ISSN 2229-5518

Design & Performance Evaluation of Wastewater Treatment Plant-D at Tirumala

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Abstract:- The increasing of population in pilgrimage area Tirumala near Tirupati in Chittoor District of Andhra Pradesh, observed as a result of the development of the modern societies is accompanied by concerns in the water sector, as a result of the increasing requirements for water supply and wastewater treatment. This situation justifies the evaluation of the system performance that covers protection of water resources &management.Poorly treated wastewater with high levels of pollutants caused by poor design, operation or maintenance of treatment systems creates major environmental problems, when such wastewater is discharged to surface water or on land. Considering the above stated implications an attempt has been to evaluate the performance of wastewater treatment plant (WWTP) near balaji nagar area at Tirumala (Plant-D) capacity of 3 MLD, were collected from each units (Screening & Grit chamber, Aeration tanks, Secondary Clarifier, Storage Tank) at a peak hour. Parameters analyzed for evaluation of performance of WWTP are Total Solids, Oil &Grease, Chlorides, Sulfates, Nitrates, Nitrites, COD, and BOD5@ 20° C. Tests were performed to find the fate of pollutants in WWTP. The present study shows that COD removal efficiency of WWTP was found to be 69.39% and BOD5 removal efficiency of WWTP was found to be 62.78%. The production of sludge in the treatment plant is used as a fertilizer. The treated effluent water goes to the territory treatment plant i.e., plant –D.

Keywords: Performance, Screening, Aeration Tank, biological oxygen demand, chemical oxygen demand

1. INTRODUCTION

1.1 LOCATION OF STUDY

The increasing of population in pilgrimage area Tirumala near Tirupati in Chittoor District of Andhra Pradesh, observed as a result of the development of the modern societies is accompanied by concerns in the water sector, as a result of the increasing requirements for water supply and wastewater treatment. This situation justifies the evaluation of the system performance that covers protection of water resources & management.

The temple (13°40′59.7″N 79°20′49.9″E) is visited by about 50,000 to 100,000 pilgrims daily (30 to 40 million people annually on average), while on special occasions and festivals, like the annual Brahmotsavam, the number of pilgrims shoots up to 500,000, making it the most-visited holy place in the world. The Tirumala Hill is 853m above sea level and is about 10.33 square miles (27 km2) in area. Total average wastewater produce in tirumala are 10MLD.they were design four wastewater treatment plants in different areas i.e.,

- Sri Varimetlu (Block-A) capacity of 2MLD,
- Opposite to Annaprasdham (Block-B) capacity of 3MLD,
- GangammaGudi Area (Block-C) capacity of 5 (2+3)MLD,
- Balaji Nagar Area (Block-D) capacity of 3MLD.

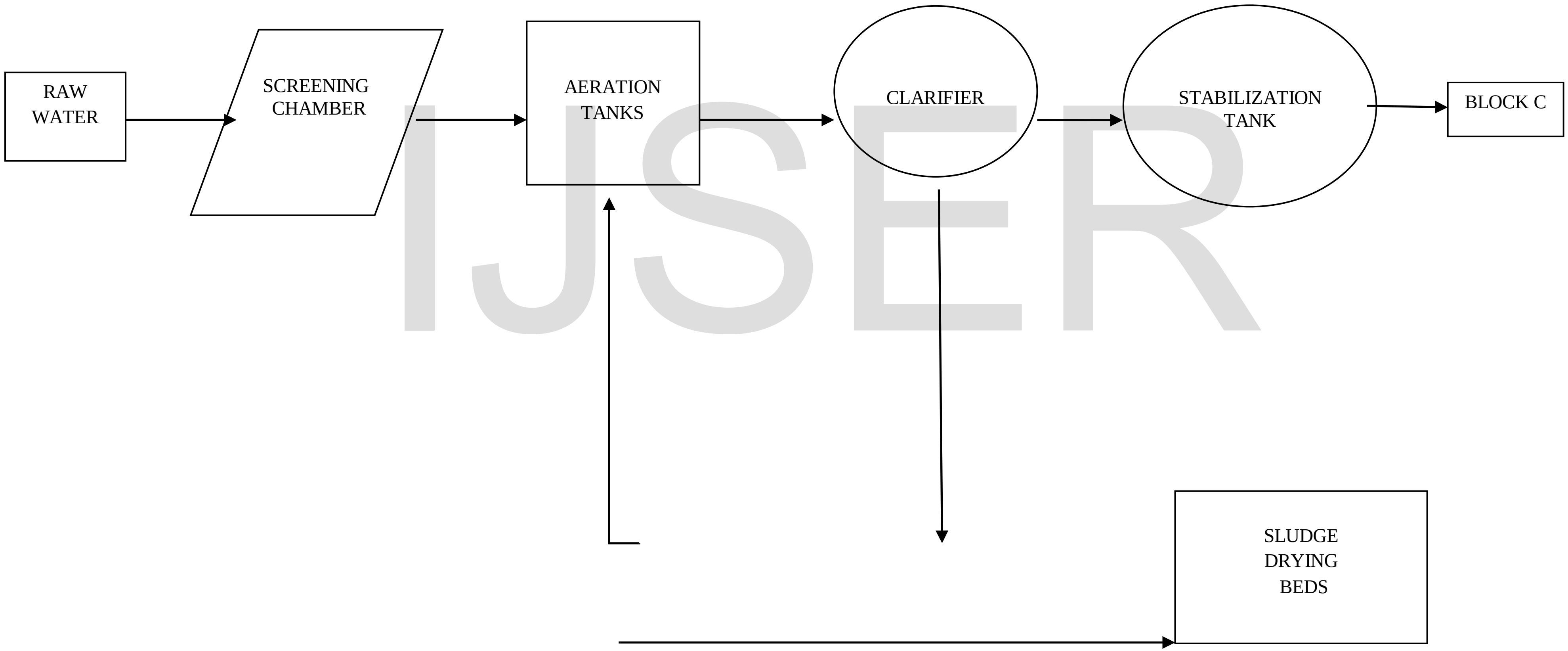
From the above wastewater treatment plants. We have taken Block-D for the performance evaluation.

