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A THEORITICAL DESCRIPTION ON EFFLUENT TREATMENT PROCESS – WITH A CASE STUDY OF UREA PLANT EFFLUENT TREATMENT

Modi Musalaiah[1] ,D.Thrimurthi Naik[2] ,M.Sindhuja[3],P.Palankaiah[4]

[1]Assistant Professor, Indira Institute of Technology and Sciences

[2]Assistant Professor, Indira Institute of Technology and Sciences

[3]Assistant Professor, Indira Institute of Technology and Sciences

[4]Assistant Professor, Indira Institute of Technology and Sciences

Abstract: Rapid industrialization is going all over the world, especially in the developing countries. Because, the major source of country's income will comes through the industries. The increasing in the number of the industries, pollute the environment by releasing the toxic gases and toxic waste into the air and water thus contributing the air and water pollution respectively. As a result, the air and water quality of the surrounding villages will be put in danger. So, periodic survey has to be done by the industry/government/state or central pollution control boards, in order to investigate the concentration of various air and water pollutants in the industry surrounding villages.

Key Words: Environment, Pollution, Effluent, Fertilizer and Urea.

1. Introduction:

Environmental pollution is any discharge of material or energy into water, land, or air that causes or may cause acute (short-term) or chronic (long-term) detriment to the Earth's ecological balance or that lowers the quality of life. Pollutants may cause primary damage, with direct identifiable impact on the environment, or secondary damage in the form of minor perturbations in the delicate balance of the biological food web that are detectable only over long time periods [1]. Smog has seriously affected more persons than any other type of air pollution. It can be loosely defined as a multisource, widespread air pollution that occurs in the air of cities. Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal. The infamous London fogs about 4,000 deaths were attributed to the severe fog of 1952 were smog of this type. Another type, ice fog, occurs only at high latitudes and extremely low temperatures and is a combination of smoke particles and ice crystals. Furthermore, automobiles are polluters even in the absence of photochemical reactions. They are responsible for much of the particulate material in the air [2].

2. Effects of Pollution:

The prime factors affecting the human health are: 1. Nature of Pollutant 2. Concentration of the pollutant 3. Duration of exposure 4. State of health of the receptor and 5. Age group of the

receptor. In general the susceptibility of the effects of the air pollution is great among infants, children, the elderly, and the infirm. Those with diseases of lungs or heart are thought to be at great risk. Pre-school and school children appear to be sensitive to the air pollution health effects. The effect of air pollution on human health generally occurs as a result of contact between the pollutants and the body. Normally body contact occurs at the surfaces of the skin, eye and exposed membranes. Air pollution directly affects the membranes of eyes, nose, throat, larynx, trachea-bronchial tree and the alveoli sacs.

On Human Health - Air pollutants are classified into different categories based on different criterion. One such classification is aerosols and gaseous pollutant. Particulate matter is further classified as Total Suspended Particulate Matter (TSPM) and Respirable Suspended Particulate Matter (RSPM). The RSPM is more harmful as it will have an entry into the alveoli sacs and interfere with the oxygen and CO_2 transfer into or from the blood through lungs. The respiratory system is affected more than any other part of the human body because, the basic functions of the respiratory system are to inhale air into the lungs, filter impurities from the inhaled air, supply oxygen to the circulatory system, and exhaling CO_2 from the circulatory system. It is across the alveolar membranes that oxygen diffuses from air in the sacs to the pulmonary capillaries and CO_2 diffuses in the opposite direction. The upper respiratory tract removes particulates larger than 10 microns in diameter.

On Vegetation and Animals - The pollution and gases diffuse to the surface of the cells within the leaf and inner tissues through stomata, where destroy the chlorophyll and disrupt photo synthesis. When acute illness and death of animals occur on large scale, the toxic pollutants like metal fumes and radioactive residues in pesticides cause indirect health hazard through possible transmission to the plant and animal population.

On Materials and Property - Particulate matter causes economic loss and aesthetic upon non-living material and property. By their abrasive nature caused damage to exposed surfaces, when they are driven by light velocities. It causes reduction in visibility, which effects transpiration operations on land, sea and in the air increased operational costs, passenger inconvenience hazard to safety resulting in personal injury and property decay [3].

