NATIONAL OPEN UNIVERSITY OF NIGERIA

FACULTY OF HEALTH SCIENCES

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES

COURSE CODE: EHS 318

COURSE TITLE: INTRODUCTION TO WATER RESOURCES MANAGEMENT

COURSE GUIDE

EHS 318: INTRODUCTION TO WATER RESOURCES MANAGEMENT

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COURSE GUIDE

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COURSE UNIT: 2 UNITS

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Introduction

Water emergency is any event that disrupts the normal supply of clean water to your home. Water issues and problems in developing countries are diverse and serious: Problems include the natural scarcity of drinking-water in certain areas, floods, the siltation of river systems, as well as the contamination of rivers and large dams. These problems are more severe and widespread in the developing countries than in developed countries. Some 1.1 billion people in developing countries have inadequate access to clean water. 2.6 billion lack access to sanitation. 1.8 million Children die each year from diarrhea and millions of women spend hours a day collecting water. Barriers to addressing water problems in developing nations are focused mainly around issues of poverty, education, and poor governance. Despite the many seemingly intractable problems, there are also many low-tech low-cost solutions in use around the world, which provide health, albeit on a small scale. Humanity demands a need for freshwater for agricultural, industrial, and commercial processes like the production of beer, food, and refined oil. With a rising demand, the quality and supply of water diminishes drastically on top of an increasing waste and scarcity. To address this challenge, organizations have begun to focus on increasing the supply of freshwater, mitigating its demand, and enabling reuse and recycling.

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. It is general overview of the course materials you will be using 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 Aims

The course aims to give you an understanding on water resources management.

Course Objective

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 guide you on what to concentrate / focus on while studying the unit. Please read the objective before studying the unit and during your study to check your progress.

The Comprehensive Objectives of the Course are given below. By the end of the course/after going through this course, you should be able to:

- Define the term water emergency
- Socio-political and legal issues related to water supply
- Water security
- Water treatment
- Water quality survey etc

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.

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 should 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 hour you should allocate your time to each unit so as to finish on time and successfully.

The Course Materials

The main components of the course are:

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

Study Unit

The study units in this course are given below:

MODULE 1 What is water Emergency?

Unit 1: Introduction

Unit 2: Socio-political and legal issues related to water supply

Unit 3: Water security

MODULE 2 Water Treatment Processes and Techniques

Unit 1: Water treatment

Unit 2: Municipal and urban water treatment systems

MODULE 3 Water quality assessment routine

Unit 1: catchment mapping

Unit 2: Water quality survey

MODULE 4 Health and safety in water treatment

Unit 1: Health hazards associated with water treatment

Unit 2: Underground water and aquifers

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.

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 falling 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 Assignment

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 are to be returned to your facilitator.

You're 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

Assignment	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.

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.

Summary

Water Resources Management is a course that introduces you water emergency and factors that could lead to water emergency and consequents effects of it.

On completion of this course, you will have an understanding of basic knowledge on the factors that could lead to water emergency and consequents effects of it. In addition you will be able to answer the following questions:

- Define the term water emergency
- Water treatment
- Water quality survey
- Health and safety in water treatment

The list of questions expected to be 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.

Course Code: EHS 318

Course Title: Water Resources Management

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MAIN COURSE

CONTENTS

Module 1 critically examines water emergency and factors that could lead to water emergency and consequents effects of it. Unit two in module one looks at social and political issues related to water sharing and utilization among individuals, community and nations. Unit three examines security as it relates to water supply and distribution.

Module 2 takes a look at water treatment processes and the various techniques employed to ensure the water is safe for consumption. Unit 2 discusses urban and municipal water treatments and distribution while unit three of the module examines water catchment and water levels in the soil

Module 3 puts more emphasis on water quality assessment for the presence of particles and living organisms. Other units look at water catchment, quality survey and analysis of bio-data relating to water.

Module 4 further examines hazards associated with water treatment. These may include but not limited to injuries, consumption of chemicals, inhalation and exposure. Unit 2 talks about underground water storage and aquifers and the need to protect these water storages.

MODULE 1 What is Water Emergency

Unit 1 Water emergency

Unit 2 Socio-political and legal issues related to water supply

Unit 3 Water security

UNIT ONE WATER EMERGENCY

CONTENTS

I.0 Introduction

A water emergency is any event that disrupts the normal supply of clean water to your home. Water issues and problems in developing countries are diverse and serious: Problems include the natural scarcity of drinking-water in certain areas, floods, the siltation of river systems, as well as the contamination of rivers and large dams. These problems are more severe and widespread in the developing countries than in developed countries. Some 1.1 billion people in developing countries have inadequate access to clean water. 2.6 billion lack access to sanitation. 1.8 million Children die each year from diarrhea and millions of women spend hours a day collecting water. Barriers to addressing water problems in developing nations are focused mainly around issues of poverty, education, and poor governance. Despite the many seemingly intractable problems, there are also many low-tech low-cost solutions in use around the world, which provide health, albeit on a small scale. Humanity demands a need for freshwater for agricultural, industrial, and commercial processes like the production of beer, food, and refined oil. With a rising demand, the quality and supply of water diminishes drastically on top of an increasing waste and scarcity. To address this challenge, organizations have begun to focus on increasing the supply of freshwater, mitigating its demand, and enabling reuse and recycling.

Approximately 71.230% of all illnesses in developing countries are caused by poor water and sanitation conditions. It is common for women and girls to have to walk several kilometers every day to fetch water for their families. Once filled, water jugs can weigh as much as 20 kg .

In the last century, water use has greatly outpaced the rate of population growth: people are using more water than ever before. By 2025, up to 1.8 billion people could face water scarcity. Water scarcity can take two forms: physical water scarcity, or low quantity of water, and economic water scarcity, or low quality of water.

Water emergencies can be caused by natural disasters or other emergencies that affect the water system: Hurricanes, Floods, Tornadoes, Forest/brush fires, Droughts, Earthquakes, Chemical spills, Broken water main, Power outage, Failure of storage tanks or other equipment, Contamination of water.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Explain water emergency
- List various factors responsible for water emergency
- Explain water scarcity by nations

3.0 MAIN CONTENT

3.1Physical Water Scarcity

Earth's most dominant feature at first glance is the ocean, taking up approximately 70% of the planet's surface, connected to major lakes, watersheds, and waterways; whether it's through a channel or through the water cycle. Explained by the United States Geological Survey (USGS), the scarce of fresh water resource and push for supplying water of it is already a growing vital issue, especially in many arid regions around the world. These dry regions do not have the access to fresh water resource in common bodies of water such as lakes and rivers; most of the fresh water sources in these areas are groundwater that are limited and quickly reducing as it becomes contaminated into brackish water and people continue to extract from the well. The scarcity of freshwater resource has been a growing issue for centuries and less than 2.5% of the water on Earth is freshwater, and of it, about 0.014% is available to humans as groundwater mitigates due to constant groundwater tapping and the rest sit in untouched ice caps and glaciers.

This term typically applies to dry, arid regions where fresh water naturally occurs in low quantities. This is being greatly exacerbated by anthropogenic activities that take surface and ground water faster than the environment can replenish it. Regions most affected by this type of water scarcity are Mexico, Northern and Southern Africa, the Middle East, India, and Northern China.

3.2 Economic water Scarcity

Economic water scarcity applies to areas or cultures that lack the fiscal resources and/or human capacity to invest in water sources and meet the local demand. Water is often only available to those who can pay for it or those in political power; leaving millions of the world's poorest without access. Regions most affected by this type of scarcity are portions of Central and South America, Central Africa, India, and South East Asia.[4] It is important to highlight the distinction between these two forms of scarcity: water can be physically available, but the resources are not available to improve it and distribute it to those who need it.

3.3 Case Study of Some Nations

India

India's growing population is putting a strain on the country's water resources. The country is classified as "water stressed" and a water availability of 1,000-1,700 m^3/person/year. According to UNICEF, in 2008 88% of the population had access and was using improved drinking water sources. "Improved drinking water source" is an ambiguous term, ranging in meaning from fully treated and 24-hour availability to merely being piped through a city and sporadically available. This is in part due to large inefficiencies in the water infrastructure in which up to 40% of water leaks out.

In the same 2008 UNICEF report, only 31% of the population had access and used improved sanitation facilities. Open sewers are common place in urban areas. A little more than half of the 16 million residents of New Delhi, the capital city, have access to this service. Every day, 950 million gallons of sewage flows from New Delhi into the Yamuna River without any significant forms of treatment. This river bubbles with methane and was found to have a fecal coliform count 10,000 time than the safe limit for bathing.

Due to surface water contamination due to lack of sewage treatment and industrial discharge, groundwater is becoming increasingly dependent on and exploited in many regions of India. This process is being expedited by heavily subsidized energy costs for agriculture practices; which make up roughly 80% of India's water resource demand.[12]

Kenya

Kenya, a country of 36.6 million, struggles with a staggering population growth rate of 2.6% per year (by comparison, the US population growth rate is 0.9% and the population growth rate in India is 1.31%).This high population growth rate has pushed Kenya's natural resources to the brink of destruction. Much of the country suffers from a severe arid climate, with only scarce few areas enjoying rain and access to water resources. Deforestation and soil degradation have made the available surface water typically highly polluted and difficult to retain. The government has been unable to afford to develop water treatment or distribution systems, leaving the vast majority of the country without access to water. This has also exacerbated gender politics, as 74% of women must spend an average of 8 hours per day securing water for their families. The growing population and stagnant economy has exacerbated urban, suburban, and rural poverty—exacerbated by lack of access to clean drinking water which leaves much of the non-elite population suffering from disease and parasites. This has effectively crippled Kenya's human capital. Private water companies have taken up the slack from Kenya's government among the wealthy, but the Kenyan government prevents them from moving into the poverty-stricken areas of the country in order to stop profiteering off the poor. Unfortunately, since Kenya's government also refuses to provide services, this leaves the disenfranchised with no options at all for obtaining clean water—or any water.

Bangladesh

Historically, water sources in Bangladesh came from surface water contaminated with bacteria. As a result of drinking infected water, infants and children suffered from acute gastrointestinal disease, causing significant burden of mortality. During the 1970s, UNICEF worked with the Department of Public Health Engineering to install tube-wells, which drew water from underground aquifers, to provide a presumably safe source of water for the nation. As of 2010, 67% of the Bangladeshis had a permanent water source and majority of them used tube wells. The wells consist of tubes 5 cm in diameter that were inserted less than 200 m into the ground, and capped with an iron or steel hand pump. At that time, standard water testing procedures did not include arsenic testing. This lack of precaution led to one of the largest mass poisoning of a population twenty years later because the ground water used for drinking is naturally contaminated with arsenic. Because arsenic has no taste, no smell, and no color, its long term health risks can be harder for the inhabitants to grasp compared to the immediate threats caused by diarrhoea. Nonetheless, intervention measures such as awareness programs and painting tube-wells red if the water is above the government limit of 50 ppb arsenic (green otherwise) have seen success. As of 2010, 80% of Bangladeshis recognize arsenic as a problem. Available options for providing safe drinking water include deep wells, traditional dug wells, treatment of surface water, and rainwater harvesting. Between 2000 and 2009, more than 160,000 safe water devices have been installed in arsenic-affected regions of Bangladesh

4.0 Conclusion

For human consumption, various innovations and solutions (both high and low-technology based) exist throughout the developing world to treat water at the 'point of use' (PoU) and have been shown to an effective solution to addressing poor quality water supplies. Studies have shown that PoU treatment to reduce diaherrea mortality in children under 5 by 29% However, home water treatment solutions may not be widely considered in development strategies, as they are not recognized under the water supply indicator in the United Nations' Millennium

Development Goals. Additionally, various challenges may reduce the effectiveness of home treatment solutions- such as low education, low-dedication to repair and replacement (especially if the treatment was initially free, did not meet expectations or was time intensive), or local repair services or parts are unavailable

5.0 Summary

Despite the clear benefits of improving water sources (a WHO study showed a potential economic benefit of $3–34 USD for every $1 USD invested), aid for water improvements have declined from 1998 to 2008 and generally is less than is needed to meet the MDG targets. In addition to increasing funding resources towards water quality, many development plans stress the importance of improving policy, market and governance structures to implement, monitor and enforce water quality improvements.

6.0 Tutor-Marked Assignment

- List any five causes of water emergency
- What is economic water scarcity?

Solution

- List any five causes of water emergency

Hurricanes, Floods, Tornadoes, Forest/bush fires, Droughts, Earthquakes, Chemical spills, broken water main, Power outage

- What is economic water scarcity?

Economic water scarcity applies to areas or cultures that lack the fiscal resources and/or human capacity to invest in water sources and meet the local demand. Water is often only available to those who can pay for it or those in political power; leaving millions of the world's poorest without access. Regions most affected by this type of scarcity are portions of Central and South America, Central Africa, India, and South East Asia.[4] It is important to highlight the distinction between these two forms of scarcity: water can be physically available, but the resources are not available to improve it and distribute it to those who need it.

7.0 Reference/Further Reading

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UNIT 2 Socio-Political and Legal Issues Related to Water Supply

CONTENTS

1.0 Introduction

Water politics, sometimes called hydropolitics, is politics affected by the availability of water and water resources, a necessity for all life forms and human development. Hydropolitics is "the systematic study of conflict and cooperation between states over water resources that transcend international borders". The availability of drinking water per capita is inadequate and shrinking worldwide. The causes, related to both quantity and quality, are many and varied; they include local scarcity, limited availability and population pressures, but also human activities of mass consumption, misuse, environmental degradation and water pollution, as well as climate change.