1.2 THE AREAS COVERED UNDER THIS BLOCK-D PLANT ARE

- Pilgrim Amenity Complex I,II.III,
- CRO Complex
- JEO'S Office
- Choultries I II,&III
- Panchjanyam Rest House
- Koushbham Rest House
- Police Quarters
- RTC Garage Area Near Balaji Nagar Area
- Donor Guest House Near Balaji Nagar Area
- Part Of Employees Quartets

1.3 FLOW DIAGRAM OF WASTEWATER TREATMENT PLANT -D

In this WWTP only Primary, Secondary Treatment units are present form the fig-1, effluents came from this plant goes for further treatment to Block-C.



ISSN 2229-5518

Figure 1: Wastewater Treatment Plant Flow Diagram (BLOCK-D) Capacity of 3MLD.

1.4. EXPERIMENTAL PROCESSES IN SEWAGE TREATMENT

The degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics after reviewing the treatment objectives and applicable regulations. Although these operations and processes occur in a variety of combinations in treatment systems, it has been found advantageous to study their scientific basis separately because the principals involved do not change3.

2. CLASSIFICATION OF SEWAGE/WASTEWATER TREATMENT METHODS

2.1 PRELIMINARY WASTEWATER TREATMENT

Preliminary wastewater treatment is the removal of such wastewater constituents that may cause maintenance or operational problems in the treatment operations, processes, and ancillary systems. It consists solely of separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood etc.) and the heavy settle able inorganic solids. It also helps in removing the oils and greases, etc. from the sewage. This treatment reduces the BOD of the wastewater, by about 15 to 30%. Examples of preliminary operations are:

- Screening and combination for the removal of debris and rags.
- Grit removal for the elimination of coarse suspended matter that may cause wear or clogging of equipment and
- Floatation / skimming for the removal of oil and grease.

2.2 PRIMARY WASTEWATER TREATMENT

In primary treatment, a portion of the suspended solids and organic matter is removed from the wastewater. This removal is usually accomplished by physical operations such as sedimentation in Settling Basins. The liquid effluent from primary treatment, often contains a large amount of suspended organic materials, and has a high BOD (about 60% of original). Sometimes, the preliminary as well as primary treatments are classified together, under primary treatment. The organic solids, which are separated out in the sedimentation tanks (in primary treatment), are often stabilized by anaerobic decomposition in a digestion tank or are incinerated. The residue is used for landfills or as a soil conditioner. The principal function of primary treatment is to act as a precursor to secondary treatment.

2.3 SECONDARY WASTEWATER TREATMENT

Secondary treatment involves further treatment of the effluent, coming from the primary sedimentation tank and is directed principally towards the removal of biodegradable organics and suspended solids through biological decomposition of organic matter, either under aerobic or anaerobic conditions. In these biological units, bacteria will decompose the fine organic matter, to produce a clearer effluent. The treatment reactors, in which the organic matter is decomposed (oxidized) by aerobic bacteria are known as Aerobic biological units; and may consist of:

- Filters (intermittent sand filters as well as trickling filters),
- Aeration tanks, with the feed of recycled activated sludge (i.e. the sludge, which is settled in secondary sedimentation tank, receiving effluents from the aeration tank), and
- Oxidation ponds and aerated lagoons.

Since all these aerobic units, generally make use of primary settled sewage; they are easily classified as secondary units. The treatment reactors, in which the organic matter is destroyed and stabilized by anaerobic bacteria, are known as anaerobic biological units and may consist of:

- Anaerobic lagoons, Septic tanks, Inhofe tanks, etc.

Out of these units, only anaerobic lagoons make use of primary settled sewage, and hence, only they can be classified under secondary biological units. Septic tanks and Inhofe tanks, which use raw sewage, are not classified as secondary units. The effluent from the secondary biological treatment will usually contain a little BOD (5 to 10% of the original), and may even contain several mg/L of DO. The organic solids/ sludge separated out in the primary as well as in the secondary settling tanks are disposed off by stabilizing under anaerobic conditions in a Sludge digestion tank.

2.4. TERTIARY/ ADVANCED WASTEWATER TREATMENT AND WASTEWATER RECLAMATION

Advanced wastewater treatment, also called tertiary treatment is defined as the level of treatment required beyond conventional secondary treatment to remove constituents of concern including nutrients, toxic compounds, and increased amounts of organic material and suspended solids and particularly to kill the pathogenic bacteria. In addition to the nutrient removal processes, unit operations or processes frequently employed in advanced

ISSN 2229-5518

wastewater treatment are chemical coagulation, flocculation, and sedimentation followed by filtration and chlorination. Less used processes include ion exchange and reverse osmosis for specific ion removal or for the reduction in dissolved solids. Tertiary treatment is generally not carried out for disposal of sewage in water, but it is carried out, while using the river stream for collecting water for re-use or for water supplies for purposes like industrial cooling and groundwater recharge

3. METHODOLOGY

3.1 PERFORMANCE ANALYSIS OF THE WWTPS

The methodology developed to study the performance of the WWTP is divided into the following steps:

- Identification and characterization of flows associated to the operation of WWTP, namely:
- Pollutants – Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Oil & Grease, Chlorides, Sulfates, Nitrates, Nitrites, Phosphorus;

Determination of the specific consumption indicator and specific production for each identified parameter, by dividing the annual flow of a given parameter by the affluent flow rate, thus facilitating the comparison between treatment plants of different sizes.

The determination of the pollutant loads present in the wastewater entering and leaving the WWTP was carried out monthly, considering the monthly average flow rate and the monthly average concentration of each pollutant, being the annual value given by the sum of all monthly values.

