

## WATER CHEMISTRY

Water is the most abundant molecule on the Earth's surface and one of the most important molecules to study in chemistry. Each molecule of water, H<sub>2</sub>O or HOH, consists of two atoms of hydrogen bonded to one atom of oxygen. The basic chemistry of water includes the followings:

- ✓ molecular formula of water: H<sub>2</sub>O
- ✓ molar mass of water: 18.01528(33) g/mol
- ✓ density 1000 kg/m<sup>3</sup>, liquid; (4 °C) or 917 kg/m<sup>3</sup>, solid. This is why ice floats on water.
- ✓ melting point: 0 °C, 32 °F (273.15 K)
- ✓ boiling point: 100 °C, 212 °F (373.15 K)
- ✓ acidity (pKa): 15.74
- ✓ refractive index: (n<sub>D</sub>) 1.3330
- ✓ viscosity: 0.001 Pa s at 20 °C
- ✓ crystal structure: hexagonal
- ✓ molecular shape: bent
- ✓ Pure liquid water at room temperature is odourless, tasteless and nearly colourless. Water has a faint blue colour, which becomes more apparent in large volumes of water.
- ✓ Water has the second highest specific enthalpy of fusion of all substance (after ammonia). The specific enthalpy of fusion of water is 333.55 kJ·kg<sup>-1</sup> at 0 °C.
- ✓ Water has the second highest specific heat capacity of all known substances. (Ammonia has the highest specific heat.) Water also has a high heat of vaporization (40.65 kJ·mol<sup>-1</sup>). The high specific heat and heat of vaporization result from the high degree of hydrogen bonding between water molecules. One consequence of this is that water is not

subject to rapid temperature fluctuations. On Earth, this helps to prevent dramatic climate changes.

Water plays an important role as a chemical substance. Its many important functions include being a good solvent for dissolving many solids, serving as an excellent coolant both mechanically and biologically, and acting as a reactant in many chemical reactions. Blood, sweat and tears; are all solutions of water.

### **HARD & SOFT WATER**

Hard water is any water containing an appreciable quantity of dissolved minerals. Soft water is treated water in which the only cation is sodium. The minerals in water give it a characteristic taste. Some natural mineral waters are highly sought for their flavor and the health benefits they may confer. Soft water, on the other hand, may taste salty and may not be suitable for drinking. The reason for the use of water softener in extremely hard water is that hard water may shorten the life of plumbing and lessen the effectiveness of certain cleaning agents. When hard water is heated, the carbonates precipitate out of solution, forming scale in pipes and tea kettles. In addition to narrowing and potentially clogging the pipes, scale prevents efficient heat transfer, so a water heater with scale will have to use a lot of energy to give hot water. Soap is less effective in hard water because it reacts to form the calcium or magnesium salt of the organic acid of the soap. These salts are insoluble and form grayish soap scum, but no cleansing lather. Detergents, on the other hand, lather in both hard and soft water. Calcium and magnesium salts of the detergent's organic acids form, but these salts are soluble in water.

Hard water can be softened (have its minerals removed) by treating it with lime or by passing it over an ion exchange resin. The ion exchange resins are complex sodium salts. Water flows over the resin surface, dissolving the sodium. The calcium, magnesium, and other cations precipitate onto the resin surface. Sodium goes into the water, but the other cations stay with the resin. Most of the ions have been removed in soft water, but sodium and various anions (negatively charged ions) still remain. Water can be deionized by using a resin that replaces cations with hydrogen and anions with hydroxide. With this type of resin, the cations stick to the resin and the hydrogen and hydroxide that are released combine to form pure water.

## **WATER POLLUTION**

Water is an essential raw material for human survival because of its usefulness in domestic and industrial activities. It is also one of the most abundant resources on earth. About 78% of the earth crust is water which could create an impression that water is readily available for human uses. However, there is a global increasing scarcity of water because of the pollution of water due to various anthropogenic activities. **Water pollution** is the contamination of water bodies such as lakes, rivers, oceans, and groundwater caused by human activities, which can be harmful to organisms and plants which live in these water bodies. Although natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water, water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use (like serving as drinking water) or undergoes a marked shift in its ability to support its constituent biotic communities.

Water pollution is a serious environmental problem which arises as a result of the unprecedented population growth, urbanization, and industrialization. As the urbanization process continues, water pollution problems have become increasingly evident, and have led to serious ecological and environmental problems. Industrial production without adequate regard for environmental impacts has increased water and air pollution, and has led to soil degradation and large-scale global impacts such as acid rain, global warming, and ozone depletion.

