Feasibility Studies on Recycling/Reuse of Wastewater from Automobile Industry

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CERTIFICATE

This is to certify, that the M.Tech project entitled **"Feasibility Studies on Recycling/Reuse of Wastewater from Automobile Industry"** is an original piece of work carried out by Shuchi Tayal, a student of M.Tech (Environmental Science and Technology) for the partial fulfillment of the degree of Master of Technology, Thapar University, Patiala, This project report is upto required standard of its contents and presentation and no part of this project has been submitted for the award of any other degree.

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Declaration

I, the undersigned hereby declare that the research work presented in the M.Tech project entitled "Feasibility Studies on Recycling/Reuse of Wastewater from Automobile Industry" has been carried out under the guidance of Mr. Pravin Manekar, Scientist 'C', NEERI, Nagpur and supervision of Dr. Tapas Nandy, Scientist G & Head, WWT Division, NEERI, Nagpur. Further, I declare that no part of this Dissertation has been submitted for a degree or any other qualification of any other university or examining body in India/elsewhere.

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1.0 INTRODUCTION

Water is a resource circulated through ecosystem and is capable of diversion, transport, storage, and recycling. Groundwater and surface water are the two major sources available for human consumption. Water is critical for development. Over the decades, the demand for water has multiplied due to population growth, rapid industrialization, climatic changes & overexploitation of existing water resources. Therefore existing water recourses demand sustainable management through scientific approach. India is a large country having uncertain monsoon patterns which leads to water scarcity & droughts. The total water requirement for various activities in year 2050 has been assessed at 1450 km^3/annum. This is significantly more than the current estimate of utilizable water resource potential (1122 km^3/annum). Therefore, when compared with the existing availability of 500 km^3/annum, the water availability around 2050 needs to be almost trebled.

The alternative approaches for conservation of water through rainwater harvesting & groundwater recharge, inter basin transfer (Gupta and Deshpande, 2004) recycle/reuse of domestic sewage and industrial wastewater. Rainwater harvesting is the technology used for collecting and storing water from rooftops. The techniques usually found in Asia and Africa arise from practices employed by ancient civilizations within these regions and still serve as a major source of drinking water supply in rural areas. The main advantages of this technology are simple to install and operate, provides water at the point of consumption, less operational and maintenance costs. The disadvantages are limited supply and uncertainty of rainfall. Another approach is interlinking of Rivers.

The main aim of interlinking of rivers is to mitigate flood problem and drought in different regions of the country. Apart from addressing the problems of floods and water scarcity, interlinking of rivers has enormous potential to deliver substantial and cost-effective hydroelectric power, enhancing food security and an alternative transport system of navigable waterways. The disadvantages are rehabilitation problems, increased water logging, new breeding grounds for mosquitoes and epidemics such as malaria.

Some of the sources of water availability for reclamation and recycle/reuse are seawater, brackish water, sanitary sewage, industrial effluents and agricultural runoff. There are many industries namely textile, tannery, distillery, pulp and paper refinery and dairy, where recycle/reuse of treated wastewater are practiced. The footprint of automobile industries for recycle/reuse of treated effluent is less.

The manufacturing of heavy commercial vehicle had given rise to a new era in the Indian history. Slowly many firms started setting up various small manufacturing units. Automobile industry in India is one of the largest in the world. India manufactures over 11 million vehicles (including 2 wheelers and 4 wheelers) and exports about 1.5 million every year. India is the world's second largest manufacturer of motorcycles, with annual sales exceeding 8.5 million in 2009. India's passenger car and commercial vehicle manufacturing industry is the seventh largest in the world, with an annual production of more than 2.6 million units in 2009.

Indian automobile industry is the tenth largest in the world with an annual production of approximately 2 million units. This industry plays a vital role in the Indian economy. Its connections with various other sectors become an important component of the economy. Various industries such as steel and rubber largely depend on the auto industry. The automobile industry plays a significant role in shaping the country’s economy and development. This industry demands high water consumption and generates large quantity of effluent with variety of pollutants.

The wastewater from automobile industry consists of high organic, inorganic matter with oil and grease and heavy metals. If partially treated or untreated wastewater is discharged to damage the geo-environment. Sustainable growth in automobile industry warrants water conservation. The effluents recycle/reuse provides a novel opportunity to augment the increasing demand and enhance the idea of closing the water cycle (Takashi Asano, 2002). Water reclamation refers to the capture, treatment, and recycling/reuse of wastewater, typically for non-potable purposes. Implementation of wastewater reclamation, recycling/reuse need to be promoted for preservation of limited water resources. The automobile industry is therefore, a prime member for the recycle/reuse of treated wastewater. Recycled water satisfies more water demands in automobile industry, as long as it is adequately treated. The issues like water quality criteria, techno-economic analysis are essential components for water reuse.

The treatment technologies engaged for treating the automobile effluent are dissolved air floatation (DAF) (Reed et. al. 1998), oil & water separator and chemical treatment, where coagulant like alum, ferrous sulphate and calcium chlorite and coagulant aid PAC are added (Mazumder and Mukherjee; 2011). The biological treatment includes biological filter, sequencing batch reactor (SBR), anaerobic sequencing batch biofilm reactor **(**Oliveira et al; 2007) and constructed wetlands (Cañizares et al. 2008). In advance treatment system such as ultrafiltration (UF) (Zhao et al. 2006) is used for water recovery. Among all technologies, ultrafiltraion is found to be most efficient (Mazumder and Mukherjee; 2011) for recovery of water.

An attempt is made to access the feasibility of recycle/ reuse of wastewater from automobile industry through conventional and advanced treatment process. Studies were carried out on secondary treated effluent on laboratory and pilot scale model on sand filtration and activated carbon column with chlorination process. The treatment scheme comprises oil and grease separator, chemical treatment, and bio-oxidation process followed by filtration and adsorption processes with or without membrane separation process is a techno-economical viable option for recycle/reuse of treated water. The water conservation in automobile industry can achieved through recycle/reuse of treated effluent.

2.0 AIMS AND OBJECTIVES

The main aim of the project is to assess the feasibility of recycling/reuse of treated effluent from automobile industry. The objectives of the project are as follows:

- Characterization of industrial effluent and domestic wastewater.
- Performance of existing effluent treatment plant.
- Characterization of secondary treated effluent.
- Lab scale studies on secondary treated effluent for recycle/reuse.
- Optimization of engineering parameter of sand filter and activated carbon column.
- Determination of adsorption capacity of granular activated carbon (GAC).
- Delineation of appropriate treatment scheme for recycle/reuse of automobile industry.
- Design of proposed treatment scheme.

3.0 STUDY AREA

Tata Motors Limited (TML), Pimpri, Pune was established in 1966, and spread over 800 acres of land. The company is the second and fourth largest bus and truck manufacturer in the world. It is mainly engaged in the design and manufacture of sophisticate press tools, jigs, fixtures, gauges, metal pattern and special tools. TML has introduced new products to improve the existing one. For that four assembly lines have been established, each one for heavy commercial vehicles (HCVs), medium commercial vehicles (MCVs) and low commercial vehicles (LCVs).

The annual vehicles production at TML, Pimpri are around 3 lakhs and generates huge quantity of effluents from different machines, paint booths, pretreatment tanks, floor washing etc. Apart from industrial effluent, it also generates considerable amount of domestic sewage from canteens and various toilets in shops, offices and locker rooms.

4.0 LITERATURE REVIEW

In many parts of the world, health problems and diseases have often been caused by discharging untreated or inadequately treated industrial wastewater and domestic sewage. This results in the spreading of diseases, fish skills and destruction of other forms of aquatic life. Water quality degradation is a global concern that will intensify with increasing water demand. Saving water to save the planet earth and to ensure a safe future for mankind is the ultimate need of the hour. With the growth of mankind, society, science and technology our world is reaching to new high horizons but the cost which we are paying or will pay in near future is surely going to be too high. Therefore, selection of appropriate wastewater treatment technologies is most important thing in planning the water reuse system. The technology must be environmentally suitable, appropriate to the local conditions, techno-economical, protect the consumer from pathogens and should be compatible for recycle/reuse of water for industrial process. Technology available are many and well known, but choice should rely on those not entailing excessive cost, providing sound environmental practice and option for reuse of wastewater.

Technologies for treating the wastewater are conventional and advanced treatment in which pollutants are converted to the environmental acceptable form. The conventional treatment comprises physical, chemical and biological methods and advanced treatment process includes advanced oxidation process and membrane separation process. In conventional treatment, primary treatment is designed for removal of oil and grease, suspended solids and partial removal of organic matter. The objective of secondary treatment is to remove the dissolved and colloidal organics and suspended solids that have escaped from primary treatment. In fact, the conventional wastewater treatment processes have been long established in removing many chemical and microbial contaminants of concern to public health and the environment. However, the effectiveness of these processes have become limited over the last decades because of new challenges and public awareness. Tertiary and advanced treatment technologies have potential to remove various harmful compounds with conventional treatment processes. The conventional and advanced treatment processes are as follows:

4.1 Oil and Grease Removal

Recent studies show that the benzene, toluene and xylene pollutants are occasionally associated with oil and grease discharges. Benzene is of particular concern as it has been listed as a Carcinogen (Paul et al; 1986). Oil and grease in the wastewater can be removed by the use of widely accepted techniques. Since the removal of oil and grease depends on the condition of the oil-water mixture, the type of equipment must be carefully selected. The type of oil-water mixture may be classified as oil and grease present as free oil, dispersed oil, emulsified oil or dissolved oil (Snider et al.; 1983). Dissolved air flotation (DAF) devices utilize the gravity separation concept for the removal of oil and grease from wastewater but tend to be more effective than API Separators in removing the dispersed oil mixture (James et al.; 1985). Induced Air Flotation Oil-Water Separation system separates oil and suspended solids attached to the air bubbles, these are carried to the surface of the water, where they form a froth. A skimmer paddle sweeps the oil and solids-laden froth into an overflow chamber (Hossian et al.; 1973). Carbon adsorption or membrane filtration using reserve osmosis treatment is very effective to remove dissolved and emulsified oils (Nori et al., 1999). The concept of ultrafiltration is based on the sieving action of a membrane retaining molecules larger than the membrane pores. The effluent from these operations contains essentially no oil and grease (Davis et al.; 1977). The disadvantage of oil removal are that the dissolved oils present in the wastewater cannot be removed and also the removed oil is to be disposed off and the water needs further treatment and it is also sensitive to shock loadings (Kalrt et al., 1995).

4.2 Chemical precipitation

Chemical precipitation is widely used physico – chemical technique in which the chemical equilibrium of a waste is changed to reduce the solubility of the undesired components. The method which combines coagulation and filtration is called contact filtration and has become more popular in recent years (Boller et al., 1984). Conventional filtration processes are normally preceded by coagulation, flocculation, and sedimentation. Direct filtration processes are preceded by coagulation and flocculation only; the flocs formed are removed directly by the filters (Manning et al., 1983).

(Hultman et al., 1984) found that that two-point precipitation is advantageous if low effluent pollutant concentration is required. (Menar et al., 1970) presented an involvement of the precipitation mechanism in an enhanced phosphorus removal. (Greben et al., 1991) found that chemical precipitation makes an important contribution to pollutant removal because of the occurrence of natural precipitants.The various chemicals used for chemical precipitation treatment are sodium hydroxide, sodium sulphide, Alum, iron salts such as iron sulphide, ferric sulphate, phosphate salts (especially for heavy metals such as As, Cd, Cr, Zn, Cu, Pb, Hg and Ni) and hydrated lime (Else et al., 1996). The chemical precipitation is widely adopted because there is no upper limit of concentrations that can be treated also it requires very less energy and can be applied economically to very large volumes of wastewater (Webb et al., 1992). But there are some serious problems associated with this process are that the properties of wastewater continuously changes so the dose of chemicals has to be changed continuously also large quantities of hazardous sludge is generated. High total dissolved solids and chelating reagents reduce the performance of chemical precipitation process (Wooler et al., 1999).

4.3 Trickling filter

A trickling filter consists of a bed of rocks, gravel, slag, peat moss, or plastic media over which wastewater trickles and contacts a layer (or film) of microbial slime covering the bed media (Burton et al.; 2003). Aerobic conditions are maintained by forced air flowing through the bed or by natural convection of air. The process involves adsorption of organic compounds in the wastewater by the microbial slime layer, diffusion of air into the slime layer to provide the oxygen required for the biochemical oxidation of the organic compounds (Milton et al 1967). Trickling filters are very efficient at removing B.O.D. and ammonia from wastewater. The organisms present in the biofilm aerobically decompose the solids producing more organisms and stable wastes, which either become part of the slime or are discharged back into the wastewater flowing over the media. The wastewater continues through the filter to the underdrain system where it is collected and carried out of the filter. At the same time air flows through the filter (bottom to the top or top to bommtom depending on temperature).

Oxygen is transferred from the air to the wastewater and slime to maintain the aerobic conditions. Periodically the slime on the media becomes too heavy and portions are released (Onis et al., 2003). Trickling filter is preferred because it is effective in treating high concentrations of organic material depending on the type of media used and it is also very efficient in removal of ammonia from wastewater and also because the cost to operate a trickling filter is very low (Minc et al., 1993). There are also some problems associated with trickling filters like additional treatment may be needed for the effluent to meet strict discharge standards also, relatively high incidence of clogging occur so in order to prevent these relatively low loadings required depending on the media (Ben et al., 1990).

