A thesis on

Plant Design For Microbial Treatment of Waste Water With Advanced Oxidation Process

Submitted By

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Bachelor of Technology in Chemical Engineering

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CERTIFICATE

This is to be certified that **Mr. Susanta Sethi** bearing institute Roll No. 110CH0109 had successfully completed the project report entitled ***"Plant Design For Microbial Treatment of Waste Water With Advanced Oxidation Process"*** with keen interest and hard work under my supervision and guidance.

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Nomenclature

ASP – Activated Sludge Process

AOP – Advanced Oxidation Process

UV – Ultra-Violet

kWh – Kilo Watt Hour

TOC – Total Organic Carbon

TDS – Total Dissolved Solid

SS – Suspended Solids

VSS – Volatile Suspended Solids

MLSS – Mixed Liquor Suspended Solids

BOD – Biological Oxygen Demand

COD – Chemical Oxygen Demand

RAS – Return Activated Sludge

HRT – Hydraulic Retention Time

SVI – Sludge Volume Index

TC – Total Carbon

IC – Inorganic Carbon

TKN – Total kjeldahl Nitrogen

TU – Turbidity Unit

PPM – Parts Per Million

ABSTRACT

About one-fifth of the people on earth are deficient to safe drinking water. About 71 % of agricultural lands are devoid of proper irrigation water. Industrial waste water when flows through the rivers results in water pollution by affecting both aquatic life as well as crops which are being irrigated by river water. Contaminated water plays significant role in affecting numerous lives. Again in some areas during summer we face water problems as lots of water after day to day domestic use are simply unutilized. This waste water from domestic use and industries constitute a major part of processed water that is not only being unutilized but also causing water pollution.

In the present project work we had tried to develop and design waste water purifying technique and whole plant set-up for the purification of both industrial and domestic used waste water. The whole plant set-up is being design in order to purify waste water containing a significant level of organic and inorganic compounds both in dissolved and undissolved form. This water treatment process basically utilizes the ASP (Activated Sludge Process) and AOP (Advanced Oxidation Process) which are not only highly efficient in organic and inorganic compounds removal but also provide a high level of disinfection. In ASP microorganisms were cultured in ASP tank and removal of organic compounds takes place. In AOP tank UV light is used with H_2O_2 in order to remove odor, inorganic components and to achieve a high level of disinfection. Along with the above two processes, the general water treatment processes like preliminary and primary water treatment were also done in order to remove inorganic and colloidal particles. The treated water from the designed plant set up was found to be almost free of any organic & inorganic contaminants and was found to be ideal for use in irrigation process, day to day domestic use, as process water in the industries itself and can also be used for drinking purpose.

Keywords: Activated sludge process, Advanced oxidation process, Microbial degradation, UV-H_2O_2 , BOD.

1. Introduction

According to a 2007 World Health Organization report, near about 1.1 billion people is lacking access to an improved drinking water supply. In India about 71% of agricultural lands are deficient in proper irrigation water. The waste water from the industries is more prone to water pollution and affect the aquatic lives. Apart from this in urban areas lots of processed water after domestic use is wasted in the form of sewage water. In our country we generally face water problems in summer due to drop in ground water level as well as very less water running through the rivers. The need of water for drinking and domestic use becomes severe during the summer days in comparatively populated areas. So there is a need for the treatment of waste water.

This waste water both from industries and sewage basically contains a high proportion of organic compounds as well as significant level of inorganic, suspended solids and undissolved ions. So in order to purify the waste water we should opt for a highly efficient treatment process. In our present project work we have tried to develop an efficient water treatment process which basically takes the advantage of both Activated Sludge Process (ASP) and Advanced Oxidation Process (AOP) which are considered to be highly efficient water treatment process.

ASP basically is a biological water treatment process in which the microorganisms are cultured and for their growth they basically convert the organic matter into CO_2. During this process they also utilize the phosphates ant nitrates for their growth. Along with these matters they also utilizes the trace elements like potassium, magnesium, and iron while calcium, sodium, and silica may be necessary for the growth of the microorganism. There may also be a requirement for traces of zinc, copper, cobalt, manganese, and molybdenum for their growth. So the ASP is ideal for removal of a no. of impurities from the waste water. The conventional activated sludge process consists of an aeration tank followed by a settling tank, as shown below.

One is the ASP tank where the microorganism are grown and the other one is a clarifier which is basically separates the solid sludge and clear water. After direct treatment of water it can be used for irrigation purposes and after proper disinfection can also be used for drinking purpose. One of the other uses of this process is that the solid sludge after being recovered can be used a s solid fuels in the industries itself as well as can be used for bio-fertilizer preparation.

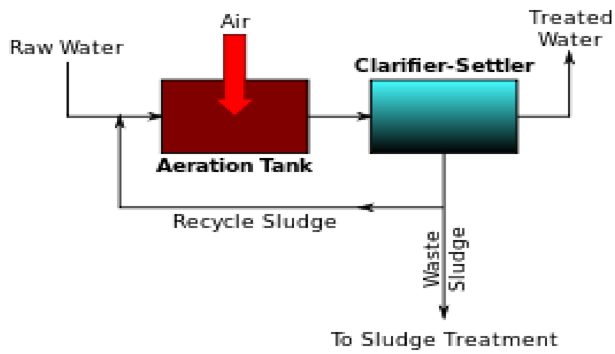


Fig.1 Two stage ASP process

The usual source of carbon for microorganisms is carbohydrates, especially polysaccharides because of their abundance. Nevertheless, other sources used include fats, hydrocarbons such as methane and proteins. Cellulose is preferred by some fungi. The inertness of atmospheric nitrogen precludes its availability for microorganisms. The usual source is nitrogen-containing compounds such as amino acids, ammonia, nucleotides, uric acid and urea. Sulfur is plentiful in naturally occurring compounds. Inorganic sulfates can be reduced via the sulfide and incorporated into amino acids. Hydrogen sulfide is used as a source of sulfur by some microorganisms. Organic sulfur may represent an alternative sulfur-containing nutrient.

The combination of wastewater and biological mass is commonly known as mixed liquor. In all activated sludge plants, once the wastewater has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant is stopped to undergo further treatment before discharge. Part of the settled material called as the sludge is returned to the head of the aeration system to re-seed the new wastewater entering the tank. This portion of the floc is called return activated sludge (RAS.). Excess sludge is termed as waste activated sludge (WAS). WAS is removed from the treatment process to keep the biomass to food ratio supplied in the wastewater in balance and is further treated by digestion, either under anaerobic/ aerobic conditions prior to disposal.

