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IMPROVING THE DISSOLVED OXYGEN LEVELS IN WASTE WATER USING OXYGEN CONCENTRATOR

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ABSTRACT

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In the case of aeration process, dissolved oxygen is highly significant as microorganisms depend on the dissolved oxygen for their growth. The microorganisms use this dissolved oxygen in order to breakdown the organic waste present in the effluent and thus helps to reduce the Biological Oxygen Demand (BOD)/Chemical Oxygen Demand (COD) of the effluent. If the dissolved oxygen is too low, certain microorganisms might perish thus increasing the MLSS: MLVSS (Mixed liquor suspended solids: Mixed liquor suspended solids) ratio. On the other hand, if the dissolved oxygen is too high, again there is growth of unwanted micro-organisms which harm the aeration process. When ideal dissolved oxygen is maintained, maximum efficiency of organic waste breakdown in the effluent is attained. In order to serve this purpose an oxygen concentrator is being used to provide an economical source of oxygen in industrial processes. Current technology advocates the use of the Pressure Swing Adsorption (PSA) method utilizing various adsorbents, mostly zeolites to obtain upto 99% pure oxygen.

KEYWORDS – Adsorbents, Aeration Process, BOD, COD, Pressure Swing Adsorption.

1. Introduction

Industrial waste water is one of the main pollution sources in the pollution of water environment. During the last century a huge amount of industrial waste water was discharged into rivers, lakes, and coastal areas. This resulted in serious pollution problems in the water environment and caused negative effects to the ecosystem and human life.

2. Why treat wastewater?

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. We cannot allow wastewater to be disposed of in a manner dangerous to human health and lesser life forms or damaging to the natural environment. Basic Sewage Treatment facilities reduce organic and suspended solids to limit pollution to the environment. Advancement in needs and technology has necessitated the evolving of treatment processes that remove dissolved matter and toxic substances. Currently, the advancement of scientific knowledge and moral awareness has led to a reduction of discharges through pollution prevention and recycling, with the noble goal of zero discharge of pollutants [7].

Treatment technology includes physical, biological, and chemical methods. Residual substances removed or created by treatment processes must be dealt with and reused or disposed of in a safe way. The purified water is discharged to surface water or ground water. Residuals, called sludges, may be reused by carefully controlled composting or land application [1][6].

3. Types of wastes

The types of wastes in effluent waste water are broadly divided into the following two categories:

1. Inorganic Waste: Waste material such as sand, salt, iron, calcium, and other mineral materials that are only slightly affected by the action of organisms. Inorganic wastes are basically chemical substances of mineral origin.
2. Organic Waste: Waste material that may come from animal or plant sources. Natural organic wastes generally can be consumed by bacteria and other small organisms [6].

4. Effluent Treatment Process

Effluent treatment entails the treatment of all the wastewater generated in the plant. The effluent treatment plant, or ETP, is responsible for making the generated wastewater fit for reuse and also for draining of the water into municipal drains, in compliance with the standards for drainage water set by the Pollution Control Board (PCB).

