Environmental Science
Lecture 16

Hydrological Cycle

Now move on to the Hydrological cycle, you have two main processes; precipitation and evaporation. The water that is present in oceans, rivers, any water body because the heat of the sun is evaporating and is getting settled as clouds and water vapour. Again when that gets saturated, it comes down as precipitation depending on the location it comes as snow at higher altitudes, comes as rain in the lower altitudes. This is basically powered by Solar energy or energy from the sun and this Hydrological cycle basically acts as purifying agent and it ensures that water remains pure. This is the global Hydrological cycle in the sense you have Aquifers below the ground level, groundwater and precipitation that is coming in different forms. Then you have water vapour, evaporation constantly happening through surface water because of the sun, that gets settled down as clouds and then you have precipitation happening and condensation. In different areas, in higher altitudes, it snows and in tropical areas and plains, it comes down as rain. That gets perculated and gradually gets collected as ground water if it's absorbed by the soil or it ends up filling rivers or oceans or seas. Two processes that occurs in this hydrological cycle is evaporation and precipitation. Precipitation could be any form and evaporation could occur from different sources but the result and process ends up being the same. Looking into the water cycle, salt water evaporates from Sun's energy producing fresh water in clouds; leaving salts in the ocean. The water vapour cools and condenses to precipitation over oceans and lands. Runoff forms fresh water lakes, streams, ponds, groundwater which is held in plants and transpired during photosynthesis.

Moving on to Pollution of Water. Pollution of water happens from different directions. Organic pollutants are controllable and it can be dealt with but inorganic pollutants especially from industries, fertilizers and treated sewage becomes difficult to deal with. You have Point sources. If you look at source of water pollutants, the first is point sources where you can actually identify a particular point as source pollution. This could either be a factory, a sewage plant, etc. This can be monitored or regulated. Moving on to non-point sources, not one single sources but a wide range of sources, eg: runoff from urban areas, or farmland. You won't know which acre or which piece of land is getting more polluted water but you will realize that the land overall is polluted. Non-point sources are much more difficult to monitor and control.

Pollution of Water; you have Industrial pollution, Surface pollution, Groundwater contamination, Sewage pollution, Oil pollution and Thermal pollution. You look at surface water contamination, you have hazardous dumps and wastes, runoff from cities and roads. Road runoff could be any oil residue from all kinds of vehicles, pollutants, all of that is a part of the runoff. Fewer chemical storage, feed lots and manures, then you have pesticides and fertilizers;

all of this waste water entering, seepage and then it enters your surface water which could be rivers, lakes or streams. Similarly, Pesticides and Fertilizers, even if it does not enter the nearby river or canal, it goes into the ground and it gradually enters the groundwater and sometimes even the Aquifers which are much below the subsoil and when those get polluted, that enters the water bodies. Water pollution can occur in a combination with air as well as soil pollution. Water pollutants, Industrial Effluents -This wastewater may contain acids, alkalis, salts, poison oils and in some cases harmful bacteria. Mining and Agricultural Wastes - Mines, especially gold and coal mines, are responsible for large quantities of acid water. Agricultural pesticides, fertilizers and herbicides; may wash into rivers and stagnant water bodies. Sewage Disposal and Domestic wastes - Sewage as well as domestic and farm wastes are often allowed to pollute rivers and dams. This again is a misconception. Once your crops and all of those are getting polluted because of fertilizers and the animals like other farm animals are going to consume this, their manure that can be used is no longer considered safe. Their excreta also becomes polluted because of metal content in that and that can again enter the soil or groundwater or sometimes directly enter the surface running water like canals or rivers. Water pollution, stagnant water or moving canal or stream because of pollution can be made into a stagnant water body.