Chemical oxidation technologies are defined as the processes that use oxidizing agents to degrade or transform complex hazardous chemicals to simpler nontoxic ones. Advanced oxidation process (AOP) constitutes, in general, the generation and the use of hydroxyl radicals to oxidize hazardous chemicals, which are otherwise very recalcitrant to conventional oxidation processes. Apart from this AOP serves as a highly efficient disinfection (about 99.9%) process. Apart from disinfection it also removes the bad odor and taste. Advanced oxidation process in a broad sense, refers to a set of chemical treatment procedures designed to remove organic and sometimes inorganic materials in water and waste water by oxidation through reactions with hydroxyl radicals (•OH). In real-world applications of wastewater treatment, however, this term usually refers more specifically to a subset of such chemical processes that employ ozone (O_3), hydrogen peroxide (H_2O_2) and or UV light. In our present study we have taken H_2O_2 and UV light as the AOP.

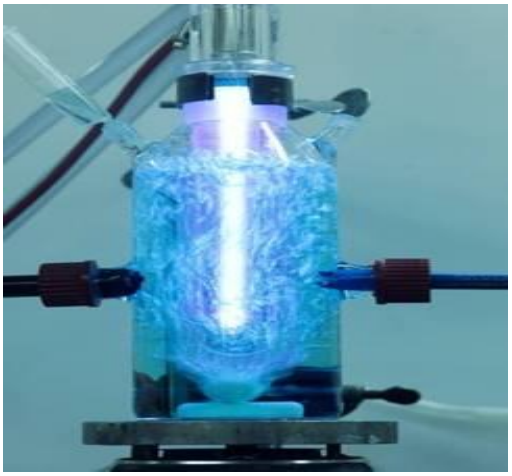


Fig.2 UV- H_2O_2 advanced oxidation process

Generally speaking, chemistry in AOPs could be essentially divided into three parts.

1. Formation of ·OH.
2. Initial attacks on target molecules by ·OH and their breakdown to fragments.
3. Subsequent attacks by ·OH until ultimate mineralization.

The advantage of this process is that H_2O_2 ultimately forms water. So there is no harmful effect of the oxidation process. The UV light destroys the nucleic acid part of any pathogenic microorganism if present and thereby providing a greater extent of disinfection.

The whole plant set up which we have tried to develop is basically uses the ASP as secondary and AOP as tertiary water treatment process. We have performed the preliminary and primary water treatment as conventional water treatment process. The water after treatment can be used either as drinking purpose if permissible or more generally can be used for irrigation purposes, day to day domestic use. The treated water can also be used as process water in industries which will eliminate the risk of water pollution and lowers the cost for preparation of process water. In populated area it can be advantageous in order to process a huge amount of water.

2. Literature Review

Wastewater treatment occurs in a treatment plant in several stages depending on the degree of treatment desired. In the first stage, the preliminary treatment processes prepare the influent wastewater for treatment in subsequent processes. Bar-screens, grit-chamber, and flow equalization tank are some of the processes included in the preliminary treatment. There is no significant removal of biodegradable organic matter expressed in terms of 5-day biochemical oxygen demand (BOD) or suspended solids by these processes. The next stage is the primary treatment process where settle able and floatable solids present in the wastewater are removed by gravity sedimentation. In some rare instances, the flotation process can be used instead of gravity sedimentation for the removal of settle able solids. The primary treatment process can remove up to 40% of the incoming BOD and 50–70% of the suspended solids. The subsequent stage is the secondary treatment process, which is needed to remove the remaining soluble and colloidal organic matter from the wastewater that was not removed during the primary treatment processes.

The secondary processes invariably use aerobic biological treatment processes to remove the soluble and colloidal organic matter from the wastewater. The biological treatment process converts the soluble and colloidal organic matter into settle-able solids and micro-organisms (sludge), which are removed in the secondary settling tank leaving a clearer supernatant effluent for discharge. Thus, the settling tank following the aeration tank is an integral part of the process. In this entry, the secondary tank details are not included. These processes in combination with the primary process can remove 90% BOD (carbonaceous BOD) and suspended solids. AOP considered being tertiary treatment process which basically removes harmful organic and inorganic compounds and also serves a strong disinfectants providing upto 99.9 % disinfection.

2.1 Activated Sludge Process(ASP)

In simple terms ASP can be refferd as a biological process for treating sewage and industrial waste water using air and microorganisms preferably bacteria or fungi.

- Biological treatment was unquestionably a primitive science in the late 1800's, having only recently been elucidated through progressive European (Mueller, Frankland, Bailey-Denton, Dibdin) and American (Mills, Hazen, Drown and Sedgwick of the Lawrence Experimental Station situated in Lawrence, Massachusetts) filtration research. (Peters & Alleman, 1982) The basic derivatives of their work included intermittent filters, contact beds and trickling filters.

- The activated sludge process was discovered in 1913 in the UK by two engineers, Edward Ardern and W.T. Lockett, who were conducting research for the Manchester Corporation Rivers Department at Davyhulme Sewage Works. Dr. G Fowler, co-founder of the activated sludge process should have the credit for originating the process even though Ardern and Lockett did much to develop it. All three of these men are better described as chemists than engineers. Experiments on treating sewage in a draw-and-fill reactor (the precursor to today's sequencing batch reactor) produced a highly treated effluent. Believing that the sludge had been activated (in a similar manner to activated carbon) the process was named activated sludge. Not until much later was it realized that what had actually occurred was a means to concentrate biological organisms, decoupling the liquid retention time (ideally, low, for a compact treatment system) from the solids retention time (ideally, fairly high, for an effluent low in BOD and ammonia).

- According to Sundstrom (1979) The activated sludge process consists of an aeration tank followed by a settling tank, as shown in figure given below.. The wastewater from the primary settling tank enters the aeration tank and mixes with the micro-organisms or biomass present. A portion of the settled sludge (biomass) in the secondary settling tank is recycled back to the head of the aeration tank. This recycled sludge is referred to as return activated sludge (RAS). The term sludge in the secondary settling tank refers to solids that have settled in the tank bottom because of gravity forces. The recycling of the sludge maintains a desired amount of biomass concentration in the aeration tank. The solids responsible for the bio-oxidation of organic matter consist of microorganisms solids (MLVSS). Mixed liquor volatile suspended solids are often considered to represent the active biomass in the system. The remaining settled sludge from the secondary settling tank is withdrawn as waste activated sludge (WAS) for further processing before disposal.

