Text

Definition of Air Pollution

Air pollution is the presence of foreign substances in the air. There are some specific definitions available for air pollution:

"***Air pollution is defined as the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce harmful environmental effects"*** (the United States Environmental Protection Agency, 2007).

"Air pollution is the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property" (WHO,1972)

Classification of Air Pollutants

A substance in the air that can cause harm humans and the environment is known as an air pollutant. Pollutants can be in the form of solid particles, liquid droplets, or gases. Besides, they may be natural or human-made.

Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Instead, they form in the air when primary pollutants react or interact. An important example of a secondary contaminant is ground-level ozone — one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Major primary pollutants produced by human activity include

- **Sulphur oxides (SO_x):** SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulfur compounds, their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4 and acid rain. This is one of the causes for concern over the environmental impact of using these fuels as power sources.

- **Nitrogen oxides (NO_x)**: especially nitrogen dioxide is emitted from high-temperature combustion, and are also produced naturally during thunderstorms by electrical discharge. Can be seen as the brown haze dome above or plume downwind of cities. Nitrogen dioxide is the chemical compound with the formula NO_2. It is one of the several nitrogen oxides. This reddish-brown toxic gas has a characteristic sharp, biting odour. NO_2 is one of the most prominent air pollutants.
- **Carbon monoxide (CO):** is a colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a significant source of carbon monoxide.
- **Carbon dioxide (CO_2)**: is a colourless, odourless, non-toxic greenhouse gas also associated with ocean acidification, emitted from sources such as combustion, cement production, and respiration. It is otherwise recycled in the atmosphere in the carbon cycle.
- **Volatile organic compounds:** VOCs are an important outdoor air pollutant. They are often divided into separate categories of methane (CH_4) and non-methane (NMVOCs) in this field. Methane is an extremely efficient greenhouse gas that contributes to enhanced global warming. Other hydrocarbon VOCs is also significant greenhouse gases via their role in creating ozone and prolonging methane's life in the atmosphere. However, the effect varies depending on local air quality. Within the NMVOCs, the aromatic compounds benzene, toluene, and xylene are suspected carcinogens and may lead to leukaemia through prolonged exposure. 1,3-butadiene is another dangerous compound that is often associated with industrial uses.
- **Atmospheric particulate matter**: Particulates, referred to as particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In

contrast, aerosol refers to particles and gas together. Sources of particulate matter can be human-made or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as burning fossil fuels in vehicles, power plants and various industrial processes, also generate significant amounts of aerosols. Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10 per cent of the total amount of aerosols in our atmosphere. Increased fine particles levels are linked to health hazards such as heart disease, altered lung function, and lung cancer.

- **Chlorofluorocarbons (CFCs):** harmful to the ozone layer emitted from refrigerators, air conditioners used as a coolant and in plastic foam such as a thermocouple.
- **Ammonia (NH_3)**: emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is usually encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to terrestrial organisms' nutritional needs by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.
- **Radioactive pollutants:** produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.

Secondary pollutants include

- **Smog:** is a kind of air pollution; the word "smog" is synchrony of two words, smoke and fog. ***Classic smog*** results from large amounts of coal burning in an area caused by a mixture of smoke and sulfur dioxide. ***Modern*** pollution does not usually come from coal but from vehicular and industrial emissions acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.
- **Ground-level ozone (O_3)**: formed from NO_x and VOCs. Ozone (O_3) is a vital constituent of the troposphere. It is also an essential constituent of some areas of the stratosphere commonly known as the Ozone layer. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and night. At abnormally high concentrations brought about

by human activities (mostly the combustion of fossil fuel), it is a pollutant and a constituent of smog.

- **Peroxyacetyl nitrate (PAN):** similarly formed from NO_x and VOCs.

Minor air pollutants include many little hazardous air pollutants—a variety of persistent organic pollutants, which can attach to particulate matter. Persistent organic pollutants (POPs) are organic compounds resistant to environmental degradation through chemical, biological, and photolytic processes. Because of this, they have been observed to persist in the environment, to be capable of long-range transport, bioaccumulate in human and animal tissue, biomagnify in food chains, and to have potentially significant impacts on human health and the environment.

Sources of Air Pollution

Stationary and Area Sources

A stationary air pollution source refers to an emission source that does not move, also known as a point source. Stationary sources include factories, power plants, dry cleaners and degreasing operations. The term area source is used to describe many small air pollution sources located together whose individual emissions may be below thresholds of concern, but whose collective emissions can be significant. Residential wood burners are an excellent example of a small source, but they can contribute to local and regional air pollution levels when combined with many other short sources. Area sources can also be thought of as non-point sources, such as housing developments, dry lakebeds, and landfills.

Mobile Sources

A mobile source of air pollution refers to a source that is capable of moving under its power. In general, mobile references imply "on-road" transportation, including vehicles such as cars, sport utility vehicles, and buses. Besides, there is also a "non-road" or "off-road" category that includes gas-powered lawn tools and mowers, farm and construction equipment, recreational vehicles, boats, planes, and trains.

Agricultural Sources

Agricultural operations, which raise animals and grow crops, can generate emissions of gases and particulate matter. For example, animals confined to a barn or restricted area (rather than field grazing), produce large amounts of manure. Manure emits various gases, particularly ammonia into the air. This ammonia can be ejected from the animal houses, manure storage areas, or the land after the manure is applied. In crop production, the misapplication of fertilizers, herbicides, and pesticides can potentially result in an aerial drift of these materials and harm may be caused.

Natural Sources

Although industrialization and the use of motor vehicles are overwhelmingly the most significant contributors to air pollution, there are important natural sources of "pollution". Wildland fires, dust storms, and volcanic activity also contribute gases and particulates to our atmosphere.

Unlike the air mentioned above, people or their activities do not cause pollution sources, natural “air pollution”. An erupting volcano emits particulate matter and gases; forest and prairie fires can emit large quantities of "pollutants"; plants and trees naturally emit VOCs that are oxidized, and form aerosols cause a natural blue haze, and dust storms can create large amounts of particulate matter. Wild animals in their natural habitat are also considered natural sources of "pollution". The National Park Service recognizes that each of these sources emits gases and particulate matter into the atmosphere, but we regard these as constituents resulting from natural processes.

Effects of Air Pollution

A variety of air pollutants have known or suspected harmful effects on human health and the environment. In most areas of Europe, these pollutants are principally the combustion products from space heating, power generation, or motor vehicle traffic. Pollutants from these sources may not only prove a problem near these sources but can travel long distances.

Health Effects:

Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments. The health effects vary significantly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. Children are at greater risk because they are generally more active outdoors, and their lungs are still developing. Exposure to air pollution can cause both acute (short-term) and chronic (long-term) health effects. Acute effects are usually immediate and often reversible when exposure to the pollutant ends. Some acute health effects include eye irritation, Headache, and nausea. Chronic effects are generally not direct and tend not to be reversible when exposure to the pollutant ends. Some chronic health effects include decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants. The scientific techniques for assessing air pollution's health impacts include air pollutant monitoring, exposure assessment, dosimetry, toxicology, and epidemiology.

Although in humans, pollutants can affect the skin, eyes and other body systems, they involve the respiratory system primarily. Both gaseous and particulate air pollutants can have adverse effects on the lungs. The lungs are the organs responsible for absorbing oxygen from the air and removing carbon dioxide from the blood-stream. Damage to the lungs from air pollution can inhibit this process and contribute to respiratory diseases such as bronchitis, emphysema, and cancer. This can also put an additional burden on the heart and circulatory system.

Table 1 summarizes the sources, health and welfare effects for the Criteria Pollutants. Hazardous air pollutants may cause other less common but potentially dangerous health effects, including cancer and damage to the immune system, and neurological, reproductive and developmental problems. Acute exposure to some hazardous air pollutants can cause immediate death.

Table 1: Sources, Health and Welfare Effects for Criteria Pollutants.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	The colourless, odourless gas	Motor vehicle exhaust, indoor sources include kerosene or wood-burning stoves.	Headache reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colourless gas dissolves in water vapour to form acid and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish-brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to smog formation, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. It is formed from other air pollutants in the	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.

		presence of sunlight.		
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anaemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Microscopic particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage

Source: http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT Delhi/

Effects on Farm Animals:

The process by which farm animals get poisoned is entirely different from how human beings exposed to the polluted atmosphere are poisoned. In the case of farm animals, it is a two-step process:

1) Accumulation of the airborne contaminant in the forage.

2) Subsequent poising of the animals when they eat the contaminated vegetation.

In the case of farm animals, the danger is not in inhaling the polluted air, but rather the ingestion of forage contaminated with pollutants like fluorine from the air. The three pollutants responsible for most livestock damage are fluorine, arsenic and lead. These pollutants originate from industrial sources or dusting and spraying.

Effects on Vegetation:

Air pollutants, such as sulphur dioxide, HF, particulate fluorides, smog, oxidants like ozone, ethylene (from automobiles), NOx, Chlorine and herbicides and weedicide sprays exert toxic effects on vegetation. The damage usually occurs in the form of visual injury such as chlorotic marking, banding, silvering or bronzing of the leaf's underside. Retardation of plant growth may also occur in some cases. The extent of damage to a pant depends upon the nature and concentration of the pollutants, time of exposure, soil and plant condition, stage of growth, relative humidity and the extent of sunlight.

