TREATMENT OF WASTE WATER WITH ADVANCED OXIDATION PROCESS AND PLANT DESIGN FOR MICROBIAL

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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 H2O2 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.

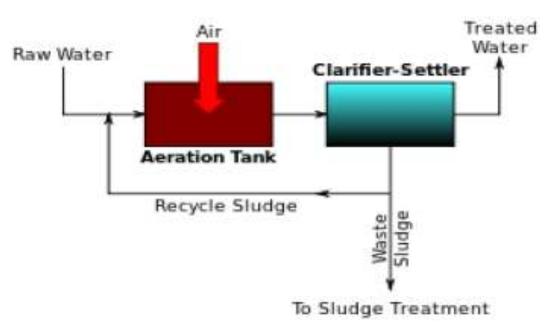
Keywords: Activated sludge process, Advanced oxidation process, Microbial degradation, UV-H2O2 , BOD.

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.

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.



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.

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.

2. LITERATURE REVIEW

According to Sundstrom (1979) The activated sludge process consists of an aeration tank followed by a settling tank,. The wastewater from the primary settling tank enters the aeration tank and mixes with the microorganisms or biomass present.

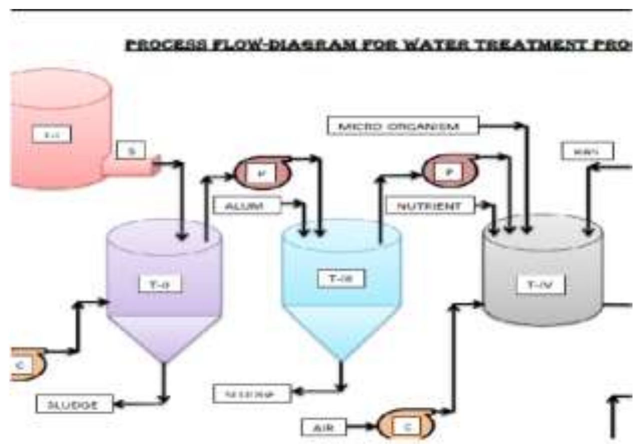
The activated sludge process was discovered in 1913 in the UK by two engineers, Edward Ardern and W.T. Lockett, who were conducting research for the Manchester Corporation Rivers Department at Davyhulme Sewage Works. Dr. G Fowler, cofounder of the activated sludge process should have the credit for originating the process even though Ardern and Lockett did much to develop it.

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.

3. MODELLING OF WASTE WATER TREATMENT PLANT

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

Steps for treatment process



Water treatment process

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

EQUIPMENT & UTILITIES REQUIRED

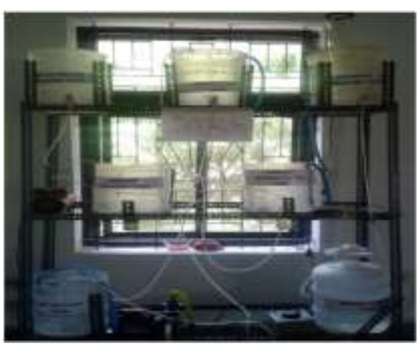
- Cylindrical Tanks - 4 nos. (20 liter water bottles)
- Conical Tanks - 3 nos. (20 liter water bottles)
- Water pumps - 2 nos. (0.5 HP – 2780 RPM)
- Air pumps - 2nos. (1/3 HP)
- Water pipes - 12 meters (2mm diameter)
- Water pipes – 6 meters (1.5 inch diameter)
- U.V. Light – 1 nos. (25 watt)
- *E.Coli*
- 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.

4. 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

Plant Lay-Out

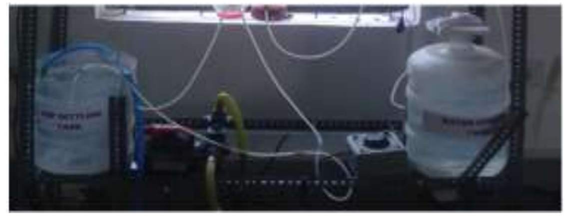


The complete plant Layout

Stage Wise Layout

Upper stage

Middle stage



Lower stage

5. 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 m3/day
Let us consider BOD5 = 10 g/person/day
So total BOD5 = 10g x 10,000/(250000L/day)
= 0.4 g/L
= 400 mg/LBODu = 1.47 * BOD5 = 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,

Yield coefficient Y = 0.6
Decay constant Kd = 0.07 per day

Specific substrate utilization rate (q) = (0.038 mg/l)-1 (h)-1 at 25°C

Assuming 30% raw BOD5 is removed in primary sedimentation, and BOD5 going to aeration is therefore, 0.7 x 400 mg/l =280 mg/L.

5.1 Design:

5.1.1 Selection of Qc, t and MLSS concentration

Considering the operating temperature and the desire to have nitrification and good sludge settling characteristics, adopting Q**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

5.1.2 EFFLUENT BOD5

Substrate concentration, S = (1/Q**c** + kd)/ q*Y

= (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

BOD5 of VSS in effluent = 0.7 x (0.8x20) = 11.2 mg/L.

Thus, total effluent BOD5 = S + VSS

= (11.84 + 11.2) mg/L

= 23.04 mg/L (Acceptable)

5.1.3 Aeration Tank

VX = Y*Q*Q**c** (SO - S)/(1+ kd*Q**c** =)

Where X = 0.8 x 4000 = 3200 mg/l

Initial BOD5 = S0 = 280 mg/L

or 3200 * V = (0.6)*(5)*(250)*(280-23.04)/[1 + (0.07)*(5)]

Thus, V = 14.61 m3

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

5.1.4 FOOD/MASS RATIO (F/M)

F/M = (SO - Si) x q/ (V*X)

= (280 – 11.84) * 250 / (44.61 * 3200) [mg of BOD5 /mg of MLSS/day]

= 0.46 [mg of BOD5 /mg of MLSS/day]

5.1.5 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, Qr = 0.5 x 250 m3/day

= 125 m3/day

5.1.6 Surplus sludge production

Net VSS produced Qw * Xr = VX / Q**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

5.1.7 OXYGEN REQUIREMENT

1. For carbonaceous demand, oxygen required

= (BODu removed) - (BODu 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/ m3 tank volume

= 0.094 kg/h/m3 tank volume

6. 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.

6.1 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.

6.2 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 m3 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 m3 volume is
= $ 3324
(http://www.enduramaxx.co.uk/1752281515000-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.

6.3 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.

Observation

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

Before treatment

After treatment

Settled sludge

Advanced oxidation process

7. RESULTS AND DISCUSSIONS

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	25	10
6	pH	7.5 – 7.0	9.8	7.2
7	Iron (ppm)	0.2 – 0.5	13.7	7.5
8	Chloride (mg/l)	0.025 – 0.05	0.395	0.017
9	Total hardness (ppm)	20	182	24
10	Copper (mg/l)	Up to 0.05	0.215	0.026
11	Total Dissolved Solid(TDS) (mg/l)	Up to 500	788	67
12	Total Organic Carbon (mg/l)	Up to 50	248	17
13	BOD (mg/l of O_2)	Up to 5	524	8.69
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	1.54	0.015
21	Zinc (ppm)	Up to 0.05	3.3	0.25
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)

8. CONCLUSIONS

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.

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