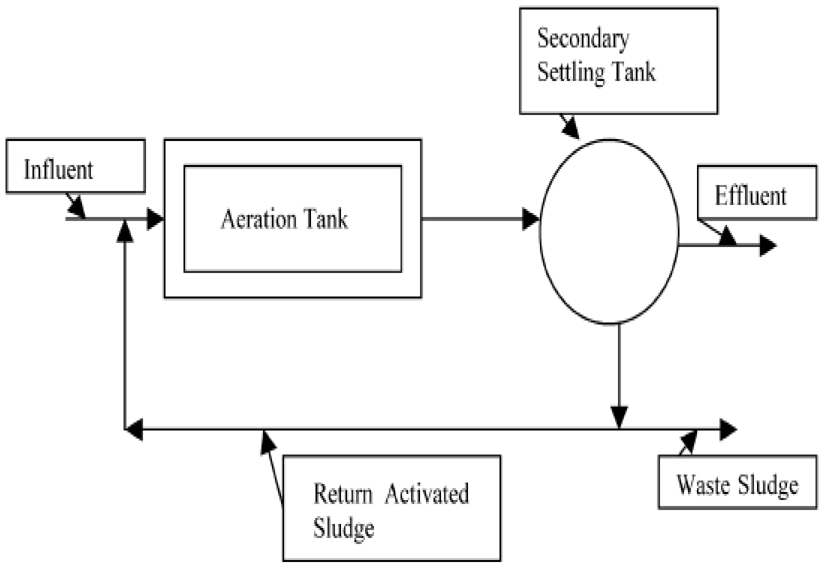


Fig.3 Activated sludge schematic diagram

The biological process taking place in the ASP tank can be in the following form.

Organic matter + N + P + O_2 + micro-organisms → CO_2 + H_2O + new micro-organisms

The microorganisms utilize the phosphates ant nitrates for their growth. Along with these matters they also utilize the trace elements like potassium, magnesium, and iron while calcium, sodium, and silica may be necessary for the growth of the microorganism. There may also be a requirement for traces of zinc, copper, cobalt, manganese, and molybdenum for their growth. There is a specific requirement of food to microorganism ratio in order to maintain activation of the microorganisms.

2.1.1 Loading Rate

A loading parameter that has been developed over the years is the *hydraulic retention time* (HRT), q, d

q = V/Q

where; V= volume of aeration tank, m^3, and Q= sewage inflow, m^3/day.

2.1.2 Specific Substrate Utilization Rate

A rational loading parameter which has found wider acceptance and is preferred is ***specific substrate utilization rate***, q, per day.

$$q= Q*(S - S_e) /(V*X)$$

Where;

X = MLSS concentration in aeration tank.

Where, S_O and S_e are influent and effluent organic matter concentration respectively.

2.1.3 Food to Microorganism ratio (F/M)

$$F/M = Q * (S_O - S_e) / (X*V) = Q * S_O /(X*V)$$

2.1.4 Sludge Recycle

The sludge settling ability is determined by sludge volume index (SVI) defined as volume occupied in mL by one gram of solids in the mixed liquor after settling for 30 min. If it is assumed that sedimentation of suspended solids in the laboratory is similar to that in sedimentation tank, then $X_r = 10^6/SVI$. Values of SVI between 100 and 150 ml/g indicate good settling of suspended solids. The X_r value may not be taken more than 10,000 g/m^3unless separate thickeners are provided to concentrate the settled solids or secondary sedimentation tank is designed to yield a higher value.

2.2 Advanced Oxidation Process(AOP)

- Advanced oxidation processes have been used for the treatment of drinking water, wastewater, and soil/ groundwater contaminated with unwanted and hazardous substances. The processes are, in general, based on the generation and the use of highly reactive hydroxyl radicals ($^{\cdot}OH$) that react indiscriminately with many organic and inorganic substances. This entry provides the readers with an overview of such AOP in terms of fundamentals of the reaction mechanisms and their application to drinking water, wastewater, and soil/groundwater treatment processes.

- The use of chemical reagents with high oxidizing potential is the most effective way of oxidizing substances. The most highly oxidizing reagent available is the hydroxyl radical ($^{\cdot}OH$). In this regard, most AOPs are performed in conjunction with the generation of $^{\cdot}OH$ to initiate oxidations. A radical is a compound containing an atom with a single unpaired electron.[4] Structurally, $^{\cdot}OH$ is a highly reactive radical because of its orbital characteristics. The four outermost orbitals of $^{\cdot}OH$ have only seven electrons so that it has a great tendency to gain the eighth one to form the stable state. In the presence of an organic contaminant(s), $^{\cdot}OH$ can abstract a hydrogen atom, thereby provoking contaminant oxidation. Such abstraction reaction is thermodynamically favored strongly, releasing about 119 kcal=mol of energy.

$$^{\cdot}OH + ^{\cdot}H \rightarrow H_2O \quad \Delta H +119 \text{ kcal/mol}$$

- Arslan et al. have investigated the AOPs for the treatment of reactive dye wastewater. The investigators found that H_2O_2, in presence of UV light was capable of completely decolorizing and partially mineralizing the dye wastewater within 1 hr.

- Using a batch recycle mode, oily wastewater was treated in the photo assisted advanced oxidation systems. Their results indicated that UV/H_2O_2 oxidized oily compounds into organic acids with the efficiency being greater at acidic pH. The oxidation rate was enhanced in the presence of Fe^{3+}.
- Advanced oxidation process basically provides higher degree of disinfection by breaking up the nucleic acid part of pathogenic microorganisms.

2.3 Preliminary & Primary water Treatment

2.3.1 Pre-Treatment

- Pumping and containment – The majority of water must be pumped from its source or directed into pipes or holding tanks. To avoid addition of contaminants to the water, this physical infrastructure must be made from appropriate materials and constructed so that accidental contamination does not occur.

1. Screening – The first step in purifying surface water is to remove large debris such as sticks, leaves, rubbish and other large particles which may interfere with subsequent purification steps. Most deep groundwater does not need screening before other purification steps.

2.3.2 Primary Treatment

- The addition of inorganic coagulants such as aluminum sulfate (or alum) or iron (III) salts such as iron (III) chloride cause several simultaneous chemical and physical interactions on and among the particles. Within seconds, negative charges on the particles are neutralized by inorganic coagulants. Also within seconds, metal hydroxide precipitates of the aluminum and iron (III) ions begin to form. These precipitates combine into larger particles under natural processes such as Brownian motion and through induced mixing which is sometimes referred to as flocculation.

- Water exiting the flocculation basin may enter the sedimentation basin, also called a clarifier or settling basin. It is a large tank with low water velocities, allowing floc to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between the two processes does not permit settlement or floc break up. Sedimentation basins may be rectangular, where water flows from end to end or circular where flow is from the center outward. Sedimentation basin outflow is typically over a weir so only a thin top layer of water that furthest from the sludge exits.

- As far as our whole treatment process is concerned we have to be ensure the after treatment of the raw water if it is used as drinking water or day to day domestic use then it should have quality which meets the standard for safe drinking water.

