EFFLUENT TREATMENT: BASICS & A CASE STUDY

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INTRODUCTION

Water is one of the most important elements on earth. Every living being needs water for its survival. Without water, plants, animals, microbes – everything will perish. Population growth - coupled with industrialization and urbanization has resulted in an increasing demand for water thus leading to water crisis and serious consequences on the environment. The requirement of fresh water for industrial use will increase from 30 BCM (Billion Cubic Meters) to 120 BCM by 2025 AD. A rapid industrialization has lead to the industrial effluents and sewage, resulting in water pollution which leads to water crisis in India and all over the world. The effluent stream coming out of the industries is mainly comprised of hazardous chemicals and heavy metal ions such as chromium, nickel, copper, lead, arsenic, etc. Heavy metals are very toxic in nature and harmful to the environment.

"Wastewater," also known as "sewage," originates from household wastes, human and animal wastes, industrial wastewaters, storm runoff, and groundwater infiltration. Wastewater, basically, is the flow of used water from a community. The nature of wastewater includes physical, chemical, and biological characteristics which depend on the water usage in the community, the industrial and commercial contributions, weather, and infiltration/inflow. It is 99.94 percent water by weight (Water Pollution Control Federation 1980). The remaining 0.06 percent is material dissolved or suspended in the water. The dissolved and suspended solids in wastewater contain organic and inorganic material. Organic matter may include carbohydrates, fats, oils, grease, surfactants, proteins, pesticides and agricultural chemicals, volatile organic compounds, and other toxic chemicals. Inorganic matter may cover heavy metals, nutrients (nitrogen and phosphorus), pH, alkalinity, chlorides, sulfur, and other inorganic pollutants. Gases such as carbon dioxide, nitrogen, oxygen, hydrogen sulfide, and methane may be present in wastewater (Lee and Lin, 2000). Wastewaters are normally treated by a combination of physical-chemical and biological operations. However, it is possible to treat waste waters solely with physical-chemical methods (Droste, 2004).

Figure 1 shows a typical schematic of an example wastewater treatment process providing primary and secondary treatment using the activated sludge process. There are three commonly used approaches namely trickling filter, activated sludge, and oxidation ponds in the secondary treatment. It provides biochemical oxygen demand (BOD) removal beyond what is achievable by simple sedimentation (Spellman, 2003).

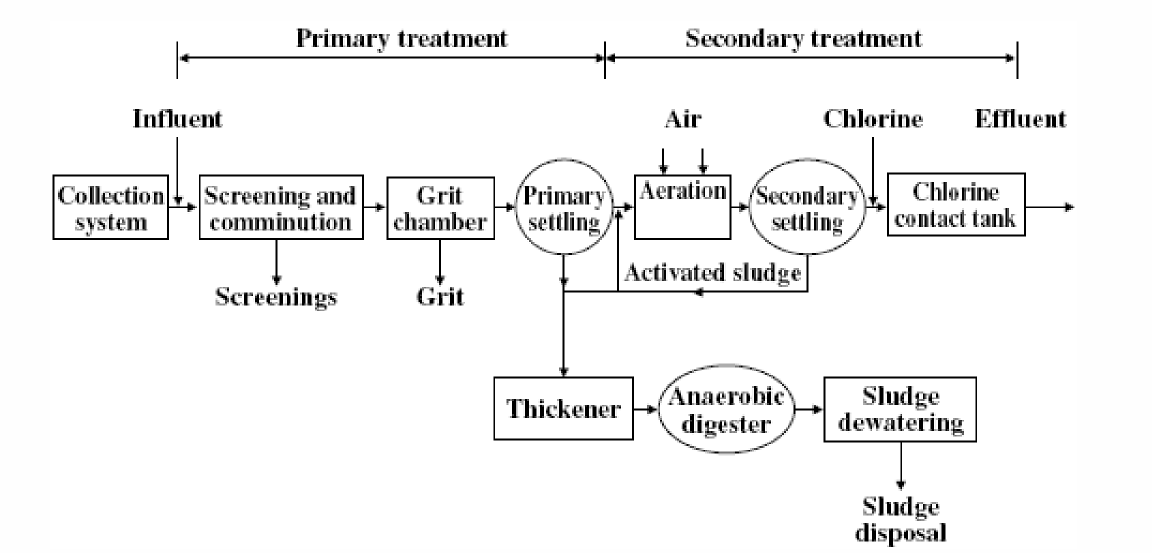


Fig. 1 Schematic of an example wastewater treatment process providing primary and secondary treatment using activated sludge process

Wastewater treatment is a series of steps. Each of the steps can be accomplished using one or more treatment processes or types of equipment. The major categories of treatment steps are:

1. Preliminary treatment - Removes materials that could damage plant equipment or would occupy treatment capacity without being treated.
2. Primary treatment - Removes settleable and floatable solids (may not be present in all treatment plants).
3. Secondary treatment - Removes BOD and dissolved and colloidal suspended organic matter by biological action. Organics are converted to stable solids, carbon dioxide and more organisms.
4. Disinfection - Removes microorganisms to eliminate or reduce the possibility of disease when the flow is discharged.