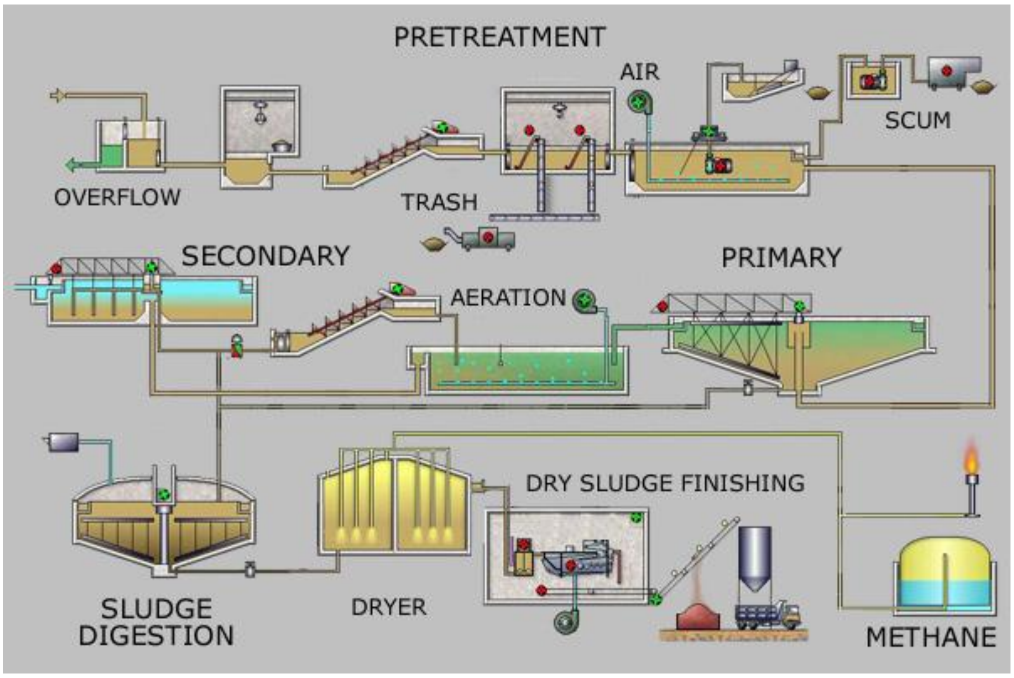

Figure 1: Step-by-step ETP process

The step-by-step ETP process is as follows:

1. Bar screen chamber: This is where all the wastewater is first sent for pretreatment. It consists of multiple meshes through which the effluent water is passed. The mesh sizes are 30mm and 3mm. This is where the big size solid waste is removed.
2. Oil trap chamber: The effluent from the bar screen is collected in this chamber. This chamber is used to separate the floating oil present in the raw effluent. Belt type motorized oil skimmer is provided for the removal of settled floating oil from the oil trap chamber and is transferred to slop oil tank by gravity. The oil and grease present in the effluent sticks to the belt provided in the skimmer and is thus removed from the effluent.
3. Collection tank: The water from the oil trap is then collected in the collection tank where some settling takes place. The pH of the collected effluent is generally in the range of 9-12

4. Equalization tank: Before the aeration process starts, the pH of the effluent must be brought down to 6.5-8.5 in order to facilitate proper functioning of the micro-organisms. For this purpose, the water in the equalization tank is maintained at a pH of 7-7.5, which is achieved by acid dosing. Hydrochloric acid is used for this dosing purpose.
5. Biox tank: The equalized effluent water is then sent to the biox tank where a bio filling using polypropylene material is mixed with it in order to reduce the Biological Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) of the water. The BOD/COD of the effluent is brought down to nearly 50% of its original value in the Biox tank. Also, air is circulated at a relatively lower flowrate in order to facilitate microorganism growth.
6. Aeration tank: The process involves air or oxygen being introduced into the effluent combined with organisms to develop a biological floc which reduces the organic content of the sewage. This material is largely composed of saprotrophic bacteria, Spirotrichs, Peritrichs including Vorticellids and a range of other filter feeding species. This mixture is known as Mixed Liquor. The air is circulated with a relatively higher flow rate in this tank in order to increase the Dissolved Oxygen (DO), which is utilized by the introduced microorganisms to breakdown the organic waste present in the effluent. The BOD/COD is thus, brought down to 10% of the original value.
7. Secondary Clarifiers: The water from the aeration tanks is made to flow the bottom to top in this tank. The flocculated sludge is collected at the bottom and is recirculated back to the aeration tank. A part of the clarified water is sent to storage tanks as per the plant’s requirement whereas the rest of the water is sent into municipal drains. All the water from the secondary clarifier is treated with 5% Sodium Meta Bi Sulphate in order to kill the Chlorine content of the treated water. The conditions of the water sent to municipal drains is as follows: pH 5-9, COD<250ppm, BOD< 30ppm, Total Dissolved Solids (TDS)< 2100ppm, Total Suspended Solids (TSS)< 100, Oil/Grease< 10. The water is now totally safe to dispose of into government drains [8].