As a result of the water pollution, serious conflicts have arisen; industry competes with agriculture to obtain water, agriculture competes for water with the environment, and upstream areas compete for water with downstream areas. In most cities with water scarcity urban and industrial wastes are generally disposed of without adequate treatment; urban discharge of domestic sewage and industrial wastewater discharge are increasing, exacerbating foreseeable water shortages. Only if we act to improve water use and water management will we meet the acute freshwater challenges facing us over the coming years.

### **Sources of water pollution**

Sources of water pollution are activities, facilities, and conditions that contribute pollutants resulting in impairment of water quality. Understanding source of water pollution is essential to water sanitation. Two broad categories of sources of water pollution are *Point source* and *nonpoint source*.

#### **A. “Point source” pollution**

*Point source* occurs when harmful substances are emitted directly into a body of water. An example of a point source of water pollution is a pipe from an industrial facility discharging effluent directly into a river. *Point sources* are identifiable sources of pollutant dispersion among which are:

- Minor and major industrial point sources like effluents and waste from various manufacturing companies discharge at a specific point into the environment.
- Minor and major domestic and municipal point sources which include domestic waste disposal, landfill and solid waste dumpsite, septic tank leakage, and inappropriate disposal of sewage which all have effect on the aquifer.
- Others are leakages from active and abandoned mines, petroleum exploration and refining activities, petroleum product transportation and dispensing activities nationwide, hospital waste, etc.

*Point-source pollution is usually monitored and regulated, at least in Western countries, though political factors may complicate how successful efforts are at true pollution control.*

## **B. “Nonpoint source” pollution**

*Nonpoint source* delivers pollutants indirectly through transport or environmental change. An example of a nonpoint-source of water pollution is when fertilizer from a farm field is carried into a stream by rain (i.e. run-off).

Nonpoint source are diffused sources of pollution and are difficult to identify. Among this are: roof run-off; road run-off; agricultural based contamination through fertilizer usage; pesticide residue; metals from the use of organic manure; pasture grazing metal pollution; sewage water irrigation. Others are discharge from automobile exhaust pipes; electricity generating sets and other internal combustion engine. Pollutants from the last set of sources are precipitated by rainfall and find their way into the aquatic habitat beside the

ones inhaled. Flood actions, erosion of geological structure, accidental oil spillage are also among these non-point sources of pollution.

*'Nonpoint sources' pollution is much more difficult to monitor and control, and today they account for the majority of contaminants in streams and lakes.*

## **Water Sanitation**

The sanitation of water will make it support various human uses such as drinking, other domestic uses, irrigation, livestock watering, swimming, recreational uses, among others. According to World Health Organisation, an important share of the total burden of disease worldwide—around 10%—could be prevented by improvements related to drinking-water, sanitation, hygiene and water resource management. Some examples of global disease burdens that are known to be preventable in this manner are: diarrhoea, malnutrition, intestinal nematode infections, lymphatic filariasis, trachoma, schistosomiasis, malaria, etc. The water sanitation could be either preventive or remediation.

### **A. Preventive water sanitation**

Prevention is better than cure. The prevention of waste/contaminant in entering the water bodies is preferable to remediation of polluted water system. Industries that pollutes the environment must learn to or be made to prevent such by introduction of cleaner production technology. They should review their production process such that less waste-water is generated (waste reduction). Likewise, the generated waste should be considered for reuse and or recycling instead of being discharged into the environment to cause pollutions. Also, domestic waste discharge, sewage disposal into water bodies should be strongly discouraged. The water system cannot assimilate pollutants

indefinitely. The waste disposed in water system get back at us; the ecosystem is a closed system. Thus, prevention should be emphasised.

## **B. Remediation**

On a large scale, remediation and purification of water especially for human consumption involve coagulation, sedimentation, filtration, deodourization, ozonation, chlorination. The last stage is meant to disinfecting. Disinfection reduces microbes and improve water quality for consumption. Finally, transportation of water in pipes to homes or packaging processes have also being observed to contaminate the water. Thus, care must be ensured that the integrity of the water is maintained in distribution.

## **DOMESTIC AND INDUSTRIAL EFFLUENTS**

Domestic and industrial effluents are liquid waste discharged from a municipal waste, sewage system, factory, nuclear power station, or other industrial plant. When insoluble particles, soluble salts, sewage (waste water), garbage, low level of radioactive substances, industrial wastes, algae, bacteria, etc. go into the water, water gets polluted. A lot of industrial wastes are generated by industrial processes which are invariably disposed to the environment. These do result into pollution when the assimilative capacity of the environment is exceeded.