Methods of wastewater treatment were first developed in response to the adverse conditions caused by the discharge of wastewater to the environment and the concern for public health. Further, as cities became larger; limited land was available for wastewater treatment and disposal, principally by irrigation and intermittent filtration. Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies. Therefore, other methods of treatment were developed to accelerate the forces of nature under controlled conditions in treatment facilities of comparatively smaller size. In general from about 1900 to the early 1970s, treatment objectives were concerned with:-

(i) The removal of suspended and floatable material from wastewater,
(ii) The treatment of biodegradable organics (BOD removal) and
(iii) The elimination of disease-causing pathogenic micro-organisms.

3.2 SCREENING

Screening is the first unit operation used at wastewater treatment plants (WWTPs). Screening removes objects such as rags, paper, plastics, and metals to prevent damage and clogging of downstream equipment, piping, and appurtenances. Some modern wastewater treatment plants use both coarse screens and fine screens.

3.2.1 DESIGN CRITERIA

Screening devices are classified based on the size of the material they remove (the screenings). The "size" of screening material refers to its diameter. Table 2 lists the correlation between screening sizes and screening device classification. In addition to screening size, other design considerations include the depth, width, and approach velocity of the channel.

TABLE 1: SCREENING DEVICES CLASSIFICATION

Screening Device	Size Classification/Size Range of Screen Opening
Bar Screen	
Manually Cleaned	Coarse/25-50 mm
Mechanically Cleaned	Coarse/15-75 mm

Fine Bar or Perforated Coarse Screen (Mechanically Cleaned)	
Fine Bar	Fine Coarse/3-12.5 mm
Perforated Plate	Fine Coarse/3-9.5 mm
Rotary Drum	Fine Coarse/3-12.5 mm
Fine Screen (Mechanically Cleaned)	
Fixed Parabolic	Fine/0.25-3.2 mm
Rotary Drum	Fine/0.25-3.2 mm
Rotary Disk	Very Fine (Micro)/0.15-0.38 mm

3.2.2 DESIGN OF BAR SCREENING:

Capacity of the plant –D, Q =3MLD
=$3*10^6*10^{-3}m^3$/day
=$3000m^3$/day
=3000/24*60*60
= $0.0347m^3$/sec

Design flow velocity V=0.3m/sec

Cross-sectional area of screen channel, A= Q/V
=$0.1157m^2$

(Cross-sectional area is increased by 50% to compensate for the obstruction posed by the bars of the grill)

Adjust for the flow area blocked by the bars
= 0.1157*1.5= $0.18m^2$
Depth of screening, d = 1m

Width of screening b= 0.18m

Gap between two bars of the screen = 10mm

Width of a bar = 5mm

So, Number of Bar screens= 12

3.3. AERATION TANK

The aeration tanks, which are used to hold the wastewater while oxygen is mixed into it, are made of reinforced concrete and are left open to the atmosphere at the top. An oxygen source supplies the oxygen and an agitator which mixes the water so that oxygen gets dispersed evenly throughout the entire volume of water.

3.3.1. DESIGN CONSIDERATION

The items for consideration in the design of activated sludge plant are aeration tank capacity and dimensions, aeration facilities, secondary sludge settling and recycle and excess sludge wasting.

The length of the tank depends upon the type of activated sludge plant. Except in the case of extended aeration plants and completely mixed plants, the aeration tanks are designed as long narrow channels. The width and depth of the aeration tank depends on the type of aeration equipment employed. The depth controls the aeration efficiency and usually ranges from 3 to 4.5 m. The width controls the mixing and is usually kept between 5 to 10 m. Width depth ratio should be adjusted to be between 1.2 to 2.2. The length should not be less than 30 or not ordinarily longer than 100 m

3.3.2 DESIGN OF AREATION TANK:

Capacity of the plant –D, Q = 3MLD

= $3000m^3$/day

Empirical value, for typical Indian domestic sewage. BOD may range from 200-250mg/L. we have taken the highest value in the range: so that the STP can deal with lighter loads also

BOD in sewage =250mg/lit (Inlet)
= 0.000250kg/lit

BOD load/da =3000*0.000250*10^3

= 750kg/day

F/M = 0.12

The above value is taken from the available range of 0.10-0.12.the higher limit represents the worst case scenario (more food in the sewage for the bacteria existing in the aeration tank)

M (Biomass) = 750/0.12

= 6250 kg

We will choose to introduce a 20% safety margin

=6250*1.2

= 7500kg

Design MLSS (Level) = 3500mg/lit

= 3.5kg/m^3

Aeration tank volume, V= 7500/3.5

=2142.85m^3

Average Retention time, = 2142.85*24/3000

= 17.14Hrs

Provide 3 Aeration tanks,

So, each tank volume = 2142.85/3

= 714.28m^3

Depth of each tank, D= 4.5m

Area of each tank, A= 158.72m^2

We provide,

Breadth of each tank, B = 10m

Length of each tank, L = 16m

Size of each tank, L*B*D= 16m*10m*4.5m

3.4 CLARIFIER

The next step is transferring the fluid into the primary clarifying or settling tank. As the debris containing, and now aerated, fluid flows into the clarifying or sedimentation tanks, it is slowed down considerably to allow the remaining debris mixed in with the wastewater to separate from the actual water. The water is dumped into the middle of the tank and flows out in the radial direction. A mechanical scraper runs on the bottom to remove all of the debris that settles, while a strip of jagged metal around the top to catch all of the floating debris (Metcalf & Eddy, Wastewater Engineering, 1972).

3.4.1. DESIGN OF CLARIFIER:

Capacity of the plant –D,Q = 3000m^3/day

Assuming 24 hours of pumping in small plants. The 4 hours of down time of a worst-case scenario. in practice, pumping will be done for more than 24 hours.

Maximum hourly throughput = 3000/24

= 125m^3/hr

Design overflow rate =25m^3/m^2/day

= 1.041m^3/m^2/hrs.

Cross sectional area of tank = 125/1.041

= 120.076m^2

Dimensions For circular tank Diameter= 12.36m

Depth of Tank,d= 3m

Solids load =Hourly throughput*MLSS

= 125*3.5

=437.5kg/hrs.