Non-persistent or degradable Water pollutants. This includes domestic sewage, fertilizers or certain kinds of industrial wastes. Non-persistent or non-degradable water pollutants, these compounds can be broken down by chemical reactions or by natural bacteria into simple, non-polluting substances such as carbon dioxide and nitrogen. If the pollution load is high, this process can lead to low oxygen levels and eutrophication. This damage is reversible. It's not permanent. Persistent Water pollution, certain pesticides like DDT, dieldrin. Some leachate components from landfill sites, especially municipal or industrial. Petroleum and Petroleum products. PCBs, dioxins, polyaromatic hydrocarbons (PAHs). Radioactive materials such as strontium-90, cesium-137, radium-226 and uranium. Metas such as lead, mercury and cadmium. This is the most rapidly growing type of pollution. This includes substances that degrade very slowly or cannot be broken down at all. They may remain in the aquatic environment for years or longer periods of time. The damage they cause is either irreversible or repairable only over decades or centuries.

Other Water Quality Pollutants - Warm water from cooling towers i.e thermal pollution. When you input warm water, you might wonder what kind of pollution is that going to cause. Warm water kills certain good bacteria that is required. It is not conducive for certain kinds of aquatic plant form and animal form. Floating debris especially from construction sites, garbages and foam. These physical pollutants interfere mainly with the usability and/or aesthetic appeal of the water. In certain cases, thermal pollution can kill fish.

Classes of Water Pollutants

You have Pathogens like Bacteria, Viruses, Protozoa, Parasitic worms and Coliform Bacteria that is used as indicators of water quality. Oxygen Demanding wastes - Organics that are decomposed by bacteria and that use a lot of O_2, Dissolved Oxygen (DO) Decreases, and BOD increases. Water Soluble Inorganic Chemicals - Acids, Salts, Toxic Metal Compounds like Mercury and Lead. Inorganic Plant Nutrients: water soluble phosphates, Nitrates - Algal Blooms, Decreased Dissolved O_2, Increased BOD.

All of this is class I. Next, you have organic chemicals. Organic Chemicals could be Oil, Gas, Plastics, Pesticides, Cleaning Solvents, Detergents, etc. Sediment and Suspended Matter - Insoluble soil particulates and other solids, clouds the water which decreases photosynthesis, carries pesticides and disrupts aquatic food webs. Plantains which are plant forms in the aquatic system, are very crucial. They cannot be discarded. If Plantains are seen to be dying in a particular form in any aquatic body, it is the first sign of something wrong in the water body and water quality has to be checked right away. Once plantains begin dying, it's going to lead to the death of other organic matter and fish forms. Radioactive Isotopes - These are biologically amplified to higher concentrations in the food chain. Ionizing Radiation causing birth defects and cancer. Warmed water - this is basically from power plants that decrease dissolved oxygen and increases susceptibility to diseases, parasites and toxic wastes. Alien species like Zebra Mussels, Asiatic Catfish, Sea Lamprey, etc. All of these compete with certain native species and ultimately decrease biodiversity.

Industrial Water Pollution - Industries discharge a variety of pollutants in their wastewater including heavy metals, resin pellets, organic toxins, oils. Microbial contamination of water - Over 1 billion people lack access to safe water supplies, while 2.6 billion people lack adequate sanitation. This has led to widespread microbial contamination of drinking water. Water-associated infectious diseases claim up to 3.2 million lives each year, approximately 6% of all deaths globally.

Eutrophication - increasing in nutrient loading may lead to eutrophication. Organic wastes such as sewage impose high oxygen demands on the receiving water leading to oxygen depletion.

Sources of Eutrophication - When there is an excessive growth of a wrong kind of an aquatic plant which absorbs further oxygen or it could be reducing dissolved oxygen, all of these are sources of different forms of Eutrophication. It could be discharged from untreated plants and other municipal sewage, nitrogen compounds produced by cars and other factories. Inorganic fertilizers from fields, Manure runoff from plant farms and animal farms, runoff from different streets, lawns and other construction sites. Runoff and erosion from cultivation and other

construction sites. Dissolving of nitrogen oxides which is basically from internal combustion engines and furnaces. Basically, the lake ecosystem nutrient overload and breakdown causing a lot of illogical chemical cycling or improper chemical cycling which makes it inappropriate for certain plant forms to thrive and certain animal forms to thrive in water bodies.