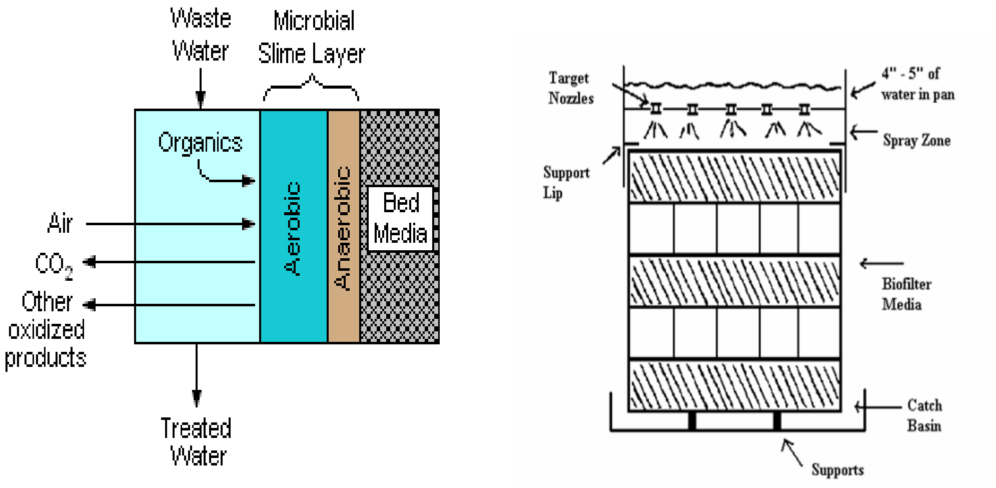

Figure 4.1 Trickling Filter

4.4 Sequential batch reactor (SBR)

Sequential batch reactors (SBRs) are used all over the world. These are used to treat both municipal and industrial wastewater (Ghough et al., 2001) High strength wastewaters are produced from various industrial plants including dairy, paper mill, tanneries and textiles and can be effectively treated using SBR (Whichard et al., 1998). It is used in sewage treatment especially for nutrient removal. In the SBR operation, the aeration and sedimentation processes are carried out sequentially in the same tank rather than simultaneously in separate tanks as for the conventional activated sludge system (Neczaj et al., 2002) . SBR treats wastewater such as sewage or output from anaerobic digesters or mechanical biological treatment facilities in batches. Oxygen is bubbled through the waste water to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) to make suitable for discharge into sewers or for use on land. The reactor has a “flow through” system, with raw wastewater (influent) coming in at one end and treated water (effluent) flowing out the other, while one tank is in settle/decant mode the other is aerating and filling (Kapdan et al., 1990). The advantages of SBR are that Equalization, primary clarification, biological treatment, and secondary clarification can be achieved in a single reactor vessel and the potential capital cost is saved by eliminating clarifiers and other equipment (Allen et al., 1992). But there are certain disadvantages of SBR like requirement for equalization after the SBR, depending on the downstream processes also efficiently discharging of floating or settled sludge during the decant phase (Jern et al., 2003).

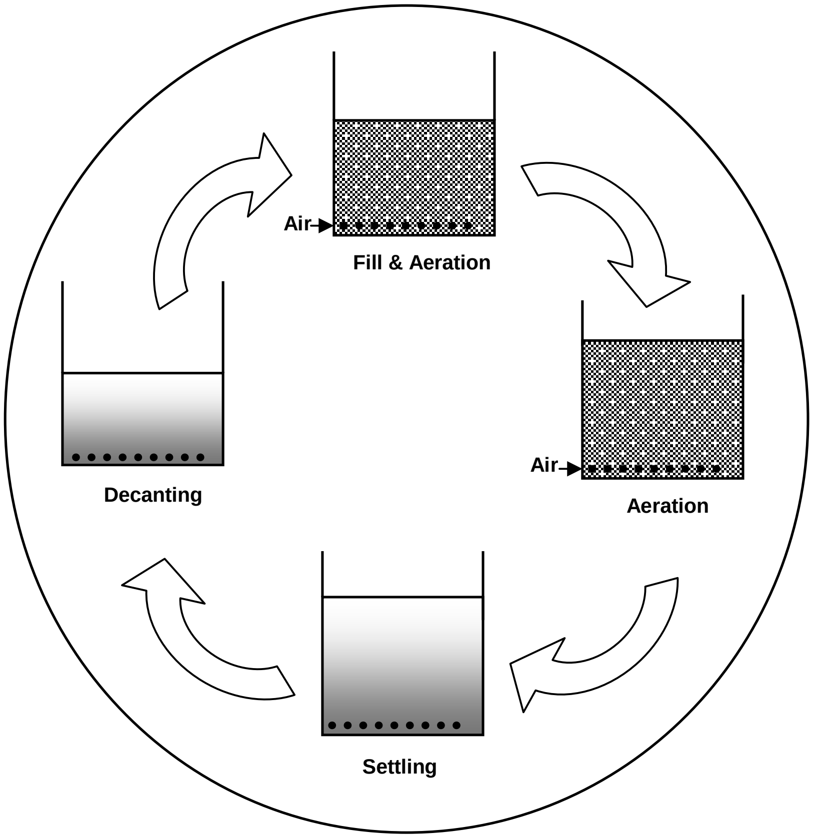

Figure 4.2: Cycle phases of SBR operation

4.5 Activated Sludge Process

Activated sludge is a process for treating sewage and industrial wastewaters using air and a biological floc composed of bacteria and protozoans. The activated sludge process is a continuous or semicontinuous(fill and draw) aerobic method for biological wastewater treatment, including carbonaceous oxidation and nitrification (Heymann et al.,2010). The process involves air or oxygen being introduced into a mixture of primary treated or screened sewage or industrial wastewater (called wastewater from now on) combined with organisms to develop a biological floc which reduces the organic content of the sewage (Rich et al.,2004). The separation of the flocs from the treated wastewater is performed by settling (gravity separation) but it may also be done by flotation. The advantages of activates sludge process are that it is capable of removing 97% of the suspended solids and also it does not require addition of any chemical for removal of biological phosphorus and it also efficiently separates the solids and liquids (Beychok et al.,1997). But there are certain disadvantages of activated sludge process and these are that it is inefficient in removing color from industrial wastewater rather it adds to the color due to the formation of highly colored intermediates through oxidation and is also insufficient in removing nutrients for which tertiary treatment is required (Wiley et al.,1992).

4.6 Anaerobic Process

Anaerobic digestion is a process in which microorganisms break down biodegradable material in the absence of oxygen, it is used for industrial or domestic purposes to manage waste (Buchanan et al.,2003).The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria (Smith et al.,2000). Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide (Shaw et al.,2001). It is widely used as a source of renewable energy as the process produces a biogas, comprising of methane and carbon dioxide. The utilization of biogas as a fuel helps to replace fossil fuels. The nutrient-rich digestate that is also produced can be used as fertilizer. It also reduces the emission of landfill gas into the atmosphere. The advantages of using anaerobic process are less production of biological sludge, production of methane gas and almost all organic matter is biodegraded (Tsao et al.,2004). Inspite of so many advantages there are some disadvantages which limit the use of anaerobic process such as it takes long start up time, after anaerobic process anerobic process may be required to meet discharge requirements and also produces high odors and corrosive gases (Dhruti et al.,1994).

4.7 Filtration process

There are basically two types of filtration processes, surface filtration and depth filtration. In surface filtration the suspended particles are adhered only on the surface of the filtering media. Removal of solids is effected by the previously deposited solids or cake, as cake builds up resistance to flow also increases (Bryan et al.; 1960). Filter aids, such as, diatomaceous earth and porous silica particles, are often added as a layer on the medium for additional support (called precoat) to reduce compression of the cake and impart high permeability. Frequent Backwashing is required in such type of filtration process. In contrast, to this in depth filtration the suspended particles enter into the porous medium. In this case the medium provides the surface area for attachment and cake growth forms around the grains. (Example: sand filters). Basically there are two types of depth filters, slow sand filters and Rapid sand filters.

4.7.1 Slow sand filters

Slow sand filter consists of the fine sand, supported by gravel. It has been found that biological action occurs in slow sand filter beds. It is due to low hydraulic loading and smaller sand size found in slow sand filters. Most of the solid particles are removed within the top 0.5 - 2 cm of sand. With time biological film called the schmutzdecke (dirty layer) also known as a zone of biological activity within the sand bed develops (Calaway et al., 1952). Rate of filtration in case of slow sand filters is small, that is 0.04 to 0.4 m^3/m^2 hr. The particles are captured near the surface of the bed and are usually cleaned by scrapping away the top layer of the sand that contains the particles. Effective size of slow sand filters lies between 0.15mm to 0.35mm.

4.7.2 Rapid sand filters

Rapid sand filter consist of larger sand grains supported by gravel and capture particles throughout the bed. These are cleaned by backwashing mechanism. Rate of filtration in case of rapid sand filters is 5-8 m^3/m^2 hr. At low rates of filtration, particles are primarily removed in the upper layers of the filter, causing clogging even though pore spaces in the lower layers are relatively unobstructed. At higher filtration rates, however, large particles penetrate deeper into the filter bed before they are removed such that the head loss per mass of particles removed is lower (Darby et al., 1991; Kauet al., 1995). Furthermore, most studies have demonstrated that increasing the filtration rate has only a minimal impact on removal efficiency of suspended solids (Tebbutt et al., 1971; Dawda et al., 1978; Darby et al., 1991; Kau et al., 1995). In case of rapid sand filters the sand used has an effective size of 0.35 to 0.55 mm. Rapid sand filters are quite flexible for meeting reasonable variation in demand as compared to slow sand filters. Depth filters are also classified on the basis of type of operation (down flow or upflow). Down flow filters are mainly conventional down flow filters or deep bed down flow filters in which the flow of water is from the top of the filter (Tchobanoglous et al.; 1970). In Upflow filters the water or waste water to be treated is introduced into the bottom of the filter and is distributed evenly into the sand bed through the open bottom.

4.7.3 Mechanism

The principle processes by which particles are brought into contact with the filter medium consists of screening, sedimentation, inertial and centrifugal forces, diffusion, mass attraction and electrostatic and electro kinetic attraction.

4.7.3.1 Screening

Screening is the process for the interception and retention of particles too large to pass through the interstices between the grains of sand. It takes place almost entirely at the surface of the filter, and is independent of the filtration rate. Interception occurs when particle motion along a streamline is close enough to the collector for contact to occur. Although interception has been considered a distinct transport mechanism, some researchers have incorporated it as a boundary condition for attachment resulting from diffusion and sedimentation (Amirtharajah et al,; 1988).

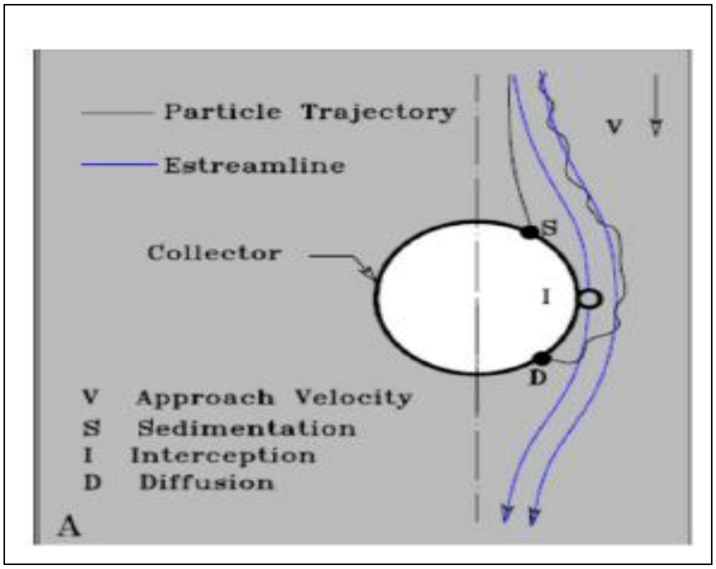

Figure 4.3 Mechanism of interception

4.7.3.2 Sedimentation

The settling action within the pores, whereby particulate suspended matter is precipitated onto the sand grains. (Yao et al., 1971), it plays an important role in filtration because of the large surface area on the grains available for deposition. Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained, and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity, centrifugal acceleration or electromagnetism (David et al., 2009).

4.7.3.3 Inertial and centrifugal forces

The particles having specific gravity higher than the surrounding water, leave the flow lines due to the inertial and centrifugal forces acting upon them (Figure 4.4).

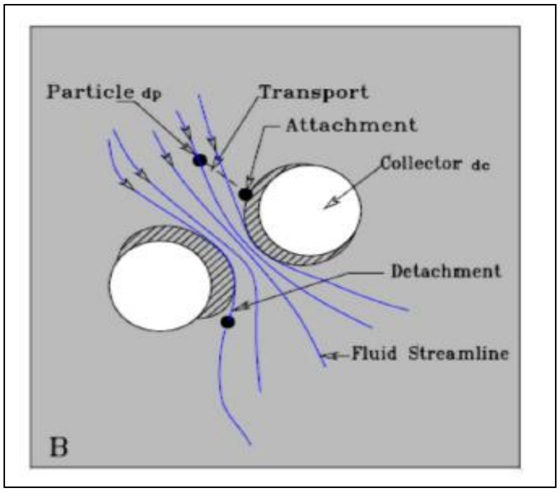

Figure 4.4 :Transport mechanism due to centrifugal and inertial forces

4.7.3.4 Diffusion

Diffusion brings suspended particles into contact with the surface of the sand (Yao et al., 1971). It describes the spread of particles through random motion from regions of higher concentration to regions of lower concentration (Zistt et al., 1989).

4.7.3.5 Mass attraction

Mass attraction is also known as Vander Walls force of attraction. This force acts universally and contributes to both the transport and the attachment mechanisms (Eliassen et al., 1970).

4.8 Types of rapid filters

There are number of different types of RSFs depending upon bed depth (example, shallow, conventional and deep bed) and the type of filtering medium used (monomedia, dual- media, and multi medium). Typically sand is used as the filtering material in single medium filters. Dual- media filters usually consist of a layer of anthracite over a layer of sand (Al-Saqqar et al., 2008). The dual media filter was tested in one of the study carried out by Department of civil engineering, Amanet Baghdad College of Engineering, Water Sector, University of Baghdad, Baghdad. The results had shown that the dual filters perform better than sand filters. The results also showed that the dual filters were better in turbidity and bacterial removal as compared to single media sand filters.

4.8.1 Gravity filters

Gravity sand filters are open vessels that depend upon system gravity head for operation. Apart from filter media, the essential components of gravity filter includes filter shell (either concrete or steel), an under drain system (which ensures uniform collection of filtered water and uniform distribution of backwash water), Wash water troughs (large enough to collect backwash water without flooding), Control devices that maximize filter operation efficiency (Fuller et al., 1898).