Environmental Effects:

Climate change on a global scale has been attributed to increased emissions of carbon dioxide (CO2), a greenhouse gas. A global average temperature rise of the only 1ºC could have profound implications. Possible consequences include melting of polar ice caps, increased sea level; and increases in precipitation and severe weather events like hurricanes, tornadoes, heat waves, floods, and droughts. Indirect effects include increases in infectious disease, weather-related deaths, and food and water shortages. All these effects put stress on ecosystems and agriculture and threaten our planet as a whole.

Other atmospheric effects of air pollution include urban smog and reduced visibility, associated with ozone-forming nitrogen oxides and volatile organic compound emissions. Sulphur dioxide and nitrogen oxides combine with water in the atmosphere to cause acid rain, which is detrimental to forests and other vegetation, soil, lakes, and aquatic life. Acid rain also causes monuments and buildings to deteriorate.

Air Pollution Control

The following two basic approaches are used for controlling air pollution:

1. Controlling or confining the pollutants at the source. This can be achieved by:
   - Modifying the process in such a way that pollutants do not form at all beyond permissible concentration.
   - We are reducing the pollutant concentrations to tolerable levels before they are released to the environment, using suitable Equipment we can destroy, alter or trap the pollutants formed.
2. Dilution of the pollutants in the atmosphere to permissible levels before they can reach the receptor. This can be achieved by using tall stacks, controlling the process parameters with due regard to the local meteorological conditions and proper community planning to prevent the accumulation of dangerous ground-level concentrations within the designated areas.

<u>Methods and Equipment used to control gaseous pollutants:</u>

1) **<u>Combustion:</u>** This technique is used when pollutants contain gases or vapours, which are organic. Flame combustion or catalytic combustion of these pollutants converts them into water vapours and relatively innocuous products, such as CO2. The Equipment used for flame combustion includes fume incinerators, steam injection or venture flares and afterburners.
2) **<u>Absorption:</u>** In this technique, the gaseous effluents are passed through scrubbers or absorbers containing a suitable liquid absorbent to remove or modify one or more pollutants present in the gas stream. The efficiency of the gas absorption process depends upon:
   - The chemical reactivity of the gaseous pollutants in the liquid phase.
   - The extent of surface contact between the liquid and the gas.
   - The contact time and
   - The concentration of the absorbing medium.

The types of Equipment used include plate towers, spray towers, packed towers etc. The gas absorption technique is widely used for removing pollutants like NOx, H_2S, SO_2, SO_3 etc.

3) **Adsorption:** In this technique, the gaseous effluents are passed through porous solid adsorbents taken in suitable containers. The effluent gases' organic and inorganic constituents are held at the stable adsorbent interface by physical adsorption or chemisorptions. The efficiency of adsorption depends upon the surface area per unit weight of the adsorbent, other physical and chemical characteristics of the adsorbent and nature and concentration of the gas being adsorbed.

Methods and Equipment used for controlling particulate emissions:

Particulate materials in ambient air may originate from stationary as well as mobile sources. The various devices used may be classified as follows:

1) **Mechanical devices:** These devices mostly operate based on the following two mechanisms:
    - Gravity settling in which the velocity of the horizontal carrier gas is reduced adequately so that the particles settle by gravitational force.
    - A sudden change of direction of the gas flow causes the particles to separate due to their more significant momentum.

Settling chambers, buffer chambers and cyclone separators commonly use mechanical devices to separate particulates from gases.

2) **Filtration Systems:** Dust laden gases are forced through a porous medium such as woven or filled fabric. The particles are trapped and collected in the filters, and the gases devoid of the particles are discharged out. Fibrous or deep-bed filters and cloth bag filters are commonly used. Gas fibre filters have superior chemical resistance.

3) **Electrostatic Precipitators**: When a gas or an air stream containing aerosols, e.g., dust, fumes or mist is passed between two electrodes which are electrically insulated from each other and between which appreciable difference in electrical potential exists, then the aerosols particles get precipitated on the electrodes that are at a lower potential.

Electrostatic precipitators are the devices of choice when

- Vast volumes of gases are to be handled
- Valuable dry material is to be recovered
- Very high collecting efficiency for the removal of fine particulates is essential and
- When the gas temperatures are very high.

4) **<u>Wet Scrubbers</u>**: Wet scrubbers are used

- When fine particles have to be efficiently removed
- When particulates, as well as gaseous contaminants, have to be removed
- When the gases to be treated are combustible
- When the volume of the gases being treated is low.

Wet scrubbers are classified according to the method of particle collection as follows:

- Liquid carriage type where the gas stream containing the particles is allowed to strike a liquid surface within the collector. The liquid carrying the trapped gas particles moves to a location outside the collector for ultimate disposal.
- Particle conditioning type where the dust particles in the gas stream are brought into intimate contact with water so that the particles' sufficient size is increased due to the formation of heavier water particulate agglomerates. These can be more easily separated from the gas stream by any of the collection mechanisms.

Many wet scrubbers are in use in air pollution control, including venture scrubber, gravity spray scrubber, wet impinger scrubber, cyclone spray chambers, and wet centrifugal scrubber.

Units of Measurement of Air Pollution:

The concentration of the air pollutants is most often expressed in one of two ways. One of these, parts per million, is based on volume measurements and represents contaminants' volume in 1 million works of air. The importance of pollutant and air is determined at a standard temperate and pressure of 25ºC and 760 torrs (atmospheric pressure at sea level).

The second way of expressing concentration relates to the mass of pollutants to the air volume containing it. The unit is often used as a microgram per cubic meter ($\mu g/m^3$), where one microgram is equal to 10^{-6} grams. In heavily polluted areas, milligrams (10^{-3} grams) per cubic meter are used to avoid large numbers. A milligram is 1000 times larger than a microgram, so a concentration of 10,000 $\mu g/m^3$ becomes 10 mg/m^3.

TEXT

Air pollution: The London Smog and Los Angeles Smog

The London Smog (Industrial Smog-1952)

Smog is a type of air pollution. The word "smog" was made in the early 20th century as a portmanteau of the words smoke and fog to refer to smoky fog. Coinage of the term "smog" is generally attributed to Dr. Henry Antoine Des Voeux in his 1905 paper, "Fog and Smoke" for a meeting of the Public Health Congress.

A fog so thick and polluted, it left thousands dead wreaked havoc on London in 1952. The smoke-like pollution was so toxic it was even reported to have choked cows to death in the fields. It was so thick it brought road, air and rail transport to a virtual standstill. This was certainly an event to remember, but not the first smog of its kind to hit the capital. The smog had become a frequent part of London life, but nothing quite compared to the smoke-laden fog that shrouded the capital from Friday 5 December to Tuesday 9 December 1952. While it heavily affected the population of London, causing a huge death toll and inconveniencing millions of people, the people it affected were also partly to blame for the smog.

During the day on 5th December, the fog was not especially dense and generally possessed a dry, smoky character. When nightfall came, however, the fog thickened. Visibility dropped to a few meters. The following day, the sun was too low in the sky to burn the fog away. That night and on the Sunday and Monday nights, the fog again thickened. In many parts of London, it was impossible at night for pedestrians to find their way, even in familiar districts. In The Isle of Dogs area, the fog there was so thick people could not see their feet.

Formation and cause of Smog 1952

The weather in November and early December 1952 had been very cold, with heavy snowfalls across the region. To keep warm, the people of London were burning large quantities of coal in their homes. Smoke was pouring from the chimneys of their houses and coal was used in the industries released tremendous amount of particulate matter, VOCs, NO_2 and SO_2 into the atmosphere, they can form industrial smog (sometimes called London smog), Under normal conditions, smoke would rise into the atmosphere and disperse, but an anticyclone was hanging over the region. This pushes air downwards, warming it as it descends. This creates an inversion, where air close to the ground is cooler than the air higher above it. So when the warm smoke comes out of the chimney, it is trapped. The inversion of 1952 also trapped particles and gases area, along with pollution that the winds from the east had brought from industrial areas on the continent.

Early on 5th December, in the London area, the sky was clear, winds were light and the air near the ground was moist. Accordingly, conditions were ideal for the formation of radiation fog. The sky was clear, so a net loss of long-wave radiation occurred and the ground cooled. When the moist air came into contact with the ground it cooled to its dew-point temperature and condensation occurred. Beneath the inversion of the anticyclone, the very light wind stirred the saturated air upwards to form a layer of fog 100-200 meters deep. Along with the water droplets of the fog, the atmosphere beneath the inversion contained the smoke from innumerable chimneys in the London area.

During the period of the fog, huge amounts of impurities were released into the atmosphere. On each day during the foggy period, the following pollutants were emitted: 1,000 tones of smoke particles, 2,000 tons of carbon dioxide, 140 tones of hydrochloric acid and 14 tones of fluorine compounds. In addition, and perhaps most dangerously, 370 tons of sulphur dioxide were converted into 800 tons of sulphuric acid.

Los Angeles Smog (Photochemical Smog)

Photochemical smog is a serious environmental concern, and it poses a health problem to people living in many metropolitan regions around the world. In fact, sometimes levels of ozone - a major component of smog - are so high that school children in Los Angeles, California, are kept from going outside for recess because of the potential health risks

Photochemical smog was first identified in Los Angeles in 1944. Although several other kinds of smog occur, photochemical smog (or Los Angeles- smog) is a yellow-brown haze produced by the reaction of sunlight with exhaust from automobiles and power plants that burn coal. Ozone, nitrogen dioxide, and other volatile organic compounds that make up this smog irritate eyes and nasal passages. These are particularly dangerous to people who have heart disease, asthma, or other respiratory illnesses, and to anyone who exercises or does manual labor outdoors when smog is heavy.