1. PRELIMINARY TREATMENT

The initial stage in the wastewater treatment process (following collection and influent pumping) is preliminary treatment. Raw influent entering the treatment plant may contain many kinds of materials (trash). The purpose of preliminary treatment is to protect plant equipment by removing these materials that could cause clogs, jams, or excessive wear to plant machinery. In addition, the removal of various materials at the beginning of the treatment process saves valuable space within the treatment plant. Preliminary treatment may include many different processes. Each is designed to remove a specific type of material — a potential problem for the treatment process. Processes include: wastewater collections (influent pumping, screening, shredding, grit removal, flow measurement, preaeration, chemical addition, and flow equalization). The major processes are shown in Figure 1. In this section, each of these processes and their importance in the treatment process is discussed and described.

1.1 Screening

The purpose of screening is to remove large solids, such as rags, cans, rocks, branches, leaves, roots, etc., from the flow before the flow moves on to downstream processes. A bar screen traps debris as wastewater influent passes through. Typically, a bar screen consists of a series of parallel, evenly spaced bars or a perforated screen placed in a channel.

1.2 Shredding

As an alternative to screening, shredding can be used to reduce solids to a size that can enter the plant without causing mechanical problems or clogging. Shredding processes include comminution (comminute means cut up) and barminution devices.

1.3 Grit Removal

The purpose of grit removal is to remove the heavy inorganic solids that could cause excessive mechanical wear. Grit is heavier than inorganic solids and includes, sand, gravel, clay, egg shells, coffee grounds, metal filings, seeds, and other similar materials. All the processes are based on the fact that grit is heavier than the organic solids, which should be kept in suspension for treatment in following processes. Grit removal may be accomplished in grit chambers or by the centrifugal separation of sludge. Processes use gravity and velocity, aeration, or centrifugal force to separate the solids from the wastewater.

1.4 Preaeration

In the preaeration process (diffused or mechanical), wastewater is aerated to achieve and maintain an aerobic state (to freshen septic wastes), strip off hydrogen sulfide (to reduce odors and corrosion), agitate solids (to release trapped gases and improve solids separation and settling), and to reduce BOD. All of this can be accomplished by aerating the wastewater for 10 to 30 min. To reduce BOD, preaeration must be conducted from 45 to 60 min.

1.5 Chemical Addition

Chemical addition is made (either via dry chemical metering or solution feed metering) to the wastestream to improve settling, reduce odors, neutralize acids or bases, reduce corrosion, reduce BOD, improve solids and grease removal, reduce loading on the plant, add or remove nutrients, add organisms, and aid subsequent downstream processes. The particular chemical and amount used depends on the desired result. Chemicals must be added at a point where sufficient mixing will occur to obtain maximum benefit. Chemicals typically used in wastewater treatment include chlorine, peroxide, acids and bases, miner salts (ferric chloride, alum, etc.), and bioadditives and enzymes.

2. PRIMARY TREATMENT

The purpose of primary treatment (primary sedimentation or primary clarification) is to remove settleable organic and flotable solids. Normally, each primary clarification unit can be expected to remove 90 to 95% settleable solids, 40 to 60% TSS, and 25 to 35% BOD. Primary treatment reduces the organic loading on downstream treatment processes by removing a large amount of settleable, suspended, and floatable materials. Primary treatment reduces the velocity of the wastewater through a clarifier to approximately 1 to 2 ft/min, so that settling and floatation can take place. Slowing the flow enhances removal of suspended solids in wastewater. Primary settling tanks remove floated grease and scum, remove the settled sludge solids, and collect them for pumped transfer to disposal or further treatment. Clarifiers used may be rectangular or circular. In rectangular clarifiers, wastewater flows from one end to the other, and the settled sludge is moved to a hopper at the one end, either by flights set on parallel chains or by a single bottom scraper set on a traveling bridge. Floating material (mostly grease and oil) is collected by a surface skimmer. In circular tanks, the wastewater usually enters at the middle and flows outward. Settled sludge is pushed to a hopper in the middle of the tank bottom, and a surface skimmer removes floating material.

