pollute ground water. The characteristic of toxicity is defined in the hazardous waste regulations.

3.3 Disposing of Hazardous Waste

- **Sanitary landfills:** which are a method of waste disposal where the waste is buried either underground or in large piles. Although non-hazardous waste is often disposed of in landfills, the landfills for hazardous waste are constructed and monitored differently. Landfills for hazardous waste are made with thicker, impervious liners and with more heavy-duty removal systems for leaching materials. They are also constructed far from aquifers to reduce the risk of water contamination.
- Hazardous waste that is liquid or has been dissolved is often placed in **surface impoundments**, which are shallow depressions in the earth that are lined with plastic and impervious materials. The liquid hazardous waste is dumped in the impoundment and left to evaporate. Once the liquid has evaporated, the solid hazardous waste residue remains at the bottom of the impoundment and can be removed and transported to a landfill. Surface impoundments pose many risks, including contamination, and are only used for temporary processing and storage.
- The third method of hazardous waste disposal is **deep-well injection**, which is when liquid waste is injected into a well that has been created in the porous rock deep below the water table. Around nine billion gallons of hazardous waste are injected into deep-wells each year in the United States. Although this method of hazardous waste disposal is designed to be long-term and keep the waste away from humans and ground water, sometimes the wells leak or are damaged and waste contaminates the water supply.

3.4 Transport of Hazardous Waste

Hazardous waste generated at a particular site often requires transport to an approved treatment, storage, or disposal facility (TSDF). Because of potential threats to public safety and the environment, transport is given special attention by governmental agencies. In addition to the occasional accidental spill hazardous has, in the past, been intentionally spilled or abandoned at random locations in a practice known as “midnight dumping.” This practice has been greatly curtailed by the enactment of laws that require proper labelling, transport, and tracking of all hazardous wastes.

3.5 Treatment of Hazardous Wastes

Hazardous waste can be treated by chemical, thermal, biological, and physical methods.

3.5.1 Chemical Methods

Chemical methods include ions exchange precipitation oxidation reduction and neutralisation.

3.5.2 Thermal Methods

Among thermal methods is high-temperature incineration which not only can detoxify certain organic wastes but also can destroy them. Special types of thermal equipment are used for burning waste in either solid, liquid, or sludge form. These include the fluidized-bed incinerator, multiple-hearth furnace, rotary kiln, and liquid-injection incinerator. One problem posed by hazardous-waste incineration is the potential for air pollution.

3.5.3 Biological Treatment

Biological treatment of certain organic wastes, such as those from the petroleum industry, is also an option. One method used to treat hazardous waste biologically is called land farming. In this technique the waste is carefully mixed with surface soil on a suitable tract of land. Microbes that can metabolize the waste may be added, along with nutrients. In some cases a genetically engineered species of bacteria is used. Food or forage crops are not grown on the same site. Microbes can also be used for stabilizing hazardous wastes on previously contaminated sites; in that case the process is called bioremediation.

The chemical, thermal, and biological treatment methods outlined above change the molecular form of the waste material.

3.5.4 Physical Treatment

Physical treatment, on the other hand, concentrates, solidifies, or reduces the volume of the waste. Physical processes include evaporation, sedimentation, flotation, and filtration. Yet another process is solidification, which is achieved by encapsulating the waste in concrete, asphalt, or plastic. Encapsulation produces a solid mass of material that is resistant to leaching. Waste can also be mixed with lime, fly ash, and water to form solid, cement like product.

3.6 Surface Storage and Land Disposal

Hazardous wastes that are not destroyed by incineration or other chemical processes need to be disposed of properly. For most such wastes, land disposal is the ultimate destination, although it is not an attractive practice, because of the inherent environmental risks involved. Two basic methods of land disposal include landfilling and underground injection. Prior to land disposal, surface storage or containment systems are often employed as a temporary method.

3.7 Remedial Action

- Disposal of hazardous waste in unlined pits, ponds, or lagoons poses a threat to human health and environmental quality. Many such uncontrolled disposal sites were used in the past and have been abandoned. Depending on a determination of the level of risk, it may be necessary to remediate those sites. In some cases, the risk may require emergency action. In other instances, engineering studies may be required to assess the situation thoroughly before remedial action is undertaken.
- One option for remediation is to completely remove all the waste material from the site and transport it to another location for treatment and proper disposal. This so-called off-site solution is usually the most expensive option. An alternative is on-site remediation, which reduces the production of leachate and lessens the chance of groundwater contamination.
- On-site remediation may include temporary removal of the hazardous waste, construction of a secure landfill on the same site, and proper replacement of the waste. It may also include treatment of any contaminated soil or groundwater. Treated soil may be replaced on-site and treated groundwater returned to the aquifer by deep-well injection.