Water is a strategic natural resource, and scarcity of potable water is a frequent contributor to political conflicts throughout the world. With decreasing availability and increasing demand for water, some have predicted that clean water will become the "next oil"; making countries like Canada, Chile, Norway, Colombia and Peru, with this resource in abundance, the water-rich countries in the world. The UN World Water Development Report (WWDR, 2003) from the World Water Assessment Program indicates that, in the next 20 years, the quantity of water available to everyone is predicted to decrease by 30%. Currently, 40% of the world's inhabitants have insufficient fresh water for minimal hygiene. More than 2.2 million people died in 2000 from diseases related to the consumption of contaminated water or drought. In 2004, the UK charity WaterAid reported that a child dies every 15 seconds from easily preventable water-related diseases; often this means lack of sewage disposal; see toilet. The United Nations Development Programme sums up world water distribution in the 2006 development report: "One part of the world, sustains a designer bottled water market that generates no tangible health benefits, another part suffers acute public health risks because people have to drink water from drains or from lakes and rivers."[7] Fresh water—now more precious than ever in our history for its extensive use in agriculture, high-tech manufacturing, and energy production—is increasingly receiving attention as a resource requiring better management and sustainable use.

2.0 Objectives

At the end of this unit, you should be able to:

- Explain water use by nations
- Examine some international conflicts relating to water use

3.0 Main Content

3.1 Water as a critical resource

Most importantly, fresh water is a fundamental requirement of all living organisms, crops, livestock and humanity included. The UNDP considers access to it a basic human right and a prerequisite for peace. The Ex-UN Secretary-

General Kofi Annan stated in 2001, "Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity." With increased development, many industries, including forestry, agriculture, mining, manufacturing and recreation require sizable additional amounts of freshwater to operate. This, however, has led to increases in air and water pollution, which in turn have reduced the quality of water supply. More sustainable development practices are advantageous and necessary.

According to the WHO, each human being requires a bare minimum of 20 litres of fresh water per day for basic hygiene this equals 7.3 cubic metres (about 255 ft^3) per person, per year. Based on the availability, access and development of water supplies, the specific usage figures vary widely from country to country, with developed nations having existing systems to treat water for human consumption, and deliver it to every home. At the same time however, some nations across Latin America, parts of Asia, South East Asia, Africa and the Middle East either do not have sufficient water resources or have not developed these or the infrastructure to the levels required. This occurs for many varied reasons. It has resulted in conflict and often results in a reduced level or quantity of fresh water per capita consumption; this situation leads toward disease, and at times, to starvation and death.

The source of virtually all freshwater is precipitation from the atmosphere, in the form of mist, rain and snow, as part of the water cycle over eons, millennia and in the present day. Freshwater constitutes only 3% of all water on Earth, and of that, slightly over two thirds is stored frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is mainly found as groundwater, with only a small fraction present in the air, or on the ground surface. Surface water is stored in wetlands or lakes or flows in a stream or river, and is the most commonly utilized resource for water. In places, surface water can be stored in a reservoir behind a dam, and then used for municipal and industrial water supply, for irrigation and to generate power in the form of hydroelectricity. Sub-surface groundwater, although stored in the pore space of soil and rock; it is utilized most as water flowing within aquifers below the water table. Groundwater can exist both as a renewable water system closely associated with surface water and as a separate, deep sub-surface water system in an aquifer. This latter case is sometimes called "fossil water", and is realistically non-renewable. Normally, groundwater is utilized where surface sources are unavailable or when surface supply distribution is limited.

Rivers sometimes flow through several countries and often serve as the boundary or demarcation between them. With these rivers, water supply, allocation, control, and use are of great consequence to survival, quality of life, and economic success. The control of a nation's water resources is considered vital to the survival of a state. Similar cross-border groundwater flow also occurs. Competition for these resources, particularly where limited, have caused or been additive to conflicts in the past.

3.2 Socio-Political Causes of Water Scarcity

Poverty and economic policy

Poverty is a major factor in water scarcity and susceptibility to drought. This can be illustrated in a number of ways. Firstly, as was seen in the drought emergency of the early 1990s in South Africa, the price of water in rural areas for basic survival can become very high. As traditional sources failed, people did not have the resources to provide alternatives (such as drilling new boreholes) and had to resort to buying water from vendors at extremely high costs. In periods of stress, those communities which have resources and access to credit, are able to survive. In other words, a given situation of water shortage will have more extreme consequences for the poor than for the rich – for one set of people it will spell disaster and for the other it will mean only inconvenience.

It is for this reason that the macroeconomic policy of a country, and its effectiveness in addressing poverty, will have an important role in determining what constitutes conditions of water stress. Similar climatic conditions in two countries will cause famine in the poorer country and a temporary, limited economic depression in the wealthier country.

Legislation and water resource management

Poor or inadequate legislation can exacerbate the effects of water scarcity. Water law which gives certain users exclusive rights to use of water is necessary to provide security for investment (usually in the agricultural sector), but it can result in other users being put in serious jeopardy during times of scarcity. Whilst existing and future water law in South Africa will no doubt protect the rights of all people to basic minimum supplies of water, a legislative system which is not equitable will result in restrictions on the development of some sectors of society. This is clearly illustrated in the effects of the riparian doctrine in the existing Water Act (1956). The management of water resources and the policies guiding the development of water resources can also have a direct effect on the ability of some sectors to survive periods of water scarcity. If these are inequitable, inefficient, or do not provide for at least the basic needs of all citizens, then a particular occurrence of water scarcity will result in conditions of drought where, if the water resource management regime had been different, this would have been avoided.

International waters

The use of water in international rivers by upstream countries may lead to conditions of drought in downstream countries. South Africa has many international rivers and is in the position of being both an upstream and downstream riparian country. This is a problem which is obviously exacerbated during times of scarcity. It is important that communication is maintained between riparian countries through a variety of mechanisms including special protocols, joint commissions, memoranda of agreement, treaties etc.. It is important that these are established during times of plenty rather than in times of crisis. The effect of proper and equitable sharing of international water resources is to assist in avoiding disaster conditions in neighbouring states and to avoid the inevitable social, economic and political repercussions of these conditions within South Africa.

Sectoral resources and institutional capacity

Knowing what needs to be done and implementing it are two separate issues. Because of the overall economic status of most of the countries in Southern Africa, the resources to implement programmes designed to reduce water scarcity are very limited. This is also the cause of institutional weaknesses which result in overbearing bureaucracy and inefficiencies. Although South Africa does not have the same economic problems of its neighbours, very little has been invested in the past in implementing sound disaster management policy. In South Africa it is not so much a matter of lack of resources as a lack of will.

Institutional and financial weakness results in water not being available which could otherwise have relieved water scarcity.

Sectoral professional capacity

Closely related to the financial and institutional circumstances noted above is the critical problem facing water sector professionals. South Africa and the region is not without highly competent and motivated professionals, but the conditions of employment and the incentives are generally not able to compete, particularly with those offered in the private sector. Disaster management has not been a professional option where experience and expertise have been developed in South Africa. The lack of sufficient expertise to manage water resources and develop and implement policy is a direct contributor to water scarcity.

Political realities

Politicians and decision-makers are the persons who have greatest influence on the allocation of scarce budgets and the adoption of policy. Unfortunately, the horizons of many politicians do not coincide with the horizons of prudent water resource management, resulting in decisions being made on the basis of short term political expediency. To have the political will to develop policy and supportive legislation which will introduce the discipline necessary to manage water scarcity in South Africa and the sub-Continent, requires considerable political courage and foresight. Political tension and conflict within countries and between countries often have a greater influence on de facto policy than the practice of sound water policy.

Sociological issues

There are a number of sociological and cultural issues which exacerbate the water scarcity situation. These are often as a result of practices which were not originally a threat to the environment but have become a threat as population pressures and modern consumerism increases. The resulting pressures on the environment, for example from over grazing, have a direct and detrimental effect on water resources.

Other phenomena such as racism, tribalism and civil war also result in critical incidences of water scarcity for some sectors of the population. The apartheid era in South Africa resulted in large proportions of the population suffering critical shortages of water whilst neighbouring communities enjoyed, and often wasted, an excess of water. The protracted civil wars in Mozambique and Angola have resulted in the already limited infrastructure being destroyed or lapsing into disrepair. The long-term economic and social impacts of these issues often predetermine the overall political and economic framework from which many of the other causes of water scarcity stem.

3.2 Economy

Globalization has benefitted the economy greatly through increased trade and production of food, energy, and goods. However, the increase of trade and production of goods requires large quantities of water, in fact the OECD countries predict that by 2050, the global demand for water will increase by 55%. Multiple countries and organizations have declared a water crisis. Water is a finite resource that is shared between nations, within nations, multiple interest groups and private organizations. Roughly 50% of all water available is located between two or more nation states. Water politics and management requires efficient water allocation through policies and cooperation between nations. Poor water politics and practices can result in water conflict, which is more common surrounding freshwater due to its necessity for survival. Countries that have a greater supply of water have greater economic success due to an increase in agricultural business and the production of goods, whereas countries, which have limited access to water, have less economic success. This gap in economic success due to water availability can also result in water conflict. The World Trade Organization has emerged as a key figure in the allocation of water in order to protect the agricultural trade. Water is an essential commodity in the global market for economic success.

Local economy

Water politics is present within nations, otherwise known as subnational. The shared jurisdiction of access to water between intergovernmental actors is crucial to efficient water politics. Inefficient water politics at the subnational level has a greater impact on the local economy through increased costs for businesses, increased costs for the agricultural sector, decreased local competitiveness, decrease in local jobs and infrastructure costs. For instance, Texas plans to build reservoirs to combat water shortages; these reservoirs will cost more than $600 per acre-foot for construction. Subnational states have a crucial role in water politics through managing local water sources and addressing issues concerning water politics such as allocation, scarcity and water pollution.

Colorado River basin

The Colorado River basin is transboundary basin shared between the United States and Mexico. However at the subnational level within United States, the basin is shared between Colorado, Utah, Arizona, Nevada and California. The Colorado River Basin demonstrates intergovernmental conflict over the autonomy of water politics. Intergovernmental water politics has many actors such as private organizations and interest groups. Cooperation in subnational water politics can result in economic benefits through shared costs and risk for infrastructure. In addition, efficient water politic management results in profitable allocations of water that can sustain irrigation and the agricultural sector.

4.0 Conclusion

There has been a proposition in a more balanced approach for water-sharing and allocation through a combination of large scale politics on the international level and smaller scale politics (hydropsychology) rather than focusing strictly one a singular approach. This balanced approach would include policies created at community levels and national levels in order to address the issue of water-sharing and allocation.

5.0 Summary

It is of great importance for nations of the world to reach a consensus on water use to avoid future wars that would be about water and not oil

6.0 Tutor-Marked Assignment

- Explain water as a resource
- What is sociological issues

Solution

- **Explain water as a resource**

Fresh water is a fundamental requirement of all living organisms, crops, livestock and humanity included. The UNDP considers access to it a basic human right and a prerequisite for peace. The Ex-UN Secretary-General Kofi Annan stated in 2001, "Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity

- **What is sociological issues**

There are a number of sociological and cultural issues which exacerbate the water scarcity situation. These are often as a result of practices which were not originally a threat to the environment but have become a threat as population pressures and modern consumerism increases. The resulting pressures on the environment, for example from over grazing, have a direct and detrimental effect on water resources.

Other phenomena such as racism, tribalism and civil war also result in critical incidences of water scarcity for some sectors of the population

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UNIT 3: Water Security

CONTENTS

1.0 Introduction

Water security has been defined as "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risk. It is realized to the degree that water scarcity is non-existent, or has been decreased or eliminated, and to the degree that floods and contamination of freshwater supplies are non-threatening.

"Sustainable development will not be achieved without a water secure world. A water secure world integrates a concern for the intrinsic value of water with a concern for its use for human survival and well-being. A water secure world harnesses water's productive power and minimizes its destructive force. Water security also means addressing environmental protection and the negative effects of poor management. It is also concerned with ending fragmented responsibility for water and integrating water resources management across all sectors—finance, planning, agriculture, energy, tourism, industry, education and health. A water secure world reduces poverty, advances education, and increases living standards. It is a world where there is an improved quality of life for all, especially for the most vulnerable—usually women and children—who benefit most from good water governance.

The areas of the world that are most likely to have water insecurity are places with low rainfall, places with rapid population growth in a freshwater scarce area, and areas with international competition over a water source

2.0 Objectives

At the end of this unit, you should be able to:

- Explain water security
- List various threats to water security
- Explain water scarcity by nations
- Examine countries competing for water resource

3.0 Main Content

3.1 Background to water security

Water security is achieved when there is enough water for everyone in a region and the water supply is not at risk of disappearing. According to the Pacific Institute "While regional impacts will vary, global climate change will potentially alter agricultural productivity, freshwater availability and quality, access to vital minerals, coastal and island flooding, and more. Among the consequences of these impacts will be challenges to political relationships, realignment of energy markets and regional economies, and threats to security.

It impacts regions, states and countries. Tensions exist between upstream and downstream users of water within individual jurisdictions.

During history there has been much conflict over use of water from rivers such as the Tigris and Euphrates Rivers. Another highly politicized example is Israel's control of water resources in the Levant region since its creation, where Israel securing its water resources was one of several drivers for the 1967 Six-Day War.

Water security is sometimes sought by implementing water desalination, pipelines between sources and users, water licenses with different security levels and war.