3. Treatment History:

In ancient Greek and Sanskrit (India) writings dating back to 2000 BC, water treatment methods were recommended. People back than knew that heating water might purify it, and they were also educated in sand and gravel filtration, boiling, and straining. After 1500 BC, the Egyptians first discovered the principle of coagulation. They applied the chemical alum for suspended particle settlement. After 500 BC, Hippocrates discovered the healing powers of water. He invented the practice of sieving water, and obtained the first bag filter. In 300-200 BC, Rome built its first aqueducts. Archimedes invented his water screw. During the Middle Ages (500-1500 AD). In 1627 the water treatment history continued as Sir Francis Bacon started experimenting with seawater desalination. He attempted to remove salt particles by means of an unsophisticated form of sand filtration. In the 1700s the first water filters for domestic application were applied. These were made of wool, sponge and charcoal. In 1804 the first actual municipal water treatment plant designed by Robert Thom, was built in Scotland. In 1854 it was

discovered that a cholera epidemic spread through water. The outbreak seemed less severe in areas where sand filters were installed. British scientist John Snow found that the direct cause of the outbreak was water pump contamination by sewage water. He applied chlorine to purify the water, and this paved the way for water disinfection. In the 1890s America started building large sand filters to protect public health. These turned out to be a success. Instead of slow sand filtration, rapid sand filtration was now applied. In 1902calcium hypo chlorite and ferric chloride were mixed in a drinking water supply in Belgium, resulting in both coagulation and disinfection. In 1906ozone was first applied as a disinfectant in France. Additionally, people started installing home water filters and shower filters to prevent negative effects of chlorine in water. In 1903 water softening was invented as a technique for water desalination. Cations were removed from water by exchanging them by sodium or other cations, in ion exchangers. Eventually, starting 1914drinking water standards were implemented for drinking water supplies in public traffic, based on coliform growth. It would take until the 1940s before drinking water standards applied to municipal drinking water. In 1972, the Clean Water Act was passed in the United States. In 1974 the Safe Drinking Water Act (SDWA) was formulated. The general principle in the developed world now was that every person had the right to safe drinking water. Techniques such as aeration, flocculation, and active carbon adsorption were applied. In the 1980s, membrane development for reverse osmosis was added to the list. Risk assessments were enabled after 1990. Water treatment experimentation today mainly focuses on disinfection by-products [4].

4. Treatment Criteria:

There are three types of effluents are observed in process industries, Such as, Gasses, Liquids and solids (Sludge). Waste water, solid wastes, SO_X, NO_X, CO, HFCS, CFCS, Aldehydes, Ketones etc. are major pollutants liberating from the process industries.

4.1.Control of Air Pollutants:

Gaseous emissions can be controlled by, Absorption – it's a bulk phenomena, different absorbents are used to treat emissions, generally Water. Adsorption – it's a surface phenomena, different adsorbent materials are used to treat emissions. Like, Silicagel, Zeolite, Activated Carbon etc.Catalytic Reduction – gasses are diffused into a catalytic bed as like adsorption but here we use catalytic bed instead of adsorbent. Different equipments are available for absorption and adsorption columns like, plate column, packed column, tray towers, spray column, etc. For example, A spray tower (or spray column or spray chamber) is gas-liquid contactor used to achieve the mass and heat transfer between a continuous gas phase (that can contain dispersed solid particles) and a dispersed liquid phase. It consists of empty cylindrical vessel made of steel or plastic and nozzles that spray liquid into the vessel. The inlet gas stream usually enters the bottom of the tower and moves upward, while liquid is sprayed downward from one or more levels. This flow of inlet gas and liquid in the opposite direction is called countercurrent flow. Spray towers can be used for gas absorption. Spray towers can be very effective in removing pollutants if the pollutants are highly soluble or if a chemical reagent is added to the liquid.

Dust leaden gas is nothing but particulates Particulates can be controlled by using, settling chambers, cyclone separators, baffle chambers, wet scrubbers, electrostatic precipitators etc. Centrifugal collectors— Centrifugal collectors used cyclonic action to separate dust particles from the gas stream. In a typical cyclonic, the dust gas enters at an angle and is spun rapidly. The centrifugal force created by the circular flow throws the dust particles toward the wall of the cyclone. After striking the wall, those particles fall into a hopper located underneath [5].

4.2.Sewage & its Treatment:

Sewage treatment generally involves different stages, called Pretreatment, Primary, Secondary and Tertiary (Advanced) treatment, shown in Figure 1.