3.8 Final Disposal of Hazardous Waste

Historically, some hazardous wastes were disposed of in regular landfills this resulted in unfavorable amounts of hazardous materials seeping into the ground. These chemicals eventually entered natural hydrologic systems. Many landfills now require countermeasures against groundwater contamination, an example being installing a barrier along the foundation of the landfill to contain the hazardous substances that may remain in the disposed waste. Currently, hazardous wastes must often be stabilised and solidified in order to enter a landfill and many hazardous wastes undergo different treatments in order to stabilize and dispose of them. Most flammable materials can be recycled. One example they can be recycled into is industrial fuel. Some materials with hazardous constituents can be recycled, lead acid batteries are one example.

3.8.1 Recycling

Many hazardous wastes can be recycled into new products. Examples might include lead-acid batteries or electronic circuit boards. Where the heavy metals these types of ashes go through the proper treatment, they could bind to other pollutants and convert them into easier-to-dispose solids, or they could be used as pavement filling. Such treatments reduce the level of threat of harmful chemicals, like fly and bottom ashwhile also recycling the safe product.

3.8.2 Cementing

Another commonly used treatment is cement based solidification and stabilisation. Cement is used because it can treat a range of hazardous wastes by improving physical characteristics and decreasing the toxicity and transmission of contaminants. The cement produced is categorized into five different divisions, depending on its strength and components. This process of converting sludge into cement might include the addition of pH adjustment agents, phosphates, or sulfur reagents to reduce the settling or curing time, increase the compressive strength, or reduce the leach ability of contaminants.

3.8.2 Incineration, Destruction and Waste-To-Energy

A HW may be "destroyed" for example by incinerating at a high temperature, flammable wastes can sometimes be burned as energy sources. For example, many cement kilns burn HWs like used oils or solvents. Today, incineration treatments not only reduce the amount of hazardous waste, but also they generate energy from the gases released in the process. It is known that this particular waste treatment releases toxic gases produced by the combustion of byproduct or other materials, and this can affect the environment. However, current technology has developed more efficient incinerator units that control these emissions to a point where this treatment is considered a more beneficial option.

There are different types of incinerators and they vary depending on the characteristics of the waste.

Starved air incineration is another method used to treat hazardous wastes. Just like in common incineration, burning occurs, however controlling the amount of oxygen allowed proves to be significant to reduce the amount of harmful byproducts produced. Starved air incineration is an improvement of the traditional incinerators in terms of air pollution. Using this technology, it is possible to control the combustion rate of the waste and therefore reduce the air pollutants produced in the process.

3.8.4 Hazardous Waste Landfill (Sequestering, Isolation, Etc.)

A HW may be sequestered in a HW landfill or permanent disposal facility. "In terms of hazardous waste, a landfill is defined as a disposal facility or part of a facility where hazardous waste is placed or on land and which is not a pile, a land treatment facility, a surface impoundment, an underground injection well, a salt dome formation, a salt bed formation, an underground mine, a cave, or a corrective action management unit.

3.8.5 Pyrolysis

Some hazardous waste types may be eliminated using pyrolysis in an ultra-high temperature electrical arc, in inert conditions to avoid combustion. This treatment method may be preferable to high temperature incineration in some circumstances such as in the destruction of concentrated organic waste types, including PCBs, pesticides and other persistent organic pollutants.

4.0 CONCLUSION

From this unit I am very optimistic that you have garnered enough knowledge to explain hazardous wastes, their types, and methods of treatment and disposal methods.

5.0 SUMMARY

You have learned the different types and characteristics of Hazardous Waste, ways of disposing and transporting of the waste as well as methods used in the treatment of Hazardous waste such as chemical, thermal, biological, and physical methods.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are hazardous wastes?
2. Explain how to dispose hazardous wastes.
3. Discuss the mode of transportation of hazardous waste.

7.0 REFERENCES/ FUTHER READING

O'Riordan, T. (Ed.). (1995). *Environmental Science for Environmental Management*. Harlow: Longman.

Miller, G.T. (1990). *Living in the Environment*. Belmont California: Wadsworth Publishing Co.