Water allocation between competing users is increasingly determined by application of market-based pricing for either water licenses or actual water. Water, in absolute terms, is not in short supply planet-wide. But, according to the United Nations water organization, UN-Water, the total usable freshwater supply for ecosystems and humans is only about 200,000 km^3 of water – less than one percent (<1%) of all freshwater resources. Usable fresh water includes water not contaminated or degraded by water-altering chemicals, such as sewage or any other harmful chemicals from continuous previous use. In the 20th century, water use has been growing at more than twice the rate of the population increase. Specifically, water withdrawals are predicted to increase by 50 percent by 2025 in developing countries, and 18 per cent in developed countries. One continent, for example, Africa, has been predicted to have 75 to 250 million inhabitants lacking access to fresh water. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. By 2050, more than half of the world's population will live in water-stressed areas, and another billion may lack sufficient water, MIT researchers find.

3.2 Threat to water security

The most common threat to water security is water scarcity. There can be several causes to water scarcity including low rainfall, climate change, high population density, and over allocation of a water source. An example of periodic water scarcity in the United States is droughts in California. Another category of threats to water security is environmental threats. These include contaminates such as biohazards (biological substances that can harm humans), climate change and natural disasters. Contaminants can enter a water source naturally through flooding. Contaminants can also be a problem if a population switches their water supply from surface water to groundwater. Natural disasters such as hurricanes, earthquakes, and wildfires can damage man-made structures such as dams and fill waterways with debris. Other threats to water security include terrorism and radiationdue to a nuclear accident.

3.3 Water competition

International competition over water can arise when one country starts drawing more water from a shared water source. This is often the most efficient route to getting needed water, but in the long term can cause conflict if water is over-drafted. More than 50 countries on five continents are said to be at risk of conflict over water.

Turkey's Southeastern Anatolia Project (Guneydogu Anadolu Projesi, or GAP) on the Euphrates has potentially serious consequences for water supplies in Syria and Iraq.

China, is constructing dams on the Mekong, leaving Vietnam, Laos, Cambodia and Thailand without same amount of water as before investment. A huge project of reversing the flow of the Brahmaputra (Chinese: Tsangpo) river, which after leaving Chinese Tibet flows through India and Bangladesh. The struggle for water in some afflicted regions has led inhabitants to hiring guards in order to protect wells. Moreover, Amu Daria River, shared by Uzbekistan, Turkmenistan, Tajikistan and Afghanistan, which has been nearly completely dried out, so much so that it has ceased to reach the Aral Sea/Lake, which is evaporating in an alarming pace. The fact that Turkmenistan retains much of the water before it flows into Uzbekistan.

Australia

In Australia there is competition for the resources of the Darling River system between Queensland, New South Wales (NSW) and South Australia. In Victoria, Australia a proposed pipeline from the Goulburn Valley to Melbourne has led to protests by farmers.

In the Macquarie Marshes of NSW grazing and irrigation interests compete for water flowing to the marshes

The Snowy Mountains Scheme diverted water from the Snowy River to the Murray River and the Murrumbidgee River for the benefit of irrigators and electricity generation through hydro-electric power. During recent years government has taken action to increase environmental flows to the Snowy in spite of severe drought in the Murray Darling Basin. The Australian Government has implemented buy-backs of water allocations, or properties with water allocations, to endeavor to increase environmental flows.

India

In India, there is competition for water resources of all inter-state rivers except the main Brahmaputra river among the riparian states of India and also with neighbouring countries which are Nepal, Bhutan, Bangladesh, etc. Vast area of the Indian subcontinent is under tropical climate which is conducive for agriculture due to favourable warm and sunny conditions provided perennial water supply is available to cater to the high rate of evapo-transpiration from the cultivated land. Though the overall water resources are adequate to meet all the requirements of the subcontinent, the water supply gaps due to temporal and spatial distribution of water resources among the states and countries in the subcontinent are to be bridged.

Water security can be achieved along with energy security as it is going to consume electricity to link the surplus water areas with the water deficit areas by lift canals, pipe lines, etc. The total water resources going waste to the sea are nearly 1200 billion cubic meters after sparing moderate environmental / salt export water requirements of all rivers. Interlinking rivers of the subcontinent is possible to achieve water security in the Indian subcontinent with the active cooperation of the countries in the region.

4.0 Conclusion

According to *Nature* (2010), about 80% of the world's population (5.6 billion in 2011) live in areas with threats to water security. The water security is a shared threat to human and nature and it is pandemic. Human water-management strategies can be detrimental to wildlife, such as migrating fish

5.0 Summary

Efficient use of water along with curbing pollution are vital to enhancing water security.

6.0 Tutor-Marked Assignment

-Threat to water security. Discuss

Solution

The most common threat to water security is water scarcity. There can be several causes to water scarcity including low rainfall, climate change, high population density, and over allocation of a water source. An example of periodic water scarcity in the United States is droughts in California. Another category of threats to water security is environmental threats. These include contaminates such as biohazards (biological substances that can harm humans), climate change and natural disasters. Contaminants can enter a water source naturally through flooding. Contaminants can also be a problem if a population switches their water supply from surface water to groundwater. Natural disasters such as hurricanes, earthquakes, and wildfires can damage man-made structures such as dams and fill waterways with debris. Other threats to water security include terrorism and radiationdue to a nuclear accident.

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MODULE 2 Water Treatment Processes and Techniques

UNIT 1 Water treatment

CONTENTS

1.0 Introduction

Water treatment is any process that improves the quality of water to make it more acceptable for a specific end-use. The end use may be drinking, industrial water supply, irrigation, river flow maintenance, water recreation or many other uses, including being safely returned to the environment. Water treatment removes contaminants and undesirable components, or reduces their concentration so that the water becomes fit for its desired end-use. Treatment for drinking water production involves the removal of contaminants from raw water to produce water that is pure enough for human consumption without any short term or long term risk of any adverse health effect. Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese.

The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation and biological processes such as slow sand filtration.

Measures taken to ensure water quality not only relate to the treatment of the water, but to its conveyance and distribution after treatment. It is therefore common practice to keep residual disinfectants in the treated water to kill bacteriological contamination during distribution.

2.0 OBJECTIVES

At the end of this unit, you should be able to

- Explain water purification
- List and explain the purification processes

3.0 MAIN CONTENT

3.1 water treatment

Clean, safe water is vital for everyday life. Water is essential for health, hygiene and the productivity of our community. The water treatment process may vary slightly at different locations, depending on the technology of the plant and the water it needs to process, but the basic principles are largely the same. This section describes standard water treatment processes.

Coagulation / Flocculation

During coagulation, liquid aluminium sulfate (alum) and/or polymer is added to untreated (raw) water. When mixed with the water, this causes the tiny particles of dirt in the water to stick together or coagulate. Next, groups of dirt particles stick together to form larger, heavier particles called flocs which are easier to remove by settling or filtration.

Sedimentation

As the water and the floc particles progress through the treatment process, they move into sedimentation basins where the water moves slowly, causing the heavy floc particles to settle to the bottom. Floc which collects on the bottom of the basin is called sludge, and is piped to drying lagoons. In Direct Filtration, the sedimentation step is not included, and the floc is removed by filtration only.

Filtration

Water flows through a filter designed to remove particles in the water. The filters are made of layers of sand and gravel, and in some cases, crushed anthracite. Filtration collects the suspended impurities in water and enhances the effectiveness of disinfection. The filters are routinely cleaned by backwashing.

Disinfection

Water is disinfected before it enters the distribution system to ensure that any disease-causing bacteria, viruses, and parasites are destroyed. Chlorine is used because it is a very effective disinfectant, and residual concentrations can be maintained to guard against possible biological contamination in the water distribution system.

Sludge Drying

Solids that are collected and settled out of the water by sedimentation and filtration are removed to drying lagoons.

Fluoridation

Water fluoridation is the treatment of community water supplies for the purpose of adjusting the concentration of the free fluoride ion to the optimum level sufficient to reduce dental caries. Hunter Water is required to fluoridate water in accordance with the NSW Fluoridation of Public Water Supplies Act 1957.

pH Correction

Lime is added to the filtered water to adjust the pH and stabilise the naturally soft water in order to minimize corrosion in the distribution system, and within customers' plumbing.

3.2 Municipal/ urban water treatment

Treatment of the Public Water Supply

What, then, must be removed from public water supplies, and what other chemicals are added to the water? How do public water facilities treat our water to make it safe for us to drink and appropriate for other human uses? There are six major steps in the treatment of our water: screening, sedimentation, precipitation, filtration, adsorption, and disinfection. Some of these steps, such as precipitation, involve chemical reactions among the aqueous species dissolved in the water; others, such as screening, involve only separation of particles on the basis of physical characteristics like size. Many of these steps depend on one another. For instance, precipitation generates solids in the water from particles that had been dissolved; these solids must then be removed through sedimentation or filtration. We shall discuss each of the six steps in water treatment below, and then present a schematic showing how the steps work together to produce clean, usable freshwater.

Screening

Surface water (water from lakes and rivers) often has large debris, such as sticks, leaves, fish, and trash, floating in it. These objects can clog the water-treatment system and must be removed before the water enters the treatment plant. Treatment facilities that use surface water have large screens covering the site of water intake. The debris is too large to pass through the holes in the screens. Thus, as the water enters the plant, the large debris is removed. The screens must be cleaned periodically to remove any objects that have become stuck, so that they do not clog the screen and impede water flow into the plant.

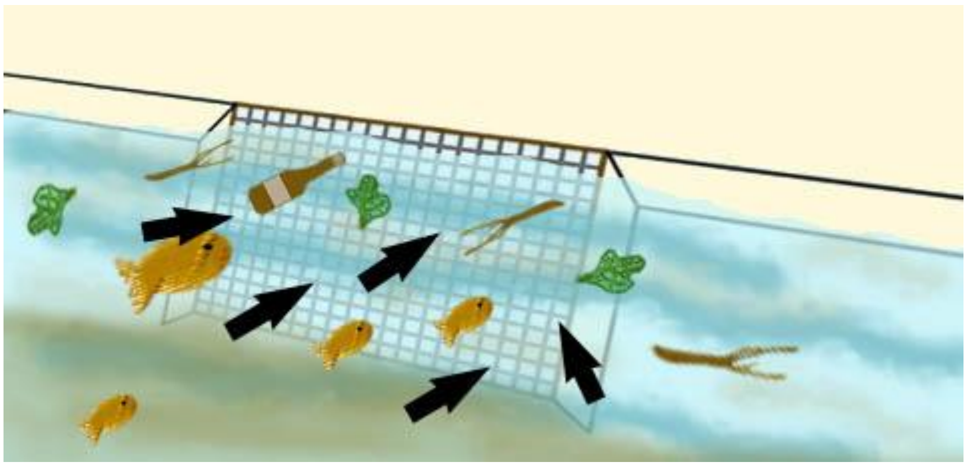

Figure 4: screening of large objects in surface water

www.researchgate.net

This drawing shows some of the large objects in surface water that are removed as the water pass through a screen into the water-treatment facility. The large black arrows show the direction of water flow through the screen.

Sedimentation

Other suspended (insoluble) particles, such as sand and dirt, are small enough to pass easily through the screens. These particles must be removed from the water by another process known as **sedimentation**. When water is allowed to sit, heavy suspended particles (*e.g.*, sand) will settle to the bottom over time because they are denser than water. The water, now free of the suspended impurities, can be collected from the top without disturbing the layer of sediment at the bottom (which is eventually discarded).

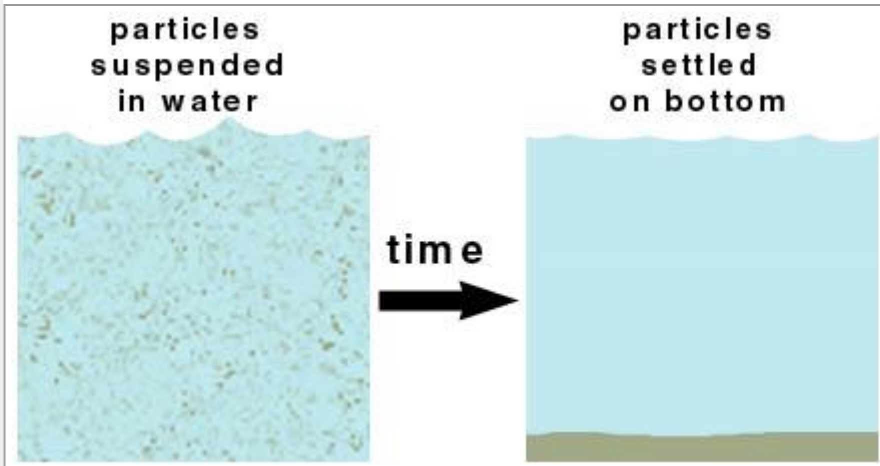

Figure 5: suspended and settled particles in water

www.researchgate.net

Particles that are insoluble in water may be suspended in the water, particularly if the water is turbulent (stirred up). If the particles are heavy enough, they will settle to the bottom when the water is allowed to sit still over time.