- Again if we are concerned with industrial waste water then it should meet the standard for industrial effluent discharge to environment. So the data for safe drinking water as well as safe discharge of industrial effluent water has been given below.

Table-1: Drinking Water Specification

S.NO.	Parameter	Requirement desirable Limit	Remarks
1.	Colour	5	May be extended up to 50 if toxic substances are suspected
2.	Turbidity	10	May be relaxed up to 25 in the absence of alternate
3.	pH	6.5 to 8.5	May be relaxed up to 9.2 in the absence
4.	Total Hardness	300	May be extended up to 600
5.	Calcium as Ca	75	May be extended up to 200
6.	Magnesium as Mg	30	May be extended up to 100
7.	Copper as Cu	0.05	May be relaxed up to 1.5
8.	Iron	0.3	May be extended up to 1
9.	Manganese	0.1	May be extended up to 0.5
10.	Chlorides	250	May be extended up to 1000
11.	Sulphates	150	May be extended up to 400
12.	Nitrates	45	No relaxation
13.	Fluoride	0.6 to 1.2	If the limit is below 0.6 water should be rejected, Max. Limit is extended to 1.5
14.	Phenols	0.001	May be relaxed up to 0.002
15.	Mercury	0.001	No relaxation
16.	Cadmium	0.01	No relaxation
17.	Selenium	0.01	No relaxation
18.	Arsenic	0.05	No relaxation
19.	Cyanide	0.05	No relaxation
20.	Lead	0.1	No relaxation
21.	Zinc	5.0	May be extended up to 10.0
22.	Anionic detergents (MBAS)	0.2	May be relaxed up to 1
23.	Chromium as Cr^{+6}	0.05	No relaxation
24.	Poly nuclear aromatic Hydrocarbons	--	--
25.	Mineral Oil	0.01	May be relaxed up to 0.03
26.	Residual free Chlorine	0.2	Applicable only when water is chlorinated
27.	Pesticides	Absent	--

Table-2: Water Specification For Discharge For Pollution Limits

Sl. No.	Parameter	Standards			
		Inland Surface water	Public Sewers	Land of irrigation	Marine/Costal areas
1.	Colour and odour	Of Annexure-1	--	See 6 of Annexure -1	See 6 of Annexure -1
2.	Suspended solids mg/1, max.	100	600	200	a. For process waste water 100 b. For cooling water effluent 10 per cent above total suspended mater of influent
3.	Particle size of suspended solids	Shall pass 850 micron IS Sieve	--		a. Floatable solids, solids max. 3 mm b. Settleable solids. Max 856 microns
4.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5.	Temperature	Shall not exceed 5°C above the receiving water temperature	--	--	Shall not exceed 5°C above the receiving water temperature
6.	Oil and grease, mg/1 max.	10	20	10	20
7.	Total residual chlorine, mg/1 max	1.0	--	--	1.0
8.	Ammonical nitrogen (as N), mg/l, max.	50	50	--	50
9.	Total nitrogen (as N), mg/l, max.	100	--	--	100
10.	Free ammonia (as NH_3), mg/l, max	5.0	--	--	5.0
11.	Biochemical oxygen demand (3 days at 27°C), mg/l, max	30	350	100	100

12.	Chemical oxygen demand, mg/l, max	250	--	--	250
13.	Arsenic (as As) mg/l, max	0.2	0.2	0.2	0.2
14.	Mercury (as Hg), mg/l, max	0.01	0.01	--	0.01
15.	Lead (as Pb), mg/l, max	0.1	0.1	--	2.0
16.	Cadmium (as Cd) , mg/l, max	2.0	1.0	--	2.0
17.	Hexavalent chromium (as Cr+6), mg/l, max	0.1	2.0	--	1.0
18.	Total chromium (as Cr), mg/l, max	2.0	2.0	--	2.0
19.	Copper (as Cu), mg/l, max	3.0	3.0	--	30
20.	Zinc (as Zn), mg/l, max	5.0	15	--	15
21.	Selenium (as Se), mg/l, max	0.05	0.05	--	0.05
22.	Nickel (as Ni), mg/l, max	3.0	3.0	--	50
23.	Cyanide (as CN), mg/l, max	0.2	2.0	0.2	0.2
24.	Fluoride (as F), mg/l, max	2.0	15	--	15
25.	Dissolved phosphates (as P), mg/l, max	5.0	--	--	--
26.	Sulphide (as S), mg/l, max	2.0	--	--	5.0
27.	Phenolic compounds (as C_6H_5OH), mg/l, max	1.0	5.0	--	5.0
28.	Radioactive materials				
	a. α emitters micro cure mg/l, max	10^{-7}	10^{-7}	10^{-8}	10^{-7}
	β emitters micro curemg/l, max	10^{-6}	10^{-6}	10^{-7}	10^{-6}

3. Objective

The objective of the present project work is:

- Modelling of the waste water treatment plant.
- Selection of optimum parameters for modelling.
- Design of the treatment plant for a specific water treatment requirement.
- Economic calculation of the whole plant set-up.
- Installation and set-up of whole plant in a small scale.
- Pre and post treatment water quality analysis.

4. Modelling of Waste Water Treatment Plant

We had tried to develop an efficient waste water treatment plant which basically according in following process flow chart.

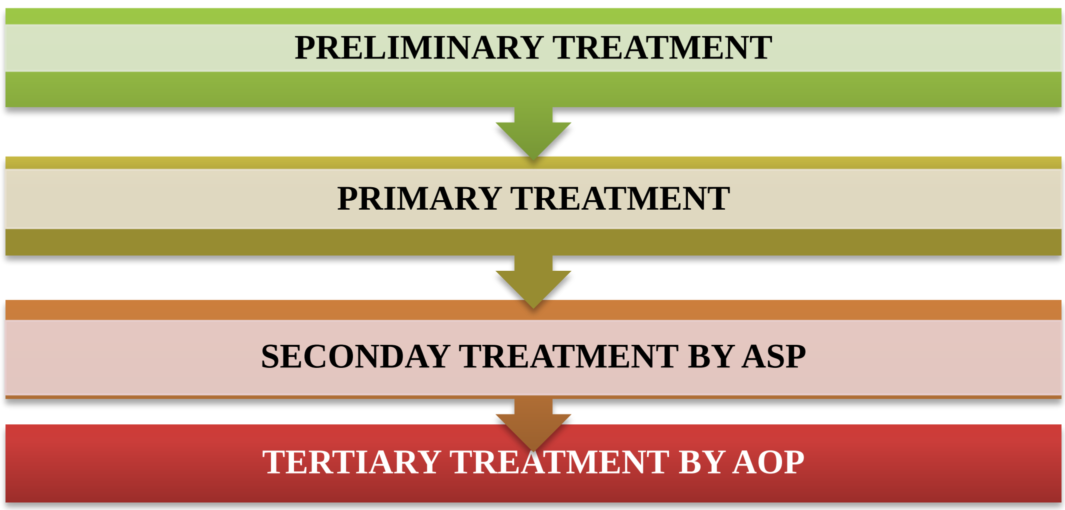


Fig.4 Steps for treatment process

4.1 Preliminary Treatment

- For primary treatment we had a cylindrical tank with basically for sedimentation of large particles. Screen bar had been provided in order to remove large particles from entering in the treatment process.