5. Activated Sludge Process

The term activated sludge is used to indicate the sludge which is obtained by settling the effluent in presence of abundant oxygen. The sludge is biologically active and it contains a great number of aerobic bacteria and other microorganisms which effectively oxidize the organic matter. After pH adjustment, the effluent is routed for two stage biological treatment for the carbonaceous organic removal. The activated sludge process essentially consists of an aeration tank with aerators, a clarifier and a sludge recirculation system. The nutrient requirement of nitrogen and phosphorous for the microbial growth will be fulfilled by the addition of urea and DAP (Diammonium phosphate) solution. The urea solution serves as the N-P source. The quantity of both the chemicals added is such as to maintain BOD:N:P ration of 100:10:1. The neutralized effluent is received in the biox tank which is provided with aerators for COD/BOD reduction. The COD/BOD reduction at this stage is about 50% as mentioned before. The effluent ex-Biox tank is routed to the aeration tank. The BOD reduction then is about 90% the exit of the effluent from the aeration tank is routed to the clarifier where the microbial solids are separated under gravity. Solids separation is he final step in the production of a well-clarified, stable effluent, low in BOD and suspended solids and as such represents a critical link in the operation of an activated sludge treatment process. The clarifier is provided with a clarifier mechanism to remove the sludge at the bottom. The separated biomass settles in the conical shaped bottom of the clarifier. This biomass collected will be pumped via non-clog centrifugal pumps. A portion of the settled solids is recycled back to maintain the desired concentration of microorganisms in the aeration tank and excess sludge is pumped to sludge drying beds for solar drying provided in the ETP area. About 162kg of 100% bio solids is collected every day.

Aeration is generally provided to three tanks, namely, equalization, biox and aeration tank. Aeration of the effluent is done with the help of air blowers. In the case of biox and equalization tanks, air is supplied through course bubble diffusers and in aeration tank by fine membrane diffusers for homogenizing the effluent and also to keep it fresh during storage. Butterfly valve is provided to regulate the flow at the outlet of blower and to isolate the equalization tank

6. Significance of Dissolved Oxygen in Water

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality. Non-compound oxygen, or free oxygen (O_2), is oxygen that is not bonded to any other element. Dissolved oxygen is the presence of these free O_2 molecules within water. The bonded oxygen molecule in water (H_2O) is in a compound and does not count toward dissolved oxygen levels. One can imagine that free oxygen molecules dissolve in water much the way salt or sugar does when it is stirred. Dissolved oxygen enters water through the air or as a plant byproduct. From the air, oxygen can slowly diffuse across the water's surface from the surrounding atmosphere, or be mixed in quickly through aeration [3].

DO can be measured in mg/l or %saturation. The level of DO in water is mainly dependent on temperature, pressure and alkalinity of water. The normal operating DO level in an aeration tank should be 1-2 mg/l (ideally 2mg/l) or 10-20% saturation. In the case of the aeration process, DO is highly significant as microorganisms depend on the DO for their growth. The microorganisms use this DO in order to breakdown the organic waste present in the effluent and thus helps to reduce the BOD/COD of the effluent. If the DO is too low, certain microorganisms might perish thus increasing the MLSS: MLVSS ratio. Also the growth of certain unwanted bacteria is facilitated. In this anaerobic phase, organisms also excrete certain waste products which darken the colour of the effluent. COD/BOD value too, increases significantly. On the flip side, if the DO is too high, again there is growth of unwanted microorganisms which harm the aeration process. When ideal DO is maintained, maximum efficiency of organic waste breakdown in the effluent is attained and the colour of water in the aeration tank remains golden brown. The water turns black and turbid when the DO is below the required ideal value.

7. Methods to improve the dissolved oxygen levels in the activated sludge

- The air blowers cannot be used at their maximum outputs even if the DO is extremely low, because if they are, then the membrane bursts. So, bigger sized membranes should be used or membranes made of materials with higher yield stress should be used. Also, the tube type diffusers in the biox and equalization tank expand and burst if the pressure is increased beyond a particular value. Tube diffusers with larger diameters should be used to enable greater air supply. At the current point in time, not more than 2 blowers can be used, each running at not more than a third of their output capacity can be used safely.

- Oxygen concentrators should be placed before the air blowers in order to increase the oxygen quantity being supplied to the aeration process. This will drastically improve the dissolved oxygen levels in the effluent [2].

- A proper sludge removal system for the equalization tank should be in place. This must be done in order to stabilize the MLSS value of the effluent. If the sludge is removed frequently, then aeration can be provided more often to the equalization tank.

- Filters must be added between the equalization and biox tanks. This will help to bring down the MLSS value of the effluent in the aeration tank. These filters can be cleaned easily by backwash. Occasional manual cleaning might also be required.

- Partially cover the aeration tank- Partially or completely covering the tank may be an option to regulate seasonal changes. Atmospheric pressure is a seasonal factor that can affect dissolved oxygen concentrations within the tanks. Low pressure conditions, such as strong winter winds, and high pressure conditions, such as humid, stagnant summer days, can decrease or increase dissolved oxygen concentrations, respectively. By partially or completely covering the aeration tank, the plant can have more control over the efficiency of the biological processes taking place. A retractable type geo-membrane cover would be highly beneficial in controlling temperature fluctuations and also eliminate the bad odor given off by the effluent.