Sometimes the insoluble particles are too small to settle out quickly enough to use sedimentation alone. Two processes, known as **flocculation** and **coagulation**, are used to create larger particles that will settle quickly to the bottom. In flocculation, small particles with non-rigid surfaces are made to agglomerate by mixing the water (and thus bringing the particles into contact with one another so that the surfaces can become stuck together). When the agglomeration of the particles gets large enough, the aggregate can settle in still water by sedimentation. Other suspended particles do not agglomerate well by flocculation. To remove these particles from the water, coagulation must be used. Coagulation is the process of gathering particles into a cluster or clot, often achieved by the addition of special chemicals known as **coagulants.** The most common coagulant used in water-treatment facilities is **aluminum sulfate** (alum, $Al_2(SO_4)_3$). Other Al and Fe salts, including poly-aluminum chloride, ferric chloride, and ferric sulfate, may be used as well. These salts react with ions naturally found in the water to produce a solid precipitate (Equation 2). As this precipitate forms, other particles are caught in the solid, forming a mass that will settle to the bottom via sedimentation (Figure 6).

$$Al^{3+}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ca^{2+}_{(aq)} + 3HCO_3^-{}_{(aq)} \longrightarrow Al(OH)_{3(s)} + Ca(SO_4)_{(s)} + 3CO_{2(g)} \quad \textbf{(2)}$$

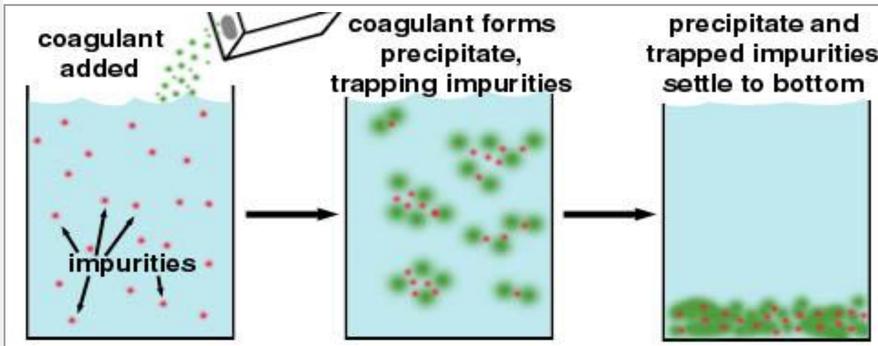

Figure 6: Coagulation of suspended particles in water treatment plant.

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When coagulants such as $Al_2(SO_4)_3$ are added to the water supply, they form solid precipitates (green), as shown in Equation 2, above. These precipitates catch other impurities (red) in the water, forming a solid mass containing the precipitate formed by coagulation and the trapped impurities. This mass will settle to the bottom by sedimentation, and the water (with the trapped impurities now removed) can be drained off from the top.

Precipitation

The steps in the water-treatment process described above are used to remove insoluble particles from the water supply. But recall from above ("Species (Other Than H_2O) Contained in Water") that water also contains many molecules and ions in solution. Many of the ions in solution can be removed by **precipitation:** reacting the ions (to be removed) with other ions to produce insoluble solids that can be removed by sedimentation.

A typical precipitation reaction used to remove ions in water treatment follows the reaction shown in Equation 3, below. This is the same reaction type that you performed in the Experiment when the reaction between ions from two aqueous solutions produced a solid precipitate.

$$\underset{\text{ion to be removed}}{A_{(aq)}} + \underset{\text{added ion}}{B_{(aq)}} \longrightarrow \underset{\text{precipitate}}{C_{(s)}} \qquad \textbf{(3)}$$

Two major classes of ions are typically removed via precipitation:

- Calcium (Ca^{2+}) ions and magnesium (Mg^{2+}) ions that have been leached from minerals in the ground cause the condition known as **"water hardness".** These ions do not pose any health threat, but they can engage in reactions that leave insoluble mineral deposits, such as scum rings on bathtubs and cooking vessels, or scale on industrial boilers, which decreases the boilers' efficiency. These deposits can make hard water unsuitable for many uses.
- Iron (Fe^{2+}) ions and manganese (Mn^{2+}) ions can stain plumbing fixtures and laundered clothes. These ions may also promote the growth of certain bacteria, which give foul tastes and odors to the water.

Treating Water Hardness

The process of removing Ca^{2+} and Mg^{2+} from the water is known as **water softening.** Two minerals, **lime** ($Ca(OH)_2$) and **soda ash** (Na_2CO_3), are typically used to soften public water supplies. (Incidentally, one important source of lime is near St. Genevieve, Missouri.) When lime is added to water, it dissolves to give three aqueous (solvated) ions: one Ca^{2+} ion and two OH^- ions for each unit of $Ca(OH)_2$. Likewise, soda ash dissolves to give two Na^+ ions and one CO_3^{2-} ion for each unit of Na_2CO_3 that dissolves.

A number of reactions occur to generate the insoluble precipitates $CaCO_{3(s)}$ and $Mg(OH)_{2(s)}$ from the Ca^{2+} and Mg^{2+} ions. The most important reaction for the removal of Mg^{2+} is shown in Equation 4.

$$Mg^{2+}_{(aq)} + Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} \longrightarrow Mg(OH)_{2\ (s)} + Ca^{2+}_{(aq)} \qquad \textbf{(4)}$$

from water   from lime   precipitate

Notice that Ca^{2+} appears on both sides of Equation 4. The calcium ion from lime does not actually participate in the reaction to generate insoluble $Mg(OH)_2$. Hence, this ion is called a **spectator ion** and can be omitted from the equation. We can write the reaction more correctly with the **net ionic equation**, given by Equation 5.

$$Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Mg(OH)_{2(s)} \qquad \textbf{(5)}$$

The solids generated by the water-softening precipitation reaction are then removed by sedimentation or filtration. If an excess of lime was used to precipitate magnesium ions in the water (Equation 4), some unused hydroxide (OH^-) ions will remain in the water after the calcium is precipitated, resulting in a high (or basic) pH. If necessary, the pH can be lowered by bubbling carbon dioxide gas through the water. The net ionic equations for this recarbonation are given in Equations 7 and 8.

$$CO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3\,(aq)} \quad \textbf{(7)}$$

$$H_2CO_{3\,(aq)} + OH^-_{(aq)} \rightleftharpoons H_2O + HCO_3^-{}_{(aq)} \quad \textbf{(8)}$$

Bicarbonate (HCO_3^-) remaining in the water is nontoxic and does not negatively affect the flavor of the water.

Removing Iron and Manganese

Two types of precipitation reactions may be used to remove Fe^{2+} and Mn^{2+} from water.

1. The most important of these reactions is **oxidation.** Using molecular oxygen (O_2) or another oxidant such as potassium permanganate ($KMnO_4$), Fe(II) is readily oxidized to Fe(III) in solution (Equation 9). If the solution is alkaline (high pH, basic), the Fe(III) forms $Fe(OH)_3$. As the concentration of $Fe(OH)_3$ increases, the oxygens start to coordinate between multiple iron ions, and a lattice begins to form. (Recall the definition of a lattice from the discussion above on "The Solvation Process.") At some point in this lattice formation, the $Fe(OH)_3$ starts to look like Fe_2O_3 (rust) and precipitates. Hence, by adding an oxidant to the water and raising the water's pH at the water-treatment plant, an insoluble precipitate is formed. The insoluble rust can then be removed by sedimentation or filtration.

$$3Fe^{2+}_{(aq)} + MnO_4^-{}_{(aq)} + 2H_2O_{(l)} \longrightarrow 3Fe^{3+}_{(aq)} + MnO_{2\,(s)} + 4OH^- \quad \textbf{(9)}$$

2. The water-softening agents described in the "Treating Water Hardness" section above can also help to make insoluble precipitates from $Fe^{2+}$and Mn^{2+}.

- Equation 4 shows how Mg^{2+} is removed using lime. However, this process introduces the new water-hardness problem of Ca^{2+} in the water.

Filtration

Often, the particles generated by the precipitation reactions described above are too small to settle efficiently by sedimentation. One strategy that is frequently employed to remove these solids is **gravity filtration**. In this process, water containing solid impurities (*e.g.*, precipitates from water softening) is passed through a porous medium, typically layers of sand and gravel. The force of gravity is used to push the water through the medium. The small water molecules pass through the holes between sand and gravel pieces. However, the solids (from precipitation) get stuck in the holes, and are thus retained in the porous medium. The water that passes through the bottom of the filter no longer contains those solid impurities.

Gravity filters at water-treatment plants have a pipe feeding into the under drain, the bottom layer where the clean water is collected. By adding water to the filter through this pipe, clean water can be forced upward through the filter to remove the solids that have collected in the filter. This process is used to clean the filter.

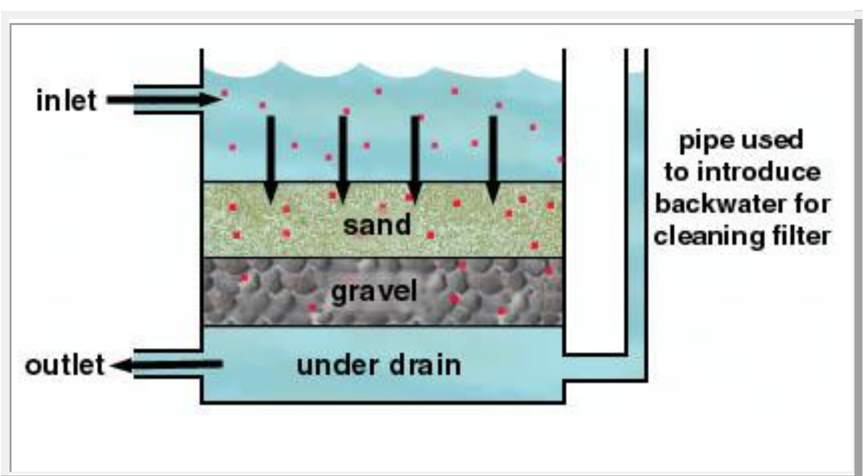

Figure 7

Water containing solid impurities (red) enters the filter through an inlet at the top and is forced by gravity through layers of sand and gravel. The solids get trapped between the sand and gravel pieces. The water that emerges into the under drain at the bottom of the filter is cleaned of these solids and exits the filter through an outlet at the bottom.

Adsorption

Dissolved organic compounds in water (*e.g.*, atrazine, an herbicide, and industrial waste products) can pose a significant health threat, and may affect the taste and odor of drinking water. To remove them, the process of **adsorption** is used. Adsorption is a process in which one substance is attached to the surface of another substance (Figure 8). **Powdered activated carbon** (PAC), a finely ground charcoal, is used for this process. When PAC is added to the water, the organic compounds attach to the surface of the powder granules. The granules of PAC have irregularly shaped surfaces, which gives PAC a very large surface area to attract organic compounds. It is estimated that 1 pound of PAC has a surface area of 100 acres! The carbon can then be removed by filtration, taking the unwanted organic compounds with it.

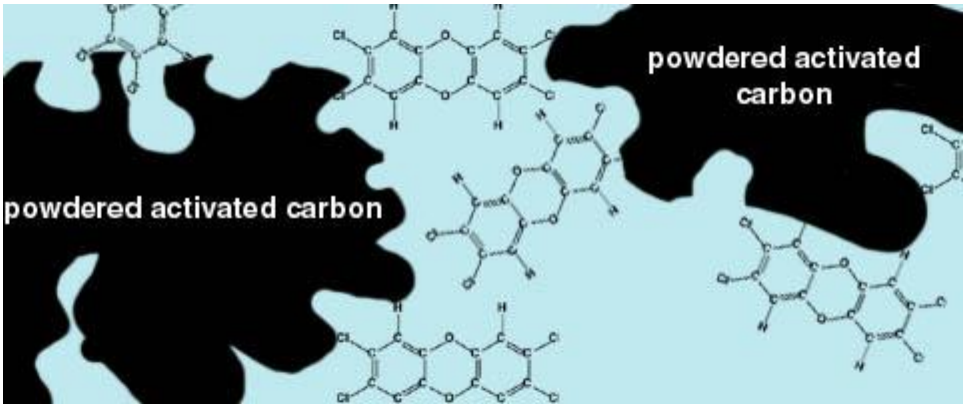

Figure 8

This figure shows the irregular surface area of powdered activated carbon (PAC). Organic molecules, such as the dioxin (a toxic byproduct of chemical bleaching and a precursur to powerful pesticides) shown here, adhere to the surface of the PAC granules. When the PAC is removed by filtration, the adsorbed organic molecules are removed with the carbon.

Disinfection

In many water supplies, the most serious health threats are posed not by chemicals, but by infectious organisms (bacteria) in the water. Chlorine (Cl_2) is a major disinfectant that is cheap and kills most of the serious disease-causing bacteria in the water. However, chlorine disinfection results in a wide variety of by-products. One class of chlorination by-products, known as trihalomethanes (THM's), are suspected carcinogens. Because of concern about these by-products in the water supply, chlorine is now kept to minimum levels, and other methods of disinfection are being used more frequently. Chloramines form more stable disinfectants and pose less risk of harmful by-products, but cost more to use. Other methods focus on removing the organisms through coagulation, sedimentation, and improved filtration.

Addition of Other Chemicals to the Water Supply

Certainly a principal objective of the water-treatment process is to remove substances from water that are harmful, or that otherwise make the water unsuitable for human use. However, another important component of the process is the addition of chemicals that make the water better for human use. For example, fluoride (F^-) is routinely added to public water supplies to protect the teeth of those who drink the water. Cities that add appropriate amounts of fluoride to their drinking-water supplies have successfully reduced the incidence of cavities among the children who inhabit those cities.

Schematic of a Water-Treatment Plant

The processes of screening, sedimentation, precipitation, filtration, adsorption, and disinfection work together to remove the unwanted substances from our water supply, making it safe to drink and appropriate for other uses. Addition of other chemicals, such as fluoride, further enhance the quality of the water for drinking. Figure 9, below, depicts a flowchart showing how these processes work together. Once the water is treated, it is sent to storage chambers and then distributed to household consumers, businesses, and industries.