Photochemistry of Los Angeles Smog

As its name implies, photochemical smog forms in the presence of light, so this type of smog is seen most frequently during the hot and sunny summer months. Though the components of photochemical smog might be in the air, if sunlight does not reach them or they are not concentrated enough, the smog will not form. The worst cases of smog occur when winds are calm and smog is trapped near the surface by a temperature inversion, a condition in which cooler air near the Earth's surface has warmer air above it. These ideal smog-forming conditions commonly occur near cities that are adjacent to mountains.

Photochemical smog forms through a series of chemical reactions among compounds in the atmosphere. When nitric oxide (NO), a component of the exhaust from cars and power plants, enters the atmosphere, it reacts with oxygen to produce nitrogen dioxide (NO_2). Sunlight can break nitrogen dioxide down. This process initiates other chemical reactions that lead to the formation of low-level ozone. Although ozone (O_3) that is high in the stratosphere filters out harmful UV radiation, ozone's presence at the ground level poses a health risk. Also, Volatile Organic Compounds (VOCs), molecules that enter the atmosphere from substances such as gasoline, cleaning solvents, and trees, play a crucial role in forming photochemical smog.

While, NO_2 is a major component of photochemical smog, and the focus of this Case Study, several other components of smog also deserve mention because of their role in climate change. These gases include Methane, (CH_4); Nitrous Oxide, (N_2O); and Ozone, (O_3).

Methane (CH4); is a potent, although short-lived greenhouse gas. It is largely an agricultural by product. It is naturally produced in swamps and wetlands and a by-product of coal and oil extraction. Car and truck emissions, pollution from factories, and burning vegetation, produce compounds of carbon and nitrogen that, when acted on by sunlight, produce ozone in the troposphere. This component of photochemical smog is an important greenhouse gas. Concentrations of ozone have risen 30% since the pre-industrial era and it is now considered the 3rd most significant greenhouse gas, behind Carbon Dioxide and Methane.

Nitrous Oxide (NO_2) is another significant, but lesser known, greenhouse gas. It is a product of the use of fertilizers, as well as a by-product of the production of nylon and nitric acid. It is far more potent than CO_2.

Chlorofluorocarbons (CFCs) are entirely man-made. They were synthesized for use as refrigerants and cleaning solvents in the 1920s. Their production has been banned since 1978, but they remain in the atmosphere due to their long half-lives.

Impacts of the smog

Smog poses a serious threat to human health. It is particularly dangerous to very young children, the elderly, and anyone with respiratory disease. Some constituents of smog can also damage vegetation and agricultural crops. Smog conditions are worse in large cities, but due to atmospheric circulation, smog also affects rural communities that are downwind. Smog continues to grow worldwide as the human population increases and more countries become industrialized.

•About 4,000 people were known to have died in 1952 as a result of the smog, but it could be many more.

- ❖ Many people suffered from breathing and respiratory disease related problems
- ❖ Press reports claimed the smog had asphyxiated cattle at Smithfield.
- ❖ Travel was disrupted for days
- ❖ Response to the smog

A series of laws were brought in to avoid a repeat of the situation. This included the Clean Air Acts of 1956 and 1968. These acts banned emissions of black smoke and decreed residents of urban areas and operators of factories must convert to smokeless fuels.

People were given time to adapt to the new rules, however, and fogs continued to be smoky for some time after the Act of 1956 was passed. In 1962, for example, 750 Londoners died as a result of a fog, but nothing on the scale of the 1952 Great Smog has ever occurred again. This kind of smog has now become a thing of the past, thanks partly to pollution legislation and also to modern developments, such as the widespread use of central heating.

In brief, the chronological history of air pollution control in the UK is:

- ❖ 1905 Des Voeux coins the word smog

- ❖ 1926 Public Health (Smoke Abatement Act) alkali inspectors able to inspect unregistered works
- ❖ 1956 Clean Air Act introduced as private members bill by Gerald Nabarro MP (banned dark smoke emissions)
- ❖ 1968 Clean Air Act introduced by Robert Maxwell MP (limits for grit dust and fumes, chimney heights etc.
- ❖ 1990 Environmental Protection Act: covers integrated pollution control down to local level
- ❖ 1996 Environment Agency and SEPA take over functions of the National Rivers Authority, HMIPI and the Scottish River Purification Authorities
- ❖ 1997 National Air Quality Strategy published
- ❖ 1998 Local authorities take up duties for review and assessment of local air quality management
- ❖ 2005 Review of National Air Quality Strategy

Case Study 2: Industrial Disaster: Bhopal Gas Episode – A Case Study

Industrialization has a great impact on our lives. Philosophers have been warning us about the danger of industrialization. Some of the major industrial accidents that took place in the past.

We realize the price paid for progress only when a nightmarish incident like Bhopal Gas Tragedy involving loss of numerous lives and many after effects occurs on December 3rd 1984, in the city of Bhopal, a highly toxic cloud of methyl isocyanate (MIC) vapour burst from the union carbide pesticide plant.

Of the 800000 people living in Bhopal at the time, 2000 died immediately and 300000 were injured (Stix, 1999) MIC was a major component for the production of the pesticide Sevin by the Union carbide factory at Bhopal. This incident we now refer to as the as the Bhopal gas tragedy is one of the worst commercial industrial disaster in history. It is described as a low probability-high consequence accident. The tumultuous outcome of the accident was a cumulative effect of the following seven reasons (Bowonder, 1987)

- ❖ Large release of chemical from the plant
- ❖ Release of colorless, odorless MIC, which is highly toxic
- ❖ Heavily populated areas adjacent to the plant

- ❖ Calm weather conditions, bringing the vapor cloud down
- ❖ Leak occurs at night when people are sleeping
- ❖ Failure or late warnings
- ❖ Unqualified and unaware people working at the plant

Approximately 40 tons of Methyl Iso-Cyanate spilled over and caused the world's worst disaster (Verma 1986, 1989). The number of people died in the incident was over 3000 and the number of people injured ranged between 2,00,000 to 6,00,000 (Kumar 1994; Kumar 1995; Sriramachari and Chandra 1997).

The Bhopal plant of Union Carbide India Limited (UCIL) is the second of its own kind in the World and only plant built outside U.S.A. It is one of the leading pesticides units in the country and has a licensed capacity of 5000 tones of Pesticides (UCC, 1984) in the procedure for manufacturing the pesticides Sevin and Temik, methyl-isocyanate (MIC) was used as an intermediate. The chemical reactions involved are as follows (Behl et al., 1978, UCC 1985).

• $2C + O_2 \rightarrow 2\ CO$

• $2CO \rightarrow 2COCl_2$ (Phosgene)

•$COCl_2 + CH_2NH_2 \rightarrow CH_3NHCOCl + HCl$

(Phosgene + methylamine) (Methyl carbamoyl Chloride)

•$CH_3NHCOCl \rightarrow CH_3NCO$ (MIC) +HCl

•MIC+α-napthol + CCl_4 → 1-napthyl methylcarbamate

MIC reacts with water exothermically, generating heat above its boiling point and thu s turns from liquid to vapor. Hence the existence of even a small amount of water can be sufficient to produce enough heat to cause and ruptures and leaks.

MIC was manufactured primarily to make the pesticide Carbaryl (Sevin) as well as smaller quantities of Aldicarb (Temic) and butylphenyl methylcarbamate, all destined for the Indian market (Merkenzie ,1984). Carbaryl was produced by reacting MIC with a slight excess of alpha-Napthol in the presence carbontetrachloride (NEERI, 1990) and was sold as the pesticide Sevin.

Cause of leakage of Methyl Isocyanate from tank 610: On the night of the disaster water inadvently entered the MIC storage tank where over two metric tons of MIC were being stored. The addition of water to the tank caused an exothermic chemical reaction resulting in a rapid rise in pressure of and temperature. The heat generated by the reaction, the presence of higher than normal concentration of chloroform and presence of an iron catalyst resulted into such a fast reaction that the gas formed could not be contained by the safety system. (UCC 1985) As A result, MIC and other reaction products in liquid and vapour form escaped from the plant into the surrounding areas causing devastating effect on the people living in the shanty settlements just over the fence.(UCC 1985, Gupta et al., 1988) .The safety systems which in any case were designed for such a runaway situation were non functioning .The scrubber designed to neutralize any escaping gas by spraying caustic soda was empty and the flare tower meant to burn off any gases from the scrubber was under repair .Hypothesis for the disaster included sabotage, prolonged bulk storage over 40 tones of MIC, non functioning refrigeration systems, the failure of safety measures and malfunctioning of neutralization facilities (Mackenzie 1984,UCC 1985 ,Milne 1988)

Impacts of the disaster on Human Health:

There are many impacts of the tragedy some of them are as follows:

1. Impact on Health

- Most of the information on the medical consequences of Union Carbide disaster in Bhopal has been detained by the Indian Council of Medical Research (ICMR, 1985). The ICMR has established that the toxins from the Union Carbide factory have caused damage to the lungs, brains, kidneys, muscles as well as gastrointestinal, reproductive, immunological and other systems bronchial asthma, Chronic Obstructive Airways disease (Gupta et al., 1988; Rastogi et al., 1988; Saxena et al., 1988; Bhandari et al., 1990; Cullinan et al., 1996 and Culillan et al., 1997).
- Recurrent chest infections and fibrosis of the lungs (ICMR, 1987-1991) are the principal effects of exposure induced lung injury. The prevalence of pulmonary tuberculosis among the exposed population has been found to be 3-4 times than that of national average

- The acute symptoms were burning in the respiratory tract and eyes, breathlessness, stomach pains and vomiting. Those living close to the factory had very severe acute as well as long term symptoms.
- The worst hit were children below 2 years, old people and persons with previous pulmonary diseases, like chronic bronchitis and emphysema (Kulling P, Lorin H.1987).
- The lungs were enlarged and oedematous, showed congestion, haemorrhage and consolidation, with microscopic findings such as bronchiolitis and pulmonary oedema.
- In addition, the consistency of the brain was softened through cerebral oedema.
- The kidneys showed congestion and tubular necrosis.
- In a large number, the liver showed fatty degeneration.
- Women's reproductive health was affected. Immediately after the gas leak, the stillbirth rate increased by up to 300 % and the perinatal and neonatal mortality rate by 200 %.