4.2 Primary Treatment

- Here we were intended to settle colloidal particles, iron particles, other inorganic compounds as well as some heavy particles by subjecting the water to aeration in a conical bottom tank and the settled impurities in the form of sludge would be taken out from the bottom.
- In order to settle some undissolved ions, inorganic and organic particles, in a conical settling tank it would be fed by alum and settling allowed to take place.

4.3 Secondary Treatment

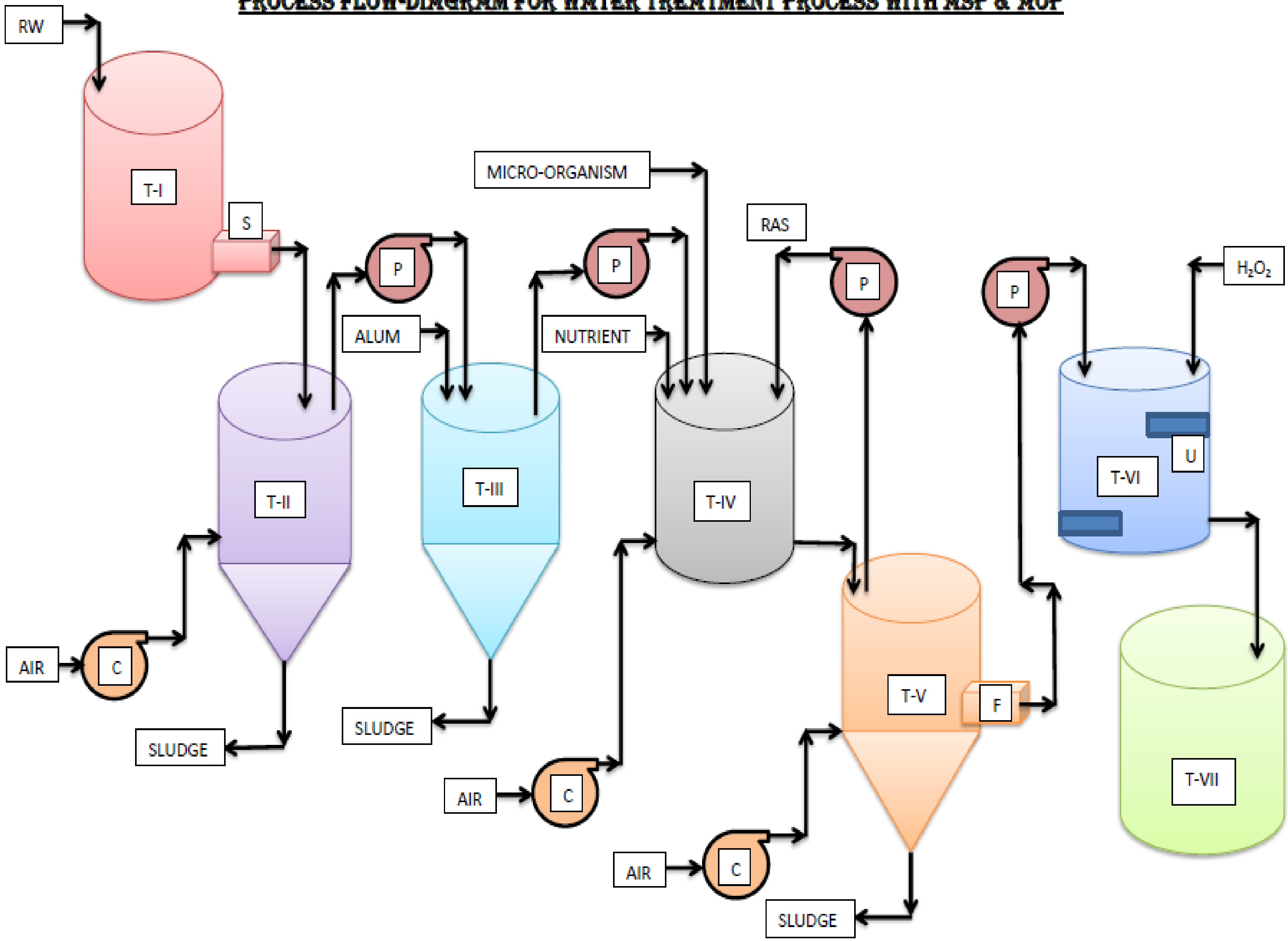
- Secondary treatment process is basically done by activated sludge process and consists of two tanks. One is for aeration tank where microorganisms are grown and second one is a clarifier where the settling of impurities takes place.
- A recycle stream known as recycle activated sludge (RAS) is there in order to maintain microorganism count in significant level.
- In clarifier air compressor has been used fo enhancing settling of particles.

4.4 Tertiary Treatment

- In our developed process, the tertiary treatment process is AOP utilizing UV light in presence of H_2O_2 in a cylindrical tank.
- It not only provides settling of organic and inorganic compounds but also provides highest degree of disinfection.

❖ For the convenience for the whole design process we had used 20 liter water tanks. So from our modelling approach we had prepared a flow sheet of the entire water treatment process shown in the next page.

PROCESS FLOW-DIAGRAM FOR WATER TREATMENT PROCESS WITH ASP & AOP



Nomenclature

T-I -----	RAW WATER STORAGE TANK
T-II -----	AERATION TANK
T-III -----	SEDIMENTATION TANK
T-IV -----	ASP TANK
T-V ------	SETTLING TANK
T-VI -----	AOP TANK
T-VII ----	PURE WATER STORAGE TANK
C ----------	AIR COMPRESSOR
P ----------	PUMPS
S ----------	SEPARATION SCREEN
F ---------	ULTRA FILTER
U --------	U.V. LAMP
RAS ----	RETURN ACTIVATED SLUDGE
RW -----	RAW WATER