3. SECONDARY TREATMENT

Secondary treatment refers to those treatment processes that use biological processes to convert dissolved, suspended, and colloidal organic wastes to more stable solids that can either be removed by settling or discharged to the environment without causing harm. The main purpose of secondary treatment (sometimes referred to as biological treatment) is to provide BOD removal beyond what is achievable by primary treatment. There are three commonly used approaches, and all take advantage of the ability of microorganisms to convert organic wastes (via biological treatment) into stabilized, low-energy compounds. Two of these approaches, the trickling filter and the activated sludge process, sequentially follow normal primary treatment. The third, ponds (oxidation ponds or lagoons), can provide equivalent results without preliminary treatment.

Secondary treatment processes can be separated into two large categories: fixed film systems and suspended growth systems. Fixed film systems are processes that use a biological growth (biomass or slime) that is attached to some form of media. Wastewater passes over or around the media and the slime. When the wastewater and slime are in contact, the organisms remove and oxidize the organic solids. The media may be stone, redwood, synthetic materials, or any other substance that is durable (capable of withstanding weather conditions for many years), provides a large area for slime growth and an open space for ventilation, and is not toxic to the organisms in the biomass. Fixed film devices include trickling filters and RBCs. Suspended growth systems are processes that use a biological growth that is mixed with the wastewater. Typical suspended growth systems consist of various modifications of the activated sludge process.

5.1 Treatment Ponds

Wastewater treatment can be accomplished using ponds. Ponds are relatively easy to build and manage, can accommodate large fluctuations in flow, and can also provide treatment that approaches conventional systems (producing a highly purified effluent) at much lower cost. Ponds can be classified (named) based upon their location in the system, the type wastes they receive, and the main biological process occurring in the pond. Types of ponds according to their location and the type of wastes they receive are: raw sewage stabilization ponds, oxidation ponds, and polishing ponds. Whereas the ponds classified by the type of processes occurring within the pond are: Aerobic Ponds, anaerobic ponds, facultative ponds, and aerated ponds.

5.2 Trickling filters

A trickling filter consists of a bed of coarse media, usually rocks or plastic, covered with microorganisms. The trickling filter process involves spraying wastewater over a solid media such as rock, plastic, or redwood slats (or laths). As the wastewater trickles over the surface of the media, a growth of microorganisms (bacteria, protozoa, fungi, algae, helminthes or worms, and larvae) develops. This growth is visible as a shiny slime very similar to the slime found on rocks in a stream. As the wastewater passes over this slime, the slime adsorbs the organic (food) matter. This organic matter is used for food by the microorganisms. At the same time, air moving through the open spaces in the filter transfers oxygen to the wastewater. This oxygen is then transferred to the slime to keep the outer layer aerobic. As the microorganisms use the food and oxygen, they produce more organisms, carbon dioxide, sulfates, nitrates, and other stable by-products; these materials are then discarded from the slime back into the wastewater flow and are carried out of the filter. The process is shown in the following equation:

Organics + Organisms → More Organisms + CO + Solid Wastes

The growth of the microorganisms and the buildup of solid wastes in the slime make it thicker and heavier. When this slime becomes too thick, the wastewater flow breaks off parts of the slime. These must be removed in the final settling tank. In some trickling filters, a portion of the filter effluent is returned to the head of the trickling filter to level out variations in flow and improves operations (recirculation).

5.3 Rotating Biological contactors

The RBC is a biological treatment system and is a variation of the attached growth idea provided by the trickling filter. Still relying on microorganisms that grow on the surface of a medium, the RBC is a fixed film biological treatment device; the basic biological process is similar to that occurring in the trickling filter. An RBC consists of a series of closely spaced (mounted side by side), circular, plastic (synthetic) disks that are typically about 3.5 m in diameter and attached to a rotating horizontal shaft. Approximately 40% of each disk is submersed in a tank containing the wastewater to be treated. As the RBC rotates, the attached biomass film (zoogleal slime) that grows on the surface of the disk moves into and out of the wastewater. While submerged in the wastewater, the microorganisms absorb organics; while they are rotated out of the wastewater, they are supplied with needed oxygen for aerobic decomposition. As the zoogleal slime reenters the wastewater, excess solids and waste products are stripped off the media as sloughings. These sloughings are transported with the wastewater flow to a settling tank for removal. Modular RBC units are placed in series simply because a single contactor is not sufficient to achieve the desired level of treatment; the resulting treatment achieved exceeds conventional secondary treatment. Each individual contactor is called a stage and the group is known as a train. Most RBC systems consist of two or more trains with three or more stages in each. The key advantage in using RBCs instead of trickling filters is that RBCs are easier to operate under varying load conditions, since it is easier to keep the solid medium wet at all times. The level of nitrification, which can be achieved by a RBC system, is also significant. This is especially the case when multiple stages are employed.