Of these various methods, the most effective and efficient method to improve the dissolved oxygen level in the activated sludge is to introduce oxygen concentrators to the process.

8. Oxygen Concentrators

Oxygen concentrators typically use pressure swing adsorption technology and are used very widely for oxygen provision in healthcare applications, especially where liquid or pressurized oxygen is too dangerous or inconvenient, such as in homes or in portable clinics. The major technique currently employed is the Pressure Swing Adsorption (PSA) technique. Pressure swing adsorption processes rely on the fact that under high pressure, gases tend to be attracted to solid surfaces, or "adsorbed". The higher the pressure, the more gas is adsorbed; when the pressure is reduced, the gas is released, or desorbed. PSA processes can be used to separate gases in a mixture because different gases tend to be attracted to different solid surfaces more or less strongly. If a gas mixture such as air, for example, is passed under pressure through a vessel containing an adsorbent bed of zeolite that attracts Nitrogen more strongly than it does Oxygen part or all of the Nitrogen will stay in the bed, and the gas coming out of the vessel will be enriched in oxygen. When the bed reaches the end of its capacity to adsorb nitrogen, it can be regenerated by reducing the pressure, thereby releasing the adsorbed nitrogen. It is then ready for another cycle of producing oxygen enriched air [2][4].

9. Adsorbents for Pressure Swing Adsorption

(i) Silica Gel:

Silica gel is used in a pretreatment bed to remove water vapor and impurities such as carbon dioxide and carbon monoxide before the air feed stream enters the adsorbent beds. Water strongly adheres to the cation sites within each zeolite rendering them useless and ineffective. Silica gel beds are necessary to remove water vapor from the air. Air at 100% humidity has approximately 3% of water vapor. Once the bed is saturated with water, the bed is heated with a heating coil to evaporate the water from the silica gel [5].

(ii) Zeolites:

Zeolites are microporous crystalline structures that govern the molecules that are adsorbed during the PSA process. The shape-selective properties of zeolites are the basis for their use in molecular adsorption. The different structures of the zeolite indicate the type of molecules that the zeolite will adsorb.

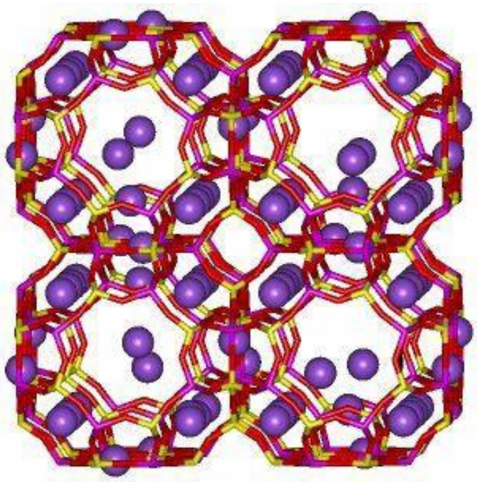

Figure 6: Zeolite structure

Zeolites have various ways of controlling adsorption. The size and shape of pores can control access into the zeolite. In another case different types of molecule enter the zeolite, but some diffuse through the channels more quickly while others are left behind and do not pass through. Cation-containing zeolites, such as silver zeolites, are extensively used in gas separation processes. These cations are indicated as the purple spheres in the figure above.

Molecules are differentiated on the basis of their electrostatic interactions with the metal ions. Zeolites can thus separate molecules based on differences of size, shape and polarity [5].
Ion exchange is another aspect of zeolites that aids in the separation process. Ion exchange involves adding metal cations to the structure of the zeolite to attract certain molecules. Calcium is the most common metal cation exchanged in zeolites, but new studies have found silver exchanged zeolites to be more effective in air separation. For zeolites to be affective, metal cations must be bound to the structure such as calcium, sodium, and in our case silver. Silver exchanged zeolites are a relatively new type of zeolite used in separation. The silver metal cation is placed in the structure of the zeolite structure as shown below. Zeolite structure types of A, X, and Y are the dominant types used in commercial use for adsorption and ion exchange [5].

10. Conclusion

The most promising property of oxygen concentrator for improving the dissolved oxygen level in waste water is its ability to selectively adsorb oxygen on the zeolite bed from the ambient air. This property translates into more oxygen levels per unit area. The scope of this technology is thus immense in the environmental and the health sectors. It opens up exciting avenues for a country like India where the problems are many and solutions are few.

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