Environmental Science
Lecture 20

Thermal Pollution

Now what is the source, cause and effect of Thermal pollution? Increase in normal temperatures of natural waters caused by the intervention of human activities is referred to as Thermal pollution because temperature is basically a physical characteristic of water which is characteristic of water which is regulated under the Clean Water Act. Areas in certain parts of the globe are supposed to reflect different types of temperature. The water should reflect certain types of temperature because of any abnormal activity, if this temperature rises, it is referred to as Thermal Pollution.

Causes and typical ways we look at Thermal Pollution as an effect; Suffocated fish, Altered food web, Decreased fish population and low dissolved oxygen. Once the temperature of the water rises, certain animals and plants thrive in a particular optimum temperature. Even a one degree difference makes a huge alteration in their life. Certain kinds of species may not be able to survive. The amount of oxygen that is dissolved will also reduce, that causes certain fish to suffocate and this alters the food web. The typical source and effect is right here in this image.

Major causes are nuclear power plants, deforestation and soil erosion. Discharge of heated water or hot waste material into water bodies, let it be from Nuclear Power plants, industrial affluents, domestic sewage, hydro-electric power and coal fired power plants. Nuclear Power plants use water as a cooling agent, after the water is used, it is put back in the - 20 degree celsius. Emissions from nuclear reactor increase the temperature of the water bodies.

Coal-fired power plants - coal is utilised as a fuel. Condenser coils are cooled with water from nearby lake or river. The heated effluents decrease the dissolved oxygen of the water and this therefore damages the marine organisms. Industrial affluents, discharged water from steam electric power industry using turbo generators will have a higher temperature ranging from 6 to 9 degree C than the receiving water. In modern stations, producing 100 MW, nearly one million gallons are discharged in an hour with increase in temperature of the cooling water passing by 8 to 10 degree C.

Domestic Sewage - sewage is commonly discharged into lakes, canals or streams. Municipal sewage normally has a higher temperature than the receiving water. Increase in temperature of the receiving water decreases the dissolved oxygen of the water. The Foul smelling gases increased in the water, resulting in the death of marine organisms. It could produce really serious and poisonous gases like Methane.

Deforestation - the decrease in vegetation, increases the amount of life that hits the water which increases the temperature of the water. Deforestation also increases erosion. This is more like an indirect way of cause. Soil erosion makes the water muddy which again increases the light absorbed and the previous point follows through.

Hydro electric power generation - Generation of hydroelectric power results in negative thermal loading in water systems which means it creates less heat on water sources than the nuclear power plant. This is dissolved oxygen vs temperature. You can see dissolved oxygen vs temperature. As the temperature rises, there is a significant drop with regard to the percentage of oxygen. That has to be seriously taken into account. When 30 degrees is there, it drops so much more when compared to 10 degrees, there is a steep drop in dissolved oxygen. Fish oxygen use vs temperature - again over here, you have oxygen consumption vs temperature. As the temperature increases, the fish requires more oxygen to sustain and because the dissolved oxygen ends up reducing, the fish wind up dying. This is a very complex relationship which can be understood very easily.

The typical response to temperature, you have pacific Salmon to Goldfish. You can see the solid dot you see over here. It's the upper lethal limit given for species and the open dot we see it the best temperature for spawning or reproduction. The solid blocks you see are the best temperature for spawning or reproduction and the solid block you see here , is the preferred temperature range. You can see here, the pathetic state of the shad, it is nearing its extinct temperature. Again over here, a couple of these temperatures are getting closer to their lethal temperature where these species will just stop existing. We need to ensure that thermal pollution is curbed completely to ensure the saving of these kinds of creatures and other supporting wildlife like plants and other large fish.

Effects of increased water temperature: Thermal shock - aquatic life adapted to certain water temperature can go into shock when the temperature even rises by 1 or 2 degree C. Oxygen dissolved in the water decreases, increases the rate of photosynthesis, which increases the amount of plant growth, developing eutrophic conditions. Increases the metabolic rate of fish which increases the need for oxygen.