Pollution is defined as the introduction to the environment by man, directly or indirectly of substance or energy into the environment resulting in deleterious effects to living resources and ecological systems and damage to structure, amenity or interference with the use of the environment.

Industrial waste encompasses a wide range of materials of varying environmental toxicity. This includes general rubbish, food wastes, acids and alkali, oils, solvents, resins, paints and sludge. About 8-9% of the total waste generated by industry is classified as 'hazardous' wastes because they contain substance that are toxic to humans, plants or animals, are corrosive, flammable or explosive or have high chemical reactivity. Hazardous wastes arise from the use of pesticides, chemicals, from wood treatments, oils, solvents, and batteries discarded.

## **CAUSES OF INDUSTRIAL POLLUTION**

1) *Technical*: Many industries use outdated manufacturing processes, obsolete equipment and technologies, failure (such as oil spillage), pipeline leakage or corrosion, leaking underground storage; any of these may lead to water pollution.

2) *Types of energy source*: The energy source is usually a major investment in industries. If this is unreliable, and obsolete, a serious air, noise pollution, and water pollution.

3) *Economical causes*: Lack of adequate financial resources may inhibit implementation of abatement technology or upgrading of old plants or ineffective environmental controls.

4) *Social causes*: This may be due to ignorance, low environmental awareness, sabotage and vandalisation of pipelines.

5) *Regulatory/Environmental failures*: this arise when the environmental protection agencies are weak or they allow culprit to pay pittance compensation for environmental damage.

6) *Racism*: This occurs from trans-boundary movement of hazardous wastes from one country to the other. Example is the 1988 illegal dumping of toxic wastes from Italy to Koko port in Delta State, Nigeria.

7) *Profit/Attitudinal perception*: Many industries perceive investment made on pollution abatement and control as reducing profit.

## **STRATEGY FOR MANAGEMENT OF DOMESTIC & INDUSTRIAL EFFLUENT.**

### **1. CONTROL of Domestic effluent**

Domestic effluent can be prevented or minimized by the following methods:

- a) The use of excess of nitrate and phosphate fertilizers should be avoided.
- b) The use of synthetic detergents should be minimized or bio-degradable detergents (bio-degradable detergents are those which can be decomposed by

the bacteria) should be used. Alternatively, a combination of washing soda and soap should be used for washing the clothes.

c) Before throwing the industrial wastes into the rivers and lakes, they should first be treated chemically to neutralize the harmful substance present in them.

d) The radioactive waste products obtained in reactors used in hospitals and scientific laboratories should be enclosed in containers made of concrete and then buried.

## 2. TREATMENT of domestic effluent

There are basically two methods of treating domestic effluents namely: primary and secondary treatment methods. In primary treatments: solids are allowed to settle and are removed from the water. Secondary treatment uses biological processes to remove 90% of the organic matter in sewage. The principal processes for secondary treatments are trickling filters and activated sludge process.

**Trickling filter** is a bed of rock or stones. The sewage is trickled over the bed and bacteria will break down the organic wastes. **Activated sludge** process removes organic matter from sewage by saturating it with air and biologically active sludge i.e. solid matter that settles to the bottom of sedimentation table. This process is free of flies and odours, but it is more costly to operate than the trickling filter.

Adequate supply of oxygen is necessary for the activated sludge process to be effective. The final phase of the secondary treatment consists of the addition of chlorine to the effluent coming from the trickling filter or the activated sludge process. Chlorine in liquid form is usually injected into the effluent before it is discharged into a water course. If done cleverly, chlorine will kill more than 99% of the harmful bacteria in an effluent.

**Tertiary treatment** is used when the waste stream must meet strict requirements governing recreational bodies if water must approach drinking water standards. This may require one or more of the following processes: a) Slow filtration b) Rapid filtration with activated carbon.

c) Adsorption by activated carbon. d) Application of ozone. e) High chlorination rate or use of other oxidizing chemical. f) By Lagooning i.e. erecting scientifically built ponds (3 – 5ft deep), in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluents from a secondary treatment plant.

## **INDUSTRIAL EFFLUENTS MANAGEMENT**

Industrial effluents can be managed through at least four distinct strategies:

- a) Installation of industrial – waste treatment plants operated within the factory.
- b) Discharge of industrial wastes to public systems for treatment
- c) Process modification and changed product formulation to reduce wastes. Example include the development of biodegradable detergents.
- d) Abandonment of a product line or process procedure.