4.8.2 Pressure filters

Pressure sand filters are similar to gravity filters in that they include filter media, supporting bed, under drain system, and control device; however, the filter shell has no wash water troughs. Pressure filters, designed vertically or horizontally, have cylindrical steel shells and dished heads. Vertical pressure filters range in diameter from 0.3 to 3 m with capacities as great as 70 m^3/hr at filtration rates of 8 m^3/m^2 hr. Horizontal pressure filters, usually 2.4 m in diameter, are 3 – 8 m long with capacities from 45 to 135 m^3/hr. Rapid pressure sand bed filter design considerations smaller sand grains provide more surface area and therefore it leads to higher decontamination of the inlet water , but it also requires more pumping energy to drive the fluid through the bed. Most rapid pressure sand bed filters use grains in the range 0.6 to 1.2 mm, larger sand grains can be used to overcome this problem, but if significant amounts of large solids are in the feed they need to be removed upstream of the sand bed filter by a process such as settling. The depth of the sand bed is recommended to be around 0.6- 1.8 m (2-6 ft) regardless of the application. Guidance on the design of rapid sand bed filters suggests that they should be operated with a maximum flow rate of 9 m^3/m^2hr (Ives et al., 1990). One of the important design considerations is that the fluid is properly distributed across the bed and that there are no preferred fluid paths where the sand may be washed away. The pressure drop across a clean sand bed is usually very low. It builds as particulate solids are captured on the bed. Particulate solids are not captured uniformly with depth, more are captured higher up with bed with the concentration gradient decaying exponentially. The shape of the filter particle size-efficiency curve is a U-shape with high rates of particle capture for the smallest and largest particles with a dip in between for mid-sized particles. The build-up of particulate solids causes an increase in the pressure loss across the bed for a given flow rate. For a pressurized rapid sand bed filter this occurs when the pressure drop is around 7 psi. The back wash fluid is pumped backwards through the bed until it is fluidized and has expanded by up to about 30% (the sand grains start to mix and as they rub together they drive off the particulate solids). The fluid flow required to fluidize the bed is typically 3 to 10 $m^3/m^2/hr$ but not run for long (a few minutes) (Coulson et al.,1991. Dual or multimedia filters are designed for 15-20 m^3/m^2 hr. On the basis of filtration methods used with different rate of flow through rapid filters may be classified as:

4.8.2.a Constant rate filtration with fixed head

In constant rate filtration with fixed head the flow through the filter is maintained at a constant rate. They are either influent controlled or effluent controlled. Pumps or weirs are used for influent control whereas effluent modulating valve that can be operated manually or mechanically (Rose et al, 1988).

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4.8.2.b Constant rate filtration with variable head

In constant rate variable filtration head, the flow through the filter is maintained at a constant rate, Pumps or weirs are used for influent control. When the head of effluent turbidity reaches a preset value, the filter is backwashed (Marker et al.; 1987)

4.8.2.c Declining-rate filtration with fixed or variable head

In declining rate filtration, the rate of flow through the filter is allowed to decline as the rate of head loss builds up with time. Declining rate filtration systems are either influent controlled or effluent controlled (Kau et al., 1995).

4.9 Components of Rapid gravity or pressure filters (Fig)

The major parts of gravity or pressure filters are

- Filter box/filter shell
- Filter media

- Gravel support
- Under drain system, and
- Wash water tanks

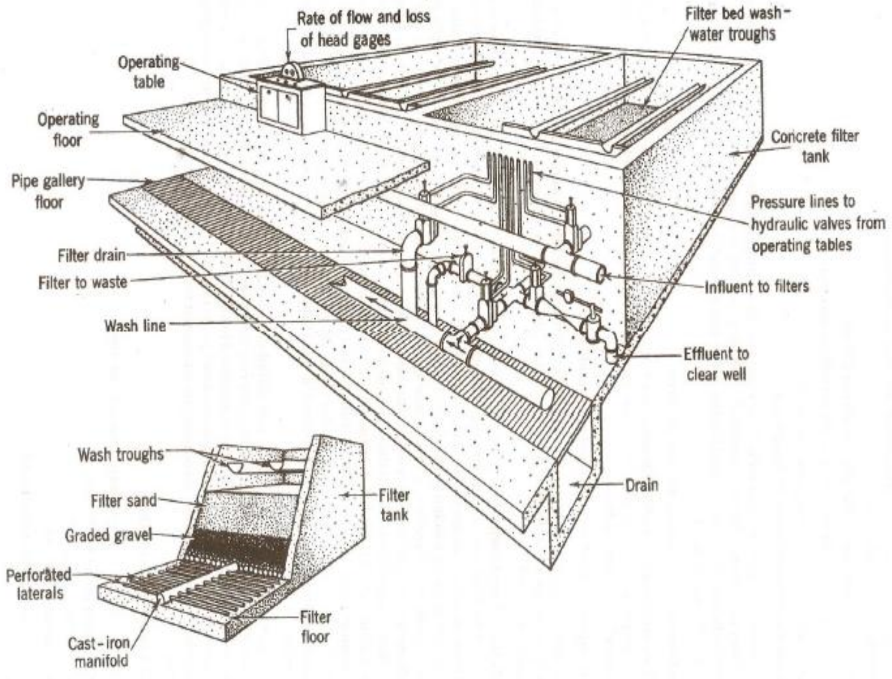

Figure 4.5: Showing different components of rapid gravity filter

In the study carried out by (Aulenbach et al., 2009) the effect of a rapid infiltration on the removal of total organic carbon (TOC) phosphorus, Cd, Cu, Pb, and Zn from a mixed industrial and domestic wastewater was evaluated. Filter media is the important component of all filter types which actually removes the particle from the water being treated. The best and most economical way to increase the capacity of the existing water treatment plants is to increase its rate of operation rather than to build additional units (Tuepker et al., 1968). This may be achieved by improving the performance of the filters, such as changing the filter medium. The media characteristics are among the most important design criteria. The primary media characteristics affecting filtration performance are the effective grain size and uniformity coefficient (Crites et al., 1998). The ideal filter medium should have such a size and material that will provide a satisfactory effluent, retain the maximum quantity of solids and is cleaned with a minimum volume of washing water (McGhee et al., 1984). It should be light in weight, enough to allow sufficient depth for long filter runs and graded to allow effective backwash cleaning (Qasim et al., 2000). Washing the filters is achieved by water backflow the velocity of which must be adjusted to the grain size of the filter medium and temperature of the water (Degremont et al.,1991) can be controlled.

4.10 Applications of rapid sand filter

4.10.1 Virus removal

The contribution of rapid filtration process to improve virus inactivation and removal in the overall tertiary treatment process has been amply demonstrated (Rose *et al.*, 1996; Sheikh *et al.*, 1998). It is generally agreed that primary contribution of the filtration step to virus inactivation is due to the removal of suspended particles and aggregated viral clumps wherein viruses can otherwise be shielded against disinfectants applied downstream.

4.10.2 Heavy metals removal

Rapid sand filtration has been used as a cost-effective tertiary treatment process for sewage and wastewaters. However, little information is available on the performance of the process for heavy metals removal. In the study carried out by (Donald et al., 1998; Chan et al.,2002) the effect of a rapid infiltration on the removal of total organic carbon (TOC) phosphorus, Cd, Cu, Pb, and Zn from a mixed industrial and domestic wastewater was evaluated. Further studies were conducted to determine the effects of calcium carbonate addition for heavy metals precipitation prior to application onto the sand column. The results revealed that sand filtration was remarkably successful in removing phosphorus from wastewater under all conditions. The data further confirmed that in a sand filtration process, the mechanism of phosphorus removal was mainly due to chemical precipitation. Under neutral pH conditions, TOC, Cd, and Cu, were removed in the order of 20%.

4.11 Activated carbon

Activated carbon (AC) is also known as a solid, porous, black carbonaceous material and tasteless. Marsh et al., 1989 defined AC as a porous carbon material, usually chars, which have been subjected to reaction with gases during or after carbonization in order to increase porosity. AC is distinguished from elemental carbon by the removal of all non-carbon impurities and the oxidation of the carbon surface. While according to Norlia et al, 1999 AC is an organic material that has an essentially graphitic structure. The main features common to all AC are; graphite like planes which show varying degrees of disorientation and the resulting spaces between these planes which constitute porosity, and the unit built of condensed aromatic rings are referred to as Basic Structure Units (BSU) (Benaddi et al, 2000). Benaddi et al, 2000 also stated that AC is predominantly an amorphous solid with a large internal surface area and pore volume. Cokes, chars and activated carbon are frequently termed amorphous carbon. X-ray studies have shown that many so-called amorphous substances have crystalline characteristics, even though they may not show certain features, such as crystal angles and faces, usually associated with crystalline state. Although these crystallites have some structural resemblance to a larger graphite crystal, differences other than size exist (Hassler et al, 1974).

It can be summarized that AC is black, amorphous solid containing major portion of fixed carbon content and other materials such as ash, water vapor and volatile matters in smaller percentage. Beside, that AC also contain physical characteristics such as internal surface area and pore volume. The large surface area results in a high capacity for absorbing chemicals from gases or liquids. The adsorptive property stems from the extensive internal pore structure that develops during the activation process.

4.12 Characterization and properties of activated carbon

Characterization for activated carbon (AC) is very important in order to classified AC for specific uses. Basically, AC characterized by physical properties and chemical properties. As mentioned by (Guo et al.,2003), the characteristics of activated carbon depends on the physical and chemical properties of the raw materials as well as activation method used. Physical properties of AC, such as ash content and moisture content can affect the use of a granular AC and render them either suitable or unsuitable for specific applications. While the specific surface area of activated carbon and surface chemistry is classified as chemical properties.

4.12.1 Moisture content

Activated carbon is generally priced on a moisture free basis, although occasionally some moisture content is stipulated e.g., 3, 8, 10%. Unless packaged in airtight containers, some activated carbons when stored under humid conditions will adsorb considerable moisture over a period of month. They may adsorb as much as 25 to 30% moisture and still appear dry. For many purposes, this moisture content does not affect the adsorptive power, but obviously it dilutes the carbon. Therefore, an additional weight of moist carbon is needed to provide the required dry weight (Dawda et al., 1978)

4.12.2 Ash content

The ash content of a carbon is the residue that remains when the carbonaceous materials is burned off. As activated carbon contain inorganic constituents derived from the source materials and from activating agents added during manufacture, the total amount of inorganic constituents will vary from one grade of carbon to another. The inorganic constituents in a carbon are usually reported as being in the form in which they appear when the carbon is ashed. Ash content can lead to increase hydrophilicity and can have catalytic effects, causing restructuring process during regeneration of used activated carbon. The inorganic material contained in activated carbon is measured as ash content, generally in the range between 2 and 10% (Yang et al, 2003).

4.12.3 Surface area

Generally, larger the specific surface area of the adsorbent, the better its adsorption performance will be (Lua et al, 2003). The most widely used commercial active carbons have a specific surface area of the order of 600- 1200 m^2/g (Nuol et.al, 2002). The pore volume limits the size of the molecules that can be adsorbed whilst the surface area limits the amount of material which can be adsorbed, assuming a suitable molecular size (Lartley et al, 1999). The adsorptive capacity of adsorbent is related to its internal surface area and pore volume. The specific surface area (m^2/g) of porous carbon is most usually determined from gas adsorption measurement using the Brunauer-Emmett-Teller BET theory (Srinivasan et al, 1999). The most commonly employed method to characterize these structural aspects of the porosity is based on the interpretation of adsorption isotherm (e.g., N_2 at 77K). Nitrogen at its boiling point of 77K is the recommended adsorptive, although argon is also used at 77 K.

4.12.4 Surface functional group of activated carbon

The selectivity of activated carbons for adsorption is depended upon their surface chemistry, as well as their pore size distribution (Radovic et al,2001). Normally, the adsorptive surface of activated carbon is approximately neutral such as that polar and ionic species are less readily adsorbed than organic molecules. For many applications it would be advantageous to be able to tailor the surface chemistry of activated carbon in order to improve their effectiveness. The chemical composition of the raw material influence the surface chemistry and offer a potentially lower cost method for adjusting the properties of activated carbons. These surface groups play a key role in the surface chemistry of activated carbon (Yang et al ,2003). There are numerous methods of determining surface functional groups and attempts have been made to study the surface groups by spectroscopic methods, for examples by infrared(IR). Figure 2.1 presents several IR- active functional groups that may be found at the edges of and within graphite layers after the oxidative treatment of active carbon.

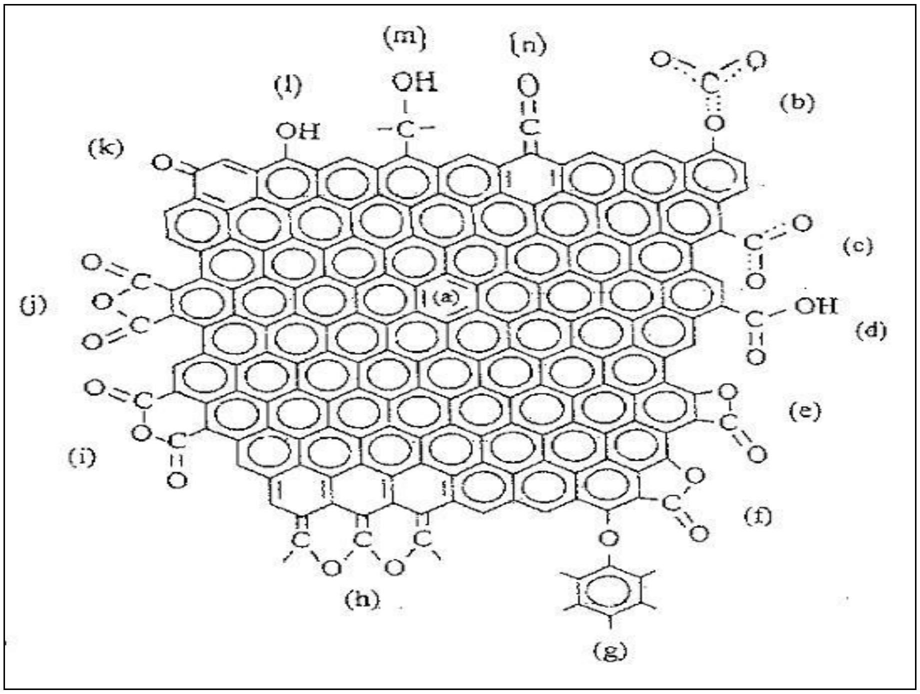

Figure 4.6 - IR- active functionalities on carbon surfaces

Legends

(a) aromatic c=c stretching;

(b) and (c) carboxyl-carbonates;

(d) carboxylic acid;

(e)lactone(4-membered ring);

(f) lactone (5- membered ring);

(g) ether brigde;

(h) cyclic ether;

(i) cyclic anhydride (5- membered ring);

(j) cyclic anhydride (6-membered ring);

(k) quinine;

(l) phenol;

(m) alcohol; and (n) ketene (Radovic, 2001**).**

4.12.5 Pore structure.

Porosity is classified into three different groups of pore sizes (Guo et al, 2003):

i. Micropores- width less than 2nm

ii. Mesopores- width between 2 and 50nm

iii. Macropores- width greater than 50nm

Differences in pore sizes affect the capacity for molecules of different shapes and sizes, and this is one of the criteria by which carbons are selected for a specific application.

The schematic of internal pores structure in activated carbon was shown in Figure 4.7 below.