Solids loading rate = (solids load)/ (area of tank)

=437.5/120.076

= 3.622kg/m^2/hrs.

Weir length in clarifier= π* Dia

= 3.14* 12.36

= 38.81m

Weir loading rate = (sewage flow rate)/ (length of weir)

=3000/38.81

= 77.3m^3/m/day

Volume of tank =Area * Depth

=120.76*3

=360.228 m^3

Hydraulic Detention time = (Tank volume) (throughput Rate) *24hr.

=2.88 Hrs.

Compared to ideal range of 2.5-3 hours, the above results are shown within the limits

3.5. WHY SHOULD SEWAGE/WASTEWATER IS TREATED BEFORE DISPOSAL:

Sewage/Wastewater treatment involves breakdown of complex organic compounds in the wastewater into simpler compounds that are stable and nuisance-free, either physico-chemically and or by using micro-organisms (biological treatment). The adverse environmental impact of allowing untreated wastewater to be discharged in groundwater or surface water bodies and/or land is as follows -

(i) The decomposition of the organic materials contained in wastewater can lead to the production of large quantities of malodorous gases.

(ii) Untreated wastewater (sewage) containing a large amount of organic matter, if discharged into a river/stream, will consume the dissolved oxygen for satisfying the biochemical oxygen demand (BOD) of wastewater and thus, deplete the dissolved oxygen of the stream; thereby, causing fish kills and other undesirable effects.

(iii) Wastewater may also contain nutrients, which can stimulate the growth of aquatic plants and algal blooms; thus, leading to eutrophication of the lakes and streams.

(iv) Untreated wastewater usually contains numerous pathogenic, or disease causing microorganisms and toxic compounds, that dwell in the human intestinal tract or may be present in certain industrial waste. These may contaminate the land or the water body, where such sewage is disposed. For the above-mentioned reasons, the treatment and disposal of wastewater, is not only desirable but also necessary

3.6 EXPERIMENTAL PROCESSES IN SEWAGE TREATMENT

The degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics after reviewing the treatment objectives and applicable regulations. Although these operations and processes occur in a variety of combinations in treatment systems, it has been found advantageous to study their scientific basis separately because the principals involved do not change3.

4. ANALYSIS

We did grab sampling for each and every unit influent & effluents in peak hours in quality & quantity. Parameters analyzed for evaluation of performance of WWTP are Total Solids, Oil & Grease, Chlorides, Sulfates, Nitrates, Nitrites, COD, BOD_5 @ 20°.

The analysis report as given below Table-2

TABLE 2: UNIT WISE REMOVAL EFFICIENCY OF WASTEWATER TREATMENT PLANT

SL No.	PARAMETERS		UNITS	WASTEWATER TREATMENT UNITS			
				SCREENING CHAMBER	AERATION TANK	SECONDARY CLARIFIER	STABILIZATION TANK
1	pH	Influent		7.17	7.14	7.13	7.12
		Effluent		7.14	7.13	7.12	7.12
		Removal efficiency	%	0.42	0.14	0.14	0.00
2	TDS	Influent	mg/L	200.00	400.00	210.00	0.00
		Effluent	mg/L	200.00	210.00	0.00	0.00
		Removal efficiency	%	0.00	47.50	100.00	0.00
3	TSS	Influent	mg/L	2100	2200	1200	600
		Effluent	mg/L	1800	1200	600	600
		Removal efficiency	%	14.29	45.45	50	0
4	OIL & GREASE	Influent	mg/L	5.12	3.64	2.56	1.72
		Effluent	mg/L	3.64	2.56	1.72	1.72
		Removal efficiency	%	28.91	29.67	32.81	0.00
5	BOD_5 @ 20^0C	Influent	mg/L	157.50	127.50	95.00	65.00
		Effluent	mg/L	127.50	95.00	65.00	58.62
		Removal efficiency	%	19.05	25.49	31.58	9.82

ISSN 2229-5518

6	**COD**	Influent	mg/L	202.66	160.00	101.33	62.00
		Effluent	mg/L	160.00	102.00	62.00	61.85
		Removal efficiency	%	21.05	36.25	38.81	0.24
7	**CHLORIDES**	Influent	mg/L	99.99	99.99	109.99	89.99
		Effluent	mg/L	99.99	100.00	89.99	89.99
		Removal efficiency	%	0.00	-0.01	18.18	0.00
8	**PHOSPHOROUS**	Influent	mg/L	15.60	15.60	4.00	3.52
		Effluent	mg/L	15.60	4.00	3.52	3.52
		Removal efficiency	%	0.00	74.36	12.00	0.00
9	**SULFATES**	Influent	mg/L	70.00	66.00	69.00	36.00
		Effluent	mg/L	66.00	68.00	36.00	36.00
		Removal efficiency	%	5.71	-3.03	47.83	0.00
10	**NITRITES**	Influent	mg/L	3.00	2.66	4.20	0.22
		Effluent	mg/L	2.66	4.20	0.22	0.22
		Removal efficiency	%	11.33	-57.89	94.76	0.00
11	**NITRATES**	Influent	mg/L	1.24	1.32	1.60	0.00
		Effluent	mg/L	1.32	1.60	0.00	0.00
		Removal efficiency	%	-6.45	-21.21	100.00	0.00

TABLE 3: OVERALL REMOVAL EFFICIENCY OF PARAMETERS IN BLOCK D PLANT

S.NO	NAME OF THE TEST	INLET WASTEWATER (mg/L)	OUTLET WASTE WATER (mg/L)	STANDARDS IS 2296:1992 LAND FOR IRRIGATIONWATER (mg/L)	OVERALL REMOVAL EFFICIENCY (%)
1	**TDS**	200.00	0	-	100.00
2	**TSS**	2100.00	600	200	71.43
3	**OIL & GREASE**	5.12	1.72	10	66.41
4	**BOD_5 @ 20^0C**	157.50	58.62	100	62.78
5	**COD**	202.60	61.85	250	69.40
6	**CHLORIDES**	99.99	89.99	-	10.00
7	**PHOSPHOROUS**	15.60	3.52	5	77.44
8	**SULFATES**	70.00	36	2	48.57
9	**NITRITES**	3.00	0.22	0	92.67
10	**NITRATES**	1.24	0	0	100.00
11	**MLSS**	1200			11