5.4 Activated Sludge

The biological treatment systems discussed to this point (ponds, trickling filters, and RBCs) have been around for years. The trickling filter, for example, has been around and successfully used since the late 1800s. The problem with ponds, trickling filters, and RBCs is that they are temperature sensitive and remove less BOD. In addition, trickling filters cost more to build than the activated sludge systems that were later developed.

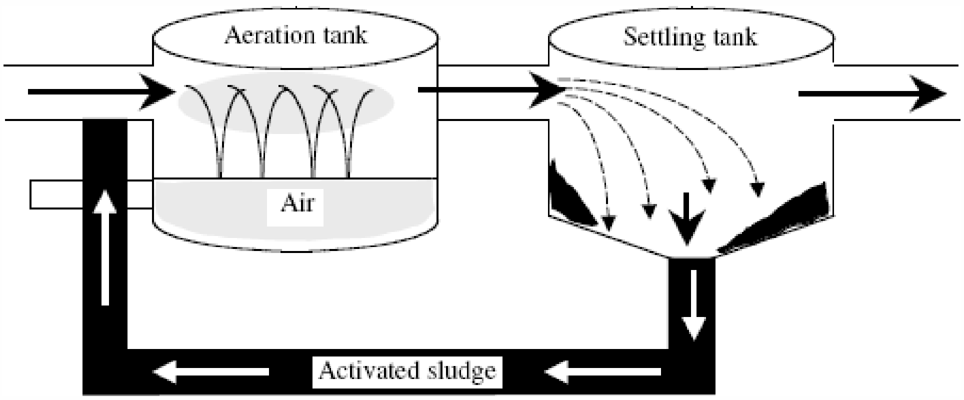


Fig. 2 Activated sludge Process

As shown in Figure 2, the activated sludge process follows primary settling. The basic components of an activated sludge sewage treatment system include an aeration tank and a secondary basin, settling basin, or clarifier (see Figure 2) Primary effluent is mixed with settled solids recycled from the secondary clarifier and is then introduced into the aeration tank. Compressed air is injected continuously into the mixture through porous diffusers located at the bottom of the tank, usually along one side. Wastewater is fed continuously into an aerated tank, where the microorganisms metabolize and biologically flocculate the organics. Microorganisms (activated sludge) are settled from the aerated mixed liquor under quiescent conditions in the final clarifier and are returned to the aeration tank. Left uncontrolled, the number of organisms would eventually become too great; therefore, some must periodically be removed (wasted). A portion of the concentrated solids from the bottom of the settling tank must be removed from the process (waste activated sludge). Clear supernatant from the final settling tank is the plant effluent.

The activated sludge process is a treatment technique in which wastewater and reused biological sludge full of living microorganisms are mixed and aerated. The biological solids are then separated from the treated wastewater in a clarifier and are returned to the aeration process or wasted. The microorganisms are mixed thoroughly with the incoming organic material, and they grow and reproduce by using the organic material as food. As they grow and are mixed with air, the individual organisms cling together (flocculate). Once flocculated, they more readily settle in the secondary clarifiers. The wastewater being treated flows continuously into an aeration tank where air is injected to mix the wastewater with the returned activated sludge and to supply the oxygen needed by the microbes to live and feed on the organics. Aeration can be supplied by injection through air diffusers in the bottom of tank or by mechanical aerators located at the surface. The mixture of activated sludge and wastewater in the aeration tank is called the mixed liquor. The mixed liquor flows to a secondary clarifier where the activated sludge is allowed to settle. The activated sludge is constantly growing, and more is produced than can be returned for use in the aeration basin. Some of this sludge must be wasted to a sludge handling system for treatment and disposal. The volume of sludge returned to the aeration basins is normally 40 to 60% of the wastewater flow. The rest is wasted.

4. DISINFECTION OF WASTEWATER

Like drinking water, liquid wastewater effluent is disinfected. Unlike drinking water, wastewater effluent is disinfected not to directly (direct end-of-pipe connection) protects a drinking water supply, but instead is treated to protect public health in general. This is particularly important when the secondary effluent is discharged into a body of water used for swimming or for a downstream water supply. Chlorination for disinfection, as shown in Figure 1, follows all other steps in conventional wastewater treatment. The purpose of chlorination is to reduce the population of organisms in the wastewater to levels low enough to ensure that pathogenic organisms will not be present in sufficient quantities to cause disease when discharged.