Biotic effects of thermal pollution - Changes in the environment may also result in a migration of organisms to another, more suitable environment, and to in-migration of organisms that normally only live in warmer waters elsewhere. As a result one has the problem of compromising food chains of the old and new environments. Biodiversity will definitely be decreased as a result. Species will begin changing their ability to adapt to the environment which is the 'survival of the fittest', that is the principal of evolution. Even man tends to adapt himself to suit the best environment possible and even creatures will start doing that, which

will reduce migration and once migration reduces, a lot of other effects will also happen. Changes of even one or two degrees Celsius can cause significant changes in organism metabolism and other adverse cellular biological effects. Principal adverse changes can include rendering cell walls less permeable to necessary osmosis, coagulation of cell proteins and alteration of enzyme metabolism. These cellular level effects can adversely affect mortality and reproduction.

How do we go about controlling thermal pollution? Cooling ponds, man-made bodies of water, designed for cooling by evaporation, convection and radiation. Cooling towers which transfer waste heat to the atmosphere either through evaporation or heat transfer. Cogeneration, a process where waste heat is recycled for domestic or industrial heating purposes.

Cooling towers, Cooling ponds, Spray ponds and artificial lakes. These artificial lakes don't have any other job but to just act as a buffer zone between the receiving water and the affluents that are getting discharged from different plants.

Nuclear Hazards

If you look at the history of when nuclear hazards and fission came into being, it was in the year 1938 in Germany when they bombarded uranium with neutrons. Fermi demonstrated that the chain reaction in a nuclear pile or reactor was completely put across in paper and in action and that was the first atomic bomb or the nuclear bomb under the manhattan project in New Mexico. 2000 million dollars was the budget estimate for the Manhattan project. The test explosion of Atomic bomb on 16th July 1945 was a complete success, that is the history of the first nuclear bomb and nuclear fision that was recorded. The test explosion was a complete success, then the bomb was dropped as a weapon on Hiroshima and the second on Nagasaki. The bomb had the power of nearly 20,000 tons of TNT and Hiroshima nuclear explosion killed nearly 100,000 people and another 100,000 people were permanently injured and disfigured. This is considered the worst risk managing effect in the history of mankind.

If you go about defining what exactly is a nuclear hazard. Nuclear pollution and hazard is pretty much the same because this as such is the new reaction that has entered our environment. We have started using nuclear reactors only recently, let it be for production of energy or as a weapon or whatever use. Any kind of risk or danger to human health or the environment posed by radiation emanating from the atomic nuclei of a given substance or the possibility of an uncontrolled explosion originating from a fusion or fission reaction of atomic nuclei.

If you look at nuclear hazards, Radioactive pollution or nuclear pollution is a special form of physical pollution related to all major-life supporting systems - air, water and soil. Radioactivity is the phenomenon of emission of energy from radioactive isotopes i.e unstabilized isotopes

such as Carbon 14, Uranium 235, Uranium 238, Uranium 239 and Radium 226, etc. Any kind of emission of energy from radioactive substances in the environment is often called as 'Radioactive pollution'. Generally radiation hazards in the environment comes from UV rays, cosmic rays, visible microwave radiation. Amongst these, X rays produce about 95% of the radiation exposure. Nuclear energy is used to produce electricity. But fuel used in power plants is radioactive, which is very dangerous and waste materials are hazardous.

Fusion is a nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy. A fission reaction is a reaction in which a heavy nucleus splits spontaneously or on impact with another particle with a huge amount of energy. Nuclear power is being used worldwide for the generation of electricity. Now we are obviously looking for alternatives for fossil fuels but our alternatives again cannot be equally hazardous. Seventeen percent of the current electricity consumption comes from nuclear power. Typical sources of nuclear hazards, natural sources are cosmic rays from outer space. The quantity depends on altitude and latitude, it is more at higher latitudes and high altitudes. Emissions from radioactive materials from the Earth's crust. Manmade sources include nuclear power plants, x rays, nuclear bombs, nuclear accidents, mining and processing of radioactive ores. Use of radioactive materials in nuclear weapons.

Pathways of exposure to man from release of radioactive materials - internal dose from eating and drinking radioactive material and water which is from food and water. This could be from well, from underground water. It could be from the cow or the milk or the meat, it could be from the fish in the water. External radiation directly from the cloud, internal dose from inhalation of radioactive materials in the air and external dose direct from radioactive materials which are deposited from the ground. Natural sources encompass about 81% which includes radon of 55%, external cosmic and terrestrial and internal K-40, C-14, etc. Man-made sources encompasses a mere 19% and they increase steadily which includes diagnostic rays - 11%, nuclear medicine - 4%, consumer products and other fallout, power plants, air travel, occupational etc.