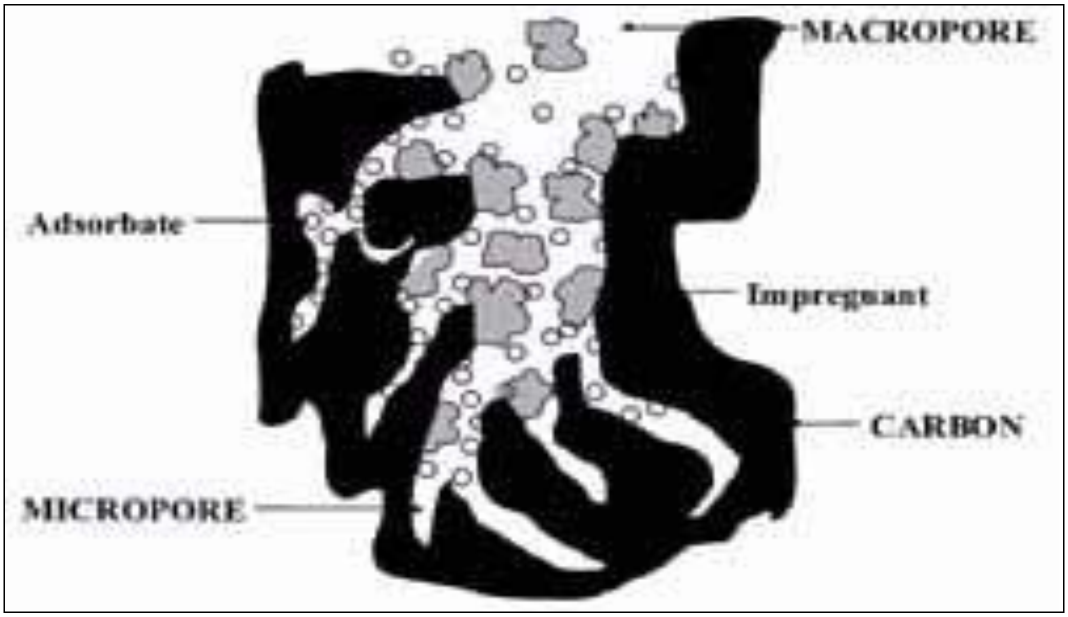

Figure 4.7 Schematic of internal pore structure in activated carbon

The shapes of pores in activated carbon vary from slit- shaped cracks to spheroidal bubbles. Cracks may follow tortuous paths through the solid and may be connected to other pores to form an extensive and irregular network. The shapes of pores can have important effects on some properties of carbons and graphite, for example mechanical strength and kinetics reaction.

Micropores are formed in the interlayer spacing with widths in the range 0.34 - 0.8nm. It is the micropores in activated carbon which have the greatest influence upon gas adsorption, while macropores and mesopores are important in transport of fluids to and from the micropores. Adsorption takes place in micropores and mesopores with macropores acting as transport channels. In adsorption from the gas phase, mainly microporous carbon is used whereas mesoporous carbon is applied in liquid phase processes (Benaddi et.al, 2000). Beside their significant contribution to adsorption, mesopores also serve as the main transport arteries for this adsorbate (Hu et al., 2001). The mesopores volume lies between the limits 0.1 to 0.5 cm^3 per gram and mesopores surface areas are in the range of 20 to 100 m^2 per gram (Hu et al., 2001). In carbon, mesopores can be formed by enlargement of micropores, for example by reaction with oxidizing gases as in activated carbon (Marsh et al, 1989).

4.13 Disinfection

Disinfection of water is the treatment process used to destroy or inactivate disease causing micro-organisms, or pathogens, present in the water supply and thereby ensure the provision of a clean water. Water is one of mankind's most important basic needs. Water is a source of life but can also be a source of destruction if it contains pathogens (Bailey et al., 2005). The filtered water may normally contain some harmful disease producing bacteria in it. These bacteria must be killed in order to make the water safe for drinking. The process of killing these bacteria is known as Disinfection (Kaneko et al., 2002). There are two kinds of disinfection: primary disinfection achieves the desired level of microorganism kill or inactivation, while secondary disinfection maintains a disinfectant residual in the finished water that prevents the re-growth of microorganisms (Zhanfang et al., 2010). Since some disinfectants produce chemical by-products, the dual objective of disinfection is to provide the required level of organism destruction and remain within the maximum contaminant level (MCL) (Yukio et al., 2002).

4.13.1 Chlorination (Sodium hypochlorite solution)

Sodium hypochlorite has long been recognized as having outstanding disinfection properties. It has been proven by the Institute Pasteur in Paris to be the most effective disinfectant against all known pathogenic bacteria, fungi and viruses (Morohashi et al., 2000).

For industrial and institutional applications the versatility and usefulness of sodium hypochlorite include:

- It is used extensively in the area of water treatment to disinfect municipal drinking water and by those taking drinking water from wells.
- It controls algae in open reservoirs.
- It remains as one of the most effective, and certainly the most cost-effective means of contolling the zebra mussel population, the presence of which is causing serious problems for industry.
- It is widely used for swimming pool water disinfection, both as a daily regimen and as a shock treatment.

Sodium hypochlorite is available as a solution in concentrations of 5 to 15 percent chlorine, but is more expensive than chlorine gas (as available chlorine). Sodium hypochlorite is easier to handle than gaseous chlorine or calcium hypochlorite. Sodium hypochlorite is very corrosive and should be stored with care and kept away from equipment that can be damaged by corrosion. Hypochlorite solutions decompose and should not be stored for more than one month. It must be stored in a cool, dark, dry area (Gray et al., 2005). Due to the presence of caustic soda in sodium hypo chlorite, the pH of the water is increased. When sodium hypo chlorite dissolves in water, two substances are formed, which play a role for oxidation and disinfection. These are hypochlorous acid (HOCl) and the less active hypochlorite ion (OCl^-). The pH of the water determines how much hypochlorous acid is formed (Dominguez et al., 2001). Sodium hypochlorite is used on a large scale. For example in agriculture, chemical industries, paint- and lime industries, food industries, glass industries, paper industries, pharmaceutical industries, synthetics industries and waste disposal industries. In the textile industry sodium hypochlorite is used to bleach textile. It is sometimes added to industrial waste water. This is done to reduce odors. Hypochlorite neutralizes sulphur, hydrogen gas and ammonia (NH_3). It is also used to detoxify cyanide baths in metal industries. Hypochlorite can be used to prevent algae and shellfish growth in cooling towers. In water treatment, hypochlorite is used to disinfect water. In households, hypochlorite is used frequently for the purification and disinfection of the house (Zehnder et al., 2002).

4.14 Membrane filtration

Membrane filtration is a technique which is used to separate particles from a liquid for the purpose of purifying it. This filtration method has a number of applications, ranging from treating wastewater to filtering milk used for cheese production, and there are several different approaches to membrane filtration (Muller et al.; 2009)

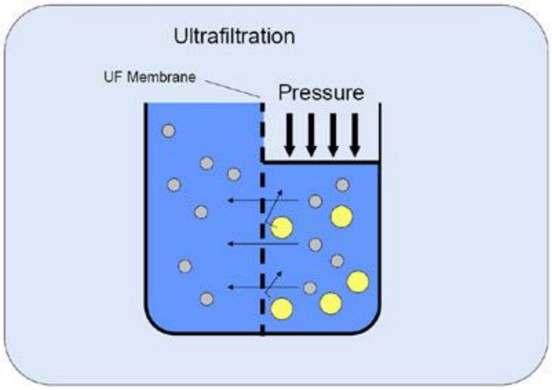

Figure 4.8: Ultrafiltration process

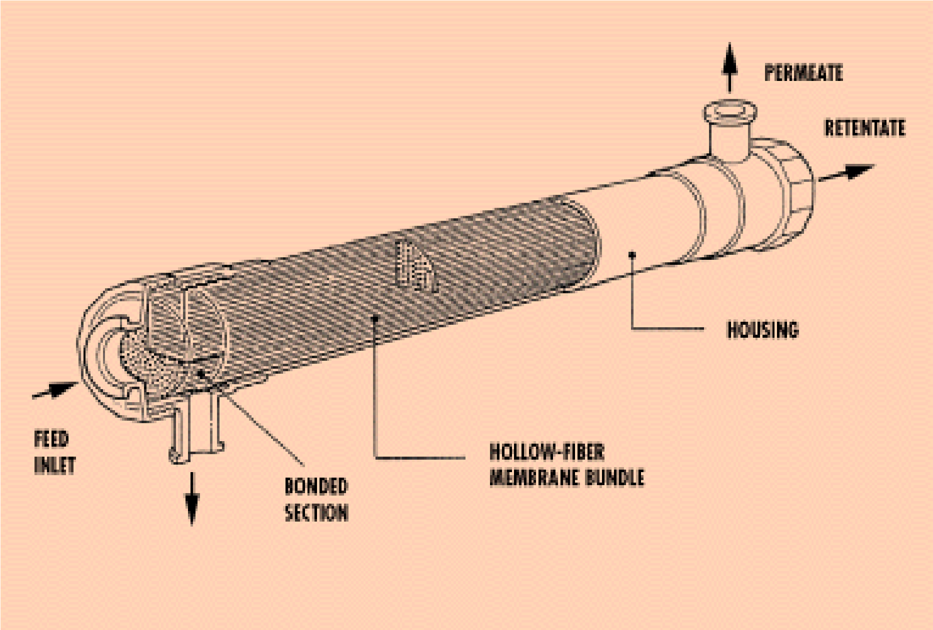

Figure 4.9 Membrane filtration process

4.14.1 Microfiltration (MF)

The purpose of microfiltration is to remove rather larger particles than the pore size. This membrane is used to remove turbid suspened solids, general bacteria, E.coli, etc. MF membrane may be manufactured from a variety of materials, including cellulose acetate, polysulfone, polythyren, etc (Rasid et al.;2001). Microfiltration (MF) is a process where ideally only suspended solids are rejected, while even proteins pass the membrane freely (Joger et al.,1988) the main disadvantages of microfiltration systems is that it does not remove dissolved contaminants, such as nitrates, fluoride, dissolved metals, sodium and VOCs (Anny et al., 2000).

4.14.2 Ultrafiltration (UF)

Ultrafiltration uses membrane with pore sizes that are significantly smaller than 0.01 µm. UF is capable of removing colloids, bacteria, viruses, and high molecular weight organic compounds. The membrane are consequently susceptible to clogging. However, certain types of UF membrane can be backwashed. Materials for the membrane include polyester, polyacrylonitrile, cellulose acetate, etc (Annie et al.; 2000). Ultrafiltration (UF) is a process where the high molecular weight components, such as protein, and suspended solids are rejected, while all low molecular weight components pass through the membrane freely. There is consequently no rejection of mono- and di-saccharides, salts, amino acids, organics, inorganic acids or sodium hydroxide (Wagner et al., 1985).

4.14.3 Nanofiltration (NF)

The recent development of generation Low Pressure Reverse Osmosis or nanofiltration membranes can effectively reject natural organic matter. The membrane is made from polymer organic compounds, aromatic polymide, polyvinyl alcohol, etc. The surface of membrane dose not have pores (Eric et al.; 1999). NF rejects only ions with more than one negative charge, such as sulfate or phosphate, while passing single charged ions. NF also rejects uncharged, dissolved materials and positively charged ions (Kelvin et al.,2002). The main problems associated with Nanofiltration membrane are that it generates a concentrate stream that must either be discharged or reused also it is designed to either run at full production or to be shut off (Ira et al 2006).

4.14.4 Reverse Osmosis (RO)

This membrane was developed for desalination of seawater. The membrane by which it separates liquids and solids has not yet been explicated, but it thought that there is a chemical affinity between the molecules of constituent elements of the membrane solute and solvent (Ehara et al,; 1998). Reverse Osmosis (RO) is the tightest possible membrane process in liquid/liquid separation. Water is in principle the only material passing through the membrane; essentially all dissolved and suspended material is rejected (Luthre et al.,2001). Reverse osmosis removes a number of healthy minerals from water, in addition to the harmful minerals and particles. The removal of these minerals, including calcium and magnesium, can actually make water unhealthy, especially for people with inadequate diets and people who live in hot climates, as water can provide these necessary minerals (Mac et al.,2000).

Table 4.1: Pore Size and Operating Pressure of different membranes

Membrane	Pore Size (micron)	Operating Pressure (bar)
Microfiltration	5 to 0.1	< 2
Ultrafiltration	0.1 to 0.01	1-10
Nanofiltration	0.001	5 -35
Reverse osmosis	0.00001	15-150

So far, pores have not been observed in RO membranes using a microscope, but inspite of this, water passes through the membrane and salt is rejected (Kelly et al.,1999).

5.0 MATERIALS AND METHODS

5.1 Characterizations of raw industrial effluent and domestic sewage

The characteristics of raw industrial effluent and domestic sewage to be treated in ETP were assessed. The composite samples were collected at inlet of screen chamber and receiving sump of domestic sewage. The physico-chemical characteristics range of raw industrial effluent and domestic sewage are presented in Table 5.1.

The characteristics of raw industrial wastewater and domestic sewage revealed that:

- The pH of the raw industrial effluent was neutral to alkaline with values in the range 7.0-8.1 and domestic sewage was slightly acidic in nature with pH in the range 6.5-6.8.
- The concentrations of oil and grease, COD and BOD of the raw industrial effluent based on composite samples collected were in the range 43-403, 240-768, and 104-176 mg/l, respectively and domestic sewage was in the range COD: 320-624 mg/l, and BOD: 208-265 mg/l. The characteristics of domestic sewage were medium strength.

Table 5.1: Physico-chemical characteristics range of raw industrial effluent and domestic sewage

Parameter	Raw	
	Industrial effluent	Domestic sewage
pH	7.0-8.1	6.5-6.8
SS	34-126	28-126
TDS	302-425	314-789
COD	240-768	320-624
BOD$_{(3d, 27°C)}$	104-176	208-265
Oil & Grease	43-403	-
Calcium	20-43	21-52
Magnesium	12-22	14-23
Chlorides	35-185	55-235
Sulphates	13-92	13-64
Sodium	28-60	30-49
Potassium	1.3-5.8	2.0-12
Phosphates	BDL-3.8	0.2-25
NH$_3$-N	0.3-8.4	0.3-23
Heavy metals		
Iron	BDL-2.92	0.71-1.34
Manganese	0.03-1.30	0.03-0.73

Contd…

Chromium	BDL -0.13	BDL
Copper	BDL -0.05	0.01-0.05
Zinc	0.01-0.44	0.04-0.13
Nickel	0.14-0.32	BDL -0.25
Cadmium	BDL	BDL
Lead	BDL -0.06	BDL -0.12

Hourly samples collected and composited for 8 hours.
All values are expressed in mg/l, except pH.
BDL - Below detectable limit.