Health care

- In the immediate aftermath of the disaster, the health care system became overloaded. Within weeks, the State Government established a number of hospitals, clinics and mobile units in the gas-affected area to treat the victims.
- The Government of India had focused primarily on increasing the hospital-based services for gas victims thus hospitals had been built after the disaster.
- It was directed by the Supreme Court to finance a 500-bed hospital for the medical care of the survivors. Thus, Bhopal Memorial Hospital and Research Centre (BMHRC) was inaugurated in 1998 and was obliged to give free care for survivors for eight years. BMHRC was a 350-bedded super speciality hospital where heart surgery and hemodialysis were done however; there was dearth of gynaecology, obstetrics and paediatrics. Eight mini-units (outreach health centres) were started and free health care for gas victims were to be offered till 2006.

Case study 3

Chernobyl Nuclear Power Plant disaster

Chernobyl is situated in the north of the Ukraine (formerly known as the USSR) by the river Dniprodzerzhirisk. Chernobyl is approximately 80 miles (which is 120 kilometers) north of the capital city of the Ukraine, Kiev. The accident at the Chernobyl atomic power station on April 26, 1986, was dangerous and vast, with long-term adverse consequences. It now is viewed as one of the national disasters of the century. The most significant damage resulting from the accident was the radioactive contamination of an enormous amount of territory, where conditions became harmful to life. The amount of radioactive material released was 400 times more than the amount the atomic bombing of Hiroshima released. The fallout would be detected in almost all parts of Europe. Equally damaging have been the losses and discomforts that residents of the contaminated areas have endured. The incident gave rise to the necessity of developing a special legal regime for the damaged territories and creating a new legal institute to defend people in the Chernobyl "ecological disaster area".

Events of the accident

RBMK reactor 4 (RBMK means in Russian: a channel-туре reactor of a large power) at the Chernobyl Nuclear Power Plant was due to temporarily close for routine maintenance on April 25 1986. The personnel decided this would be the perfect opportunity to run a particular test on this reactor. This test was to ensure that during a shutdown, enough electrical power would be available to run the emergency equipment and the water-cooling supply until the diesel power came on. Here is the sequence of events that ended in the disaster.

- April 26-1986, 1:24 am - plant exploded
- 8 tones of fuel were ejected into atmosphere including plutonium, graphite moderator, iodine-131, and cesium- 137
- 12 X 1018 Bq of radioactivity were released
- May 2-3-1986, 45 000 people were evacuated
- May 4-1986, 169 000 people were evacuated
- Later another 219 000 evacuated, to comprise 4300 square kilometers of contaminated area

Causes of the accident:

There was not one cause of this accident, there were several which all contributed to it. This accident happened while testing an RMBK reactor. A chain reaction occurred in the reactor and got out of control, causing explosions and a huge fireball which blew off the heavy concrete and steel lid on the reactor. These are the causes:

1. Design fault in RBMK reactor
2. A violation of procedures
3. Breakdown of communication
4. Lack of a 'Safety Culture' in the power plant

Consequences of the accident

1. Environmental consequences

•The radioactive fallout caused radioactive material to deposit itself over large areas of ground. It has had an effect over most of the northern hemisphere in one way or another. In some local ecosystems within a 6-mile (10km) radius of the power plant the radiation is lethally high especially in small mammals such as mice and coniferous trees. Luckily within 4 years of the accident nature began to restore itself, but genetically these plants may be scarred for life

•Will cost $400 billion and 200 years to totally clean up

2. Health effects

❖ Caused 31 deaths instantly
❖ May have caused 300000 deaths
❖ Upwards of 20 million people exposed to radioactivity
❖ 400 times more radiation was released by the disaster than had been by the atomic bombing of Hiroshima. The radiation would later be detected in almost all parts of Europe. Over one million people could have been adversely affected by the radiation.
❖ The radiation would cause numerous problems, including Down's Syndrome, chromosomal aberrations, mutations, leukemia, thyroid cancer, and birth defects.
❖ There was a huge increase in Thyroid Cancer (Thyroid Cancer is cancer of the thyroid gland, a gland found near the larynx that secretes growth and metabolism hormones) in Ukranian children (from birth to 15 years old).

3. Psychological consequences:

There has been an increase in psychological disorders such as anxiety, depression, helplessness and other disorders which lead to mental stress. These disorders are not a consequence of radiation, but a consequence from the stress of evacuation, the lack of information given after the accident and the stress of knowing that their health and their children's health could be affected.

4. Economic, political and social consequences:

The worst contaminated areas were economically, socially and politically declining as the birth rate had decreased and emigration numbers had substantially risen which had caused a shortage in labour force. These areas could not evolve industrially or agriculturally because of strict rules that were introduced because the area was too contaminated. The few products made were hard to sell or export because people were aware that it had come from the Ukraine and so were scared of being affected, this caused a further economic decline. Socially people have been limited on their activities making everyday life very difficult.

Now in the year 2000, everything is looking a lot better and is starting to rise again and probably in about 10 years time almost everything will be as good as normal in the Ukraine.

Conclusion

- This is a great example of the risks of research with volatile materials
- This is also a great example of the policy of secrecy and its impact.
- An excellent case study of what not to do
- A constant reminder of the failures of the past and a lesson for future

TEXT

Water pollution

Water pollution is any contamination of water bodies with chemicals or other foreign substances detrimental to humans, plants, or animal health. These pollutants include fertilizers and pesticides from agricultural runoff; sewage and food processing waste; lead, mercury and other heavy metals; chemical wastes from industrial discharges and chemical contamination from hazardous waste sites. Human activities very often add these contaminants. Worldwide, nearly 2 billion people drink contaminated water that could be harmful to their health. Water pollution occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove toxic compounds. Water pollution is a major global problem that requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). It has been suggested that it is the leading worldwide cause of deaths and diseases and accounts for more than 14,000 people daily. An estimated 580 people in India die of water pollution related sickness every day. About 90% of China's cities suffer from some degree of water pollution, and nearly 500 million people lack access to safe drinking water. In addition to the acute problems of water pollution in developing countries, developed countries continue to struggle with pollution problems.

Transport and chemical reactions of water pollutants

Rivers eventually carry most water pollutants into the oceans. In some areas of the world, the influence can be traced a hundred miles from the mouth by studies using hydrology transport models. Advanced computer models such as S.W.M.M. or the D.S.S.A.M. Model have been used in many locations worldwide to examine pollutants' fate in aquatic systems. Indicator filter feeding species such as copepods have also been used to study pollutant fates in the New York Bight. The highest toxin loads are not directly at the Hudson River's mouth, but 100 kilometres south, since several days are required for incorporation into planktonic tissue. The Hudson discharge flows south along the coast due to Coriolis force.

Further south then is oxygen depletion, caused by chemicals using up oxygen and by algae blooms, caused by excess nutrients from algal cell death and decomposition.

Fish and shellfish kills have been reported; because toxins climb the food chain after small fish consume copepods, then large fish eat smaller fish. Each successive step up the food chain causes a stepwise concentration of pollutants such as heavy metals (e.g. mercury) and persistent organic pollutants such as D.D.T. This is known as biomagnification, which is occasionally used interchangeably with bioaccumulation. The giant gyres (vortexes) in the oceans trap floating plastic debris. The North Pacific Gyre, for example, has collected the so-called "Great Pacific Garbage Patch" that is now estimated at 100 times the size of Texas. Plastic debris can absorb toxic chemicals from ocean pollution; potentially poisoning anything that eats it. Many of these long-lasting pieces wind up in the stomachs of marine birds and animals. This results in obstruction of digestive pathways that leads to reduced appetite or even starvation. Many chemicals undergo reactive decay or chemically change, especially over long periods in groundwater reservoirs. A particular class of such chemicals is the chlorinated hydrocarbons such as trichloroethylene (used in industrial metal degreasing and electronics manufacturing) and tetrachloroethylene used in the dry cleaning industry. These chemicals, which are carcinogens themselves, undergo partial decomposition reactions leading to new hazardous chemicals (including dichloroethylene and vinyl chloride). Groundwater pollution is much more difficult to abate than surface pollution because groundwater can move great distances through unseen aquifers. Non-porous aquifers such as clays partially purify water of bacteria by simple filtration (adsorption and absorption), dilution, and in some cases, chemical reactions and biological activity; however, in some cases, the pollutants merely transform to soil contaminants. Groundwater that moves through cracks and caverns is not filtered and can be transported as quickly as surface water. This can be aggravated by the human tendency to use natural sinkholes as dumps in Karst topography areas. There are a variety of secondary effects stemming not from the original pollutant but a derivative condition. An example is a silt-bearing surface runoff, which can inhibit sunlight's penetration through the water column, hampering photosynthesis in aquatic plants.