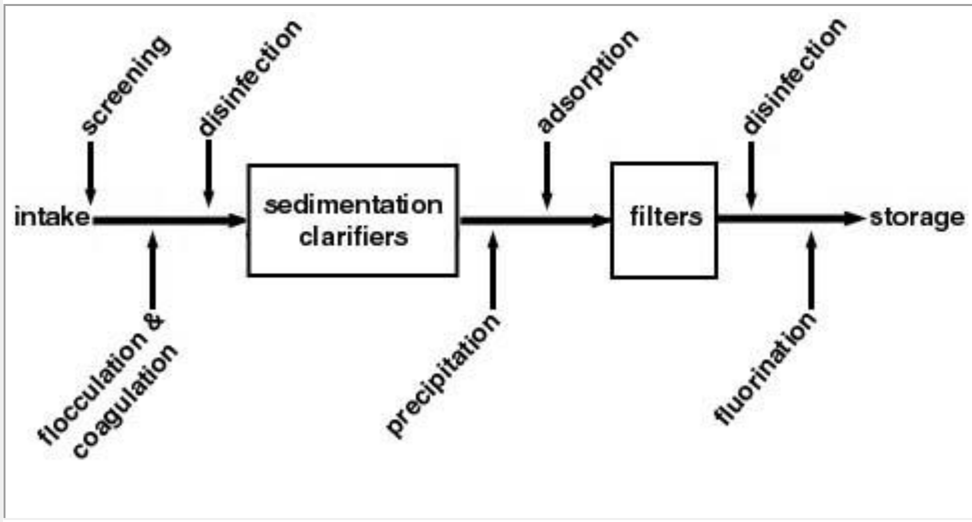

Figure 9

This flowchart shows the path that water takes from the intake of the water treatment plant (from the freshwater source) to the storage tank, from which it is pumped to homes, businesses, and industries. The specific steps and their sequence may vary somewhat from one treatment plant to another.

4.0 Conclusion

An understanding of chemistry is so important to the water-treatment process that water-treatment facilities hire many chemists to analyze the quality of the water and oversee its treatment. One of the most fundamental chemical principles in water treatment is **solubility.** It is imperative to understand which contaminants are soluble (forming solutions) and which are insoluble (forming suspensions), in order to determine how they can be effectively removed. Insoluble contaminants can usually be removed by physical-separation processes, including screening, sedimentation, and filtration. These physical processes may be aided by chemical processes, such as coagulation, that help to entrap the suspended particles. Soluble contaminants, on the other hand, must be removed by chemical methods that render them insoluble, so that they can then be removed by physical means, such as sedimentation and filtration. Furthermore, an understanding of solubility is essential in choosing reactants that will generate insoluble precipitates with the dissolved contaminants.

5.0 Summary

Water is perhaps the most important nutrient in our diets. In fact, a human adult needs to drink approximately 2 liters (8 glasses) of water every day to replenish the water that is lost from the body through the skin, respiratory tract, and urine. But some water sources cannot safely be used to meet our requirement for drinking water. In fact, 99.7% of the Earth's water supply is not usable by humans. This unusable water includes saltwater, ice, and water vapor in the atmosphere.

6.0 Tutor-Marked Assignment

-What is water treatment and state one treatment process?

Solution

Clean, safe water is vital for everyday life. Water is essential for health, hygiene and the productivity of our community. The water treatment process may vary slightly at different locations, depending on the technology of the plant and the water it needs to process, but the basic principles are largely the same. This section describes standard water treatment processes.

Coagulation / Flocculation

During coagulation, liquid aluminium sulfate (alum) and/or polymer is added to untreated (raw) water. When mixed with the water, this causes the tiny particles of dirt in the water to stick together or coagulate. Next, groups of dirt particles stick together to form larger, heavier particles called flocs which are easier to remove by settling or filtration.

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Unit 2: Municipal/urban water treatment systems

1.0 Introduction

Water treatment is any process that improves the quality of water to make it more acceptable for a specific end-use. The end use may be drinking, industrial water supply, irrigation, river flow maintenance, water recreation or many other uses, including being safely returned to the environment. Water treatment removes contaminants and undesirable components, or reduces their concentration so that the water becomes fit for its desired end-use.

Early water treatment methods still used included sand filtration and chlorination. The first documented use of sand filters to purify the water supply dates to 1804, when the owner of a bleachery in Paisley, Scotland, John Gibb, installed an experimental filter, selling his unwanted surplus to the public.[6][7] This method was refined in the following two decades, and it culminated in the first treated public water supply in the world, installed by the Chelsea Waterworks Company in London in 1829.

Urban water management involves the planning, design, and operation of infrastructure needed to meet the demands for drinking water and sanitation, the control of infiltration and stormwater runoff, and for recreational parks and the maintenance of urban ecosystems. As urban areas grow, so do the demands for such services. In addition there is an increasing need to make urban water systems more resilient to climate change. All this leads to the realization that urban water management must be an integral part of urban planning in general. Land use decisions impact water supply and wastewater system designs and operation, as well as measures needed for managing stormwater runoff. A functioning urban infrastructure system also requires energy which in turn typically requires water.

Sustainable urban development must focus on the relationships between water, energy, and land use, and often on diversifying sources of water to assure reliable supplies. Integrated urban water management (IUWM) provides both a goal and a framework for planning, designing, and managing urban water systems. It is a flexible process that responds to change and enables stakeholders to participate in, and predict the impacts of, development decisions. It includes the environmental, economic, social, technical, and political aspects of urban water management. It enables better land use planning and the management of its impacts on fresh water supplies, treatment, and distribution; wastewater collection, treatment, reuse and disposal; stormwater collection, use and disposal; and solid waste collection, recycling, and disposal systems. It makes urban development part of integrated basin management oriented toward a more economically, socially, and environmentally sustainable mixed urban–rural landscape.

While recognizing the need for and the benefits derived from a systems approach to urban planning and development, including its water related components, this chapter will serve as an introduction to each of these components separately, and not all together as a system. This understanding of each component is needed if indeed they eventually will be modelled, designed, and managed as part of the overall urban infrastructure system.

These urban water infrastructure components typically include water collection and storage facilities at source sites, water transport via aqueducts (canals, tunnels, and/or pipelines) from source sites to water treatment facilities; water treatment, storage, and distribution systems; wastewater collection (sewer) systems and treatment; and urban drainage works.

2.0 Objectives

At the end of this unit, you will get to know what water treatment is all about and the various treatment systems.

3.0 Main content

3.1 Treatment for drinking water production

Treatment for drinking water production involves the removal of contaminants from raw water to produce water that is pure enough for human consumption without any short term or long term risk of any adverse health effect. Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese.

The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation and biological processes such as slow sand filtration.

Measures taken to ensure water quality not only relate to the treatment of the water, but to its conveyance and distribution after treatment. It is therefore common practice to keep residual disinfectants in the treated water to kill bacteriological contamination during distribution.

World Health Organization (WHO) guidelines are a general set of standards intended to apply where better local standards are not implemented. More rigorous standards apply across Europe, the USA and in most other developed countries. Followed throughout the world for drinking water quality requirements.

Processes

From Wikipedia, the free encyclopedia

Empty aeration tank for iron precipitation

From Wikipedia, the free encyclopedia

Tanks with sand filters to remove precipitated iron

A combination selected from the following processes is used for municipal drinking water treatment worldwide:

- Pre-chlorination for algae control and arresting biological growth
- Aeration along with pre-chlorination for removal of dissolved iron when present with small amounts relatively of manganese
- Coagulation for flocculation or slow-sand filtration
- Coagulant aids, also known as polyelectrolytes – to improve coagulation and for more robust floc formation
- Sedimentation for solids separation that is the removal of suspended solids trapped in the floc
- Filtration to remove particles from water either by passage through a sand bed that can be washed and reused or by passage through a purpose designed filter that may be washable.
- Disinfection for killing bacteria viruses and other pathogens.

Technologies for potable water and other uses are well developed, and generalized designs are available from which treatment processes can be selected for pilot testing on the specific source water. In addition, a number of private companies provide patented technological solutions for the treatment of specific contaminants. Automation of water and waste-water treatment is common in the developed world. Source water quality through the seasons, scale, and environmental impact can dictate capital costs and operating costs. End use of the treated water dictates the necessary quality monitoring technologies, and locally available skills typically dictate the level of automation adopted.

Constituent	**Unit Processes**
Turbidity and particles	Coagulation/ flocculation, sedimentation, granular filtration
Major dissolved inorganics	Softening, aeration, membranes
Minor dissolved inorganics	Membranes
Pathogens	Sedimentation, filtration, disinfection
Major dissolved organics	Membranes, adsorption

Polluted water handling

From Wikipedia, the free encyclopedia

A sewage treatment plant in northern portugal

Wastewater treatment is the process that removes the majority of the contaminants from wastewater or sewage and produces both a liquid effluent suitable for disposal to the natural environment and a sludge. Biological processes can be employed in the treatment of wastewater and these processes may include, for example, aerated lagoons, activated sludge or slow sand filters. To be effective, sewage must be conveyed to a treatment plant by appropriate pipes and infrastructure and the process itself must be subject to regulation and controls. Some wastewaters require different and sometimes specialized treatment methods. At the simplest level, treatment of sewage and most wastewaters is carried out through separation of solids from liquids, usually by sedimentation. By progressively converting dissolved material into solids, usually a biological floc, which is then settled out, an effluent stream of increasing purity is produced.

4.0 Conclusion

While recognizing the need for and the benefits derived from a systems approach to urban planning and development, including its water related components, this chapter will serve as an introduction to each of these components separately, and not all together as a system. This understanding of each component is needed if indeed they eventually will be modelled, designed, and managed as part of the overall urban infrastructure system.

These urban water infrastructure components typically include water collection and storage facilities at source sites, water transport via aqueducts (canals, tunnels, and/or pipelines) from source sites to water treatment facilities; water treatment, storage, and distribution systems; wastewater collection (sewer) systems and treatment; and urban drainage works.

5.0 Summary

Early water treatment methods still used included sand filtration and chlorination. The first documented use of sand filters to purify the water supply dates to 1804, when the owner of a bleachery in Paisley, Scotland, John Gibb, installed an experimental filter, selling his unwanted surplus to the public.[6][7] This method was refined in the following two decades, and it culminated in the first treated public water supply in the world, installed by the Chelsea Waterworks Company in London in 1829.

6.0 Tutor-Marked Assignment

-Define water treatment

Solution

Water treatment is any process that improves the quality of water to make it more acceptable for a specific end-use. The end use may be drinking, industrial water supply, irrigation, river flow maintenance, water recreation or many other uses, including being safely returned to the environment. Water treatment removes contaminants and undesirable components, or reduces their concentration so that the water becomes fit for its desired end-use.

Early water treatment methods still used included sand filtration and chlorination. The first documented use of sand filters to purify the water supply dates to 1804, when the owner of a bleachery in Paisley, Scotland, John Gibb, installed an experimental filter, selling his unwanted surplus to the public.[6][7] This method was refined in the following two decades, and it culminated in the first treated public water supply in the world, installed by the Chelsea Waterworks Company in London in 1829.

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Unit 3: MEASUREMENT OF WATER YIELD

1.0 Introduction

2.0 Objectives

3.0 Main content

3.1 Definition of the term water yield

4.0 Conclusion

5.0 Summary

6.0 Tutor marked assignment

7.0 Reference/further reading

1.0 introduction

The water yield of a watershed may either be measured directly on a single outlet on the main stream or be calculated through empirical equations based on important physical properties of a particular watershed. Using the directly measured runoff values is, of course, the best way, but since it takes a long time and investments are delayed, the empirical method is preferred in applications. Therefore, precise prediction of the water yield from a watershed is curical for investigating the design capacity of water collecting structures and other hydraulic structures on the down streams. As in many other countries, the Turc Method is used widely in Turkey to determine the water yield and thus the reservoir volume by Turkish General Directorate of Rural Services which is responsible for the investments on agricultural and rural infrastructures. However, the method over predicts the water yield in comparison to the directly measured volumes for a region of Turkey in consideration.

2.0 Objectives

At the end of this particular unit, you will know what is meant by the term water yield and the methods used in measuring the yield.

3.0 Main content

3.1 Definition of the term water yield

The water yield of a watershed may either be measured directly on a single outlet on the main stream or be calculated through empirical equations based on important physical properties of a particular watershed. Using the directly measured runoff values is, of course, the best way, but since it takes a long time and investments are delayed, the empirical method is preferred in applications. Therefore, precise prediction of the water yield from a watershed is curical for investigating the design capacity of water collecting structures and other hydraulic structures on the down streams. As in many other countries, the Turc Method is used widely in Turkey to determine the water yield and thus the reservoir volume by Turkish General Directorate of Rural Services which is responsible for the investments on agricultural and rural infrastructures. However, the method over predicts the water yield in comparison to the directly measured volumes for a region of Turkey in consideration. Therefore the method cannot be applied in Turkey's conditions without any major modifications. This necessitates that this issue should be carefully evaluated in economical and technical aspects. In the previous study the modification of the method for Thrace Region was done. In this research, the Turc method is aimed to be modified to determine the water yield of sub-basins located at different part of Turkey using long time directly measured runoff values.

Knowing the structure of water yields no clues as to why water goes down a drain in a vortex. Similarly, in mycorrhizae, the genes are expressed and the metabolic machinery produces parts of the system, but they provide no information on how structure in mycorrhizal systems is generated. Mapping is a way of generalizing dynamics and establishing conceptual illustrations and models using simple input/output diagrams.