The other extreme is Drought. Drought cases more damage and suffering than any other natural disaster. 80 countries experience droughts lasting more than a year. According to the UN, almost 500 million people in 31 countries (40% of the world's population) experience chronic water shortage today.

Flooding is the other extreme where you have over supply of water. This is seen as Waterlogged soil, nutrient leakage and erosion of topsoil.

River Pollution - Asian rivers are considered the most polluted in the world. Three times as many bacteria from human waste as the global average. 20 times more lead than rivers in industrialized countries.

Plastic Waste in water - each year plastic waste in water and coastal areas kills up to; 1,00,000 marine mammals, 1 million sea birds and countless fish.

Acid Rain is formed when moisture in the clouds mixes with sulfur or nitrogen in the air. Acid rain includes rain, sleet or snow with a pH level that falls below 5.6 or 5. The sulphur and nitrogen get into the air by the burning of fossil fuels such as coal and gasoline. The average pH of rainfall is 4.3. This is a typical acid rain scenario. It first takes in the nitrous compounds that enter as atmospheric dry particulates. Then you have the acidic particles and gases, Acid snow and Acid rain depending on the different context and scenario.

Water Borne diseases - diseases caused by ingestion of water contaminated with pathogenic bacteria, viruses or parasites, these include: cholera, typhoid, schistosomiasis , dysentery and other diarrheal diseases.

Disease burden from Water Pollution - Water associated infectious diseases claim up to 3.2 million lives each year, approximately 6% of all deaths globally. The burden of diseases from inadequate water, sanitation and hygiene totals 1.8 million deaths and the loss of greater than 75 million healthy life years.

Water and Sanitation - It is well established that investments in safe drinking water and improved sanitation show a close correspondence with improvement in human health and

economic productivity. Each person needs 20 to 50 liters of water free from harmful chemical and microbial contaminants each day for drinking and hygiene. There remains substantial challenges to providing the basic services to large segments of the human population.

Oil Pollution of Water - both point and nonpoint sources, largest source of oil pollution sources are pipeline leaks and runoff. 61% Ocean pollution and Oil pollution river, 30% intentional discharges from tankers, 5% accidental spill from tankers.

Remedial measures - Locate the point sources of pollution. Work against acid rain, which means to work particularly against pollution, especially sources of sulphur and nitrous compounds. Educating the community, Ensure sustainable sewage treatment, Watch out for toxins, Be careful what you throw away especially what can be recycled. Certain things like batteries cannot be thrown into water bodies or thrown into the ground because that leaks and leads to heavy metal poisoning. Use water efficiently, Prevent pollution and we need to think globally but act locally.

What have developed countries done to reduce Stream pollution?

The WHO report on drinking water states; 1.4 billion people do not have safe drinking water. 9,300 die daily from water-borne diseases. Cost of 23$ to bring safe drinking water and sanitation to everyone over a period of 8 - 10 years. An act of Clean Water Act 1972 was passed in 1972. We will look at its salient features - regulate the discharge of pollutants into U.S waterways, attain water quality levels that make sure the waterways are safe for fish as well for humans to swim in, restore and maintain the chemical, physical and biological integrity of the nation's water, set water quality standards to limit pollutants, require states and tribes to complete an assessment of all state rivers impacted or potentially impacted, by nonpoint pollution. Reduce polluted runoff from urban areas and animal feeding operations. Provide enforcement mechanisms like civil actions, criminal penalties to ensure they're being followed. Establish maximum contaminant levels, regulate volatile organic compounds, require lead free plumbing as well as paints, Wellhead protection.

Water Purification

Water Purification is the process of removing undesirable chemical and biological contaminants from raw water. Designed to meet drinking, medical, pharmacology, chemical and industrial applications. Treatment process also lead to to the presence of some mineral nutrients like fluoride, calcium, zinc, manganese, phosphate, and sodium compounds.

General Methods; Physical process - filtration, Sedimentation. Biological Processes - Slow Sand Filters, Activated Sludge. Chemical Processes - Flocculation and Chlorination. Radiation -

Ultraviolet light. Certain other methods are boiling by the use of activated carbon, distillation, reverse osmosis, Direct contact membrane distillation or DCMD.