Nuclear hazards, can be divided into three groups - Short term recoverable effects, short term which leads to loss of hair, long term irrecoverable effects and finally genetical effects that get transferred to future generations. Internal bleeding and blood vessel damage may show up as red spots on the skin. Cancer is considered to be a major health issue from radiation exposure. Radiation can cause changes in DNA, which is known as Mutation. Acute exposure appears as burns and radiation sickness i.e nausea, hair loss, weakness.

These are the biological effects of ionizing radiation - you have somatic i.e affects the individual exposed. Genetic - effects even the next generation, this is basically due to chromosomal

mutation. Immediate effects that we see are; radiation sickness like vomiting, acute radiation syndrome, delayed effects that you see are Leukemia i.e blood cancer, Carcinogenesis which is against a different form of cancer that can show up later on, Fetal development abnormalities and shortening of life.

If you look at the different effects of radiation on humans, 0 - 50%, there is pretty much no visible effect. 50 - 200 you have brief periods of nausea on the day of exposure. 50% of this may experience radiation sickness, nausea and vomiting. No death as such is expected. 200 to 450, most members of the group will require medical attention, it will lead to serious radiation sickness and will result in 50% death within 2 to 4 weeks. 450 - 600 hours, serious radiation sickness in all the members of the group, more than 50% death will occur in 3 - 4 weeks. 600 hours - severe radiation sickness, 100% death in 2 weeks or less. We have to again be aware of our surroundings. We have to see what are the different sources, let it be natural or man-made and what are the source of these radiations? If you look at nuclear hazards, radioactive substances are present in nature, they undergo obvious, natural, radioactive decay in which unstable isotopes spontaneously give out. Fast moving particles, high energy radiation or both at a fixed rate until a new stable isotope is formed. The isotopes release either in the form of gamma rays or alpha beta particles. Alpha particles are fast moving positively charged particles, Beta Particles are fast moving negatively charged electrons. These ionization radiations have variable penetration powers.

If you look at it over here, this is concrete, this is lead, this is the thin as well as the thicker version - aluminium. Here you have human and the human hand is considered the first level of penetration. Finally concrete is the level. If you look at the alpha particles, it doesn't even penetrate the human hand. If you look at beta, it does penetrate to a certain extent. X-ray obviously penetrates the human hand, else we can't use it for medical purposes but it also passes through aluminium, thin lead and gamma rays goes right up to the mid level of the thick lead and neutrons also have the capacity of going right through concrete. This is the penetrating power of different types of radiation we are regularly exposed to.

How do we go about the Control of Radioactive pollution? Number 1 is time, distance and how do you shield yourselves. The first one is less time spent near the source means less radiation received. Greater the distance from the source, lesser radiation received. Finally, shield yourself from the source, less radiation received.

Control measures - Leakages from nuclear reactors, careless handling, transport and use of radioactive fuels, fission products, and radioactive isotopes have to be totally stopped. Safety measures should be enforced strictly. Waste disposal must be careful, efficient as well as

effective. There should be regular monitoring and quantitative analysis through frequent sampling in the risk areas. Preventive measures should be followed so that background radiation levels do not exceed the permissible limits. Appropriate steps should be taken against occupational exposure; and safety measures should be strengthened against nuclear accidents.

Disposal of Nuclear wastes - you have high level wastes which is HLW. These have a very high-radioactivity per unit volume. Since these wastes are too dangerous to be released anywhere in the biosphere, therefore, they must be contained either by converting them into inert solids (ceramics) and then buried deep into the earth or stored in deep salt mines. Medium level wastes like filers, reactor components, etc, are solidified and mixed with concrete in steel drums before being buried in deep mines or below the seabed in concrete chamber. Low liquid wastes - these are solids or liquids contaminated with very small traces of radioactivity, they are disposed of in steel drums in concrete-lined trenches in certain designated sites. If you look at safety measures - you need to monitor radioactivity around the disposal sites, prevention of erosion of radioactive waste disposal sites, prevention of any drilling activity in and around the waste disposal site, periodic and long-term monitoring of such disposal sites and areas of naturally occurring uranium rich rocks.

Chernobyl, 1986

Chernobyl is considered the worst accident ever in the history of nuclear power, it released more than 100 times the radiation produced by the atom bombs of Hiroshima and Nagasaki. It affected the Western Soviet Union, Eastern, Central and Northern Europe and Eastern and Northern America. 3,36,000 people evacuated and resettled elsewhere. Where exactly is the Chernobyl plant? It's in Ukraine, just about 18 km northwest of a particular town, 110 km north of Kiev.