5.1.1 Characterizations of combined effluent

The characteristics of partially treated industrial effluent and domestic sewage (combined effluent) to be post treated in the biofilter were assessed. The composite samples were collected at outlet of distribution chamber. The characteristics range of combined effluent is presented in Table 5.2.

The characteristics of combined effluent revealed that, the pH of combined effluent was in the range 7.2-8.4 with COD: 200-352 mg/l and BOD: 75-170 mg/l. The BOD/COD ratio of industrial effluent was enhanced with domestic sewage from 0.23-0.43 to 0.38-0.48 and was amicable for attached growth bio-oxidation process (biofilter).

Table 5.2: Physico-chemical characteristics range of combined effluent

Parameters	**Combined effluent**
pH	7.2-8.4
SS	24-130
TDS	310-545
COD	200-352
$BOD_{(3d, 27^{\circ}C)}$	75-170
Calcium	29-58
Magnesium	16-33
Chlorides	41-135
Sulphates	12-54
Sodium	27-40
Potassium	1.8-4.6
Phosphates	BDL-0.4
NH_3-N	1.0-9.8

Hourly samples collected and composited for 8 hours.
All values are expressed in mg/l, except pH;BDL- Below detectable limit

5.2 Performance assessment of existing ETP

The assessment of existing ETP was carried out through flow monitoring of industrial effluent and domestic sewage at the inlet of respective tanks, including collection of composite and grab samples at various stages of treatment for physico–chemical characterization. The locations of sample collected at various stages of ETP are presented in Figure 5.0. The physico-chemical characteristics including at various stages of treatment of ETP are presented in Table5.3.

Table 5.3: Physico-chemical characteristics range at various stages of ETP

Parameters	**Raw**		**Effluent from**	
	Industrial effluent	**Domestic sewage**	**Combined***	**Secondary clarifier**
pH	6.9-8.1	6.5-7.6	7.1-9.1	7.0-7.9
SS	34-126	28-126	24-130	BDL-22
TDS	302-425	314-789	310-545	300-406
COD	240-768	320-624	200-352	32-72
BOD $_{(3d,\ 27^{\circ}C)}$	104-176	208-265	75-170	12-38
Oil & Grease	43-403	-	-	1-4
Chlorides	35-185	55-235	41-135	40-85
Sulphates	13-92	13-64	12-54	12-46
Sodium	28-60	30-49	27-40	24-42
Potassium	1.3-5.8	2.0-12	1.8-4.6	1.6-3.9
Phosphates	BDL-3.8	0.2-0.4	BDL-0.4	1.6-3.1
NH_3-N	1.8-8.4	11.2-25.2	1.0-9.8	BDL-8.4
Heavy metals				
Iron	BDL-2.92	BDL-1.34	BDL-1.43	BDL-0.92
Manganese	0.03-1.30	BDL-0.73	BDL-0.86	BDL-0.41
Chromium	BDL -0.13	BDL	BDL-0.01	BDL -0.09
Copper	BDL -0.05	BDL-0.05	BDL-0.02	BDL -0.06
Zinc	0.01-0.44	BDL-0.13	BDL-0.46	BDL -0.15
Nickel	0.14-0.32	BDL-0.25	BDL-0.52	BDL -0.14
Cadmium	BDL	BDL	BDL	BDL
Lead	BDL -0.06	BDL -0.12	BDL-0.16	BDL -0.06

Partially treated industrial effluent and domestic sewage., All values are expressed in mg/l, except pH.
BDL- Below detectable limit.

5.2.1 Observation

The following observations were made during detailed assessment of the existing ETP:

- The ETP was operated at an average flow rate (combined effluent) range from 3792 – 4848 m3/d (50-64%), respectively as against the design flow rate 7570 m3/d.

- The oil was removed in oil and water separator and finally disposed off to common hazardous waste treatment storage and disposal facility (CHWTSDF).
- The lime and alum were used as coagulants and PAC as coagulant aid. The dosage of lime, ferrous sulphate and PAC were in the range 90-110, 20-25 and 20-25 mg/l respectively.
- The dosing of lime was not directly routed to the baffle channel and therefore, no chemical sludge generation was observed in clariflocculator.
- The oil and grease was removed in clariflocculator and distribution box.
- In distribution box, chemically treated industrial effluent was mixed with sewage.
- The combined effluent was settled in the primary clarifier and routed to anaerobic digester followed by sludge drying beds (SDBs).
- Sludge from the secondary clarifier was continuously recycled to the channel of distribution box.
- Portion of treated effluent from the secondary clarifier was continuously recycled at inlet of biofilter to maintain the hydraulic pressure for rotating the arms.
- The settled chemical sludge was routed to sludge thickner and thickened sludge was routed to SDBs.

5.2.1.1 Oil and water separator

- The hydraulic retention time (HRT) of oil and water separator unit was in the range 1.34-1.9 as against the design HRT 1.3 hr.
- The performance of oil and water separator with respect to oil and grease removal efficiency was in the range 4.18-65.

5.2.1.2 Chemical precipitation and biological processes

- The HRT of clariflocculator was in the range 1.6- 3.1 hr as against the design HRT 3.5 hr.
- The performance of the primary treatment (chemical precipitation) with respect to suspended solids (SS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) removal efficiencies was in the range 36- 100, 22-64 and 22-56% respectively.

- The HRT of secondary clarifier was in the range 5.7- 7.9 hr as against the design HRT 3.5 hr.
- The concentration of total solids of chemical and thickened sludge was in the range 0.28-1.5 and 0.25- 1.8 %, respectively.
- The concentration of oil and grease in secondary treated effluent were in the range 10 - 22 mg/l.
- The performance of the secondary treatment with respect to SS, COD and BOD in terms of removal efficiencies was in the range 34 – 100, 41 – 81 and 55 – 79% respectively.
- The overall performance of ETP with respect to the major parameters were:

Parameters	Percent Removal, %
SS	47 - 100
COD	53 - 97
BOD	78 - 95

- The performance of ETP along with discharge norms are presented in table. The treated effluent from the ETP conforms to be prescribed norms of the MPCB for discharges into Inland Surface Waters with respect to all parameters except BOD.
- The performance assessment of the existing ETP revealed that final treated effluent from the ETP complies with the stipulated discharge norms except BOD of MPCB. The treated effluent from the ETP was not of desired quality for recycle/reuse for processes. Therefore, treatability studies are necessary to assess the feasibility of the various treatment units and to delineate the most appropriate treatment scheme.

Table 5.4 : Physico-chemical characteristics range secondary clarifier with discharge Standard

Parameters	**Secondary clarifier**	**MPCB Standards for Effluent Discharge Into Inland Surface Waters**
pH	7.0-7.9	5.5-9.0
SS	BDL-22	100
TDS	300-406	2100
COD	32-72	250
BOD $_{(3d, 27°C)}$	**12-38**	**30**
Oil & Grease	1-4	10
Chlorides	40-85	600
Sulphates	12-46	1000
Sodium	24-42	-

Potassium	1.6-3.9	-
Phosphates	1.6-3.1	5
NH_3-N	BDL-8.4	50
Heavy metals		
Iron	BDL-0.92	3
Manganese	BDL-0.41	2
Chromium	BDL -0.09	2
Copper	BDL -0.06	3
Zinc	BDL -0.15	5
Nickel	BDL -0.14	3
Cadmium	BDL	
Lead	BDL -0.06	0.1

All values are expressed in mg/l, except pH.
BDL- Below detectable limit.
MPCB-Maharashtra Pollution Control Board.

5.3 Characterizations of secondary treated effluent

The secondary treated effluent sample was received at NEERI, Nagpure from the ETP of Tata Motors Ltd. The characterization of secondary treated effluent were carried out for major parameters and presented in Table 7.1. The characteristics of secondary treated effluent revealed that,

- The pH was neutral to alkaline in nature with values in the range 7.1-7.8.
- The concentrations of oil and grease, SS, TDS COD and BOD were in the range BDL, 8-10, 432-440, 40-50, and 10-20 mg/l, respectively.

5.4 Treatability studies

Experiments were carried out at NEERI to improve the quality of treated effluent and to delineate appropriate treatment scheme for recycle/reuse of treated water. The treatment routes investigated were sand filtration, activated carbon column and chlorination. The experimental setup for sand filtration and activated carbon column process was fabricated in the lab to carry out the treatability studies on secondary clarifier effluent. The chlorination of effluent from activated carbon column was performed in a jar test apparatus to remove the residual content. The media used for the studies are sand and activated carbon.

5.4.1 Sand media

The sand used as filter media was of size from 0.8 – 1.2 mm. The sand was washed with tap water for removal of dirt, organic and inorganic matter. It was washed till all impurities were removed and washed effluent is crystal clear. The washed sand was oven dried at 110°C to remove the moisture content.

5.4.2 Granular activated carbon

The granular activated carbon used for the work was obtained from Shri Rajpipla Amar Carbon and Chemical Industries**.** The granular activated carbon used has the following Specifications :

Appearance:	:	Black Granules
Iodine value:	:	958mg/g
Ash content:	:	4.5%
Moisture content:	:	4.2%
Bulk density:	:	0.55 GM/CC
Hardness No.	:	96
pH:	:	9.5 Alkaline

The activated carbon was washed with tap water to remove the impurities. It was washed till the impurities were removed and washed effluent is crystal clear. The washed activated carbon was oven dried at 110°C to remove the moisture content.

5.5 Sand filtration

The sand filtration experiment was conducted on secondary treated effluent of Tata Motors in a bench scale laboratory model (batch mode). The sand filter consisted of a circular glass tube with a packed bed media of sand and gravel. The size of column was 4cm diameter by 45cm in height. The size of the sand at different layers is as follows:

Layers	Size (mm)	Height (cm)
Top	0.8	5
Middle	0.8 - 1.2	11
Bottom (gravel)	1 -2 (cm)	5

The sand and gravel media were placed on was placed on glass wool and perforated plate. The effective height of column was 21 cm. The laboratory setup of sand filter is shown in Figure 5.1. The sand filter was fed from top through gravity with secondary treated effluent and filtered effluent was collected at bottom. The filtered effluent was analyzed for pH, SS and COD.

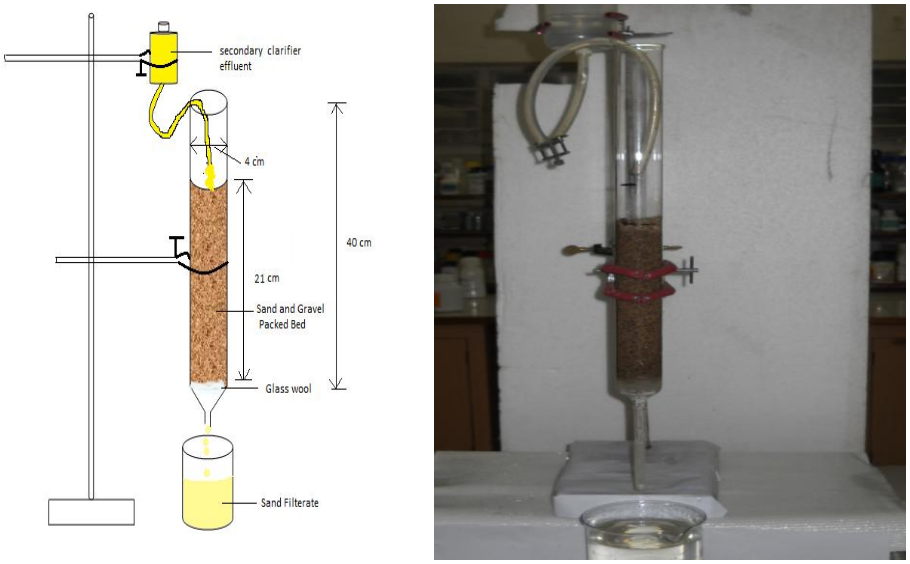

Figure 5.1: Laboratory set up for sand filter

5.6 Activated carbon column

The adsorption experiment was conducted on sand filtrate effluent in a bench scale laboratory model (batch mode). The activated carbon column consisted of a circular glass tube with a packed bed media of granular activated carbon. The size of column was 4cm in diameter by 45 cm in height. The activated charcoal of size -4 +8 BSS was placed on glass wool and perforated plate. The effective height of column was 21 cm. The laboratory setup of activated carbon is shown in figure 4.2. The activated carbon was fed from top through gravity with sand filtrate effluent and filtrated effluent was collected at bottom. The filtrate effluent was analyzed for pH and COD.

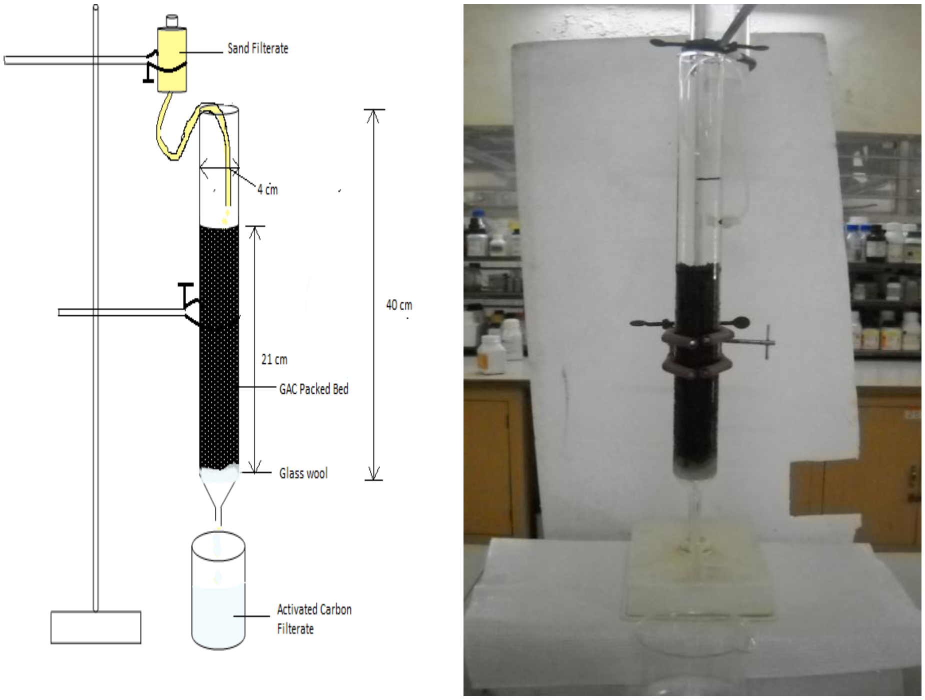

Figure 5.2: Laboratory set up for activated carbon column

5.6.1 Adsorption capacity

The washed GAC was ground to PAC with the help of mortal and pestle and passed through 0.04 mm (325 mesh sieve). Batch adsorption experiment was performed by contacting 0.6 g of PAC in 200 ml of sand filtrate effluent in 5 sets. The experiment was performed in thermal shaker at control temperature of 32 ± 2 °C. The continuous shaking was provided during the experimental period with a constant agitation speed of 150 rpm for better mass transfer with interfacial area of contact. Each set was removed from shaker after 10, 20, 30, 60 and 120 min respectively. The completely mixed activated carbon effluent was passed through the Whattman filter paper. The filtrate effluent was analyzed for COD to determine optimum time.