Measurement of water pollution

Water pollution may be analyzed through several broad categories of methods, i.e., physical, chemical and biological. Most involve the collection of samples, followed by specialized analytical tests. Some methods may be conducted *in situ*, without sampling, such as temperature. Government agencies and research organizations have published standardized, validated analytical test methods to facilitate the comparability of results from disparate testing events.

Sampling: Sampling of water for physical or chemical testing can be done by several methods, depending on the accuracy needed and the contaminant's characteristics. Many contamination events are sharply restricted in time, most commonly in association with rain events. For this reason, grab samples are often inadequate for fully quantifying contaminant levels. Scientists gathering this type of data often employ auto-sampler devices that pump increments of water at either time or discharge intervals.

Physical testing: Common physical tests of water include temperature, solids concentrations (e.g., total suspended solids (T.S.S.)) and turbidity.

Chemical testing: Water samples may be examined using the principles of analytical chemistry. Many published test methods are available for both organic and inorganic compounds. Frequently used techniques include pH, biochemical oxygen demand (B.O.D.), chemical oxygen demand (C.O.D.), nutrients (nitrate and phosphorus compounds), metals (including copper, zinc, cadmium, lead and mercury), oil and grease, total petroleum hydrocarbons (T.P.H.) and pesticides.

Biological testing: Biological testing involves using plant, animal, and microbial indicators to monitor the health of an aquatic ecosystem. Depending on the type of assessment, the organisms may be identified for bio surveys (population counts) and returned to the water body, or dissect them for bioassays to determine toxicity.

Control of water pollution

1. **Domestic sewage:** Domestic sewage is typically 99.9 per cent water with 0.1 per cent pollutants. Although found in low concentrations, these pollutants pose a risk on a large scale. In urban areas, centralized sewage treatment plants typically treat domestic sewage. Well-designed and operating systems (i.e., secondary treatment or better) can remove 90 per cent or more of these pollutants. Some plants have different approaches to extract nutrients and pathogens. Most municipal plants are not specifically designed to treat toxic pollutants found in industrial wastewater. Cities with sanitary sewer overflows or

combined sewer overflows employ one or more engineering approaches to reduce discharges of untreated sewage including:

I. Utilizing a green infrastructure approach to improve storm water management capacity throughout the system and reduce the hydraulic overloading of the treatment plant
II. Repair and replacement of leaking and malfunctioning equipment
III. Increasing the overall hydraulic capacity of the sewage collection system.

A household or business not served by a municipal treatment plant may have an individual septic tank, which treats the wastewater on-site and discharges into the soil. Alternatively, domestic wastewater may be sent to a nearby privately owned treatment system (e.g. in a rural community).

2. **Industrial wastewater:** Some industrial facilities generate ordinary domestic sewage that can be treated by municipal facilities. Industries that generate wastewater with high concentrations of conventional pollutants (e.g. oil and grease), toxic pollutants (e.g. heavy metals, volatile organic compounds) or other nonconventional pollutants such as ammonia, need specialized treatment systems. Some of these facilities can install a pre-treatment system to remove the toxic components and then send the partially treated wastewater to the municipal system. Industries generating large volumes of wastewater typically operate their own complete on-site treatment systems. Some initiatives have been thriving at redesigning their manufacturing processes to reduce or eliminate pollutants through pollution prevention. Heated water generated by power plants or manufacturing plants may be controlled with:

I. cooling ponds, human-made bodies of water designed for cooling by evaporation, convection and radiation
II. cooling towers, which transfer waste heat to the atmosphere through evaporation and heat transfer cogeneration, a process where waste heat is recycled for domestic and industrial heating purposes.

3. **Agriculture wastewater**

- **Nonpoint source wastewater treatment:** Sediment washed off fields is the largest agricultural pollution source in the United States. Farmers may utilize erosion controls to reduce runoff flows and retain soil on their fields. Standard techniques include contour ploughing, crop mulching, crop rotation, planting perennial crops and installing riparian buffers. Nutrients (nitrogen and phosphorus) are typically applied to farmland as commercial fertilizer; animal manure; or spraying of municipal or industrial wastewater (effluent) or sludge. Nutrients may also enter runoff from crop residues, irrigation water, wildlife and atmospheric deposition. Farmers can develop and implement nutrient management plans to reduce the excess application of nutrients and reduce the potential for nutrient pollution. To minimize pesticide impacts, farmers may use Integrated Pest Management (I.P.M.) techniques (which can include biological pest control) to maintain control over pests, reduce reliance on chemical pesticides and protect water quality.

- **Point source wastewater treatment:** Farms with large livestock and poultry operations, such as factory farms, are called concentrated animal feeding operations or feedlots in U.S. Animal slurries are usually treated by containment in anaerobic lagoons before disposal by spray or trickle application to grassland. Constructed wetlands are sometimes used to facilitate treatment of animal wastes. Some animal slurries are treated by mixing with straw and composted at high temperature to produce bacteriologically sterile and friable manure for soil improvement.

4. **Construction site storm water:** Sediment from construction sites is managed by installing erosion controls such as mulching and hydro seeding and sediment controls such as sediment basins and silt fences. Using spill prevention prevents discharge of toxic chemicals such as motor fuels and concrete washout and control plans and specially designed containers (e.g. for concrete washout) and structures such as overflow controls and diversion berms.
5. **Urban runoff (storm water):** Effective control of urban runoff involves reducing the velocity and flow of storm water and reducing pollutant discharges. Local governments use a variety of storm water management techniques to minimize the effects of urban runoff. These techniques called best management practices (B.M.P.s) in U.S. may focus on water quantity control, while others focus on improving water quality, and some perform both functions. Pollution prevention practices include low impact development techniques, installation of green roofs and improved chemical handling (e.g. management of motor fuels & oil, fertilizers and pesticides). Runoff mitigation systems include infiltration

basins, bio retention systems, constructed wetlands, retention basins and similar devices. Thermal pollution from runoff can be controlled by storm water management facilities that absorb the runoff or direct it into groundwater, such as bio retention systems and infiltration basins. Retention basins tend to be less effective at reducing the temperature, as may heat the sun's water before being discharged to a receiving stream.

What can we do to minimize water pollution?

- Fertilize garden and yard plants with manure or compost instead of commercial inorganic fertilizer.
- Minimize your use of pesticides.
- Do not apply fertilizer or pesticides near a body of water.
- Grow or buy organic foods.
- Do not drink bottled water unless tests show that your tap water is contaminated. Merely refill and reuse plastic bottles with tap water.
- Compost your food wastes.
- Do not use water fresheners in toilets.
- Do not flush unwanted medicines down the toilet.
- Do not pour pesticides, paints, solvents, oil, antifreeze, or other products containing harmful chemicals down the drain or onto the ground.

Governments, local councils and laws

Many governments have stringent laws that help minimize water pollution. These laws are usually directed to industries, hospitals, schools and market areas to dispose of, treat and manage sewage. In many developed cities, waste or sewage treatment is very efficient and designed to minimize water bodies' pollution. There are also lots of organizations and groups that help educate people about the dangers of water pollution. It is always great to join these groups because they regularly encourage other community members to have a better attitude towards water.

Several forms of legislation have been passed in recent decades to try to control water pollution. The Clean Water Act (C.W.A.) is the primary federal law in the United States governing water pollution. Passed in 1972, the act established the goals of eliminating releases of high amounts of toxic substances into water, eliminating additional water pollution by 1985 and ensuring that surface waters would meet standards necessary for human sports and recreation by 1983. In effect, the principal body of law is based on the Federal Water Pollution Control Amendments of 1972 that was a significant expansion of the Federal Water Pollution Control Act of 1948. Consequential amendments were enacted in the Clean Water Act of 1977 and the Water Quality Act of 1987. The Clean Water Act does not directly address groundwater contamination. Groundwater protection provisions are included in the Safe Drinking Water Act, Resource Conservation and Recovery Act, and the Superfund act.

WATER POLLUTION - CASE STUDIES

The Love Canal Tragedy: This occurred in the Suburb of Niagara falls, New York. Love canal was built by William Love that was later dug up and was used to dump sealed steel drums of chemical wastes by Hooker Chemicals and Plastic Co. between 1942-53. In 1953, the dumpsite was covered with clay and topsoil by the company and sold to the City Board of Education, which built an elementary school on this site. Houses were also built near to the school. In 1976, the residents started complaining of foul smell. Children playing in the canal area received chemical burns. In 1977, the corroded steel containers started leaking the chemicals into storm sewers, the basement of homes and the school playground. About 26 toxic organic compounds were identified. The dumpsite was covered with clay, and the leaking wastes were pumped to the new treatment plant. The affected families were relocated.

Arsenic pollution in groundwater: the toxic heavy metal arsenic severely contaminates West Bengal & Bangladesh. The first report of arsenic pollution in West Bengal came in 1975 and that in Bangladesh in 1993. Familiar people were found to be ingesting low doses of arsenic for 10-14 years after which white or black spots called melanosis started mottling the skin. Later on, these spots converted into leprosy like skin lesions, eventually rotting into gangrenous ulcers. Long exposures often lead to bladder and lung cancer. In West Bengal, 40 million out of 90 million people have exposure to arsenic threat due to contaminated water. The 24 Parganas, Hooghly and Murshidabad districts and Behala and S. Eastern fringes of Kolkata lie in Arsenic Risk Zone. Excessive use of lead arsenate and Cu arsenite as pesticides in great yielding varieties of summer paddy and jute crops are the significant causes of arsenic pollution. Arsenic contaminated tube wells in the state are being painted red while safe water tube wells are painted green for use.