4.0 Conclusion

As in many other countries, the Turc Method is used widely in Turkey to determine the water yield and thus the reservoir volume by Turkish General Directorate of Rural Services which is responsible for the investments on agricultural and rural infrastructures. However, the method over predicts the water yield in comparison to the directly measured volumes for a region of Turkey in consideration.

5.0 Summary

the Turc method is aimed to be modified to determine the water yield of sub-basins located at different part of Turkey using long time directly measured runoff values.

Knowing the structure of water yields no clues as to why water goes down a drain in a vortex. Similarly, in mycorrhizae, the genes are expressed and the metabolic machinery produces parts of the system, but they provide no information on how structure in mycorrhizal systems is generated. Mapping is a way of generalizing dynamics and establishing conceptual illustrations and models using simple input/output diagrams.

6.0 Tutor-marked Assignment

-Write on Turc method in measuring water yield.

Solution

The Turc Method is used widely in Turkey to determine runoff depths therefore, water yield from a particular watershed and subsequently the reservoir's volume by Turkish General Directorate of Rural Services which is responsible for the investments on agricultural and rural infrastructures. However the method over predicts the water yield markedly when compared to the directly measured long-term water yields, which increases the total cost for the instruction of reservoirs and leads to environmental hazards due to disturbing more agricultural areas. In this research, the Turc Method was modifi ed through replacing the new coeffi cients with the original coeffi cients of the 300 and 0.9 by fi tting the calculated values to the directly measured long-term, a total of 223 years, in 22 sub-basin distributed throughout Turkey. Coeffi cients 566 and 0.68 were proposed as average values for Turkey in general instead 300 and 0.9, respectively, though the new coeffi cients for a particular watershed varied widely from 20 to 1135 and from 0.4 to 1.32, respectively. The country's sub-basins divided into three groups in terms of basin characteristics affective on these coeffi cients and new coeffi cients were also suggested for each group. Employing the modifi ed Turc Method with these new coeffi cients for the research sub-basins can reduce the reservoir's volume by 45 % and this may decrease the total cost of the reservoirs by about 20-25 % through reducing occupied surface area, embankment and crest height.

UNIT 4 : WATER CATCHMENT AND LEVELS IN THE SOIL

A catchment area or a part of a catchment area of a water gathering installation that is subject to the protection of water utility limitation."

According to the DVGW working paper W 101 [DVGWW101], the water catchment area is usually divided into 3 protective zones:

- Zone I : Collection region (Abschnitt 6.3)
- Zone II : Inner protected zone (Abschnitt 6.4.1)
- Zone III : Extended protected zone (Abschnitt 6.5.1)

2.0 Objectives

At the end of this unit, you will get to know the different levels of water catchment in the soil.

3.0 Main content

3.1 Water catchment and levels in the soil

The water catchment area is usually divided into 3 protective zones:

- Zone I : Collection region (Abschnitt 6.3)
- Zone II : Inner protected zone (Abschnitt 6.4.1)
- Zone III : Extended protected zone (Abschnitt 6.5.1)

The limitation for particular types of utility and the protective measures for the water increase in the sequence zone III - zone II - zone I. Insofar as different requirements are applied within the protective zone III, they can be subdivided, for instance, into the zones

III B, III A

whereby A designates the inner and B the outer area.

The size of Zone I should in general extend 10 m from springs in all directions, for wells 20 m in the direction of the incoming groundwater and at least 30 m from karst groundwater inlets (Image 6.3-1).

The zone II extends from zone I up to a line from which the groundwater requires approx. 50 days to reach the drinking water gathering installation. A zone II can be dispensed with if only deeper, sealed groundwater levels or such are used that from the 50 day line up to the collection point are sealed from the elements by impermeable layers.

The zone III extends from the limit of the catchment area up to the outer limit of zone II. When the catchment area extends more than 2 km, then a subdivision into a zone III A up to approx. 2 km from the collection region and a zone III B up to the border of the catchment area can be practicable.

4.0 Conclusion

The limitation for particular types of utility and the protective measures for the water increase in the sequence zone III - zone II - zone I. Insofar as different requirements are applied within the protective zone III, they can be subdivided, for instance, into the zones

5.0 Summary

A catchment area or a part of a catchment area of a water gathering installation that is subject to the protection of water utility limitation."

According to the DVGW working paper W 101 [DVGWW101], the water catchment area is usually divided into 3 protective zones:

- Zone I : Collection region (Abschnitt 6.3)
- Zone II : Inner protected zone (Abschnitt 6.4.1)
- Zone III : Extended protected zone (Abschnitt 6.5.1)

6.0 Tutor-Marked Assignment

- List the different zones in water catchment

Solution

A catchment area or a part of a catchment area of a water gathering installation that is subject to the protection of water utility limitation."

According to the DVGW working paper W 101 [DVGWW101], the water catchment area is usually divided into 3 protective zones:

- Zone I : Collection region (Abschnitt 6.3)
- Zone II : Inner protected zone (Abschnitt 6.4.1)
- Zone III : Extended protected zone (Abschnitt 6.5.1)

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Answers to Lok Sabha and Rajya Sabha Questions

MODULE 3 Water Quality Assessment Routine

Unit 1: Drainage pattern and catchment mapping

Unit 2: Water quality survey

Unit 3: Analysis of bio data relating to H_2O

UNIT 1: DRAINAGE PATTERN AND CATCHMENT MAPPING

CONTENTS

1.0 Introduction

A drainage basin is any area of land where precipitation collects and drains off into a common outlet, such as into a river, bay, or other body of water. The drainage basin includes all the surface water from rain runoff, snowmelt, and nearby streams that run down slope towards the shared outlet, as well as the groundwater underneath the earth's surface. Drainage basins connect into other drainage basins at lower elevations in a hierarchical pattern, with smaller sub-drainage basins, which in turn drain into another common outlet.

Other terms used interchangeably with *drainage basin* are catchment area, catchment basin, drainage area, river basin, and water basin. In North America, the term *watershed* is commonly used to mean a drainage basin, though in other English-speaking countries, it is used only in its original sense, that of a drainage divide.

In a closed drainage basin, or endorheic basin, the water converges to a single point inside the basin, known as a sink, which may be a permanent lake, a dry lake, or a point where surface water is lost underground.

The drainage basin acts as a funnel by collecting all the water within the area covered by the basin and channelling it to a single point. Each drainage basin is separated topographically from adjacent basins by a perimeter, the drainage divide, making up a succession of higher geographical features (such as a ridge, hill or mountains) forming a barrier.

Drainage basins are similar but not identical to hydrologic units, which are drainage areas delineated so as to nest into a multi-level hierarchical drainage system. Hydrologic units are defined to allow multiple inlets, outlets, or sinks. In a strict sense, all drainage basins are hydrologic units but not all hydrologic units are drainage basins

2.0 Objectives

At the end of this unit, you should be able to:

- Explain basin drainage
- Describe river catchment

3.0 MAIN CONTENT

3.1 Drainage pattern and catchment mapping

- About 48.7% of the world's land drains to the Atlantic Ocean. In North America, surface water drains to the Atlantic via the Saint Lawrence River and Great Lakesbasins, the Eastern Seaboard of the United States, the Canadian Maritimes, and most of Newfoundland and Labrador. Nearly all of South America east of the Andes also drains to the Atlantic, as does most of Western and Central Europe and the greatest portion of western Sub-Saharan Africa, as well as Western Sahara and part of Morocco. The two major mediterranean seas of the world also flow to the Atlantic:
    - The Caribbean Sea and Gulf of Mexico basin includes most of the U.S. interior between the Appalachian and Rocky Mountains, a small part of the Canadian provinces of Alberta and Saskatchewan, eastern Central America, the islands of the Caribbean and the Gulf, and a small part of northern South America.
    - The Mediterranean Sea basin includes much of North Africa, east-central Africa (through the Nile River), Southern, Central, and Eastern Europe, Turkey, and the coastal areas of Israel, Lebanon, and Syria.
- The Arctic Ocean drains most of Western and Northern Canada east of the Continental Divide, northern Alaska and parts of North Dakota, South Dakota, Minnesota, and Montana in the United States, the north shore of the Scandinavian peninsula in Europe, central and northern Russia, and parts of Kazakhstan and Mongolia in Asia, which totals to about 17% of the world's land.

- Just over 13% of the land in the world drains to the Pacific Ocean. Its basin includes much of China, eastern and southeastern Russia, Japan, the Korean Peninsula, most of Indochina, Indonesia and Malaysia, the Philippines, all of the Pacific Islands, the northeast coast of Australia, and Canada and the United States west of the Continental Divide (including most of Alaska), as well as western Central America and South America west of the Andes.
- The Indian Ocean's drainage basin also comprises about 13% of Earth's land. It drains the eastern coast of Africa, the coasts of the Red Sea and the Persian Gulf, the Indian subcontinent, Burma, and most of Australia.

Importance of Drainage Basin

Geopolitical boundaries

Drainage basins have been historically important for determining territorial boundaries, particularly in regions where trade by water has been important. For example, the English crown gave the Hudson's Bay Company a monopoly on the fur trade in the entire Hudson Bay basin, an area called Rupert's Land. Bioregionalpolitical organization today includes agreements of states (e.g., international treaties and, within the U.S.A., interstate compacts) or other political entities in a particular drainage basin to manage the body or bodies of water into which it drains. Examples of such interstate compacts are the Great Lakes Commission and the Tahoe Regional Planning Agency.

Hydrology

In hydrology, the drainage basin is a logical unit of focus for studying the movement of water within the hydrological cycle, because the majority of water that discharges from the basin outlet originated as precipitation falling on the basin. A portion of the water that enters the groundwater system beneath the drainage basin may flow towards the outlet of another drainage basin because groundwater flow directions do not always match those of their overlying drainage network. Measurement of the discharge of water from a basin may be made by a stream gauge located at the basin's outlet.

Isochrone maps can be used to show the time taken for runoff water within a drainage basin to reach a lake, reservoir or outlet, assuming constant and uniform effective rainfall.

Geomorphology

Drainage basins are the principal hydrologic unit considered in fluvial geomorphology. A drainage basin is the source for water and sediment that moves from higher elevation through the river system to lower elevations as they reshape the channel forms.

Ecology

Drainage basins are important in ecology. As water flows over the ground and along rivers it can pick up nutrients, sediment, and pollutants. With the water, they are transported towards the outlet of the basin, and can affect the ecological processes along the way as well as in the receiving water source.

Modern use of artificial fertilizers, containing nitrogen, phosphorus, and potassium, has affected the mouths of drainage basins. The minerals are carried by the drainage basin to the mouth, and may accumulate there, disturbing the natural mineral balance. This can cause eutrophication where plant growth is accelerated by the additional material.

Resource management

Because drainage basins are coherent entities in a hydro-logical sense, it has become common to manage water resources on the basis of individual basins. In the U.S. state of Minnesota, governmental entities that perform this function are called "watershed districts". In New Zealand, they are called catchment boards. Comparable community groups based in Ontario, Canada, are called conservation authorities. In North America, this function is referred to as "watershed management". In Brazil, the National Policy of Water Resources, regulated by Act n° 9.433 of 1997, establishes the drainage basin as the territorial division of Brazilian water management.

When a river basin crosses at least one political border, either a border within a nation or an international boundary, it is identified as a transboundary river. Management of such basins becomes the responsibility of the countries sharing it. Nile Basin Initiative, OMVS for Senegal River, Mekong River Commission are a few examples of arrangements involving management of shared river basins

3.2 River Catchment

The catchment is the most significant factor determining the amount or likelihood of flooding.

Catchment factors are: topography, shape, size, soil type, and land use (paved or roofed areas). Catchment topography and shape determine the time taken for rain to reach the river, while catchment size, soil type, and development determine the amount of water to reach the river.

Topography

Generally, topography plays a big part in how fast runoff will reach a river. Rain that falls in steep mountainous areas will reach the primary river in the drainage basin faster than flat or slightly sloping areas (e.g., > 1% gradient).

Shape

Shape will contribute to the speed with which the runoff reaches a river. A long thin catchment will take longer to drain than a circular catchment.

Size

Size will help determine the amount of water reaching the river, as the larger the catchment the greater the potential for flooding. It is also determined on the basis of length and width of the drainage basin.

Soil type

Soil type will help determine how much water reaches the river. Certain soil types such as sandy soils are very free-draining, and rainfall on sandy soil is likely to be absorbed by the ground. However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes. After prolonged rainfall even free-draining soils can become saturated, meaning that any further rainfall will reach the river rather than being absorbed by the ground. If the surface is impermeable the precipitation will create surface run-off which will lead to higher risk of flooding; if the ground is permeable, the precipitation will infiltrate the soil.

Land use

Land use can contribute to the volume of water reaching the river, in a similar way to clay soils. For example, rainfall on roofs, pavements, and roads will be collected by rivers with almost no absorption into the groundwater.

4.0 Conclusion

About 50% of all available water is transboundary - water located in the rivers, lakes or groundwater systems of two or more countries - and cooperation over this water is often troublesome. Around two thirds of the world's transboundary rivers lack agreements between the countries that share them.

6.0 Summary

The world is facing a global water crisis. This year, the World Economic Forum and world business leaders identified that water supply crises are amongst the highest impact risks facing the modern world.

7.0 Tutor-Marked Assignment

- what is water catchment

Solution

A drainage basin is any area of land where precipitation collects and drains off into a common outlet, such as into a river, bay, or other body of water. The drainage basin includes all the surface water from rain runoff, snowmelt, and nearby streams that run down slope towards the shared outlet, as well as the groundwater underneath the earth's surface. Drainage basins connect into other drainage basins at lower elevations in a hierarchical pattern, with smaller sub-drainage basins, which in turn drain into another common outlet.