Similar, methodology was adopted for determination of adsorption capacity of GAC. Only difference was that contact time was kept constant (30 min) with varying doses of carbon from 0.2 to 0.7g. The remaining COD concentration in each set of filtrate effluent was analyzed.

5.7 Chlorination

The disinfectant used for chlorination was sodium hypochlorite. The filtrate effluent from activated carbon column was tested for disinfection. Dose of sodium hypochlorite were varied for 6 sets of activated carbon filtrate effluent. Each set was placed in the jar test apparatus. Different doses of sodium hypochlorite (0.125ml, 0.25ml, 0.375ml, 0.5ml, 0.625ml) were added in each set respectively. The rotation was set at 100 rpm for 1 min and then was reduced to 30 rpm for 15 minutes. The flocs formed were allowed to settle for 30 minutes. Then the supernatant was analyzed for COD, pH, residual chlorine and chlorides.

5.8 Glassware and apparatus

All glassware like conical flasks, measuring cylinders, beakers, pipettes etc. used were of Borosil. The instruments and Apparatus used throughout the project work are as follows:

Instrument	Manufacturer
COD Digester	Gerhardt
pH meter	Eutech Instruments
Electronic Weighing Balance	Delta Range
Spectrophotometer	Shimadzu
Phosphate Digester	Milestone
Shaker	Environmental Orbital Shaker
Hot Plate	Spinot
Oven	Shivaki
Filtration Assembly	Rocker

5.9 Analysis and procedures

5.9.1 Chemical oxygen demand (COD)

Chemical oxygen demand (COD) test determines the oxygen equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant.

a. Principle

The organic matter gets oxidized completely by potassium dichromate and silver sulphate catalyst in the presence of concentrated sulphuric acid to produce carbon dioxide and water. The excess potassium dichromate remaining after the reaction is titrated with ferrous ammonium sulphate. The dichromate consumed gives the oxygen required for oxidation of the organic matter.

b. Interferences

1. Fatty acids, straight chain aliphatic compounds, aromatic hydrocarbons, chloride, nitrite and iron interfere in the estimation:
2. The interference caused by chloride can be eliminated by the addition of mercuric sulphate to the sample prior to the addition of other reagents. [About 0.4 g of HgSO4 is adequate to complex 40 mg chloride ions in the form of poorly ionized soluble mercuric chloride complex].
3. Addition of silver sulphate to concentrated H2SO4 as a catalyst stimulates the oxidation of straight chain aliphatic and aromatic compounds [Nitrite nitrogen exerts a COD of 1.14 mg/l NO_2-N]
4. Sulphamic acid at the rate of 10 mg/mg NO_2-N may be added to potassium dichromate solution to avoid interference caused by (NO_2 - N) Nitrite nitrogen
5. For complete oxidation of organic matter, it is necessary to take volumes of sulphuric acid and sample plus potassium dichromate in 1:1 ratio. However to maintain the ratio, the volumes of oxidant/sample and strength of oxidant/titrant may suitably be varied.

c. Apparatus

1. Reflux Apparatus, consisting of a flat bottom 250 to 500 ml capacity flask with glass joint and a condenser with 24/40 joint
2. A heating mantle or hot plate with temperature regulator.

d. Reagents

1. Standard Potassium Dichromate Solution, 0.250 N : Dissolve 12.259 g K2Cr2O7 dried at 103OC for 24 hrs in distilled water and dilute to 1000 ml. Add about 120 mg sulphamic acid to take care of 6 mg/l NO2 – N.
2. Sulphuric Acid Reagent : Add 22 g Ag2SO4 to 91 bs concentrated H2SO4 or 10 gm to 1000 ml concentrated H2SO4 and let stand for 1 or 2 days for complete dissolution

3. Standard Ferrous Ammonium Sulphate (FAS), Approx. 0.1N: Dissolved 30 g Fe(NH4)2.6H_2O in about 400 ml distilled water. Add 20 ml concentrated H2SO4 and dilute to 1000 ml.
4. Ferroin Indicator: Dissolve monohydrate and 695 mg FeSO4.7H2O in distilled water and dilute to 100 ml
5. Mercuric Sulphate : $HgSO_4$ crystals, analytical grade.

e. Procedure

Standardization

1. For standardization of ferrous ammonium sulphate, 10.0 ml standard $K_2Cr_2O_7$ to about 100 ml was diluted with distilled water, acidified by adding
10.0 ml H_2SO_2 and allowed to cool. Titrated with ferrous ammonium sulphate to be standardized using 2-3 drops of ferroin indicator.
2. The 0.4 g $HgSO_4$ was placed in 250 ml reflux flask, added 20 ml sample or an aliquot of sample diluted to 20 ml with distilled water and mixed well.
3. Clean pumic stones or glass beads was added followed by 2 ml sulphuric acid, 10 ml standard $K_2Cr_2O_7$ solution and mixed.
4. Then slowly added 28 ml concentrated H_2SO_4 containing Ag_2SO_4 and mixed thoroughly. This slow addition along with swirling prevented fatty acids to escape out due to high temperature.
5. Mixed well. If the colour turns green, either take fresh sample with lesser aliquot or add more potassium dichromate and acid.
6. Connected the flask to condenser, mixed the contents before heating, refluxed for 2 hrs, cooled and then washed down the condenser with distilled water.
7. Disconnected reflux condenser and diluted the mixture to about twice its volume with distilled water. Cooled at room temperature and titrated excess $K_2Cr_2O_7$ with 0-1 N FAS using 2-3 drops of ferroin indicator. The sharp colour change from blue green to reddish brown indicated end-point. The blue-green may reappear. I used the same quantity of ferroin indicator for all titrations.
8. Then refluxed blank in the same manner using distilled water instead of sample. Alternatively for low COD samples use 0.025 N $K_2Cr_2O_7$ and 0.025 N titrate with sample volume of 50 ml.

Calculate COD from the following formula:

$$\textbf{COD as mg/l} = \frac{(a-b) \times N \times 8000}{\text{ml of sample}}$$

Where,

a = ml FAS used for blank

b = ml FAS used for sample

N = normality of FAS

5.9.2 Biochemical oxygen demand (BOD)

The biochemical oxygen demand is by definition, the quantity of oxygen utilized by a mixed population of microorganism in the aerobic oxidation of decomposable organic matter in a sample of wastewater under controlled condition of temperature and incubation period. The BOD test is widely used to determine:

The pollution load of waste water

(a) The degree of pollution in lakes and streams at any time and their . carrying capacity

(b) Performance evaluation of waste water treatment plant.

a Principle

The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material such as sulphides and ferrous ions by computing a difference between initial and final DO. It also measures the oxygen used to oxidize reduced forms of nitrogen unless their oxidation is prevented by the addition of an inhibitor.

Since the test is mainly a bio assay procedure it is necessary to provide standard condition of nutrient supply, pH (6.5-7.5) absence of microbial growth inhibiting substances and temperature. The low solubility of oxygen in water necessitates strong wastes to be diluted to ensure that the demand does not increase the available oxygen. A mixed of organism should be present in the sample otherwise the sample has to be seeded. Generally temperature is controlled at 20 ° C and the test is conducted for 5 days as 70 to 80 % of the waste is oxidized during the period. The test can be performed at any other temperature provided the correlation at any other temperature provided the correlation between BOD. 20°C is established under the same experimental condition while reporting the result the incubation period in days and temperature in degree celcius is essential to be mentioned.

b. Procedure

b.(i) Preparation of dilution water

1) The source of dilution water was not restricted and may be distilled water, tap or receiving stream water free of biodegradable organics and bioinhibitory substances such as chloride or heavy metals.
2) Aerated the required volume of dilution water in a suitable bottle by bubbling clean filtered compressed air for sufficient time to attain DO saturation at R.T or at 20 ° C.
3) Then 1ml each of phosphate buffer magnesium sulphate calcium chloride was added, ferric chloride solution for each litre of dilution water. Mixed well, Quality of dilution water may be checked by incubating a BOD bottle full of dilution water for 5 day at 20 ° C.
4) In case, if the wastes are not expected to have sufficient microbial population add seed to the dilution water.
5) Preferred seed is effluent from a biological treatment system. Where this is not available, supernatant from domestic waste water settled at room temperature for at least 1 hour but no longer than 36 hrs is considered sufficient in the proportion 1-2 ml/l of dilution water.
6) I then determined the BOD of the seeding material. This is known as seed control. From the value of seed control and knowledge of seeding material dilution I determined seed dilution uptake. The DO uptake of seeded dilution water should be between 0.6 mg/l and 0.1 mg/l.

b.(ii) Sample treatment

1) Neutralized the sample to pH around 7.0 if it is highly acidic or alkaline.

2) The sample should be free from residual chloride. If it contains residual chloride remove it by using $Na_2S_2O_3$ solution as follows:
3) 50 ml of the sample was taken and acidified with addition of 10 ml acetic acid. Added about 1 kg KI and titrated with $Na_2S_2O_3$ 0.25 N using starch indicator. Calculated the volume of $Na_2S_2O_3$ required per ml of the sample and accordingly added to the sample to be tested for BOD.
4) Certain industrial wastes for e.g., plating wastes contain toxic metals. Such samples often require specific study and treatment.
5) Sample temperature to 20^oC before making dilution.
6) Since nitrification inhibition was desired 3 mg 2- chloro 6- iodine pyridine added to each bottle before capping or added sufficient amount to the dilution water to make final concentration of 30 mg/l.
7) Samples having high DO content i.e. 9 mg/l or above due to algal growth or some other reasons reduce the DO saturation at 20 degree Celsius. By agitating or aerating with clean filtered compressed air.

$$\text{Dissolved oxygen} = \frac{Normality\ of\ thiosulphate \times 1000 \times volume\ of\ titrant}{volume\ of\ sample}$$

BOD mg/l = DO of 5th Day – DO of 1st Day

5.9.3 Suspended solids (S.S)

a. Principle:

Solid refer to matter suspended or dissolved in water or waste water. Solids may affect water or effluent quality adversly in number of ways. Water with high dissolved solids generally are inferior palability for this reason a maximum limit of 500 mg dissolved solids is permissible for drinking water. There are 3 type of solids which are analyzed for water and wastewater.

b. Procedure

1) Filtered a suitable aliquot of sample through a crucible ignited to constant weight (W1) applying suction.

2) The residue was washed three times with about 5 to 10 ml of water allowing it to drain free from water after each wash & continued the suction for about 3 min after filtration was complete. Then carefully removed the crucible/GF filter paper, dried in an oven at 105^{O}C for one hour and cooled in desiccators & weighed (W2).

The results can be obtained as follows:

W_1=initial wt of paper

W_2=final wt of paper

$$\text{Suspended Solids (mg/l)} = \frac{(W_2-W_1) \times 1000 \times 1000}{\text{ml of sample}}$$

5.9.4 pH

Measurement of pH is one of the most important and frequently used tests as every phase of water and wastewater treatment and water quality management is pH dependent. For most practical, purposes the pH of aqueous solutions can be taken as negative logarithm of hydrogen ion activity. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen in activity. pH values from 0 to 7 are diminishingly acidic, 7 to 14 increasingly alkaline and 7 is neutral.

a. Apparatus

1. **pH meter**: It consists of potentiometer, a glass electrode, a reference electrode and a temperature compensating device. A balanced circuit is completed through potentiometer when the electrodes are immersed in the test solution. Many pH meters are capable of reading pH or millivolts.
2. **Reference Electrode**: It consists of a half cell that provides a standard electrode potential. Generally, calomel silver-chloride electrodes are used as a reference electrode.
3. **Sensor (Glass) Electrode:** Several types of glass electrodes are available. The glass electrode consists essentially of a very thick walled glass bulb, made of low Melting Point. glass of high electrical conductivity, blown at the end of glass tube. This bulb contains an electrode which has a constant potential, e.g. a platinum wire inserted in a

solution of H+ (hydrochloric acid saturated with quinhydrone). The bulb is placed in the liquid where pH is to be determined.

4. **Beakers:** Preferably use polyethylene Beakers
5. **Stirrer:** Use a magnetic stirring bar.

b. Reagents

Calibrate the electrode system against standard buffer solution of known pH. Buffer tablets having pH 4.0, 7.0 and 9.2 were available. Since buffer solution deteriorated as a result of mold growth or contamination, prepare fresh as and when needed for work. The following buffer solutions are required.

i. pH 4 Buffer Solutions

10.2 grams anhydrous potassium biphthalate was dissolved; KHC_8H_4 using boiled and cooled distilled water. Dilute to 1 litre or take one buffer tablet and dissolved it in 100 ml fresh cooled double distilled water.

ii. pH 7 Buffer Solution

1.361 grams anhydrous potassium dihydrogen phosphate was dissolved, KH2PO4, and 1.42 grams anhydrous disodium hydrogen phosphate, Na2HPO4, which have been dried at 110°C to 130°C. Use distilled water which has been boiled and cooled. Dilute to 1 litre or take one buffer tablet and dissolved it in 100 ml fresh cooled double distilled water.

iii. pH 9.2 Buffer Solution

3.81 grams borax, Na2B4O7.10H2O in distilled water was dissolved, which has been previously boiled and cooled. Dilute to 1 litre or take one buffer tablet and dissolved in 100 ml fresh double distilled water.

c. Procedure

1. Wiped the electrodes by gently blotting with a soft tissue paper, standardized instrument with electrodes immersed in a buffer solution within 2 pH units of sample.

2. Then electrodes were removed from buffer solution, rinsed thoroughly with distilled water and blot dry.
3. The electrodes were dipped in sample.
4. For sample analysis established equilibrium between electrodes and sample by stirring sample to ensure homogeneity and measured the pH.