CONCLUSION

To combat water pollution, we must understand the problems and become part of the solution. The issues associated with water pollution can disrupt life on our planet to a great extent. Congress has passed laws to combat water pollution, thus acknowledging that water pollution is, indeed, a severe issue. But the government alone cannot solve the entire problem. It is ultimately up to us, to be informed, responsible and involved when it comes to the issues we face with our water. We must become familiar with our local water resources and learn about disposing of harmful household wastes to not end up in sewage treatment plants that can't handle them or landfills not designed to receive hazardous materials. In our yards, we must determine whether additional nutrients are needed before fertilizers are applied and look for alternatives where fertilizers might runoff into surface waters. We have to preserve existing trees and plant new trees and shrubs to help prevent soil erosion and promote infiltration of water into the soil.

TEXT

Introduction

Soil can be defined as the solid material on the earth's surface that results from the interaction of weathering and biological activity on the parent material or underlying hard rock. The soils study as naturally occurring phenomena is called pedology (from the Greek word pedon, meaning soil or earth). Soil is one of the essential and valuable resources of nature. Life and living on the planet would be impossible without healthy soil. 95% of human food is derived from the earth. Making a plan for having healthy and productive soil is essential to human survival. Soil is the thin layer of organic and inorganic materials that covers the earth's rocky surface. The organic portion derived from plants and animals' decayed remains are concentrated in the dark uppermost topsoil. The inorganic amount made up of rock fragments was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food.

The soil is composed of two parts.

1- Soil Living Part,

2- Soil Dead Part

The dead part of the soil includes weathered rocks and minerals obtained from the decay of plants and animals, called organic matter or humus, and water and air are categorized in this part. But the live soil is the soil which enjoys small animals like insects and worms and plants, fungi, bacteria and other microbes are grown in the live soil. The soil is composed of 50% of organic and inorganic matters, and 50% of air and water fills existing vacant spaces of the soil and keeps live organisms of the soil. The entrance of materials, biological organisms or energy into the soil will cause changes in soil quality. This problem causes the earth to remove from its natural state. A soil pollutant is any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the ground. Pollution in soil harms plant growth. Soil pollution is the introduction of substances, biological organisms, or energy into the ground, resulting in a change of the soil quality, which is likely to affect the regular use of the ground or endangering public health and the living environment. Hence, the addition of substances which adversely affect the quality of soil or its fertility is known as soil pollution, or soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease-causing agents, which have adverse effects on plant growth and animal health**.** Generally, polluted water also pollutes the soil. Solid waste is a mixture of plastics, cloth, glass, metal and organic matter, sewage, sewage sludge, building debris, generated from households, commercial and industries establishments, and soil pollution. Fly ash, iron and steel slag, medical and industrial wastes disposed on land are essential to soil pollution sources. Besides, fertilizers and pesticides from agricultural use which reach soil as runoff and landfilling by municipal waste are growing cause of soil pollution. Acid rain and dry deposition of pollutants on the land surface also contribute to soil pollution.

Causes of Soil Pollution

Soil pollution is caused due to the following reasons.

a. Deforestation and soil erosion: Soil erosion can be defined as surface litter movement and topsoil from one place to another. It is often caused by wind and flowing water, accelerated by human activities such as farming, construction, overgrazing by livestock, burning grass cover, and deforestation. Deforestation, agricultural development, temperature extremes, precipitation, acid rain, and human activities contribute to this erosion. Humans speed up this process by construction, mining, cutting of timber, over cropping and overgrazing. It results in floods and causes soil erosion. Forests and grasslands are excellent binding material that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide innumerable feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. Figure 1 and figure 2 depicted soil erosion and deforestation.

Fig.1. soil erosion leading to the loss of topsoil

(Source: en.wikipedia.org)

Fig.2. Deforestation causing barren land prone to erosion

(Source: sciencehealthen.com)

b. Industrial activity: Industrial activity has been the most significant contributor to soil pollution in the last century, significantly since the amount of mining and manufacturing has increased. Most industries are dependent on extracting minerals from the earth. Whether it is iron ore or coal, the by-products are contaminated, and they are not disposed of in a manner that can be considered safe. As a result, the industrial waste lingers in the soil surface for a long time and makes it unsuitable for use.

c. dumping of waste materials: Soil contaminants like industrial wastes, hospital wastes, nuclear wastes etc. are left onto the surface through many different activities. Most of these are the result of accidents involving the vehicles that are transporting waste material from the site at which it originated to the location at which it is to be deposited as shown in the fig. 3 and accidents involving vehicles (automobiles, trucks and aeroplanes) not transporting wastes, but carrying materials, including fuel, that when spilt contaminate the soil. Others involve nuclear accidents and human negligence.

Fig.3. Soil pollution due to the dumping of wastes
(Source: www.iaslic1955.org)

d. Municipal wastes: It includes garbage, compost, sludge from treatment plants and sewage from sanitary fills as depicted in fig.4. Pollutant might be washed away by precipitation, causing little or no harm to the ground on which it is found, however, pollutants will simply accumulate somewhere else. In the long run, these can get deposited to the soils of the surrounding area and pollute them by altering their chemical and biological properties. They also contaminate drinking water aquifer sources, causing a vast number of diseases.

Fig.4. Sewage leading to soil pollution

(Source: j-zon-divinecollege4thyrj-zon.blogspot.com)

e. Excess use of fertilizers: Soil nutrients are essential for plant growth and development. Agricultural practices, including agriculture chemicals, are primary sources of pollution on or near the ground surface. Most agricultural chemicals are water-soluble, nitrates, and phosphates applied to fields, lawn, and gardens to stimulate crops' growth, gross and flowers. Farmers generally use fertilizers to correct soil deficiency. Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate (NH_4NO_3), phosphorus as P_2O_5, and potassium as K_2O. For instance, Pb and Cd present in traces in rock phosphate mineral get transferred to superphosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers becomes an indestructible poison for crops.

f. Indiscriminate use of pesticides, insecticides and herbicides: Since plants on which we depend for food are attacked by insects, fungi, bacteria, viruses, rodents and other animals, and weeds which compete with plants for nutrients. To kill unwanted populations living in or on their crops, farmers use pesticides on a large scale as depicted in fig.5. The essential pesticides are D.D.T., BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furodan, etc. The remnants of such pesticides used on pests may get adsorbed by the soil particles, contaminating root crops grown in that soil. The consumption of such crops causes the pesticides remnants to enter human biological systems, affecting them adversely. Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil.

Fig.5. Barrels of pesticides used for agriculture

(Source: www.allvoices.com)

g. Improper irrigation practices: Reduced or excessive use of irrigation water or poorly drained soil, flood water results in accumulation of dissolved salts on the soil surface leading to high soil salinity or salination which refers to increase in the concentration of soluble salts. In dry areas water evaporate quickly leaving behind a white crust of salts in soil on the surface. The higher concentration of salts severely affects the plants' water absorption process, resulting in inadequate production. Also, irregular irrigation leads to a decrease in the moisture content of land for soil medium and replenishment of solvents for nutrients and minerals.

h. Acid rain: Acid rain is caused when pollutants present in the air mix up with the rain and then fall back on the ground, as shown in Figure 6. The polluted water with dangerous acids like sulphuric acids and nitric acids could dissolve some of the essential nutrients and minerals found in the soil and change its structure and chemistry.

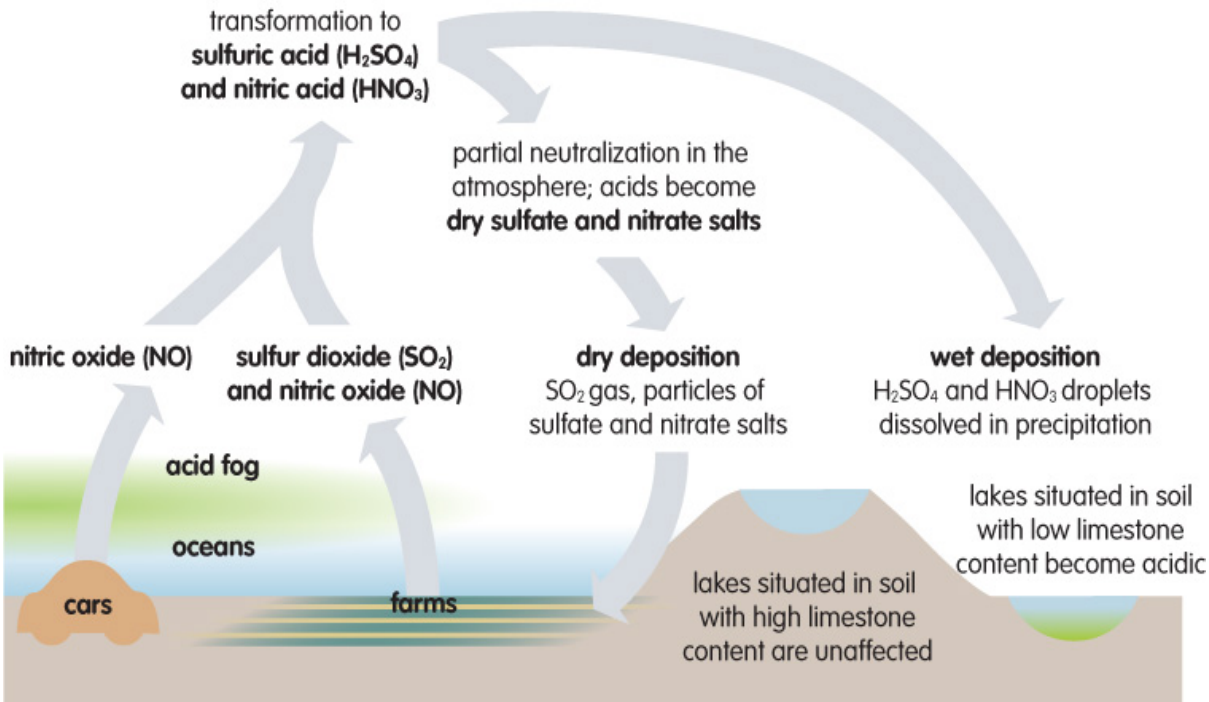

Fig.6. Process of acid rain causing soil pollution

(Source: sparkcharts.sparknotes.com)

i. Accidental oil spills: Oil leaks can happen during storage and transport of chemicals. This can be seen at most of the fuel stations. The chemicals present in the fuel deteriorate the quality of soil and make them unsuitable for cultivation. These chemicals can enter into the groundwater through the soil and make the water undrinkable.