5. CASE STUDY – EFFLUENT TREATMNET IN A TEXTILE INDUSTRY (Babu et. al., 2000)

Textile industry can be classified into three categories viz., cotton, woolen, and syntheticfibers depending upon the raw materials used. The cotton textile industry is one of the oldest industries in the country with over 1000 industries (or mills) mainly centered in Mumbai, Surat, Ahmedabad, Coimbatore, and Kanpur. The water consumption and wastewater generation from a textile industry depends upon the processing operations employed during the conversion of fiber to textile fabric. On the basis of waste and wastewater (or effluent) generation, the textile mills can be classified (ISPCH, 1995) into two main groups viz., Dry processing mill and Woven fabric finishing mills. In general, the wastewater from a typical cotton textile industry is characterized by high values of BOD, COD, color, and pH (ISPCH, 1995). Because of the high BOD, the untreated textile wastewater can cause rapid depletion of dissolved oxygen if it is directly discharged into the surface water sources. The effluents with high levels of COD are toxic to biological life (Metcalf & Eddy, 1991). The high alkalinity and traces of chromium (employed in dyes) adversely affect the aquatic life and also interfere with the biological treatment process. The high color renders the water unfit for use at the downstream of the disposal point (Rao and Datta, 1987).

The present study focuses on the improvement in wastewater treatment for a cotton textile industry located in Mumbai. The industry produces 5 lakh square meter of cloth per day with 100% cotton from 82,000 kg of cotton yarn. The wastewater generation is

2500 m3/day. The inlet BOD and COD concentrations are 600 mg/L and 1200 mg/L respectively whereas the desired concentrations of these two parameters are < 30 mg/L and < 250 mg/L respectively for disposal into surface water sources (TEDDY, 1998). The existing treatment units comprise of Neutralisation/equalisation tank, Aeration tank, Reactor-I employing anaerobic biological treatment, Reactor-II employing aerobic biological treatment, and secondary clarifier. It is observed that, presently no particular bacteria is being developed (Hitesh, 1998) and employed either in Reactor-I or Reactor-II. The industry is able to bring down the COD and BOD levels of the treated effluent below the permissible limits for disposal into surface water by employing the above mentioned unit operations. Hence, the industry is not facing any problem from the State Pollution Control Board with regard to discharge of wastewater into surface water sources. However, in view of no systematic development of bacteria at Effluent Treatment Plant (ETP), it is felt appropriate to study the effect of bacteria developed specifically for the biological treatment of wastewater from this industry. High levels of COD are expected (Hitesh, 1998) from dyeing section due to the nature of chemicals employed in the operation. Escherichia Coli (E-Coli) type bacteria is developed in the laboratory and tested for removal of COD from the effluents generated due to the usage of three different types of reactive dyeing methods viz., Exhaust, Pad-Dry-Cure, and Pad-Batch. In addition to the biological treatment, experimental study is also carried out to simulate stabilisation pond and aeration tank in the lab in a series operation. Recommendations for further polishing treatment of the effluent are also addressed in the present study.

Literature survey is carried out to study the different unit operations employed for treatment of wastewater from cotton textile industries. Pretreatment for removal of inorganic solids and floating material, flow equalisation and neutralisation, chemical coagulation, clarification, and biological treatment are the most common unit operations employed (Rao and Datta, 1987; ISPCH, 1995) in the textile wastewater treatment. Aerated lagoon or stabilisation ponds with shallow depths are also reported in giving encouraging results (Arcievala and Mohanrao, 1969; Sastry, 1972; Rao and Datta, 1987). A COD removal of 45% and BOD removal of 75% is reported for a textile industry effluent employing primary and secondary treatment units (ISPCH, 1995). The unit operations employed is flow equalisation/neutralisation, clariflocculator using alum as coagulant, and activated sludge process with secondary clarifier. Enough literature is available (Babbit and Bauman, 1958; O.Connor and Eckenfelder, 1960; Arcievala and Mohanrao, 1969; Clarke et al., 1971; Kharker et al., 1972; Mc.Kinney, 1971; Ansari, 1972; Sastry, 1972; Bela, 1974; Berthouex and Rudd, 1976; Golterman and Clymo, 1978; Arcievala, 1981; Rao and Datta, 1987; Metcalf and Eddy, 1991, Elangovan and Saseetharan, 1997) on each of the above unit operations. Little literature is available pertaining to the study of COD generation from the earlier mentioned three reactive dyeing methods and its subsequent removal in a series operation consisting a combination of unit operations reported above. And hence, in the present study, emphasis is given to reduction of COD from the effluents generated due to the usage of three different types of reactive dyeing methods. The unit operations employed in the present study are:

- Stabilisation pond
- Aeration tank

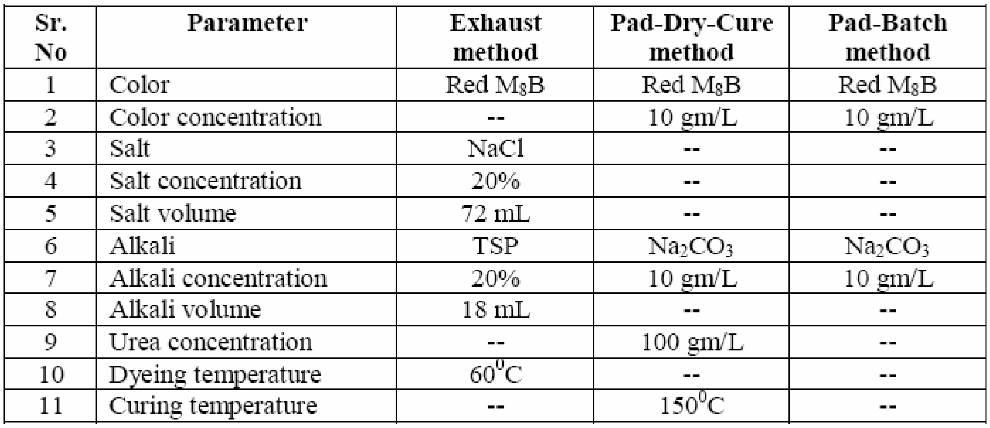
- Biological (aerobic) treatment

The results of the present study are useful in understanding the COD generation from a reactive dyeing method *vis-a vis* COD treatment technology.

5.1 Experimental Procedure

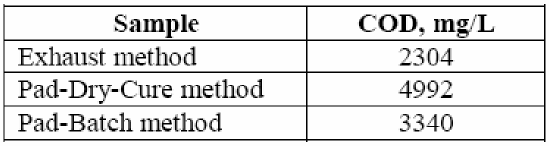
Dyes are prepared using each of the three reactive dyeing methods (CTLM, 1986). The technical details pertaining to the various chemicals used in each of three reactive dyeing methods are given in Table-1. The reactive dyeing of the cotton cloth (100% cotton) is carried out by the following procedure: 5 gm of color was taken in a beaker. For laboratory purpose, the ratio of weight of the cloth to weight of the liquor (dyeing solution) was kept at 1:3. Depending upon the color, proper amount of either common salt or Glauber's salt was added to the beaker. Proper amount of suitable alkali was used for fixing of color. The dyed cloths were washed with water and soap soda solution (2% soap and 5% soda in water). Liquor left in the container and soap water remained after washing were mixed in 1:1 ratio and were collected in three different bottles and were analysed for COD levels. The initial COD levels of the three samples are given in Table-2. The sample is made to pass through a series of the three unit operations mentioned above. All the unit operations employed in the laboratory are of batch studies only and are simulated in laboratory as follows:

Table-1 Technical details pertaining to the three reactive dyeing methods



Sr. No	Parameter	Exhaust method	Pad-Dry-Cure method	Pad-Batch method
1	Color	Red M_8B	Red M_8B	Red M_8B
2	Color concentration	--	10 gm/L	10 gm/L
3	Salt	NaCl	--	--
4	Salt concentration	20%	--	--
5	Salt volume	72 mL	--	--
6	Alkali	TSP	Na_2CO_3	Na_2CO_3
7	Alkali concentration	20%	10 gm/L	10 gm/L
8	Alkali volume	18 mL	--	--
9	Urea concentration	--	100 gm/L	--
10	Dyeing temperature	60^0C	--	--
11	Curing temperature	--	150^0C	--

Table-2 Initial COD levels of the effluent



Sample	COD, mg/L
Exhaust method	2304
Pad-Dry-Cure method	4992
Pad-Batch method	3340

5.1.1 Stabilisation Pond

Effluent generated from each of the three reactive dyeing methods is taken in three shallow circular trays of 45cm diameter and 2.5cm deep, and 180 mL of water containing algae is added to each of the trays. The effluent is mixed properly and is allowed to undergo degradation in open air in the laboratory for two days. Since the depth of the tray is very shallow, and subsequently to avoid excessive evaporation, trays are kept open to enough sunlight (Ansari, 1972) for only two hours (2 PM to 4 PM) in the day for the growth of algae. The effluent is tested for COD level after two days.

5.1.2 Aeration Tank

Three effluent samples of 650 mL from simulated stabilisation pond corresponding to those from each of the three reactive dyeing methods are collected in three different bottles and air is bubbled through all the bottles using air compressor at the rate of 0.566 m^3/min. The samples are analysed for COD level after two hours.