5.9.5 Chlorides

a. Principle

Chloride is determined in neutral or slightly alkaline solution by titration with standard silver nitrate using Potassium chromate as an indicator. Silver chloride is quantitatively precipitated before red silver chromate is formed.

b. Interferences

Bromide, iodide and cyanides are measured as equivalent of chloride ions. If the sample contains sufficient thiosulphate, thiocyanate, cyanide, sulfite and sulfide to interfere with the determination, they may be oxidized to non-interfering substances as follows: Dilute a suitable quantity of sample into a conical flask to 150 ml with water. Add 25 ml H_2O_2 (3%) and boil for 15 minutes, then add further 10 ml H_2O_2 and boil for 5 minutes. Repeat the same until the solution is thiocyanate free. If the sample is too coloured or turbid to allow the end point to be readily detected, this interference may be reduced by the following treatment with a suspension of aluminium hydroxide. Add 3 ml $Al(OH)_3$ suspension to the measured quantity of sample. Stir thoroughly, set aside for a few minutes and filter. Wash the precipitate with distilled water.

c. Reagents

1**. Potassium Chromate Indicator**

Dissolve 50 g $K_2Cr_2O_4$ in distilled water. Add $AgNO_3$ till definite red precipitate is formed. Allow to stand for 12 hrs. filter & dilute to 1000 ml.

2. **Silver Nitrate, 0.0141 N**

Dissolve 2.395 g AgNO3 and dilute to 1000 ml. Standardize against NaCl, 0.0141 N. 1 ml of 0.0141 N AgNO3 = 0.5 mg of Cl-

3. **Sodium Chloride, 0.0141 N**

Dissolve 824.1 mg NaCl (dried at 140OC) and dilute to 1000 ml.

1 ml = 0.5 mg of Cl-

4. **Special Reagent to Remove Colour and Turbidity**

Dissolve 125 g $AlK(SO_4)_2.12H_2O$ or $AlNH_4(SO_4)_2.12H_2O$ and dilute to 1000 ml. Warm to $60^{O}C$ and add 55 ml concentrated NH_4OH slowly. Let it stand for 1 hour. Transfer to a large bottle and wash precipitate by successive addition with thorough mixing and decanting with distilled water until free from chloride. When freshly prepared, the suspension occupies a volume of approximately1l.

d. Procedure

1. First 50 ml of well mixed sample was taken with adjusted to pH 7.0-8.0 and added 0.1 ml K_2CrO_4.
2. Then it was titrate with standard AgNO3 solution till AgCrO4 started precipitating.
3. Initially standardized AgNO3 against standard NaCl.
4. For better accuracy titrated distilled water (50 ml) in the same way to establish reagent blank. A blank of 0.2 to 0.3 ml is usual.

Calculate as follows:

$$\text{Chloride, mg/l as Cl- } = \frac{(A-B) \times N \times 35.45 \times 1000}{\text{ml sample}}$$

Where, A = $AgNO_3$ required for sample (ml); B =$AgNO_3$ required for blank (ml)

N = Normality of $AgNO_3$ used.

6.0DELINEATION OF PROPOSED TREATMENT SCHEME

6.1 Proposed treatment scheme

Based on extensive field investigations, laboratory scale treatability studies, an additional tertiary treatment followed by chlorination is proposed for upgradation of the existing effluent treatment plant (ETP) for recycle /reuse of treated wastewater. The schematic of the proposed ETP is presented in Figure 6.1. The anticipated physico-chemical characteristics at different stages of treatment are given in Table 6.1. The proposed treatment scheme comprises primary units as collection tanks followed by mechanical screens and detritors for industrial effluent and domestic sewage for removal of larger size particles and grits. The preliminary treated industrial effluent is routed to oil and grease separator followed by chemical treatment for removal of colloidal and suspended particles. The chemically treated effluent is mixed with domestic sewage and combined effluent is settled in primary clarifier. The clarified effluent is pumped to biofilter for removal of dissolved organic matter followed by settling in secondary clarifier. The biological treated effluent will be further treated through sand filter and activated carbon column followed by chlorination for removal of suspended particles, residual COD and disinfection. Final treated effluent from the proposed treated scheme will be of reuse quality. The biological sludge generated would be digested through anaerobic digester and digested sludge will be dried in sludge drying beds. The chemical sludge is pumped to sludge thickner for dewatering and dewatered sludge is dried on sludge drying beds.

Table 6.1: Anticipated characteristics at different stages of proposed treatment scheme

Para-meters	**Industrial effluent**	**Domestic sewage**	**Combined**	**Effluent from**			
				SC	**SF**	**ACC**	**Chlori-nation**
pH	7.0-8.1	6.5-6.8	7.2-8.4	7.0-7.9	7.1-7.5	7.5-7.8	7.8-8.0
Oil and grease	43-403	BDL	5-6	1-4	BDL	BDL	BDL
S.S	34-126	28-126	24-130	BDL-22	4	BDL	BDL
COD	240-768	320-640	200-352	32-72	28-32	4	BDL
BOD	104-176	208-265	75-170	12-38	7-8	BDL	BDL

All values are expressed in mg/l, except pH.
SF-Sand filter; SC-Secondary clarifier
ACC-Activated carbon column.; BDL- Below detectable limit.

6.2 Design of sand filter and activated carbon column

The sand filter and activated carbon column was designed for the flow rate of 12 MLD. Based on the treatability studies, the optimized filtration rate of sand filter and activated carbon column were 10 and 8 $m^3/m^3/h$, respectively. The design of collection tanks, sand filter, activated carbon column, chlorination and final treated effluent tanks are as follow:

6.2.1 Collection tank

Flow rate = 12000 m^3/day

Detention = 1 day

Volume = 12000 m^3

Assuming 2 tanks

Volume of 1 tank = 6000 m^3

Assumed 4 m height

Area = volume/height

Area = 6000 / 4 = 1500 m^2

Assumed square tank

Area = 1500 m^2

Side of tank = 39 m

Provide 2Nos.39mx39mx4m+0.5 mFB

6.2.2 Sand filter

Flow = 500 m^3/hr

Filtration rate = 10 m^3/m^2 h

Area of filter = flow / filtration rate

Area = 500 / 10 = 50 m^2

Area = $\pi / 4 \, xd^2$

d = 2.52 m = 2.5 m

Height = 3 m

Size of filter = 2.5 m Dia.x 3m Height

Provide 10Nos. x 2.5x3

6.2.3 Collection tank after sand filter

Flow = 500m^3 / hr

Detention = 20 hr

Volume = 500x20 = 10,000 m^3

Considered 2 tanks

Volume of one tank = 5000 m^3

Assumed Height = 4m

Area = Volume / Height

Area = 5000 / 4 = 1250 m^2

Assumed square tank

Area = 1250 m^2

Side of tank = 35m

Size of tank 2 Nos. = 35mx35mx4m+0.5FmB

Provide 2Nos.35mx35mx4m+0.5FB

6.2.4 Activated carbon column

Flow = 500m^3 / hr

Filtration Rate = 7 -12 m^3 / m^2 hr

Actual filtration rate = 8m^3 / m^2 hr

Area of filter = flow / filtration rate

Area = 500 / 8= 62.5 m^2

Area = 63.5 m^2

62.5 = π /4 x d^2

d = 8.9 m = 9 m

Contact time = 30 min.

Height / Dia = 2:1

HRT = 30 min

Detention time = Volume/Flow

30 = Volume / 0.833 m^3/min

Volume = 25 m^3

Volume = π/4 xd^{2}xH

H = 4.2 m

20 % extra height for expansion and backwash

H = 4.2 x 1.2 = 5 m

Provide 11 Nos. 2.75mDia. x 5m Height

6.2.5 Chlorination

Flow rate = 12000 m^3/day = 200 m^3/min

Detention time = 5 min

Volume = 200/5 = 40 m^3

Assumed 4 m height

Area = volume/height

Area = 40/3 = 13.3 m^2

Assumed square tank

Area = 13.3 m^2

Side of tank = 4 m

Provide 1Nos. 4mx4mx3m+0.5 m FB

6.2.6 Final treated effluent tank

Flow Rate = 12000 m^3/day

Considered 2 tanks

Volume of one tank = 6000 m^3

Assumed Height = 4 m

Area = 1500 m^2

Assumed square tank

Area of Tank = 1500 m^2

Side of Tank = 38 m

Size of Tank = 38x38x4+0.5m FB

Provide 2Nos. 38mx38mx4m+0.5m FB

7.0 RESULT AND DISCUSSION

7.1 Performance of exisiting ETP

The industrial wastewater was neutral to alkaline in nature with pH value ranged from 7.0 to 8.1 and domestic sewage acidic in nature with pH value ranged from 6.5 to 6.8. The domestic sewage was low strength.When chemically treated industrial wastewater is mixed with domestic sewage biodegration of combined wastewater was enhanced from 0.33 to 0.43. The combined effluent is further treated to biofilter followed by settling . The performance of the existing ETP revealed that final treated effluent complies the stipulated discharge norms precribed by MPCB except BOD but was not sutiable for recycle/reuse for processes. Therefore, further treatment is required not only to meet the regulatory norms for MPCB and to recycle/reuse of final treated effluent.

7.2 Sand filtration

The performance of sand filter at different filtration rate is present in Table 7.1. Figure 7.1 reveals the SS and COD removal from the sand filter effluent. The sand filter was fed with different flow rates ranging from 8-12 m^3/m^2 hr for 5 runs. During first three runs, COD removal was increased from 41-57% with a filtration rate of 8-10 $m^3/m^2/h$ and thereafter, the COD removal decreased from 57-40% with a filtration rate of 10-12 $m^3/m^2/h$. Among the 5 runs conducted with secondary clarifier effluent on sand filter, maximum COD removal efficiency achieved was 57% at a filtration rate 10 $m^3/m^2/h$ with the least 40% with a filtration rate of 12 $m^3/m^2/h$. The SS removal for all the runs was 100%.

Table 7.1: Performance of sand filter at different filtration rate

Parameters	Secondory clarifier effluent	Effluent from			
		Sand filter			
		Filtration rate ($m^3/m^2/h$)			
		8	9	10	11
pH	7.1-7.8	7.5	7.6	7.1	7.1
SS	8 - 10	4	4	4	4
COD	40-50	36-40	24-28	28-32	32-36
BOD	10-20	9-10	6-7	7-8	8-9

All value are expresed in mg/l excepth pH; BDL- below detectable limits.

7.3 Adsorption capacity

7.3.1 Optimum time

To obtain the optimum contact time of activated carbon batch experiment was conducted at different time intervals i.e from 0 min to 120 min. The effluent were analysed for residual COD. The concentrations of residual COD at different contact time are given below:

Time (min)	Residual COD (mg/l)
0	24
10	18
20	12
30	8
60	16
120	20

The Figure 7.2 reveals that the effect of contact time of activated carbon for COD removal. As the contact time increased from 10 – 30 min COD removal was also increased from 23.8 to 67%. Further increase in contact time from 30 – 120 min there was decrease in COD removal from 67 – 17%. The optimum contact time of activated carbon was 30 min.

7.3.2 Optimum dose

To determine the optimum carbon dose the contact time was kept constant (30 min) with varying doses of carbon from 0.2 to 0.7g. The remaining COD concentration in each set of filtrate effluent was analyzed. The concentrations of residual COD at different carbon doses are given below:

Carbon dose (g)	Residual COD (mg/l)
0.1	24
0.2	24
0.3	20
0.4	16
0.5	12
0.6	8
0.7	8

Figure 7.3 reveals the profile of residual COD concentration at different dose of activated carbon. At lower dose of activated carbon from 0.1-0.2 there was no effect on COD concentration. As the dose increases from 0.2 to 0.5 there was decrease in COD concentration. Further increase in the dose carbon lead to decrease in residual COD and became constant. The optimum dose of activated carbon is 0.6 g with residual concentration 8 mg/l of COD.

The adsorption capacity of activated carbon was determined as given below:

$$\text{Adsorption capacity} = \frac{\text{Weight of impurity removed}}{\text{Carbon dose}}$$

$$= 3.2/0.6 = 5.3 \text{ mg/g}$$

The adsorption capacityof activated carbon used for the treatability studies was determined using langmuir Isotherm. The details of carbon dose and residual COD are as follows:

Carbon dosage (g/200ml)	Carbon dosage (g/l)	Impurity remaining (mg/l)	Impurity removed (mg/l)	Ce/(X /M)
(m)	(M)	(Ce)	(X)	
0.3	1.5	20	4	7.6
0.4	2.0	16	8	4.0
0.5	2.5	12	12	2.5
0.6	3.0	8	16	1.5
0.7	3.5	8	16	1.7

Langmuir models are the most frequently employed models. The Langmuir isotherms model is valid for monolayer adsorption on to surface containing finite number of identical sorption sites. From the langmuir isotherm the adsorption capacity was calculated using the formula:

$$Ce/X/M = 1/ab + Ce/a$$

Where,

Ce = Impurity Remaining (mg/l)

X = Impurity Removed (mg/l)

M = Mass of Carbon (g)

$1/ab$ = Intercept

$1/a$ = Slope

Therefore, the adsorption capacity calculated by langmuir isotherm was 2.21 mg/g.

It can be observed from Figure 7.4 that the isotherm data fits the Langmuir equation well. The values of *a* and *b* were determined from the figure and were found to be 2.3382 mg/g and 0.4522l/mg, respectively. Maximum adsorption capacity was found to be 2.21 mg of COD concentration per g of GAC as adsorbent.

7.4 Activated carbon column

The performance of activated carbon column at different filtration rate is present in Table 7.2. . Figure 7.5 reveals the COD removal from the activated carbon column. The activated carbon column was fed with different flow rates ranging from 7-10.5 $m^3/m^2/h$ for 5 runs. During first two runs, COD removal was increased from 60-65% with a filtration rate of 7-8 $m^3/m^2/h$ and thereafter, the COD removal decreased from 65-17% with a filtration rate of 8-10 $m^3/m^2/h$. Among the 4 runs conducted with sand filter effluent on activated carbon column, maximum COD removal efficiency achieved was 65% at a filtration rate 8 $m^3/m^2/h$ with the least 17% with a filtration rate of 12 $m^3/m^2/h$.

Table 7.2 :Performance of activatedcarbon column at different filtration rate

Parameters	Secondory clarifier effluent	Effluent from				
		Sand filter				
		Filtration rate ($m^3/m^2/h$)				
		7	8	8.5	9.5	10.5
pH	7.6	8.09	8.1	8.3	8.00	7.9
SS	BDL	BDL	BDL	BDL	BDL	BDL
COD	24 - 28	12	4	16	20	24
BOD	8	2	BDL	3	5	6

All values are express in mg/l except pH.
BDL- below detectable limits.