Sources of Soil Pollution

Several materials adversely affect the soil's physical, chemical, and biological properties and thus reduce its productivity. These are

Plastic bags – Plastic bags made from low-density polyethene (LDPE), are virtually indestructible, create a colossal environmental hazard. The discarded bags block drains and sewage systems. Leftover food, vegetable waste etc. on which cows and dogs feed may die due to plastic bags choking. Plastic is non-biodegradable and burning of plastic in garbage dumps release highly toxic and poisonous gases like carbon monoxide, carbon dioxide, phosgene, dioxin and other poisonous chlorinated compounds.

Industrial sources – It includes fly ash, chemical residues, metallic and nuclear wastes. Many industrial chemicals, dyes, acids, etc. which find their way into the soil and are known to create many health hazards, including cancer and kidney diseases.

Agricultural sources – Agricultural chemicals, especially fertilizers and pesticides, pollute the soil. Fertilizers in the runoff water from these fields can cause eutrophication in water bodies. Pesticides are highly toxic chemicals that affect humans and other animals, causing respiratory problems, cancer and death.

Urbanization - Urban activities generate large quantities of city wastes including several Biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, carcasses, plant twigs, leaves, cloth wastes as well as sweepings) and many non-biodegradable materials (such as plastic bags, plastic bottles, plastic scraps, glass bottles, glass pieces, stone/cement pieces). On a rough estimate, Indian cities produce solid city wastes to the tune of 50,000 - 80,000 metric tons every day.

Types of Soil Pollution

It is of the following types-

(i) **Positive soil pollution:** Reduction in the productivity of soil due to the addition of undesirable substances like pesticides, herbicides, fertilizers, etc. is called positive decay. These pollutants have a cumulative effect and kill the soil organisms.

(ii) **Adverse soil pollution:** Reduction in the soil fertility and productivity caused by the removal of useful components and minerals from soil by erosion, deforestation and improper methods of agriculture like excessive tillage is called adverse pollution.

Effects of Soil Pollution

1. **Effect on humans' health:** Contamination of the soil has significant consequences on our health. Crops and plants are grown on polluted soil absorb much of the pollution and pass them on to us. This could result in the sudden surge in small and terminal illnesses. Long-term exposure to such soil can affect the body's genetic makeup, causing congenital diseases and chronic health problems that cannot be cured easily. It can sicken the livestock to a considerable extent and cause food poisoning over a long period. The soil pollution can even lead to widespread famines if the plants are unable to grow in it.

2. Effect on plants' growth: The ecological balance of any system gets affected due to the widespread contamination of the soil. Most plants cannot adapt when the chemistry of the soil changes so radically in a short period. Fungi and bacteria found in the ground that binds it together begin to decline, which creates an additional soil erosion problem. The fertility slowly diminishes, making land unsuitable for agriculture and any local vegetation to survive.

3. Decreased soil fertility: The toxic chemicals present in the soil can decrease soil fertility and decrease soil yield. The contaminated soil is then used to produce fruits and vegetables, which lacks quality nutrients and may contain some poisonous substance to cause serious health problems in people consuming them.

4. Toxic dust: The emission of toxic and foul gases from landfills pollutes the environment and causes severe effects on some people's health. The unpleasant smell causes inconvenience to other people.

5. Changes in soil structure: The death of many soil organisms (e.g. earthworms) in the soil can alter the soil structure. Apart from that, it could also force other predators to move to other places in search of food.

6. Food shortage: soil pollution leads to reduced food production leading to food shortage due to the loss of fertility and essential nutrients. With population growth, it becomes more critical.

7. Desertification: Continuous exposure of eroded soil to the sun for more extended periods may transform the land into sandy and rocky in nature. These are symptoms of desertification rendering the soil unsuitable for cultivation and hence decrease agricultural land.

8. Water pollution: Topsoil, which is washed away, also contributes to water pollution by clogging of lakes streams and increasing turbidity of the water, ultimately leading to loss of aquatic life.

9. Waterlogging: Excess use of irrigation leads to waterlogging and waterlogging due to surface flooding or a high water table. Excessive irrigation practices may cause waterlogging due to rise in the water table of the area. The productivity of waterlogged soil is severely affected due to the lesser availability of plants.

10. Salination: Salination refers to an increase in the concentration of soluble salts in the soil: poor irrigation practices and excessive irrigation results in accumulation of dissolved salts on the soil surface. The higher concentration of salts severely affects the plants' water absorption process, resulting in inadequate production.

10. Eutrophication: Eutrophication of waterways occurs due to the runoff of fertilizers of phosphates and nitrates and domestic sewage from soil to water bodies which disrupt the whole aquatic life.

Control measures of soil pollution

The following measures should be employed to control soil pollution.

1. Reducing the use of chemical fertilizers and pesticides: Applying bio-fertilizers and manures can reduce chemical fertilizer and pesticide use. Biological methods of pest control can also reduce the use of pesticides and thereby minimize soil pollution.

2. Reusing of materials: Materials such as glass containers, plastic bags, paper, cloth etc. can be reused at domestic levels rather than being disposed of, reducing solid waste pollution.

3. Recycling and recovery of materials: This is a reasonable solution for reducing soil pollution. Materials such as paper, some kinds of plastics and glass can and are being recycled. This decreases the volume of refuse and helps in the conservation of natural resources. For example, recovery of one tonne of paper can save 17 trees.

4. Reforestation: Control of land loss and soil erosion can be attempted through restoring the forest, shelterbelts/windbreakers and grass cover to check wastelands, soil erosion and floods. Crop rotation or mixed cropping can improve the fertility of the land.

5. Solid waste treatment: Proper methods should be adopted for the management of solid waste disposal. Industrial wastes can be treated physically, chemically and biologically until they are less hazardous. Acidic and alkaline wastes should be first neutralized; the insoluble material if biodegradable should be allowed to degrade under controlled conditions before being disposed of.

6. Treatment of industrial wastes: The industrial wastes before disposal should be treated adequately for removing hazardous materials. New areas for hazardous waste storage should be investigated, such as deep well injection and more secure landfills. Burying the waste in locations situated away from residential areas is the most straightforward and most widely used reliable waste management technique. Environmental and aesthetic considerations must be taken into consideration before selecting the dumping sites. Biomedical waste should be separately collected and incinerated in proper incinerators. But incineration of other wastes is expensive and leaves a considerable residue and adds to air pollution. Pyrolysis is a combustion process in the absence of oxygen or the material burnt under controlled atmosphere of oxygen. It is an alternative to incineration. The gas and liquid thus obtained can be used as fuels. Pyrolysis of carbonaceous wastes like firewood, coconut, palm waste, corn combs, cashew shell, rice husk paddy straw and sawdust, yields charcoal and tar products methyl alcohol, Acetic Acid, acetone and fuel gas.

7. Generation of biogas: Biodegradable organic wastes, cattle dung and night soils should be used in the biogas plants to generate inflammable methane gas.

8. Maintaining soil fertility: To maintain the soil fertility it is essential to keep the soil food web, where all the soil organisms viz, bacteria, fungi, actinomycetes, protozoa, earthworms etc., and they flourish in population in the presence of sufficient amount of soil organic matter. For that purpose, following farming practices are recommended.

- Increased use of organic manures, green manures
- Enriched vermicompost and bio composts
- Use of biofertilizers
- Crop rotation with high and low biomass crops
- Avoiding the use of chemical fertilizers

9. Stringent laws: Various environmental regulations formulated from time to time-related to pollution, management of solid wastes and hazardous wastes, industrial setup and permissible limits of various chemicals in the environment should be followed strictly and kept under check.

10. Mass awareness: Mass awareness is most important as if every individual contributes substantially the effect will be visible not only at the community, city, state or national level but also at the global level as the environment has no boundaries.

Methods of Soil treatment

Some of the techniques for cleaning polluted soils are as under:-

1. Bioremediation: It can be defined as any process that uses microorganisms, fungi, green plants, or enzymes to return the natural environment altered by contaminants to its original condition. Bioremediation may be employed to attack specific soil contaminants, such as degradation of chlorinated hydrocarbons by bacteria. Generally requires a mechanism for stimulating and maintaining the activity of the microorganisms, e.g., the addition of an electron acceptor (oxygen, nitrate); nutrients (nitrogen, phosphorus); and an energy source (carbon). An example of a more general approach is the cleanup of oil spills by adding nitrate and sulfate fertilizers to facilitate the decomposition of crude oil by indigenous or exogenous bacteria.