Other terms used interchangeably with *drainage basin* are catchment area, catchment basin, drainage area, river basin, and water basin.

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Unit 2 Water quality survey

CONTENTS

1.0 Introduction

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water. The vast majority of surface water on the Earth is neither potable nor toxic. This remains true when seawater in the oceans (which is too salty to drink) is not counted. Another general perception of water quality is that of a simple property that tells whether water is polluted or not. In fact, water quality is a complex subject, in part because water is a complex medium intrinsically tied to the ecology of the Earth. Industrial and commercial activities(e.g. manufacturing, mining, construction, transport) are a major cause of water pollution as are runoff from agricultural areas, urban runoff and discharge of treated and untreated sewage.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Explain water quality management and test
- What is water bio-survey

3.0 MAIN CONTENTS

3.1 Water Quality Survey

3.2 Environmental water quality

Contaminants that may be in untreated water include microorganisms such as viruses, protozoa and bacteria; inorganic contaminants such as salts and metals; organic chemical contaminants from industrial processes and petroleum use; pesticides and herbicides; and radioactive contaminants. Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, use of water bodies as a heat sink, and overuse (which may lower the level of the water).

The United States Environmental Protection Agency (EPA) limits the amounts of certain contaminants in tap water provided by US public water systems. The Act authorizes EPA to issue two types of standards:

- *primary standards* regulate substances that potentially affect human health;

- *secondary standards* prescribe aesthetic qualities, those that affect taste, odor, or appearance.

The National Food and Drug Administration and Control (NAFDAC) regulations establish limits for contaminants in bottled water that must provide the same protection for public health. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of these contaminants does not necessarily indicate that the water poses a health risk.

In urbanized areas around the world, water purification technology is used in municipal water systems to remove contaminants from the source water (surface water or groundwater) before it is distributed to homes, businesses, schools and other recipients. Water drawn directly from a stream, lake, or aquifer and that has no treatment will be of uncertain quality.

Industrial and domestic use

Dissolved minerals may affect suitability of water for a range of industrial and domestic purposes. The most familiar of these is probably the presence of ions of calcium (Ca^{2+}) and magnesium (Mg^{2+}) which interfere with the cleaning action of soap, and can form hard sulfate and soft carbonate deposits in water heaters or boilers. Hard water may be softened to remove these ions. The softening process often substitutes sodium cations. Hard water may be preferable to soft water for human consumption, since health problems have been associated with excess sodium and with calcium and magnesium deficiencies. Softening decreases nutrition and may increase cleaning effectiveness. Various industries' wastes and effluents can also pollute the water quality in receiving bodies of water.

3.2 Environmental water quality

Environmental water quality, also called **ambient water quality,** relates to water bodies such as lakes, rivers, and oceans. Water quality standards for surface waters vary significantly due to different environmental conditions, ecosystems, and intended human uses. Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, rafting, boating, and industrial uses. These conditions may also affect wildlife, which use the water for drinking or as a habitat. Modern water quality laws generally specify protection of fisheries and recreational use and require, as a minimum, retention of current quality standards.

Sample Measurement

The complexity of water quality as a subject is reflected in the many types of measurements of water quality indicators. The most accurate measurements of water quality are made on-site, because water exists in equilibrium with its surroundings. Measurements commonly made on-site and in direct contact with the water source in question include temperature, pH, dissolved oxygen, conductivity, oxygen reduction potential (ORP), turbidity, and Secchi disk depth.

Sample collection

More complex measurements are often made in a laboratory requiring a water sample to be collected, preserved, transported, and analyzed at another location. The process of water sampling introduces two significant problems:

- The first problem is the extent to which the sample may be representative of the water source of interest. Many water sources vary with time and with location. The measurement of interest may vary seasonally or from day to night or in response to some activity of man or natural populations of aquatic plants and animals. The measurement of interest may vary with distances from the water boundary with overlying atmosphere and underlying or confining soil.
- The second problem occurs as the sample is removed from the water source and begins to establish chemical equilibrium with its new surroundings – the sample container. Sample containers must be made of materials with minimal reactivity with substances to be measured; and pre-cleaning of sample containers is important. The water sample may dissolve part of the sample container and any residue on that container, or chemicals dissolved in the water sample may sorb onto the sample container and remain there when the water is poured out for analysis. Similar physical and chemical interactions may take place with any pumps, piping, or intermediate devices used to transfer the water sample into the sample container.

Chemical analysis

The simplest methods of chemical analysis are those measuring chemical elements without respect to their form. Elemental analysis for oxygen, as an example, would indicate a concentration of 890 g/L (grams per litre) of water sample because oxygen (O) has 89% mass of the water molecule (H_2O). The method selected to measure dissolved oxygen should differentiate between diatomic oxygen and oxygen combined with other elements. The comparative simplicity of elemental analysis has produced a large amount of sample data and water quality criteria for elements sometimes identified as heavy metals. Water analysis for heavy metals must consider soil particles suspended in the water sample. These suspended soil particles may contain measurable amounts of metal. Although the particles are not dissolved in the water, they may be consumed by people drinking the water. Adding acid to a water sample to prevent loss of dissolved metals onto the sample container may dissolve more metals from suspended soil particles. Filtration of soil particles from the water sample before acid addition, however, may cause loss of dissolved metals onto the filter.[18] The complexities of differentiating similar organic molecules are even more challenging.

Real-time monitoring

Although water quality is usually sampled and analyzed at laboratories, nowadays, citizens demand real-time information about the water they are drinking. During the last years, several companies are deploying worldwide real-time remote monitoring systems for measuring water pH, turbidity or dissolved oxygen levels.

Biosurvey

Biosurveys are used by government agencies responsible for management of public lands, environmental planning and/or environmental regulation to assess ecological resources, such as rivers, streams, lakes and wetlands. They involve collection and analysis of animal and/or plant samples which serve as bioindicators. The studies may be conducted by professional scientists or volunteer organizations. They are conducted according to published procedures to ensure consistency in data collection and analysis, and to compare findings to established metrics.

Biosurveys typically use metrics such as species composition and richness (e.g. number of species, extent of pollution-tolerant species), and ecological factors (number of individuals, proportion of predators, presence of disease). Biosurveys may identify pollution problems that are difficult or expensive to detect using chemical testing procedures.[1]

A biosurvey may be used to generate an index of biological integrity (IBI), a scoring system for an ecological resource.

4.0 Conclusion

Making these complex measurements can be expensive. Because direct measurements of water quality can be expensive, ongoing monitoring programs are typically conducted by government agencies. However, there are local volunteer programs and resources available for some general assessment.

5.0 Summary

Water quality analysis and monitoring is integral to ensuring that water is safe for diverse purposes it is employed

6.0 Tutor-Marked Assignment

- Write a brief note on biosurvey of water

Solution

Biosurveys are used by government agencies responsible for management of public lands, environmental planning and/or environmental regulation to assess ecological resources, such as rivers, streams, lakes and wetlands. They involve collection and analysis of animal and/or plant samples which serve as bioindicators. The studies may be conducted by professional scientists or volunteer organizations. They are conducted according to published procedures to ensure consistency in data collection and analysis, and to compare findings to established metrics.

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A biosurvey may be used to generate an index of biological integrity (IBI), a scoring system for an ecological resource

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Unit 3: Analysis of bio data relating to water (H_2O)

CONTENTS

1.0 Introduction

Biodata is "...factual kinds of questions about life and work experiences, as well as items involving opinions, values, beliefs, and attitudes that reflect a historical perspective."[2] Since the respondent replies to questions about themselves, there are elements of both biography and autobiography. The basis of biodata's predictive abilities is the axiom that past behaviour is the best predictor of future behavior. Biographical information is not expected to predict all future behaviours but it is useful in personnel selection in that it can give an indication of probable future behaviours based on an individual's prior learning history. Biodata instruments (also called Biographical Information Blanks) have an advantage over personality and interest inventories in that they can capture directly the past behaviour of a person, probably the best predictor of his or her future actions.[*citation* *needed*] These measures deal with facts about the person's life, not introspections and subjective judgments.

2.0 Objectives

At the end of this unit, you will understand what is meant by the term water quality.

3.0 Main Content

3.1 Water Quality

Water Quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use. As we all know, water has many uses, such as for recreation, drinking, fisheries, agriculture and industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to support that use. For example, we expect higher standards for water we drink and swim in compared to that used in agriculture and industry. What is Water Quality Analysis? Water quality standards are put in place to ensure the efficient use of water for a designated purpose. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard. Why Water Quality Analysis is required? Water quality analysis is required mainly for monitoring purpose. Some importance of such assessment includes:

1. To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use.
2. To monitor the efficiency of a system, working for water quality maintenance.
3. To check whether up gradation / change of an existing system is required and to decide what changes should take place.
4. To monitor whether water quality is in compliance with rules and regulations.

Procedures of Water Quality Analysis

The general flow of procedures for water quality analysis is as follows:

- Selection of parameters

The parameters of water quality are selected entirely according to the need for a specific use of that water. Some examples are: Drinking Industries As per WHO/CPCB Standards As per specific requirement Irrigation Domestic Consumption pH As per BIS Standards Conductivity Sodium & Potassium Water Bodies Nutrients As per CPCB guidelines Specific compounds M.Tech.

However, some of the most common parameters followed for checking portability and industrial use in India are as follows:

Physical Inorganic / Toxic Metals Organic, Bacteriological Biology Radioactive Chemical Nutrient & Elements Demand Temperature Copper Total Coliform Phytoplankton Colour Hardness Chromium Zooplankton Alpha Emitter Faecal Coliform Odour Calcium Cadmium BOD Beta Emitter Taste Magnesium Zinc COD Chloride Lead Phenols Turbidity Sulphate Mercury Oil & Grease pH Fluoride Iron Pesticides Conductivity Alkalinity Manganese NitrateTotal Dissolved Solids Nitrate Phosphate

-Selection of methods

The methods of water quality analysis are selected according to the requirement. The factors playing key role for the selection of methods are: (i) Volume and number of sample to be analyzed (ii) Cost of analysis (iii) Precision required (iv) Promptness of the analysis as required.

- Chain-of-custody

Properly designed and executed chain-of-custody forms will ensure sample integrity from collection to data reporting. This includes the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition. This process is referred to as “chain-of-custody” and is required to demonstrate sample control when the control when the data are to be used for regulation or litigation. Where litigation is not involved, chain-of-custody procedures are useful for routine control of samples.

-Proper sampling

Proper sampling is a vital condition for correct measurement of water quality parameters. Even if advanced techniques and sophisticated tools are used, the parameters can give an incorrect image of the actual scenario due to improper sampling. The proper sampling should fulfill the following criteria:

1. Representative: The data must represent the wastewater or environment being sampled. So, the following factors must be well planned for proper sampling: (i) Process of Sampling (ii) Sampling size/volume (iii) Number of Sampling Locations (iv) Number of Samples (v) Type of Samples (vi) Time Intervals During sampling, these factors must also be taken care of: (a) Choosing of proper sampling container (b) Avoiding contamination (c) Ensure the personal safety of the collector.

2. Reproducible: The data obtained must be reproducible by others following the same sampling and analytical protocols.

3. Defensible: Documentation must be available to validate the sampling procedures. The data must have a known degree of accuracy and precision.

4. Useful: The data can be used to meet the objectives of the monitoring plan.

-Proper labeling

Proper labeling prevents sample misidentification and ensures the responsibility and accountability of the collector. The sample container should be labeled properly, preferably by attaching an appropriately inscribed tagor label. Alternatively, the bottle can be labeled directly with a water-proof marker. Barcode labels are also available nowadays. Information on the sample container or the tag should include at least: (i) Sample code number (identifying location) (ii) Date and time of sampling (iii) Source and type of sample (iv) Pre-treatment or preservation carried out on the sample (v) Any special notes for the analyst (vi) Sampler's name

PRESERVATION

There is usually a delay between the collection and analysis of a sample. The nature of the sample can be changed during this period. Therefore proper preservation is required in the way to laboratory after collection, and in the laboratory up to when analysis starts.

Complete and unequivocal preservation of samples, whether domestic waste water, industrial wastes, or natural waters, is a practical impossibility because complete stability for every constituent never can be achieved. At best, preservation techniques only retard chemical (especially, hydrolysis of constituents) and biological changes that inevitably continue after sample collection. No single method of preservation is entirely satisfactory; the preservative is chosen with due regard to the determinations to be made. Preservation methods are limited to pH control, chemical addition, the use of amber and opaque bottles, refrigeration, filtration, and freezing.

4.0 Conclusion

Water quality standards are put in place to ensure the efficient use of water for a designated purpose. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard. Why Water Quality Analysis is required? Water quality analysis is required mainly for monitoring purpose.

5.0 Summary

Some importance of such assessment includes:

1. To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use.
2. To monitor the efficiency of a system, working for water quality maintenance.
3. To check whether up gradation / change of an existing system is required and to decide what changes should take place.
4. To monitor whether water quality is in compliance with rules and regulations.