These two are highly populated cities, if you look at the powerplant over here, you have four reactors of type RBMK-1 but now it is considered obsolete class of graphite moderated nuclear reactor. Reactor capacity is 1 Gigawatt provided about 10% of Ukraine's electricity at the time of the accident. It had a massive capacity, 2 additional reactors at the time of accident.

The series of events in Reactor 4 resulting in - Catastrophic 'steam explosion', nuclear meltdown and Graphite fire. This happened at 11 pm when the whole incident started. The Control rods were lowered to reduce reactor output for planned testing but it was lowered too quickly and this released to an almost complete shutdown. 1 am - the control rods were raised to increase the reactor activity for the test. At 1:23 - the reactor gets overheated, the water coolant turns to steam. 6 control rods are only left and the minimum safety number is 30. You can see the level of reaction from people who are not shutting down the plant. Only when it dropped down to six, the emergency shutdown button was pressed. Control rods were re-inserted but the

fault causes power surge in reactor. The output becomes 100 times the normal output.. Fuel pellets explode, roof gets blown off, air gets sucked in causing fire. Obviously when exposed to moisture as well as oxygen, it increases the speed of burning and combustion. If you look at the immediate aftermath, area was evacuated but quite slowly, they had an exclusion zone. Tragedy was made worse by poor preparation, equipment and assessments. Radiation was estimated at 20,000 Rontgen/hr, the lethal dose is 100 R/hr. True radiation unknown, fire burned until helicopters extinguished it by dropping water, sand, lead and boron. Radioactive cloud was observed. It was completely covered in radioactive material and not just immediately but for many years to come. Ecological effects - Radioactive cloud floated in easterly direction, radiation travelled as far as thousand hundred kilometers. Initial Soviet Union reports was 60% was contaminated, river was contaminated, fresh water was contaminated, the fish was affected, the pine forest within 4 km radius turned ginger brown and actually died. Exclusion zone became a wildlife haven. Pretty much everything collapsed.

With respect to human effects, 3,36,00 people evacuated and resettled, 237 suffered from acute radiation sickness, 31 deaths within 3 months, 9000 cancer deaths expected as direct result of radiation exposure and 4,000 thyroid cancer cases among children by 2002. Imperfection reactor design - high void coefficient weakens the convection currents. Graphite tipped control rods increase activity for a short period. Vertical water channels in the core, temperature gradient in the core, Partial containment measurements to save costs, operational for 1 year - stored fission by products; all of these were bad designed elements. Reactor vessels were wapped under intense heat preventing insertion of control rods.

Solid Waste Management

If you go about look at the different kinds of waste and waste generation, we obviously need to study what is the source of solid waste in India and what are management methods to contain solid waste and how is it contained especially in urban areas. If you look at what exactly is solid waste, it is waste that is not liquid, not gaseous, it is discarded as solid materials from municipal, industrial and agricultural activities. The term solid waste refers to anything household garbage, food waste, yard waste and demolition or construction debris.

Why should this waste be managed? Waste degrades water, soil, air quality and does environmental and ecological harm. Waste does harm to human health. Waste is unpleasant aesthetically and it creates unhygienic conditions. The repercussions of waste is just not one fold, it can be immediate as well as felt after a long period of time as well.

What is the objective of solid waste management? The objective of solid waste is to control, collect, process, dispose of solid wastes in an economical way consistent with public health

protection. Causes are: Population growth, Increase in industrial manufacturing, Urbanization, all of these causes increase the immersion of solid waste.

Types and sources of solid waste - depending upon nature, solid waste can be broadly classified into three types - urban or municipal wastes, Industrial wastes, Hazardous wastes. Moving on to the sources and characteristics of industrial waste - you have nuclear power plants, thermal power plants and chemical industries. These are the main sources especially where metals and minerals are processed.

If you look at Hazardous wastes, these are the wastes that pose a substantial danger immediately or over a period of time to human, plant or animal life. Sources of Hazardous wastes - Chemical manufacturing companies, petroleum refineries, paper mills, radioactive substances, biological wastes, heavy metal and other industries. At the end of this lecture, we looked into the cause and effect of thermal pollution; the source, cause and effect of nuclear hazards and a basic introduction to solid waste management.