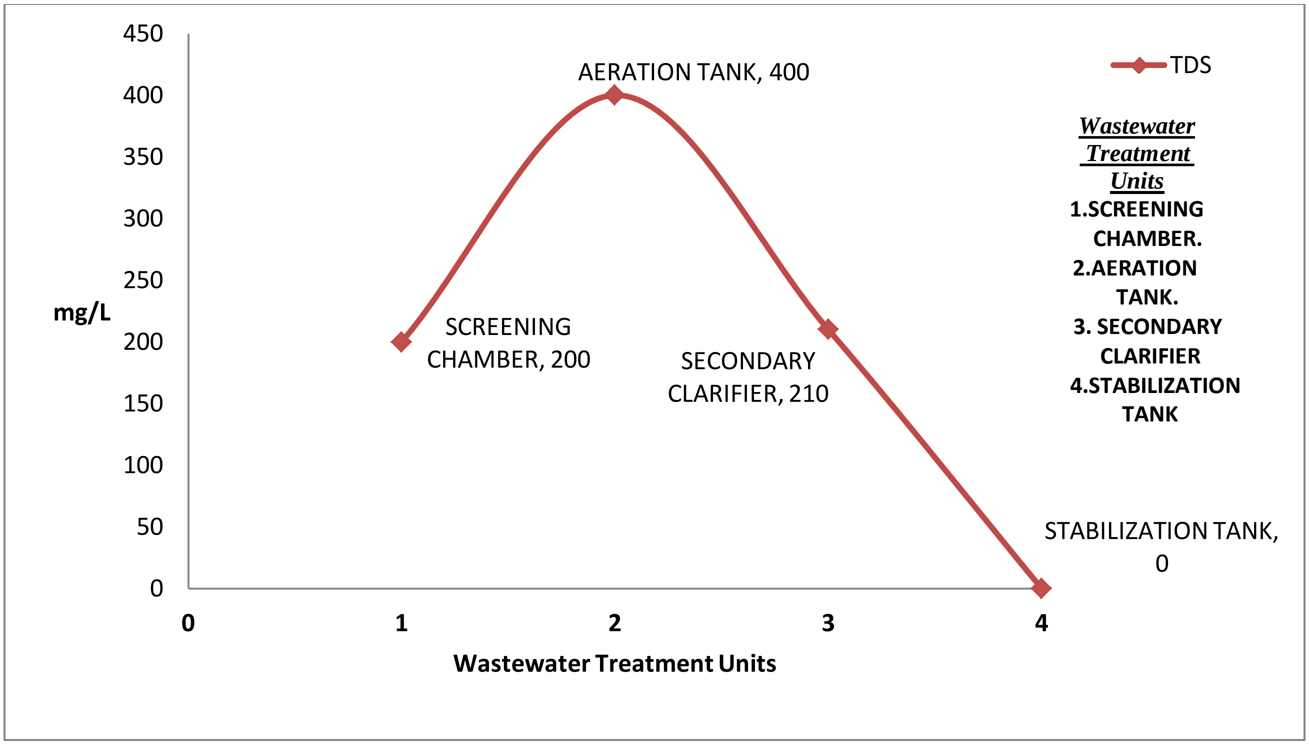


Figure 2: Graph of Unit wise TDS Removal

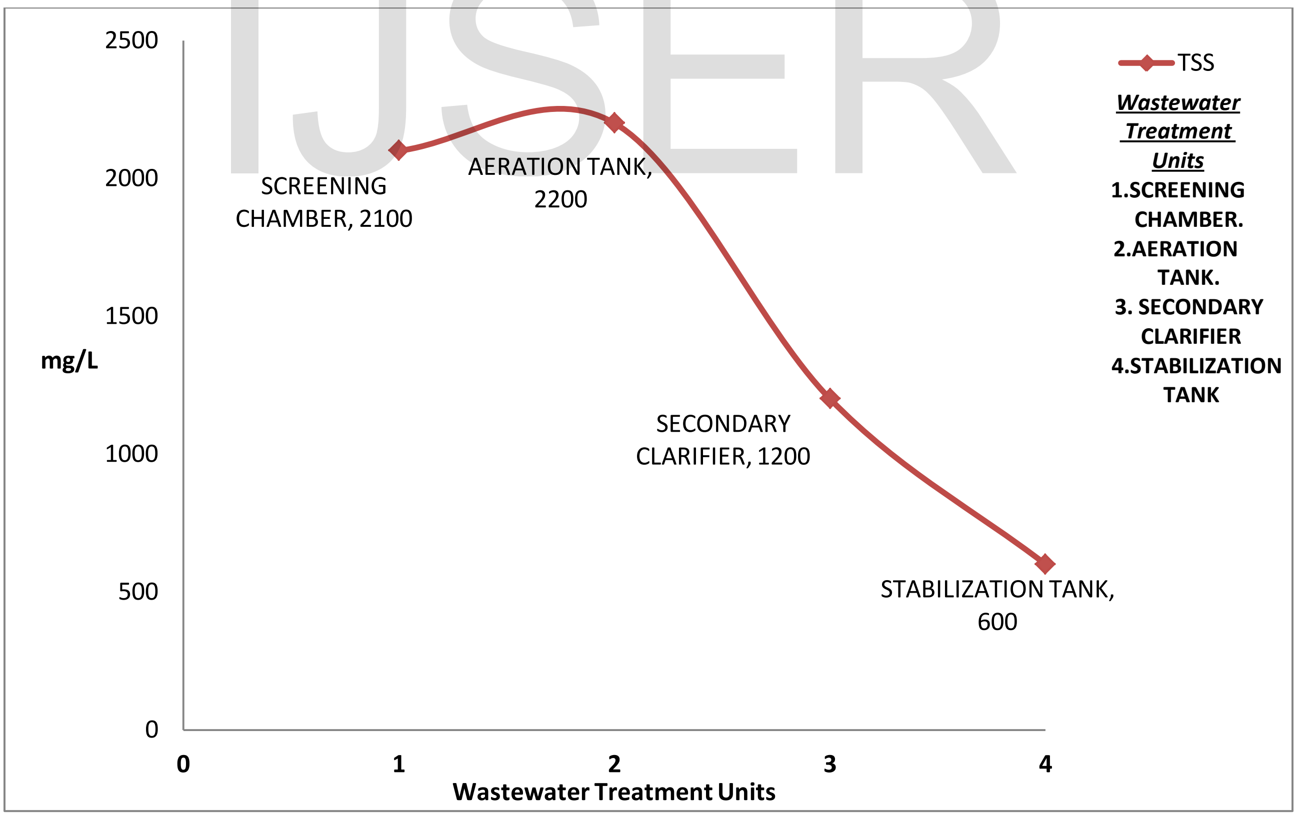


Figure 3: Graph of Unit wise TSS Removal