6.0 Tutor-marked Assignment

-What do you understand by the term biodata

Solution

Biodata is "...factual kinds of questions about life and work experiences, as well as items involving opinions, values, beliefs, and attitudes that reflect a historical perspective."[2] Since the respondent replies to questions about themselves, there are elements of both biography and autobiography. The basis of biodata's predictive abilities is the axiom that past behaviour is the best predictor of future behaviour. Biographical information is not expected to predict all future behaviours but it is useful in personnel selection in that it can give an indication of probable future behaviours based on an individual's prior learning history. Biodata instruments (also called Biographical Information Blanks) have an advantage over personality and interest inventories in that they can capture directly the past behaviour of a person, probably the best predictor of his or her future actions. These measures deal with facts about the person's life, not introspections and subjective judgements

-Define water quality

Solution

Water Quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use. As we all know, water has many uses, such as for recreation, drinking, fisheries, agriculture and industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to support that use. For example, we expect higher standards for water we drink and swim in compared to that used in agriculture and industry. Water quality standards are put in place to ensure the efficient use of water for a designated purpose. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard. Why Water Quality Analysis is required? Water quality analysis is required mainly for monitoring purpose. Some importance of such assessment includes:

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MODULE 4 Health and safety in water treatment

Unit 1 Health hazards associated with water treatment

CONTENTS

1.0 Introduction

Workers in the wastewater treatment sector are responsible for the day-to-day operation, maintenance, trouble-shooting and handling of special problems of municipal, industrial, and other wastewater treatment plants. Occupations can include: Wastewater Plant Operator, Senior Operator, Water Resources Specialist, Maintenance Operator, etc in both municipal and private facilities

2.0 Objectives

At the end of this unit, you should be able to:

- Explain hazards associated with water treatment plants
- List and explain sources of these hazards

3.0 MAIN CONTENTS

3.1 Hazards associated with water treatment

Workers in this sector are exposed to a variety of hazardous chemical and biological materials contained within the effluents and the reagents used in the water processing or generated during the water treatment.

Chemical agents may cause acute poisoning, chemical accidents (e.g., skin burns, injury to the eyes, etc.) damage to the respiratory system, allergies, dermatitis, chronic diseases, etc. Biological agents include pathogens such as bacteria, protozoa, viruses, helminths and fungi.

There may be injuries by slips, trips and falls on wet floors; by falls into treatment ponds, pits, clarifiers or vats and by splashes of hazardous liquids; they may suffer cuts and pricks from sharp tools, contusions, etc.

There is also exposure to hazards related to work in confined spaces. Strains and sprains are the most common types of injuries.

The three primary types of exposure risks are:

1. Biological

There is a high potential for illnesses arising from contact with viruses, bacteria and other microorganisms in sewage.

The most serious viral risk is hepatitis. The most serious bacterial risk is tetanus.

2 Chemical

The main routes of exposure are hand-to-mouth contact. Breathing in a suspension of particles (aerosols) is a less common means of exposure but may occur whenever sewage is agitated or aerosolized. This occurs most commonly near incoming wastewater inlets and sludge treatment areas.

3. Metals

Metals are generally not air-stripped into the air in sufficient quantities to be significant (with the exception of mercury). Therefore, they accumulate either in sludge or pass through into the receiving water. Other possible hazards include asbestos and radioactive materials from medical facilities.

The five main categories of pathogens are:

Bacteria, Viruses, Protozoa, Helminths (parasitic worms), Fungi.

Treatment processes do not eliminate the risk of exposure. The primary treatment process may remove 80 - 90% of Salmonella; 50% of Mycobacterium; and coliform removal varies from 27 - 96%. The secondary treatment process removes from 50 - 90% of these pathogens. Activated sludge has a low removal rate of 85 - 99% for pathogenic bacteria. Waste solids do contain surviving pathogens. Anaerobic digestion appears to reduce pathogens by 74% to 97%. Tuberculosis, roundworms and certain enteric viruses appear highly resistant to treatment processes.

Disease routes

1. Inhalation

This is the most common route for chemicals or pathogens to enter the body, usually via:

- air-stripping from wastewater
- bubble aeration
- workers working near weirs, outfall and aerated tanks
- dewatering processes
- drying, compacting, incineration
- exposure to chemicals while removing debris from treatment plant equipment

2. Skin Contact

This is a route of entry for both chemicals and pathogens. This includes being splashed in the mouth or on the skin. Chemicals can be absorbed through the skin from contact with wastewater or sludge. Disease organisms can enter the body through cuts, abrasions or needle sticks such as when removing screenings from a bar screen.

Ways of Improving Safety

Worker Education- Education about personal hygiene and safe work practices is extremely important to minimize contact with sewage and to prevent illnesses. While the employer bears the primary responsibility, everyone in the workplace needs to exercise caution.

Pre-planning- careful attention to personal hygiene and proper use of personal protective equipment (PPE) can greatly reduce the associated risks of exposure to sewage. It is essential that information be provided to the worker on reducing the risks of exposure and injury. Examples of worker practices include the following:

Avoid direct contact with sewage.

Avoid aerosolizing sewage water or minimizing exposure time in areas where aerosolizing is occurring. Make sure ventilation systems are functioning properly when working around areas where sewage may be aerosolized.

Thoroughly cleanse all exposed injuries with soap and water and keep them covered with a bandage (preferably waterproof) while at work. Seek medication attention immediately after suffering cuts or penetrating injuries.

If a worker is suffering from a skin problem, they should see a physician before working with sewage.

Avoid touching the face, mouth, hands, eyes or nose with dirty hands or other items and avoid nail biting.

Thoroughly wash the hands and face with soap and water before eating, drinking or smoking.

Eat/smoke in designated areas away from sewage contamination. These areas must be kept free from contamination by leaving any protective clothing and boots in a separate area, for example.

4.0 Conclusion

This is important in sectors with high injury rates such as wastewater treatment. Employers and workers should update safety practices, procedures and education on a regular basis.

6.0 Summary

To keep workers safe, operators can examine their plant practices and consider implementing safety procedures.

6.0 Tutor-Marked Assignment

- List and explain types of exposure risk in a water treatment plant

Solution

The three primary types of exposure risks are:

1. Biological

There is a high potential for illnesses arising from contact with viruses, bacteria and other microorganisms in sewage.

The most serious viral risk is hepatitis. The most serious bacterial risk is tetanus.

2 Chemical

The main routes of exposure are hand-to-mouth contact. Breathing in a suspension of particles (aerosols) is a less common means of exposure but may occur whenever sewage is agitated or aerosolized. This occurs most commonly near incoming wastewater inlets and sludge treatment areas.

3. Metals

Metals are generally not air-stripped into the air in sufficient quantities to be significant (with the exception of mercury). Therefore, they accumulate either in sludge or pass through into the receiving water. Other possible hazards include asbestos and radioactive materials from medical facilities.

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Unit 2 Underground Water and Aquifers

CONTENTS

1.0 Introduction

Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from and eventually flows to the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology.

Typically, groundwater is thought of as water flowing through shallow aquifers, but, in the technical sense, it can also contain soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of Earth's subsurface contains some water, which may be mixed with other fluids in some instances. Groundwater may not be confined only to Earth. The formation of some of the landforms observed on Mars may have been influenced by groundwater. There is also evidence that liquid water may also exist in the subsurface of Jupiter's moon Europa.

Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes. Many municipal water supplies are derived solely from groundwater

Aquifers

An *aquifer* is a layer of porous substrate that contains and transmits groundwater. When water can flow directly between the surface and the saturated zone of an aquifer, the aquifer is unconfined. The deeper parts of unconfined aquifers are usually more saturated since gravity causes water to flow downward.

The upper level of this saturated layer of an unconfined aquifer is called the *water table* or *phreatic surface*. Below the water table, where in general all pore spaces are saturated with water, is the phreatic zone. Substrate with low porosity that permits limited transmission of groundwater is known as an *aquitard*. An *aquiclude* is a substrate with porosity that is so low it is virtually impermeable to groundwater.

A *confined aquifer* is an aquifer that is overlain by a relatively impermeable layer of rock or substrate such as an aquiclude or aquitard. If a confined aquifer follows a downward grade from its *recharge zone*, groundwater can become pressurized as it flows. This can create artesian wells that flow freely without the need of a pump and rise to a higher elevation than the static water table at the above, unconfined, aquifer.

The characteristics of aquifers vary with the geology and structure of the substrate and topography in which they occur. In general, the more productive aquifers occur in sedimentary geologic formations. By comparison, weathered and fractured crystalline rocks yield smaller quantities of groundwater in many environments. Unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins are included among the most productive sources of groundwater.

2.0 Objectives

At the end of this unit, you should be able to:

- Explain the term underground water and aquifer
- Explain the relationship between underground water and rock types

3.0 **MAIN CONTENT**

3.1 **underground water and aquifers**

Aquifers are underground layers of rock that are saturated with water that can be brought to the surface through natural springs or by pumping.

The groundwater contained in aquifers is one of the most important sources of water on Earth: About 30 percent of our liquid freshwater is groundwater, according to the National Oceanic and Atmospheric Administration (NOAA). The rest is found at the surface in streams, lakes, rivers and wetlands. Most of the world's freshwater — about 69 percent — is locked away in glaciers and ice caps. Groundwater can be found in a range of different types of rock, but the most productive aquifers are found in porous, permeable rock such as sandstone, or the open cavities and caves of limestone aquifers. Groundwater moves more readily through these materials, which allows for faster pumping and other methods of extracting the water. Aquifers can also be found in regions where the rock is made of denser material — such as granite or basalt — if that rock has cracks and fractures.

Dense, impermeable material like clay or shale can act as an "aquitard," i.e., a layer of rock or other material that is almost impenetrable to water. Through groundwater might move through such material, it will do so very slowly (if at all). Faults or mountains can also block the movement of fresh groundwater,

An aquitard can trap groundwater in an aquifer and create an artesian well. When groundwater flows beneath an aquitard from a higher elevation area to a lower elevation, such as from a mountain slope to a valley floor, the pressure on the groundwater can be enough to force the water out of any well that's drilled into that aquifer. Such wells are known as artesian wells, and the aquifers they tap into are called artesian aquifers or confined aquifers.

How groundwater moves

When new surface water enters an aquifer, it "recharges" the groundwater supply. Recharge primarily happens near mountains, and groundwater flows usually flows downward from mountain slopes toward streams and rivers by the force of gravity, Phillips said. Depending on the density of the rock and soil through which groundwater moves, it can creep along as slowly as a few centimeters in a century, according to Environment Canada. In other areas, where the rock and soil are looser and more permeable, groundwater can move several feet in a day.
The water in an aquifer can be held beneath the Earth's surface for many centuries: Hydrologists estimate that the water in some aquifers is more than 10,000 years old (meaning that it fell to the Earth's surface as rain or snow roughly 6,000 years before Egypt's Great Pyramid of Giza was built). The oldest groundwater ever found was discovered 2 miles (2.4 km) deep in a Canadian mine and trapped there between 1.5 and 2.64 billion years ago.

But the deeper one digs for water, the saltier the liquid becomes.Groundwater can be very, very deep, but eventually it's a brine.

Much of the drinking water on which society depends is contained in shallow aquifers. For example, the Ogallala Aquifer — a vast, 174,000 square-mile (450,000 square kilometers) groundwater reservoir — supplies almost one-third of America's agricultural groundwater, and more than 1.8 million people rely on the

Threats to aquifers

By 2010, about 30 percent of the Ogallala Aquifer's groundwater had been tapped, according to a 2013 study from Kansas State University. Some parts of the

Ogallala Aquifer are now dry, and the water table has declined more than 300 feet in other areas.

This problem is increasingly found throughout the world, especially in areas where a rapidly growing population is placing greater demand on limited aquifer resources — pumping can, in these places, exceed the aquifer's ability to recharge its groundwater supplies.

When pumping of groundwater results in a lowering of the water table, then the water table can drop so low that it's below the depth of a well. In those cases, the well "runs dry" and no water can be removed until the groundwater is recharged — which, in some cases, can take hundreds or thousands of years.

When the ground sinks because of groundwater pumping, it is called subsidence. In California's southern San Joaquin Valley, where farmers rely on wells for irrigation, the land surface settled 28 feet (8.5 meters) between the 1920s and the 1970s. Land subsidence is a threat to aquifers and also to infrastructure on the surface.

In addition to groundwater levels, the quality of water in an aquifer can be threatened by saltwater intrusion (a particular problem in coastal areas), biological contaminants such as manure or septic tank discharge, and industrial chemicals such as pesticides or petroleum products. And once an aquifer is contaminated, it's notoriously difficult to remediate.

4.0 Conclusion

Underground water and aquifers are very important source of water for man, agricultural practices and livestock. Aquifers ensure supply of water even in very arid conditions

5.0 Summary

Aquifers come in many shapes and sizes, but they are really a contained, underground repository of water.

6.0 Tutor-Marked Assignment

- Define an aquifer

Solution

An *aquifer* is a layer of porous substrate that contains and transmits groundwater. When water can flow directly between the surface and the saturated zone of an aquifer, the aquifer is unconfined. The deeper parts of unconfined aquifers are usually more saturated since gravity causes water to flow downward.

The upper level of this saturated layer of an unconfined aquifer is called the *water table* or *phreatic surface*. Below the water table, where in general all pore spaces are saturated with water, is the phreatic zone. Substrate with low porosity that permits limited transmission of groundwater is known as an *aquitard*. An *aquiclude* is a substrate with porosity that is so low it is virtually impermeable to groundwater.

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The characteristics of aquifers vary with the geology and structure of the substrate and topography in which they occur. In general, the more productive aquifers occur in sedimentary geologic formations. By comparison, weathered and fractured crystalline rocks yield smaller quantities of groundwater in many environments. Unconsolidated to poorly cemented alluvial materials that have accumulated as valley-filling sediments in major river valleys and geologically subsiding structural basins are included among the most productive sources of groundwater.

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