5. Process Description

- Raw water is first stored in a cylindrical storage tank in order to settle heavier particles like sand and clay. A separation screen has been provided at the outlet of the storage tank in order to prevent large particles to pass through.
- After pre-treatment stage the water is entered in primary treatment where at first it is subjected to aeration and due to which heavier particles upon aeration subjected to settle for example heavier metal particles, some inorganic compounds and heavier iron particles.
- Then the water is subjected to sedimentation process in a sedimentation tank where it is fed with alum in order to settle down a no. of impurities both organic and inorganic particles as well as ions. This completes the primary water treatment process.
- After that the water is subjected to secondary treatment process which basically activated sludge process. Microorganisms are culture and proper nutrition is provided for their growth. The microorganisms basically break-up the organic compounds in carbon dioxide. They also reduces the nitrates and phosphates for their growth. Along with these matters they also utilize the trace elements like potassium, magnesium and iron while calcium, sodium and silica may be necessary for the growth of the microorganism. There may also be a requirement for traces of zinc, copper, cobalt, manganese and molybdenum for their growth.
- The settled impurities are removed in the form of activated sludge in the clarifier tank. In the secondary treatment process no. of impurities are separated from the water. At the exit of the clarifier there is a ultra-filter provided in order to prevent flow of cultured microorganisms out of the clarifier. There is also a recycling stream from the clarifier to the aeration tank in order to achieve maximum removal of the undesired components. This completes the secondary treatment.
- The water enters the tertiary treatment stage in the advanced oxidation tank. Here the water is subjected to UV light and H_2O_2 is added in order to release hydroxyl radicals. In this process if present organic compounds are completed eliminated along with that any inorganic compound present also reduces and settles down. The UV light breaks the

nucleic acid part of the microorganism there by providing about 99.9% disinfection. This AOP is helpful in further reduction of overall COD as well as color and odor removal.

- This completes the tertiary treatment process. The treated water is stored in a storage tank and can be utilized as irrigation water, process water for industries, domestic use and as drinking water.

5.1 Equipment & Utilities Required

- Cylindrical Tanks - 4 nos. (20 liter water bottles)
- Conical Tanks - 3 nos. (20 liter water bottles)
- Water pumps - 2 nos. (0.5 HP – 2780 RPM)
- Air pumps - 2nos. (1/3 HP)
- Water pipes - 12 meters (2mm diameter)
- Water pipes – 6 meters (1.5 inch diameter)
- U.V. Light – 1 nos. (25 watt)
- *E.Coli*
- Alum, Hydrogen Peroxide, Glucose, Raw water
- Electric board & Wire
- Shorted Angle for frame designing.
- Test tubes, beakers & flasks.
- Utilities for frame design.
- Silicon paste as sealant.

6.Plant Design & Layout

First of all the frame design has been considered. For that purpose shorted angle was taken to carry out framing for plant design. The dimension of the frame has been set as following.

- Height- 5 meters
- Width- 0.8 meters
- Length- 2.5 meters

6.1 Components of frame

- 4 meters of shorted angles – 4 nos. (It should be used as the pillars for the frame.)
- 2.5 meters of shorted angles – 8 nos. (Used as the base.)
- 1ft shorted angles – 34 nos. (Primarily used for various truss design in order to hold tanks & others equipment's.)

The frame has been designed so as to have a perfect design to contain all the process tanks & equipments wherever necessary. The plant layout has been done with the help of various tools. The fabrication of process tanks, piping, sealing the tanks & piping using silicon paste has been done. Fabrication of tanks has been done in such a way that under any circumstances there will not be any leakage.

Water and air pump has been installed and joined with proper piping and wiring. Most careful work was the design of the Oxidation Tank holding UV Lamp in a circular vessel inside the cylindrical tank with proper insulation to avoid any water to leak through it and result in dysfunction of UV Light.

6.2 Components of Plant

- Raw water storage tank equipped with screen.
- Primary aeration tank.
- Primary sedimentation tank.
- Activated sludge culture tank.
- ASP settling tank.
- Advanced oxidation tank.

- Treated clean water storage tank.

6.3.1 Plant Lay-Out

Fig.6 The complete plant lay-out

6.3.2 Stage Wise Layout

Fig.7 Upper Stage

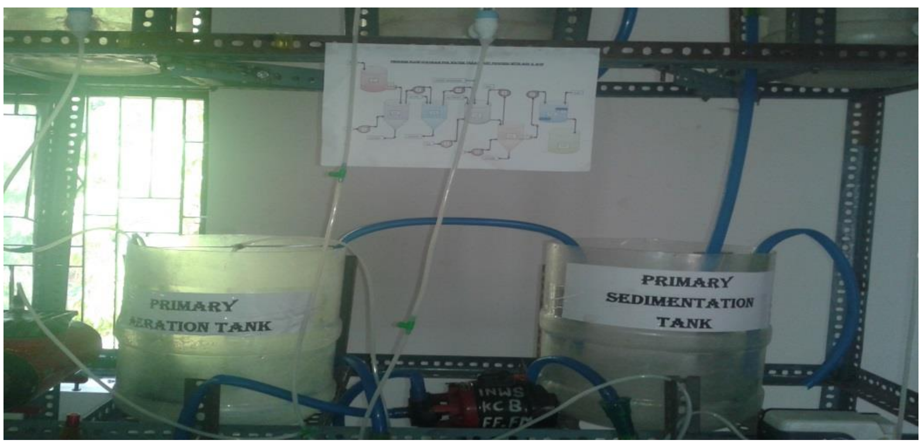


Fig.8 Middle Stage

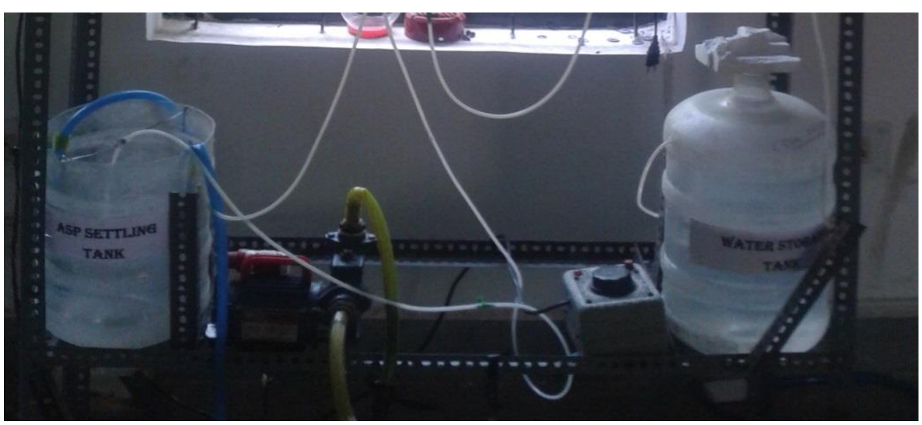


Fig.9 Lower Stage

6. Design of The Treatment Process For Activated Sludge Process

**** Let us we have considered to design a completely mixed activated sludge system to serve 10000 people that will give a final effluent has 5-day BOD not exceeding 25 mg/l.**

The following design data is considered.