Pre-treatment removes materials that can be easily collected from the raw sewage before they damage or clog the pumps and sewage lines of primary treatment clarifiers. Objects that are commonly removed during pre- treatment include trash, tree limbs, leaves, branches, and other large objects. Different types of Screens, Bar Screens and Comminutors are available for pretreatment of sewage.

Primary treatment consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment. Sedimentation Tanks, Flocculation Tanks, Flotation Tanks are some of the examples of primary treatment equipments.

Secondary treatment removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment. Activated Sludge Tanks, Trickling Filters, Aerobic and Anaerobic Ponds, and Facultative Ponds are come under secondary treatment.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow Rivers, coral reefs,). Treated water is sometimes disinfected chemically or physically prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for ground water recharge or agricultural purposes. In tertiary or advanced treatment, Micro-staining, Filtration, Adsorption, Ion-exchange, Ultra-filtration and Reverse Osmosis are some methods [6]. For Example, Reverse osmosis (RO) is a water purification technology that uses a semi permeable membrane to remove larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by chemical potential, a thermodynamic parameter. Reverse osmosis can remove many types of molecules and ions from solutions, including bacteria, and is used in both industrial processes and the production of potable water. The process of Reverse Osmosis shown in Figure 2 [7].

4.3.Sludge Treatment:

Sludge is a solid material removal from the primary sedimentation tanks and secondary clarifiers. Other sludge components may include chemical precipitates and backwash solids from tertiary filters or other processes. Stabilization-process that reduces pathogens and sludge odors. Biological stabilization is called digestion. Aerobic digestion is digestion with the presence of oxygen. Anaerobic digestion is digestion of sludge without the presence of oxygen [8]

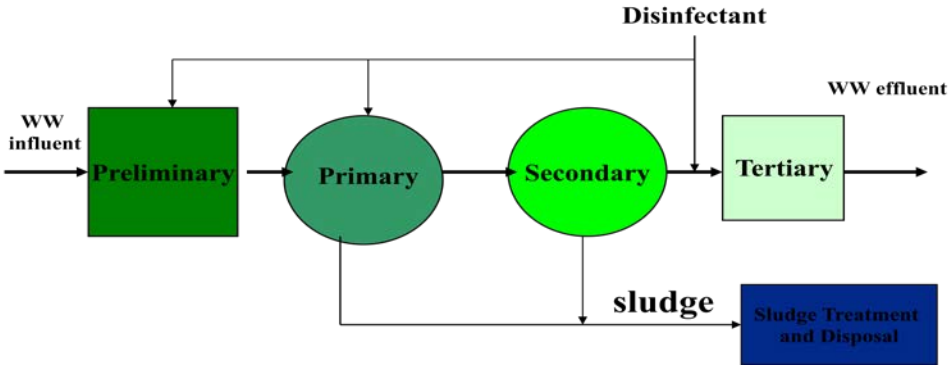

Figure 1. Waste Water Treatment Flow Sheet

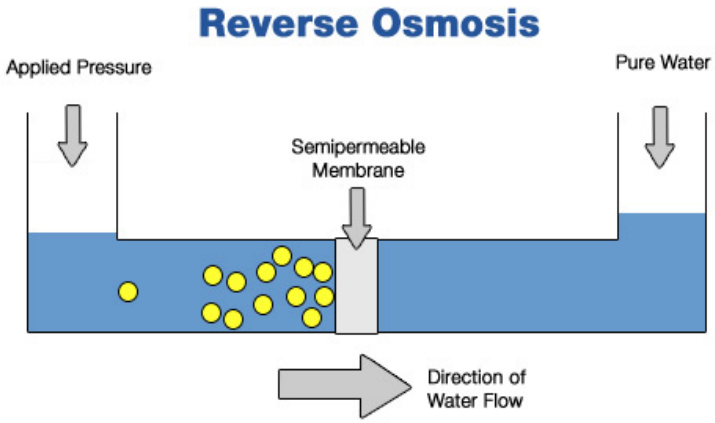

Figure 2. Process of Reverse Osmosis

5. Case Study: Urea Plant Effluent Treatment

Urea 1st identified in 1773. More than 50metric tones of urea produced yearly. It is manufactured by the reaction of ammonia and carbon dioxide to form ammonium carbamate first. Ammonium carbamate then dehydrated to form urea according to the following reaction

$$2NH_3 + CO_2 \text{ ---------> } NH_4COONH_2$$

$$NH_4COONH_2 \text{ -------> } NH_2CONH_2 + H_2O$$

Ammonium carbamate **Urea**

5.1.Composition of Effluent:

A typical composition of Urea Plant effluents are, Around 450-480 Kg of liquid effluents (water) is generated for metric tone of urea, 4-5% of ammonia, 1.5-2% carbon dioxide and 5.1% urea. Heat will also generate due to the nature of the reaction (exothermic reaction) [9].In these, ammonia and carbon dioxide are gaseous emissions and urea in the form of particulates.