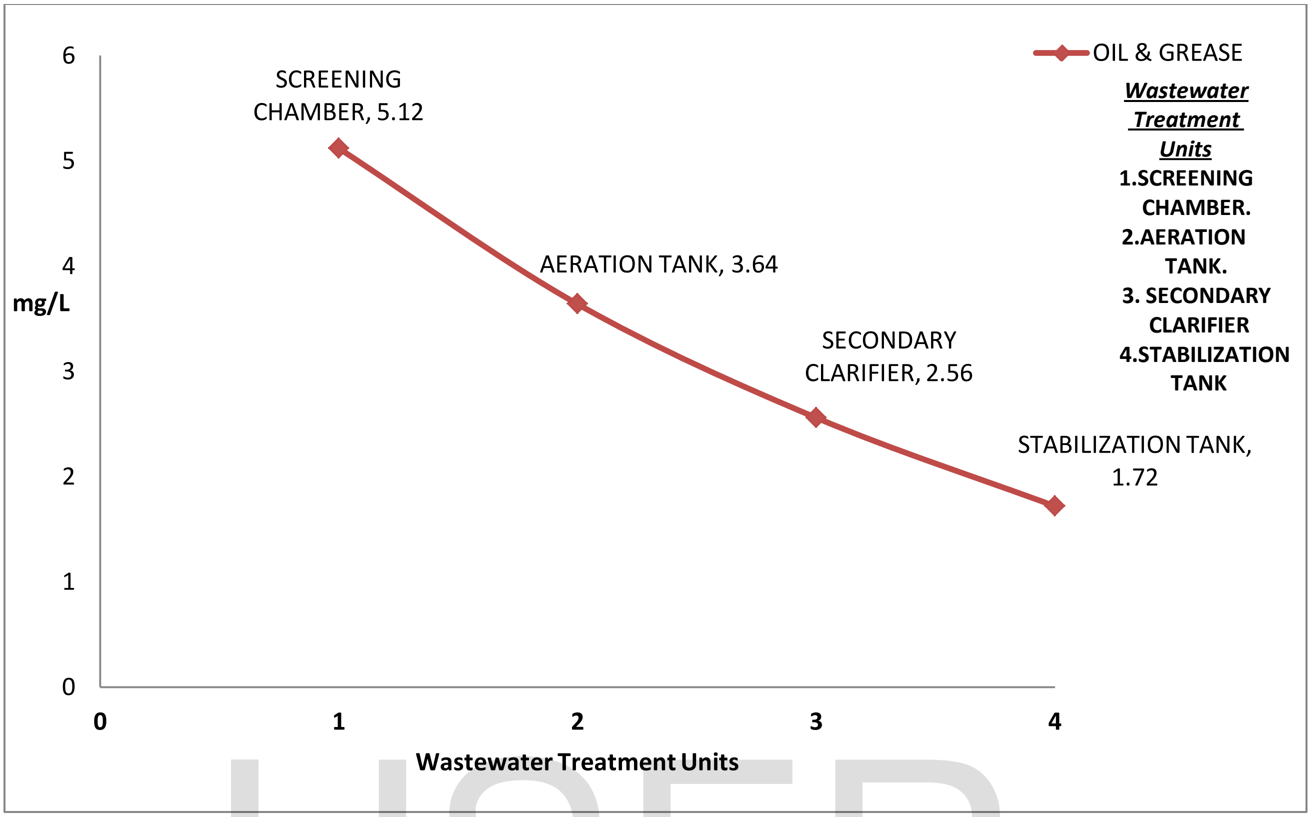


Figure 4: Graph of Unit wise Oil & Grease Removal

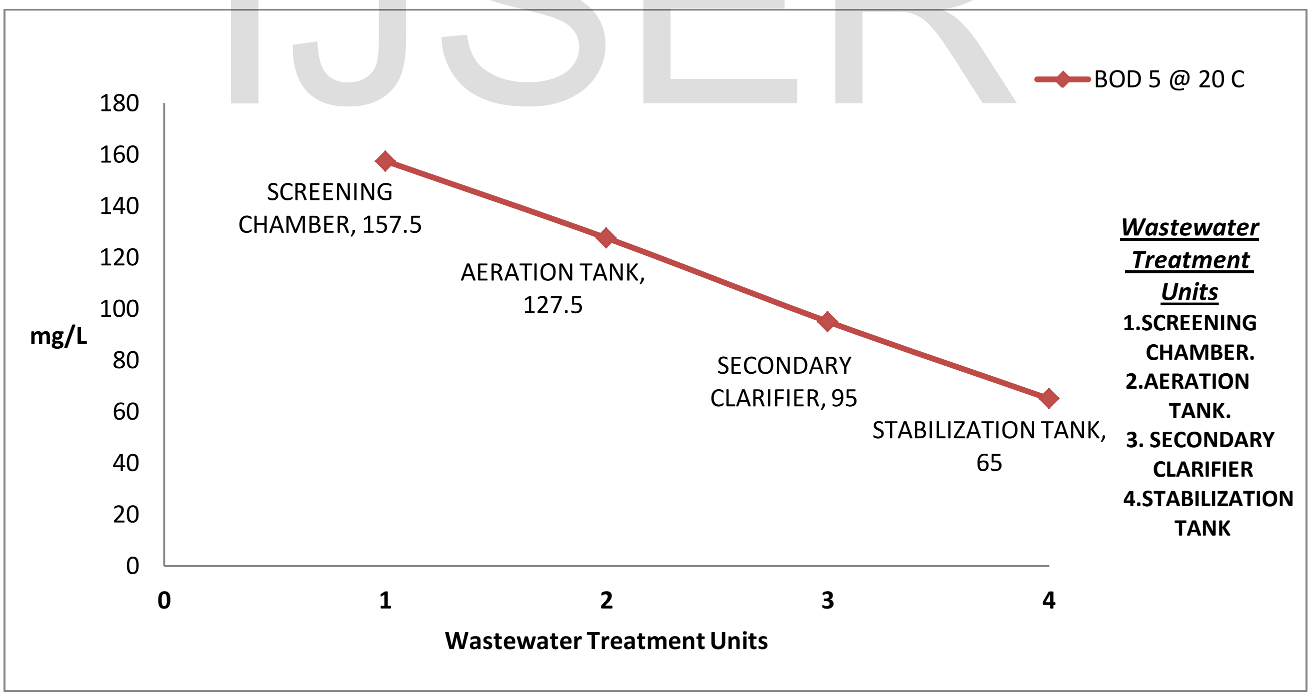