7.5 Chlorination

The disinfectant used for chlorination was sodium hypochpochlorite. The filtrate effluent from activated carbon column was tested for disinfection. Dose of sodium hypochlorite were varied from 5 to 25 mg/l. the flocs formed were allowed to settle for 30 min. Then the supernatant was analyzed for COD , pH, residual chlorine and chlorides. After analyzing the supernatant it was found that residual chlorine is negligible for all doses of sodium hypochlorite whereas COD was nil at 15 mg/l dose of NOCl and at other doses the COD was 8 - 20 mg/l, so 15 mg/l was the optimum dose of NOCl for chlorination.

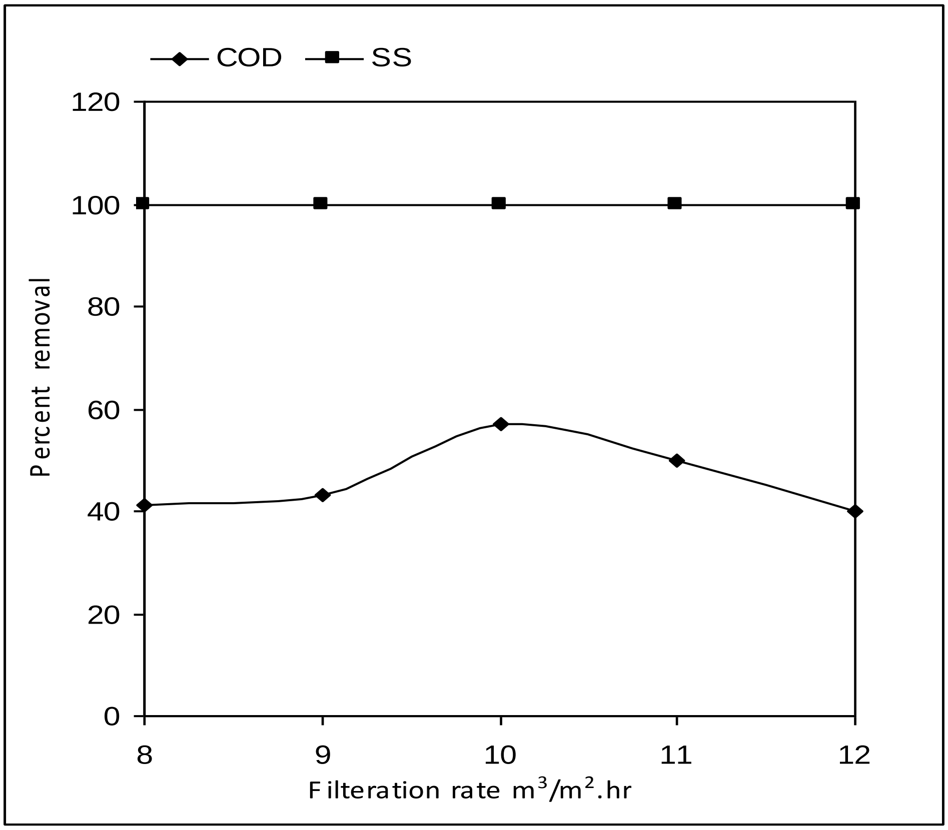

Figure 7.1: COD and SS removal at different filtration rate of sand filtration

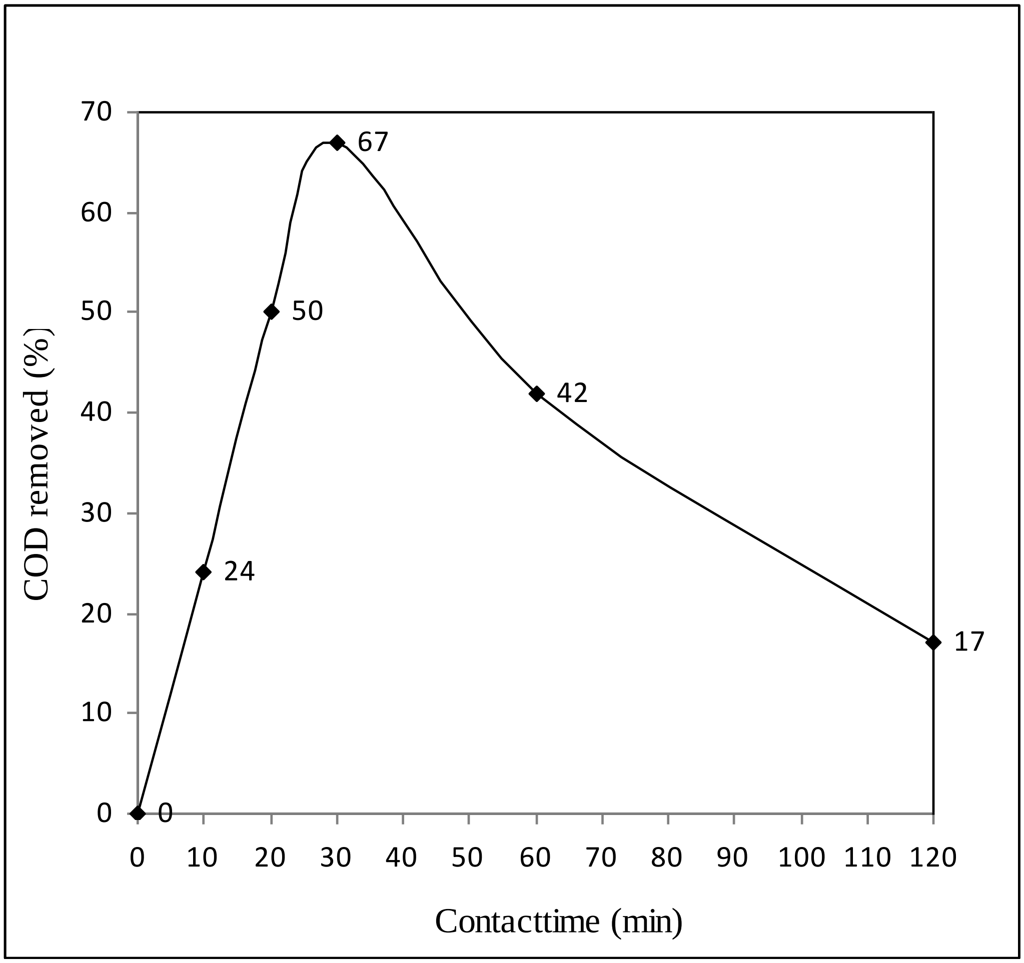

Figure 7.2: Effect of contact time at constant dose of activated carbon for COD removed

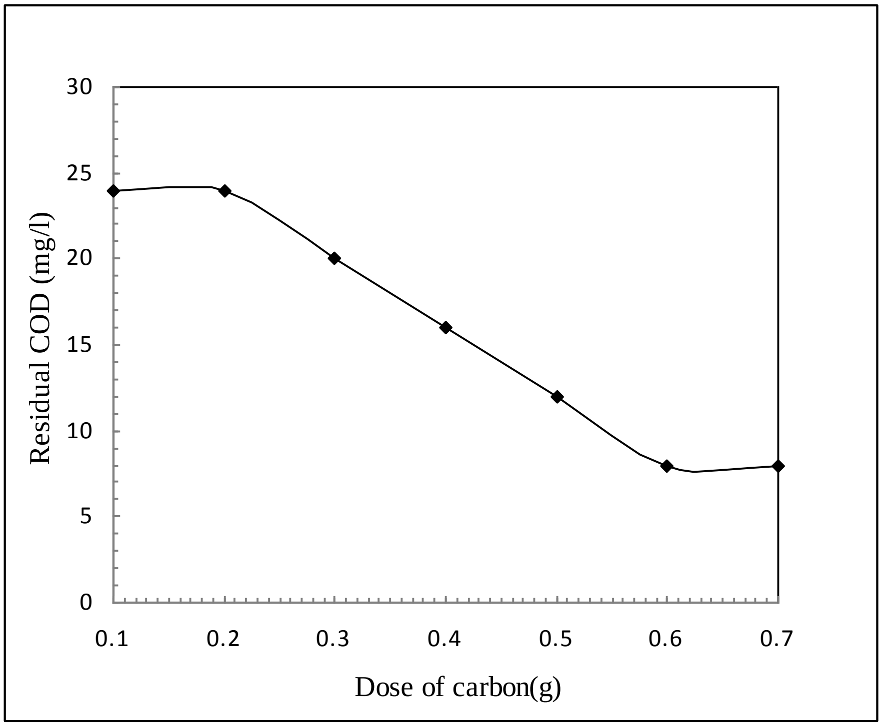

Figure 7.3: Profile of residual COD concentration at different carbon dose

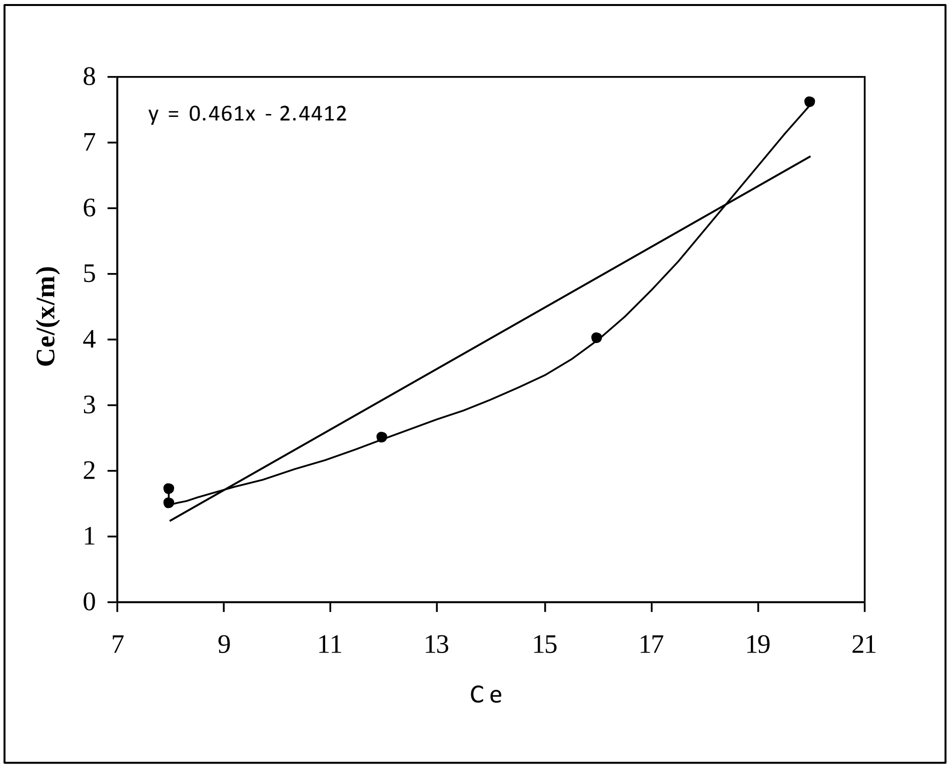

Figure 7.4: Langmuir adsorption isotherm for COD concentration at 0.6 g/200 ml of activated carbon

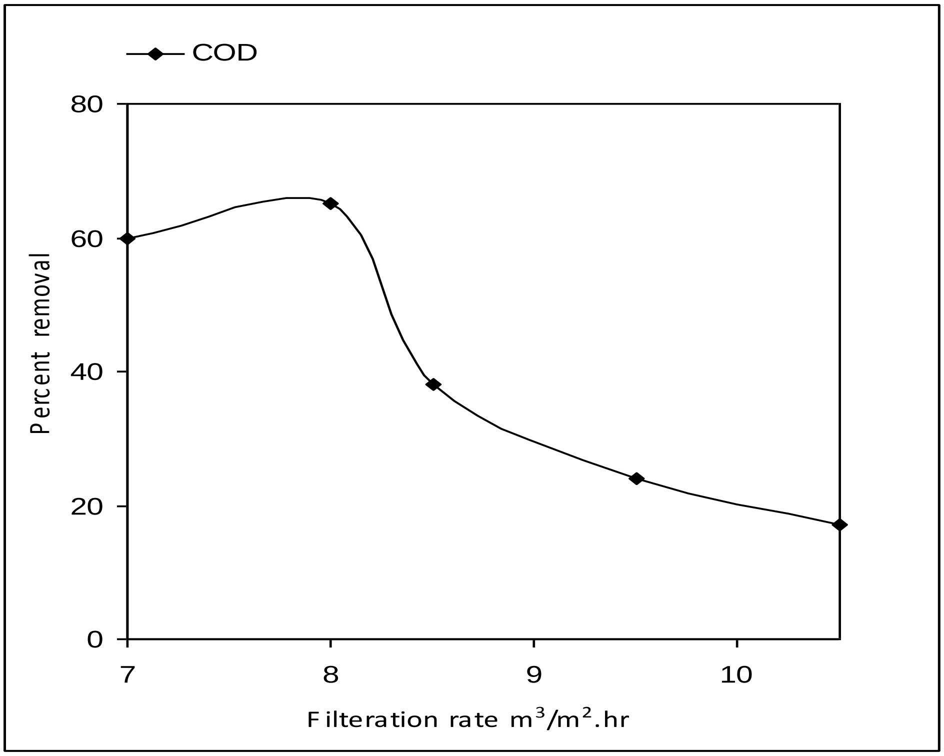

Figure 7.5: COD and SS removal at different filtration rate of activated carbon column

8.0 CONCLUSION

The effluent from automobile industry is neutral to alkaline in nature and characterized with high oil & grease, organic matter, low inorganic matter and heavy metals. Where as domestic sewage generated from industry is a low strength. The combined effluent is treated through ETP under hydraulic load of 4-5 MLD as against design load of 12 MLD. The ETP comprises oil and water separator, chemical and bio-oxidation processes. The final treated effluent from the ETP conforms to the prescribed norms of the MPCB for discharge Into Inland Surface Waters with respect to all parameters except BOD.

The treatability studies were carried out to investigate the treatment route for upgrading the existing treatment facility for recycling/reuse of treated water with in the industry for process. In sand filtration, the maximum COD removal efficiency achieved is 57% with 100 % SS removal and in activated carbon column, the maximum COD removal efficiency achieved is 65% and further residual COD is removed through chlorination.

Based on field investigation and treatability studies, the proposed treatment scheme comprising oil and water separator, chemical treatment, biofilter and sand filtration followed by activated carbon column and chlorination not only conforms the discharge norms prescribed by MPCB and also achieve the recycle/reuse quality water. The studies concluded that automobile industry effluent can be purified to the level of recycle/reuse without adopting costly membrane separation processes. Therefore, the treatment process package is a techno-economical viable option for automobile industry for recycle/reuse of final treated effluent.

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