5.2.Treatment of Effluent:

Heat recovery - The heat of the reaction in which ammonium carbamate produces steam at higher pressures. This is recovered and used in the evaporation for heating

Ammonia and Carbon dioxide Recovery - During urea decomposition a mixture of ammonia and carbon dioxide is collected and absorbed into a dilute aqueous urea solution is condensed and recycled to the feed unit. Packed column shown in the figure which is used for recovery of ammonia and carbon dioxide (Shown in Fig.3.).

Recovery of Waste Water - Around 450-480 Kg of liquid effluents (water) is generated for metric tone of urea. This water is pumped into a distillation tower. The feed in this column then preheated before entering into the column. Due to volatility difference the water and urea was separated in the tower, water can be drawn from the bottom of the tower and the urea vapors goes to the top. Due to the presence of reboiler in the top section urea decomposed into ammonia and carbon dioxide which is further fed into a feed section (Shown in Fig.4.).

Control of Urea Particulates - The final form of the urea was obtained in granules. At the time of packing and crystallization of urea solution, urea dust was emitted with some % of moisture. For the wet particulate removal wet scrubbers are used. Wet scrubber - Dust collectors that are used for wet materials are known as wet scrubbers. In this system, the scrubbing liquid (usually water) comes into contact with a gas stream containing dust particles. Greater contact of the gas and liquid streams yields higher dust removal efficiency (See Fig.5.)[10].

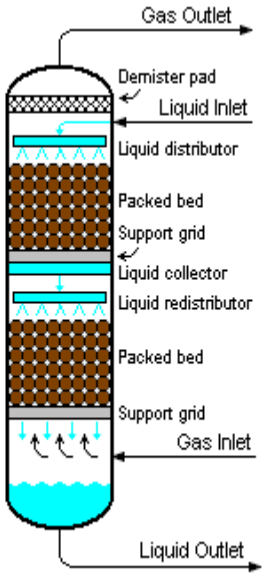

Fig.3. NH_3 and CO_2 Recovery

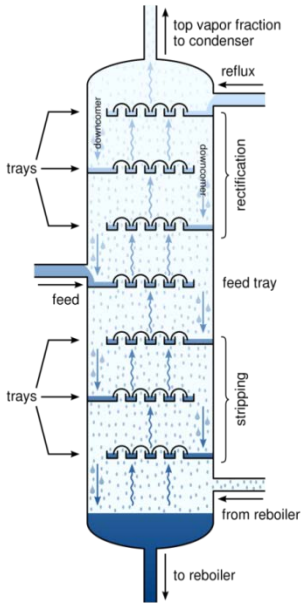

Fig.4. Recovery of Waste Water

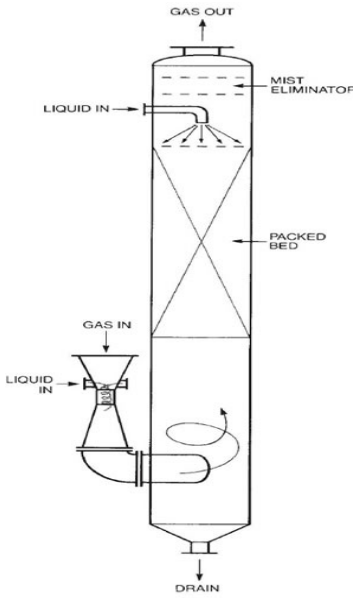

Fig.5. Collection of Particulates

6. Conclusion:

Urea can be irritating to skin when it is contact with skin. Repeated and prolonged contact with urea in fertilizer form on the skin may cause dermatitis. High concentration in the blood will cause damage of blood cells. So, **to overcome these problems the efficient treatment of wastes is needed.**

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