Figure 5: Graph of Unit wise BOD 5 @ 20 degree Celsius Removal

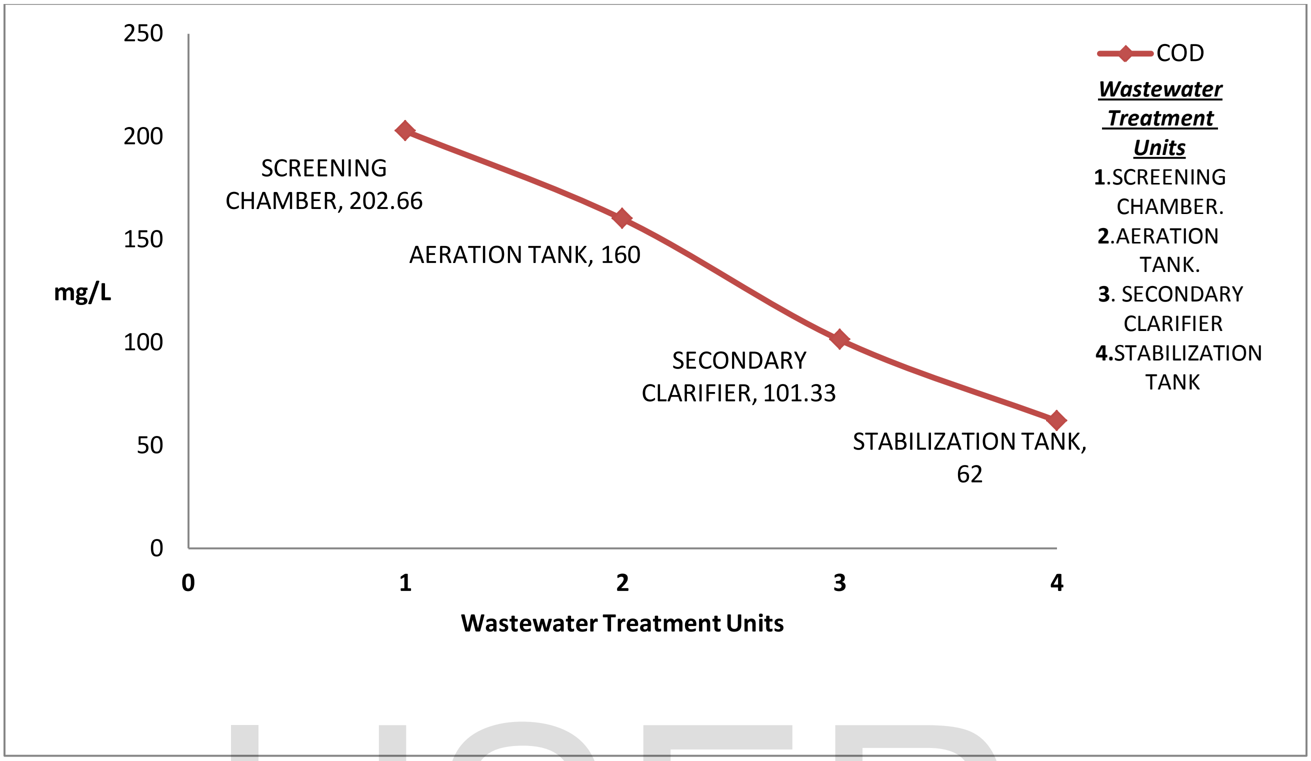


Figure 6: Graph of Unit wise COD Removal

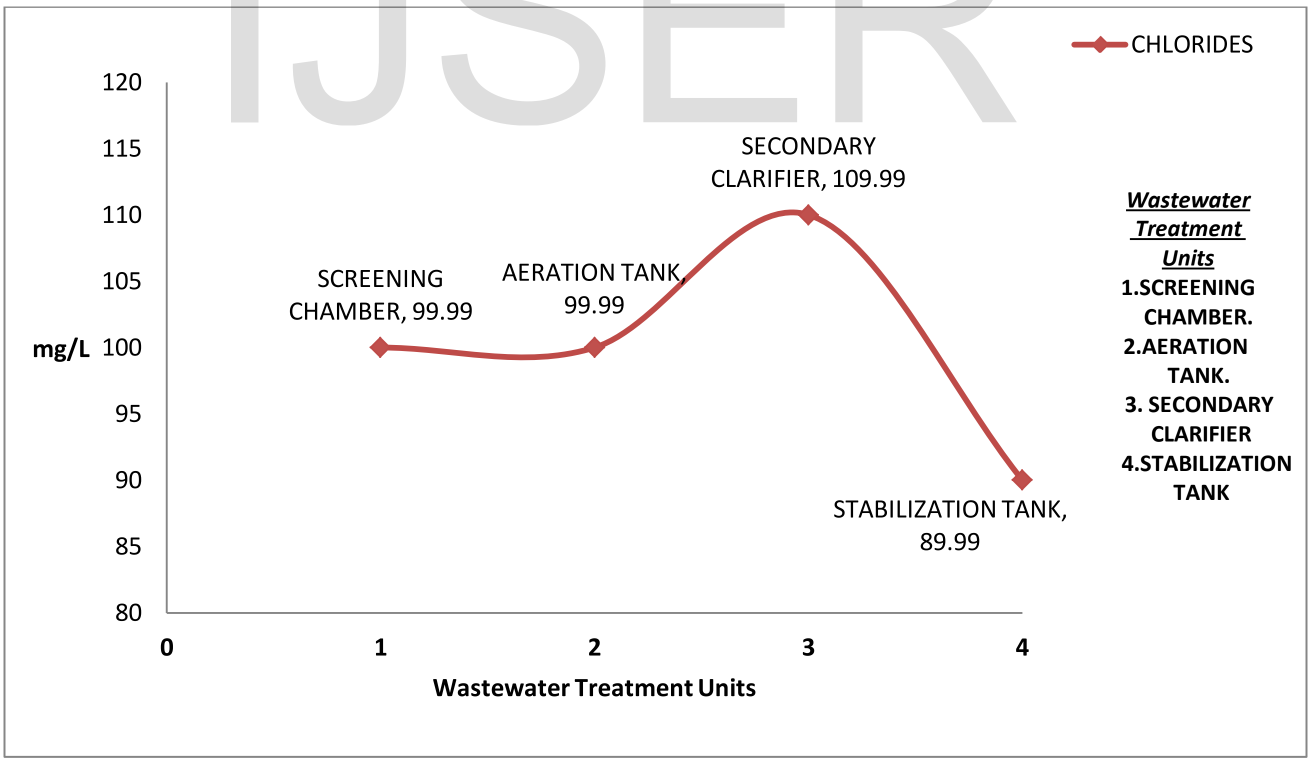