Sewage flow = 25 l/person/day

So total sewage flow = 25 x 10000 L/day

= 250,000 L/day

= 250 m^3/day

Let us consider BOD_5 = 10 g/person/day

So total BOD_5 = 10g x 10,000/(250000L/day)

= 0.4 g/L

= 400 mg/L

$BOD_u = 1.47 * BOD_5 =$ 588 mg/L

Total kjeldahl nitrogen (TKN) = 2 gram/person/day

= 2 g *10000 person/ (250,000L/day)

= 0.08 g/L

= 80 mg/L

Phosphorus = 0.5 g/person-day

= 0.5 g x 10,000person/ (250000 L/day)

= 0.02 g/L

= 20 mg/L

Temperature in aeration tank = 25°C (Room Temperature)

At This Temperature[10],
Yield coefficient Y = 0.6

Decay constant K_d = 0.07 per day

Specific substrate utilization rate (q) = $(0.038\ mg/l)^{-1}\ (h)^{-1}$ at 25°C

Assuming 30% raw BOD_5 is removed in primary sedimentation, and BOD_5 going to aeration is therefore, 0.7 x 400 mg/l =280 mg/L.

6.1 Design:

6.1.1 Selection of Θ_c, t and MLSS concentration

Considering the operating temperature and the desire to have nitrification and good sludge settling characteristics, adopting Θ_c = 5d[10]. As there is no special fear of toxic inflows, the HRT (t) may be kept between 3-4 hour and MLSS = 4 g/L[10].

= 4000 mg/L

6.1.2 Effluent BOD_5

Substrate concentration, $S = (1/\Theta_c + k_d)/ q*Y$

$S = (1/5+ 0.07)/ (0.038)(0.6)$

S = 11.84 mg/l.

Assuming, effluent suspended solids (SS) in effluent[11] = 20 mg/l

VSS/SS [11] =0.8.

If degradable fraction of volatile suspended solids (VSS) =0.7

BOD_5 of VSS in effluent = 0.7 x (0.8x20) = 11.2 mg/L.

Thus, total effluent BOD_5 = S + VSS

= (11.84 + 11.2) mg/L

= 23.04 mg/L (Acceptable)

6.1.3 Aeration Tank

$VX = Y*Q*\Theta_c (S_O - S)/(1+ k_d*\Theta_c =)$

where X = 0.8 x 4000 = 3200 mg/l

initial $BOD_5 = S_0$ = 280 mg/L

$$\text{or } 3200 * V = \frac{(0.6)*(5)*(250)*(280-23.04)}{[1 + (0.07)*(5)]}$$

Thus, V = 14.61 m^3

Detention time, t = 44.61 x 24/(250) = 4.28 hour

6.1.4 Food/Mass ratio (F/M)

$F/M = (S_O - S_i) \times q/ (V*X)$

= (280 – 11.84) * 250 / (44.61 * 3200) [mg of BOD_5 /mg of MLSS/day]

= 0.46 [mg of BOD_5 /mg of MLSS/day]

6.1.5 Return Sludge Pumping

If suspended solids concentration of return flow is 2 g/L = 2000 mg/L

R = MLSS/ (MLSS - 2000)

= 4000/ (4000 – 2000)

= 0.5

Return sludge flow rate, Q_r = 0.5 x 250 m^3/day

= 125 m^3/day

6.1.6 Surplus Sludge Production

Net VSS produced $Q_w * X_r = VX / \Theta_c$ = (44.61) * (3200) / 5 mg/day

= 28.55 kg/day

Surplus sludge produced = 28.55/0.8 = 35.70 kg/day

If SS are removed as underflow with solids concentration 1% and assuming specific gravity of sludge as 1.0,

Liquid sludge to be removed = 35.70 / 0.01 kg/day

= 3570 kg/day

6.1.7 Oxygen Requirement

1. For carbonaceous demand,

   oxygen required = (BOD_u removed) - (BOD_u of solids leaving)

   = 1.47 * (360 – 23.04 kg/d) – (35.70 kg/d)

   = 48.54 kg/day = 2.02 kg/hour

2. For nitrification,

   oxygen required = 4.33 * (TKN oxidized, kg/d)

= 2 g/person/day

= 2 g x 10000 /day

= 20 kg/day

Assuming 40 % removed during primary sedimentation.

So total kjeldahl nitrogen available = 0.6 * 20 kg/day

= 12 kg/day

Oxygen required for oxidizing nitrogenous compounds

= 4.33 x (TKN)

= 4.33 * 12 kg/day

= 51.96 kg/day

= 2.165 kg/hour

3. Total oxygen required
   = (2.02 + 2.165) kg/hour = 4.185 kg/hour

Oxygen uptake rate per unit tank volume = 4.185 /44.61 kg/hour/ m^3 tank volume
= 0.094 kg/h/m^3 tank volume

7. Economics

The major fact about any plant design is its economic consideration. Here we are basically considering only Cost of the whole plant and off-course the maintenance cost of the plant.

7.1 Power Requirement

Assume oxygenation capacity of aerators at field conditions is only 70% of the capacity at standard conditions and mechanical aerators are capable of giving 2 kg oyxgen per kWh at standard conditions [8].

Power required = 4.185/(2 * 0.7) kWh

= 2.99 kWh = 3 kWh (1 kWh = 1 Unit)

= 3 x 24 x 365 units/ year

= 26280 units/ year

= 2.62 units/person/year.

As we are using 3 aerator units, so total power consumption

= 3 x 2.62 units/person/year

= 7.86 units/person/year

Power used by 4 pumps can be given by their specification considering operating for 10 hours per day.

= 4 x 10 x 1 kWh/day

= 40 kWh/day

= 40 x 365/10000 units/person/year

= 1.44 units/person/year

Rotor Power required = 1.75 units/person/year

UV Lamp power required = 0.110 x 24 x 365 units/year

= 963.6 units/year

= 0.096 units/year/person

= 0.1 units/year/person (approx.)

Total Power Requirements = Pumping + Aeration + rotor + UV

= (7.86 + 1.44 + 1.75 + 0.1) units/person/year

= 11.15 units/person/year

= 11.15 x 4.4 Rs. /person/year

= 49.06 Rs. /person/year

= 4 Rs. /person/month

Consedering a total 1 Rs./person/month as maintenance cost

So total cost for one month = 5 Rs./person/month

= 50000 Rs./month

So not only maintenance charges but also the initial plant design charges has to be considered. But as far as the maintenance charges has been considered it seems to be economical.

7.2 Plant Design Cost

As for our design consideration we have 4 nos. of cylindrical tanks and 3 conical tanks.