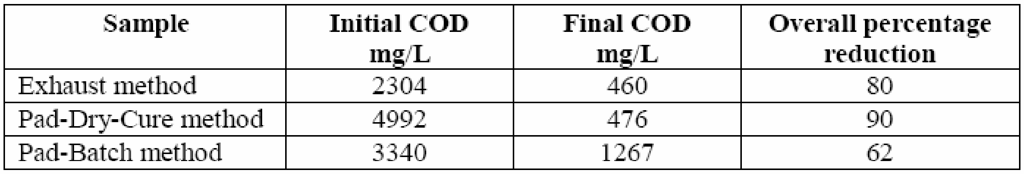
5.1.3 Biological Treatment

E-Coli type bacteria is grown in the medium for 8 hours at 350 °C and 8 to 10 mL of medium containing bacteria is added to each of the bottles containing effluent from aeration tank. The E-Coli type bacteria grow very fast, double after every 20 minutes under favorable conditions. They are predominantly aerobic bacteria in the favorable condition of pH in the range of 6 to 8. All the three bottles are kept at 350 °C temperature to ensure bacterial growth. COD levels of effluent are measured after a bacterial residence time of 8 hours.

5.2 Results and Discussion

The results of the overall reduction of COD levels in the effluent samples using the Exhaust, Pad-Dry-Cure, and Pad-Batch methods are given in Table-3.

Table-3 Overall percentage reduction of COD



Sample	Initial COD mg/L	Final COD mg/L	Overall percentage reduction
Exhaust method	2304	460	80
Pad-Dry-Cure method	4992	476	90
Pad-Batch method	3340	1267	62

From Table-3, it is clearly seen that, the COD removal efficiency of stabilisation pond, aeration tank, and aerobic biological treatments is 80%, 90%, and 62% respectively for the above three methods of reactive dyeing. The percentage COD reduction after each stage of unit operations attempted in the present study is given in Figure-1.