Naturally occurring, bioremediation and phytoremediation have been used for centuries. For example, desalination of agricultural land by phytoextraction has a long tradition. Bioremediation technologies can be generally classified as in situ or ex-situ. In situ, bioremediation involves treating the contaminated material at the site. Ex-situ consists of the removal of the contaminated material to be treated elsewhere. Conditions that favour Bioremediation includes the following:

• Temperature favourable for organisms
• Availability of water
• Availability of nutrients (N, P, K)
• C: N ratio of the contaminant material
• Availability of oxygen in sufficient quantity in the soil

Some examples of bioremediation technologies are bioventing (injection of air/nutrients into the unsaturated zone), land farming, bioreactor, composting, bioaugmentation (inoculation of soil with microbes), rhizofiltration, and biostimulation (stimulation of biological activity) and sparging (injection of air/nutrients into the unsaturated and saturated zone).

2. Phytoremediation: Since all contaminants are not easily treated by bioremediation using microorganisms. For example, heavy metals such as cadmium and lead are not readily absorbed or captured by organisms. The assimilation of metals such as mercury into the food chain may worsen matters. Phytoremediation is useful in these circumstances because natural plants or transgenic plants can bioaccumulate these toxins in their above-ground parts, which are then harvested for removal. The heavy metals in the harvested biomass may be further concentrated by incineration or even recycled for industrial use.

3. Air sparging: It is an in situ remedial technology that reduces volatile constituents' concentrations in petroleum products that are adsorbed to soils and dissolved in groundwater. This technology, also known as "in situ air stripping" and "in situ volatilization," involves injecting contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved state to a vapour phase as depicted in fig.7. The atmosphere is then vented through the unsaturated zone. Air sparging is most often used together with soil vapour extraction (S.V.E.), but it can also be used with other remedial technologies.

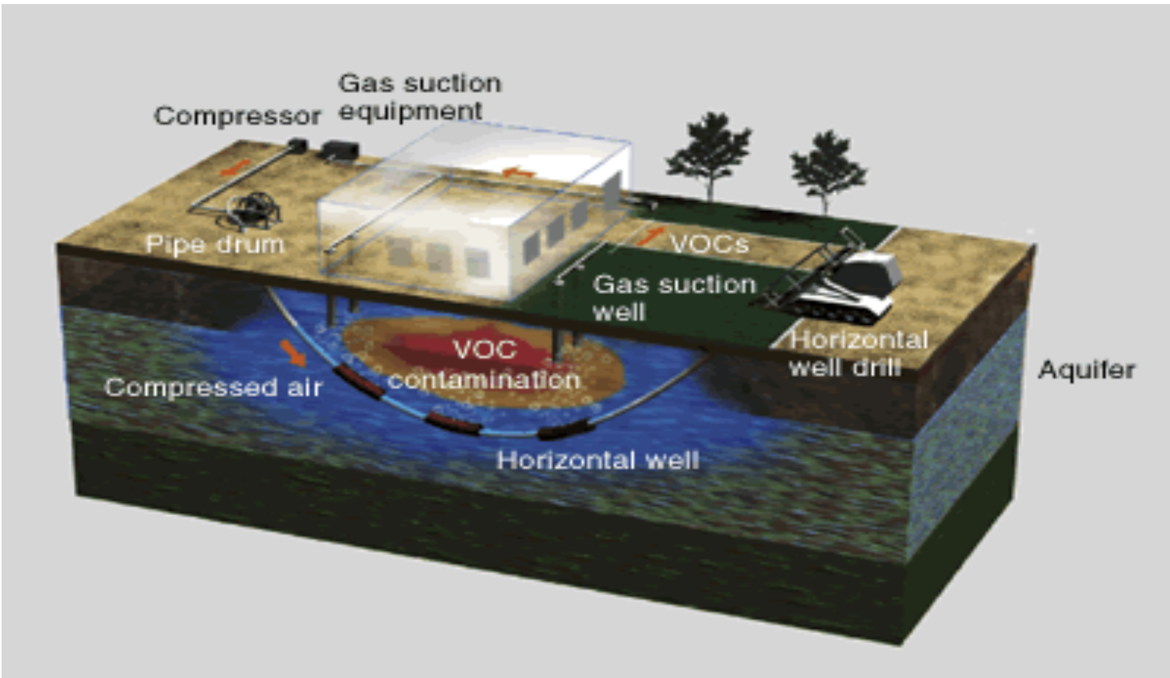

Fig.7. Process of air sparging/ air stripping

(Source: employees.oneonta.edu)

4: Soil washing: Soil washing is a water-based process for scrubbing soils ex-situ to remove contaminants. This process as shown in fig.8 removes impurities from grounds either by dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for some time); or by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to those techniques used in sand and gravel operations). The concept of reducing soil contamination through particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The mud and clay, in turn, are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (small) clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller soil volume that can be further treated or disposed of. Gravity separation is useful for removing high or low specific gravity particles such as heavy metal-containing compounds (lead, radium oxide, etc.). Attrition scrubbing removes adherent contaminant films from coarser particles. However, attrition washing can increase the fines in soils processed. The clean, larger fraction can be returned to the site for continued use. Soil washing is generally considered a media transfer technology. The contaminated water generated from soil washing is treated with the technology(s) suitable for the contaminants. The duration of soil washing is typically short- to medium- term.

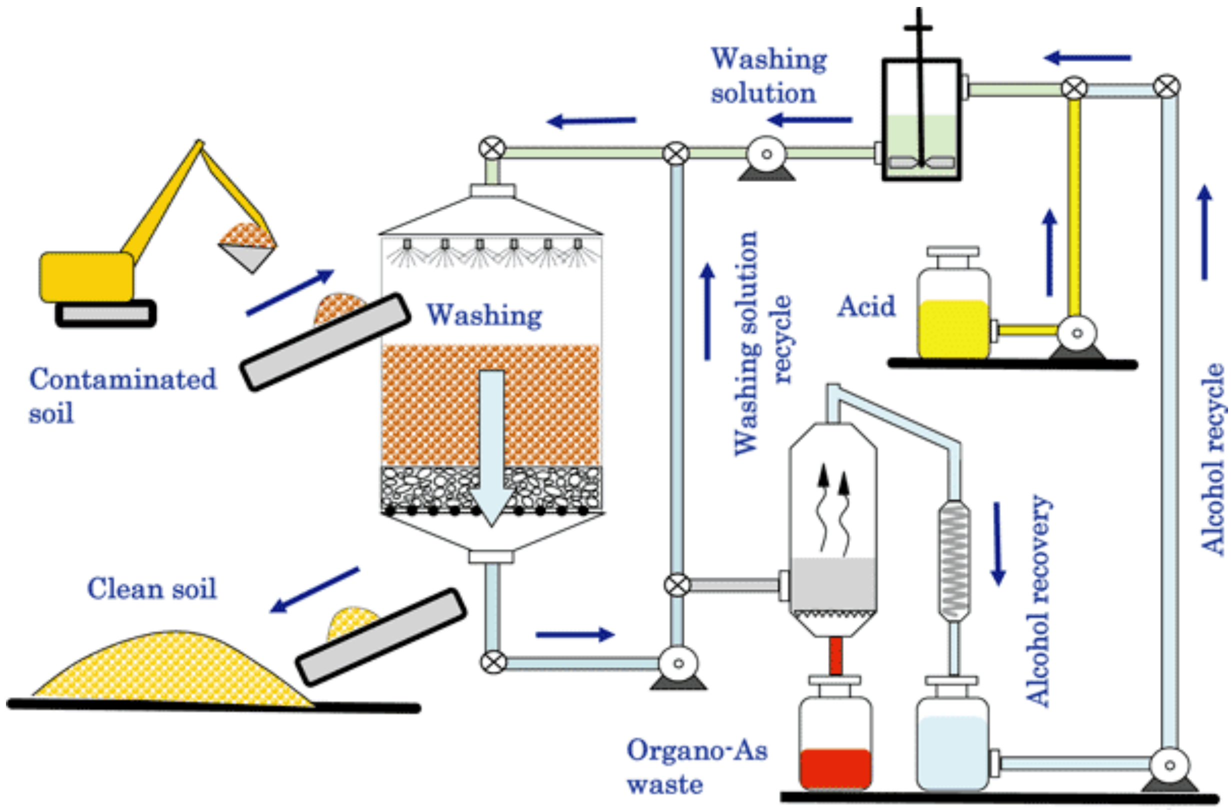

Fig.8. Process of soil washing

(Source: www.aist.go.jp)

5. Biopiles: Biopile treatment is a technology in which excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration. It is used to reduce concentrations of petroleum constituents in excavated soils through the use of biodegradation. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation. The treatment area will generally be covered or contained with an impermeable liner to minimize contaminants' risk leaching into uncontaminated soil. The drainage itself may be treated in a bioreactor before recycling. Vendors have developed proprietary nutrient and additive formulations and methods for incorporating the formulation into the soil to stimulate biodegradation. The formulations are usually modified for site-specific conditions. The soil piles can be 2-3 meters high. Soil piles may be covered with plastic to control runoff, evaporation, and volatilization and promote solar heating. If V.O.C.s in the soil will volatilize into the air stream, the air leaving can be treated to remove or destroy the V.O.C.s before they are discharged to the atmosphere. It is a short-term technology. Duration of operation and maintenance may last a few weeks to several months.