Purification of water - via the large scale process, water was stored then filtered and then disinfected. But for domestic use or small scale, household purification you had boiling or chemical disinfection like bleaching powder, chlorine solution, high test hypochlorite (HTH), chlorine tablets, Iodine, Potassium Permanganate or Household filtration like Ceramic filters. Disinfection of well by adding bleaching powder or via the Double pot method. What are the effects of Storage in natural or artificial reservoirs? Physical is gravity, 90% of suspended impurities settle down in about one day. Chemical organic matter with the presence of Organic matter going through an oxidizing reaction, it releases nitrates and free Ammonia. Biological only 10% Bacteria remains at the end of 1 week. Optimum period of storage - 2 weeks.

Filtration method - Water passes through porous media, you have slow sand or biological filters. This was first used in 19th Century in Scotland. Elements of slow sand filter - you basically have a filter box which has a Supernatant water, Sand bed and an under drainage system with certain filter control valves.

Disinfection - Criteria for satisfactory disinfectant: destroy the pathogenic organism without being influenced from properties of water which is basically pH i.e the level of alkalinity or acidity, temperature, etc, within a particular time frame. Should not be toxic and colour imparting or leave the water impotable. It should be available, cheap and easy to use such that even common man can use it without the help of professionals or a training manual. Leave the residual concentration to deal with recontamination. Detectable by rapid, simple techniques in small concentration ranges to permit the control of disinfection process.

Purification of water on a small scale: Household Purification - boiling is primarily the one used all over. Roll boiling for 10 min, kills all bacteria, spores, cysts, ova and removes temporary hardness. No residual protection. Chemical Disinfection you have bleaching powder which is white powder, pungent smell and 33% available chlorine. Storage in a cool, dark, dry place in a closed container. This is prepared by passing Chlorine gas over lime, Chlorinated lime is another name for it, Stabilized bleach- bleaching powder is mixed with excess of lime. Chlorine Solution - 200 gm bleaching powder with about 25% available chlorine + 1 litre water gives a 5% solution, 1 drop of this solution helps in disinfecting 1 litre water but when it's a chemical that is going to be used, all of these proportions are very quintessential and crucial. Anything in excess will end up leaving the water impotable and anything less will leave the water with impurities.

HTH or Perchloric - High Strength Ca Hypochlorite, 70% available chlorine, 1gm for a litre of water. Chlorine Tablets - NEERI developed cheaper good tablets which are basically to be used

as 1 tablet (0.5 g) for 20 L water. Once these tablets came into being, it was easier to control and monitor especially in villages and even in smaller urban areas where people weren't educated enough to understand the nuances of these chemicals. Iodine - 2 drops i.e 2% solution in alcohol for 1 litre water, contact time 30 minutes, used only in emergency situations. Potassium Permanganate is expensive, unreliable and not recommended. Alum for turbidity reduction: 0.4 - 1.6 g/20 L water depending on the level of suspended particles. Alum is suitable only when there are suspended particles because it pretty much absorbs all the particles and it can be filtered later.

Filtration at a household level - Four Ghara method or the Four Pot method which basically indicates that the top one has muddy water, the second one has sand, the third has charcoal and the fourth is the empty pot which is used to collect the filtered clean water. Ceramic Filters - water passes through micro-pores of candle placed inside the water container. Bacteria is unable to pass through these pores. Virus can still pass through these pores. Pasteur Chamberland Filter: porcelain candles, used in labs and dispensaries. Berkefeld Filter - infusorial earth candles which is less reliable.

Disinfection of Well - this is by adding bleaching powder depending on the level or volume of water and the level of impurities. It is basically through Chlorine contact and it needs a particular apparatus like Horrock's apparatus. Bleaching powder maximum of 100 g is mixed with water in a bucket, about three fourth of the bucket. Then you need to allow 10 minutes of sedimentation, transfer the supernatant chlorine solution to another bucket. Then this needs to be transferred to the well and one hour contact time, then you can do a test to measure free residual chlorine. If Residual chlorine is less than 0.5 mg/L, add more bleaching powder.