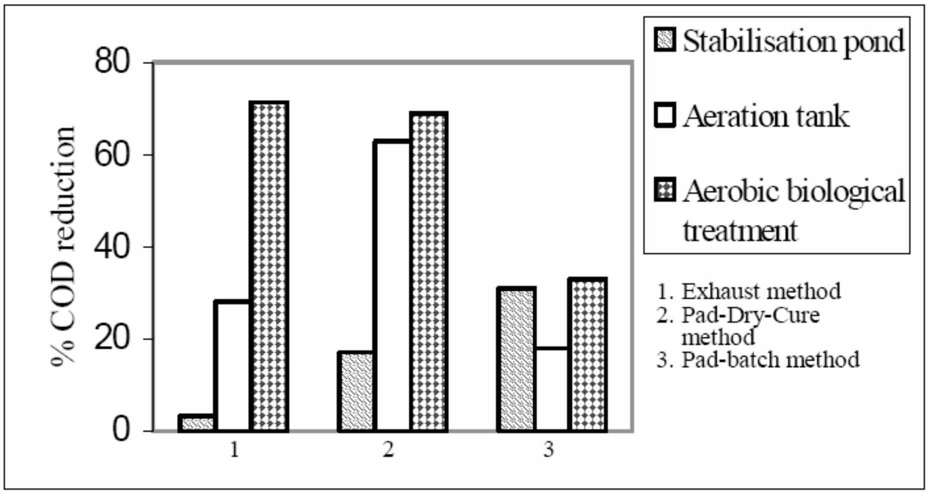


Fig. 3 Percentage COD reduction in the three Reactive Dyeing Methods

From Table-3 and Figure-1, it is to be noticed that, the overall COD removal efficiency is much higher in the samples from Exhaust and Pad-Dry-Cure methods than that of Pad-Batch sample. This could be due to the incomplete oxidation of effluent from Pad-Batch method treated in the present experimental set-up. A high COD removal efficiency is observed in the aerobic biological treatment for both Exhaust and Pad-Dry-Cure methods than that in Pad-Batch method. This can be attributed to the presence of Triple Super Phosphate (TSP) and Urea (see Table-1) and hence favorable environment for bacterial growth in the effluent from these two methods. Further, it is noticed that, the Pad-Batch sample has a high pH of 9.36, which is inhibiting the bacterial growth during biological treatment. Chemical precipitation using alum may be attempted before the Pad-Batch sample is subjected to aeration. This may help in precipitation of the chemicals present in the sample and thus encouraging further removal of COD. Despite the encouraging results obtained in the present experimental set-up, the COD level of the samples from none of the three methods has been reduced to below 250 mg/L, which is the upper limit for disposal of effluent into inland surface water. Polishing treatment using activated carbon can further reduce the COD levels of the textile industry effluents (ISPCH, 1995) by 81%. The COD levels of each of the three reactive dyeing methods after the experimental studies are 460 mg/L, 476 mg/L, and 1267 mg/L respectively (see Table-3). If the effluent is treated with activated carbon having 81% COD removal efficiency, the theoretical COD levels of the samples from each of the three reactive dyeing methods are expected to be 89.44 mg/L, 90.44 mg/L, and 241 mg/L respectively. It may be noted from the above results that, the COD levels of all the samples can be brought below 250 mg/L, which is the upper limit for disposal of effluent in surface water sources. Since the COD level of the sample from Pad-Batch method very closely matches (~ 241 mg/L) with the upper limit (250 mg/L) of COD for disposal into surface water sources, its exact COD removal efficiency after treatment with activated carbon is to be ascertained through a series of laboratory studies. A neutralisation tank may be provided to bring the variation in the pH of the effluent after biological treatment under control as per the prescribed limits (pH: 5.5 to 9) before it is safely disposed into surface water sources. A settling tank is to be provided to settle the biological solids from the biological treatment. Disinfection of bacteria remaining, if any, in the effluent renders the textile industry effluent harmless for safe disposal. After assessing the results of the present study and other technical aspects involved in further polishing the COD removal of the effluents from the three reactive dyeing methods employed in the cotton textile industry under consideration, a flow diagram (Figure-2) is proposed with a combination of unit operations for better results. The polishing treatment using activated carbon can also reduce the BOD and color of the textile industry effluents by 81% and 99.4% respectively (ISPCH, 1995). When the proposed experimental set-up is compared with that of the existing unit operations at the ETP of the industry, it is to be noticed that, Reactor-I employing anaerobic biological treatment is mainly being used for COD reduction. The results of present study revealed that, satisfactory results can be achieved with aerobic biological treatment and polishing treatment. Since the dye house effluents contribute more COD load in the overall effluent from the industry, the present study is advantageous in the cost reduction of ETP. The present study thus emphasizes the significance of *minimizing* the pollutant (COD) load in the effluent to be treated at the *end-of-pipe* i.e, at ETP. This will help the industry in minimizing the *cost* and *space requirements* needed for effluent treatment.

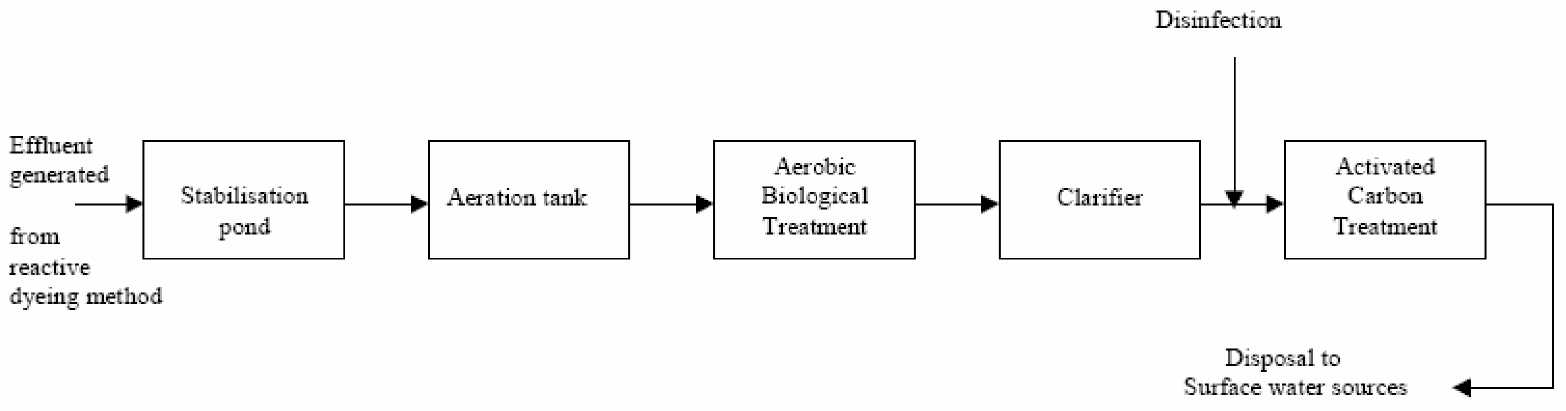


Fig. 4 Flow diagram for COD reduction for the effluents generated from a cotton textile industry Employing reactive dyeing methods

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