As of 2014 the cost of stainless steel cylindrical tanks of 15 m^3 volume (as for the required specification) is = $ 2190 (http://www.rainwatertanksdirect.com.au/water-tanks/large-tanks.php)

= 1,31,400 Rs.

For 4 tanks = 4 x 1,31,400 Rs.

= 5,25,600 Rs.

Cost of Conical Tank (as per desired specification) of 15 m^3 volume is

= $ 3324 (http://www.enduramaxx.co.uk/17522815-15000-litre-cone-bottom-tank/)

= 1,99,440 Rs.

For 3 conical tanks = 3 x 1,99,440 Rs.

= 5,98,320 Rs.

Total cost of tanks = 5,25,600 + 5,98,320 = 11,23,920 Rs.

7.3 Piping, Instrumentation & Labor Cost

Piping Cost = 10-15 % of tank cost

= 0.125 x 11,23,920 Rs. (Taking 12.5 %)

(** Plant Design & Economics Peter & temerhass)

= 1,40,490 Rs.

Instrumentation cost = 10 % of Tank Cost (Including pump & Aerator)

= 0.1 x 11,23,920 Rs.

= 1,12,392 Rs.

Labor & Supervisory cost cost = 20 % of tank cost

= 2,24,784 Rs.

Miscellaneous = 10 %

= 1,12,392 Rs.

Total cost of piping, instrumentation, labor & supervisory charges

= (1,40,490 + 1,12,392 + 2,24,784 + 1,12,392) Rs.

= 5,90,058 Rs.

So total plant Design cost = (11,23,920 + 5,90,058) Rs.

= 17,13,978 Rs.

In the view of both maintenance & initial plant design cost the system is seem to be effective in the sense of economics.

8. Observation

Table-3: Single run settling/resident time for individual tank based on single run

Sl. No.	Tank	Time
1	Raw Water Cum Screening Tank	15 min.
2	Primary Aeration Tank	30 min.
3	Primary Aeration Tank	45 min.
4	Microbial Culture Tank	4.5 hours
5	ASP Settling Tank	1.5 hours
6	Advanced Oxidation Tank	30 minutes

Fig.10 Before treatment

Fig.11 After treatment

Fig.12 Settled sludge

Fig.13 Advanced oxidation process

9. Results & Discussions

Table-4: Showing treatment results

Sl. No.	Parameter	Limiting Value	Pre-treatment value	Post- Treatment Value
1	Turbidity (NTU)	5 - 10	46	NIL
2	Odor	NIL	Quite High	NIL
3	Color	NIL	Greenish-black	NIL
4	Alkanity (mg/l CaCO3)	25 - 30	368	12
5	Acidity (mg/l CaCO3)	20 - 25	23	10
6	pH	7.5 - 7.9	9.8	7.2
7	Iron (ppm)	0.2 - 0.5	13.7	7.5
8	Chloride (mg/l)	0.025 - 0.03	0.595	0.017
9	Total hardness (ppm)	20	182	24
10	Copper (mg/l)	Up to 0.05	0.213	0.026
11	Total Dissolved Solid(TDS) (mg/l)	Up to 300	786	67
12	Total Organic Carbon (mg/l)	Up to 50	249	17
13	BOD (mg/l of O_2)	Up to 5	324	6.69
14	COD (mg/l of O_2)	Up to 50	440	16
15	Nitrates (mg/l)	Up to 50	42	1.2
16	Phosphates (mg/l)	Up to 2.0	26	0.19
17	Sulphate (mg/l)	150	48.92	24.54
18	Cadmium (µg/l)	Up to 5.0	NIL	NIL
19	Calcium (mg/l)	Up to 2.0	12.36	0.17
20	Ammonia (mg/l)	Up to 0.2	1.34	0.015
21	Zinc (ppm)	Up to 0.05	3.3	0.23
22	Fluoride (ppm)	Up to 0.5	2.7	0.23
23	Manganese (mg/l)	Up to 0.3	NIL	NIL
24	Mercury (µg/l)	Up to 1.0	NIL	NIL
25	Disinfection	99.5 %	-	100 %(No Pathogen Found)

9.1 Discussion

The design of the plant was done in such a way that to have maximum purification with low maintenance cost for about 10000 people. From the economic evaluation of the plant process maintenance cost was calculated to be Rs. 50000 for the 10000 people per month which off-course seems to be very economical. The installation cost was found to be Rs. 17,13,1978 which seems to be high. As far as treatment is concerned the TDS value was quite high (786) before treatment and reduced to 67 which is obviously low and within permissible limit. The BOD content was significantly reduced i.e. about 98 % of BOD has been removed by the concerned treatment process. There was also significant reduction in total organic carbon content level from 249 to 17 mg/l. As far as total hardness is concerned the water was said to be having lower value of post treatment of hardness. Removal of alkanity of water also a major advantage i.e. pH dropped to 7.2 from 9.8 . Before the treatment process the water was having an degraded smell while after treatment it was found to be free of any odor. The color of the water also changed from greenish brown to colorless which has been fully achieved during the advanced oxidation process. Only there is a little change in sulphate content in comparison to other parameters. The turbidity of water was found to be completely eliminated after the treatment process was completed. The settling rate of contaminants was observed and can be said that they are under usual settling data range. As far as the trace elements and metal ions are concerned they also having a reduction in their level after the post treatment analysis. The reduction in nitrates and phosphates was found after the post treatment analysis. It was found to have about complete disinfection. On comparing with the table-1 & table-2 data we can say that the process can be used both drinking water treatment as well as industrial waste water treatment.

10. Conclusion

Although the initial installment cost is high but the maintenance cost is found to be very economical and hence can be put in use. There is significant reduction in BOD level as well as Total organic carbon content. Again there is significant high reduction in hardness and water turbidity showing high purification efficiency of the concerned process. Complete removal of color and odor enhances its purification efficiency. Also about 100 % disinfection has been achieved after post treatment. There seen to be high reduction in metal ion and total dissolved solid content. Removal of alkanity of water also a major advantage i.e. pH dropped to 7.2 from 9.8 level. So from the above fact the whole treatment is seem to be economical and highly efficient for water treatment containing high organic as well as inorganic components and also gives nearly complete disinfection which may be used for drinking water. Before the advanced oxidation stage the water can be used as irrigation purpose. For textile industries the effluent water can be treated with the concerned process to have contaminants level below the environmental pollution level. One of the useful part is the solid sludge which is settled bot in culture and ASP settling tank which is rich in organic contents and can be used a solid fuel. Overall the process is found to be like take and put in use type.

11. Application

- For day to day domestic work and drinking water purification by utilizing a huge amount of waste water.
- For effluent treatment of food processing and Textile industries.
- For irrigation and watering purpose.
- Solid sludge can be used as solid fuel or bio-fertilizer.

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