Figure 7: Graph of Unit wise Chlorides Removal

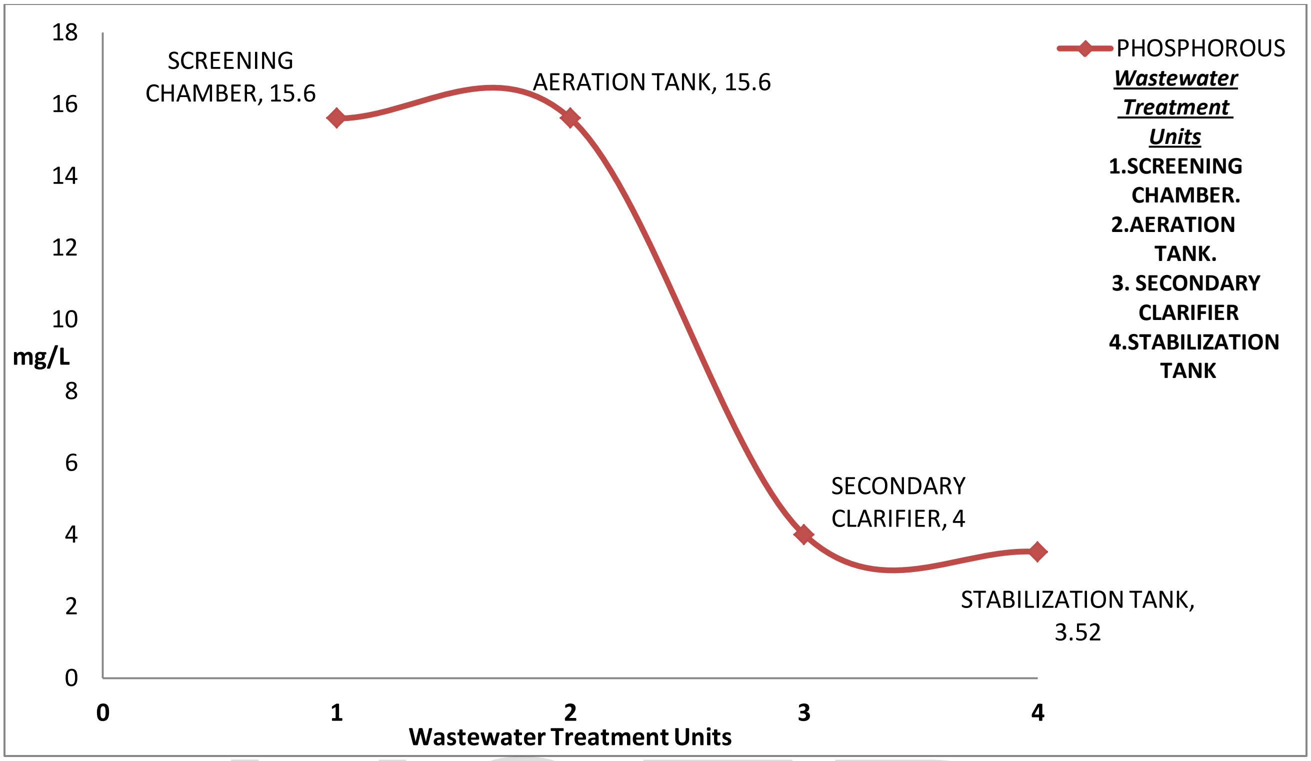


Figure 8: Graph of Unit wise Phosphorous Removal

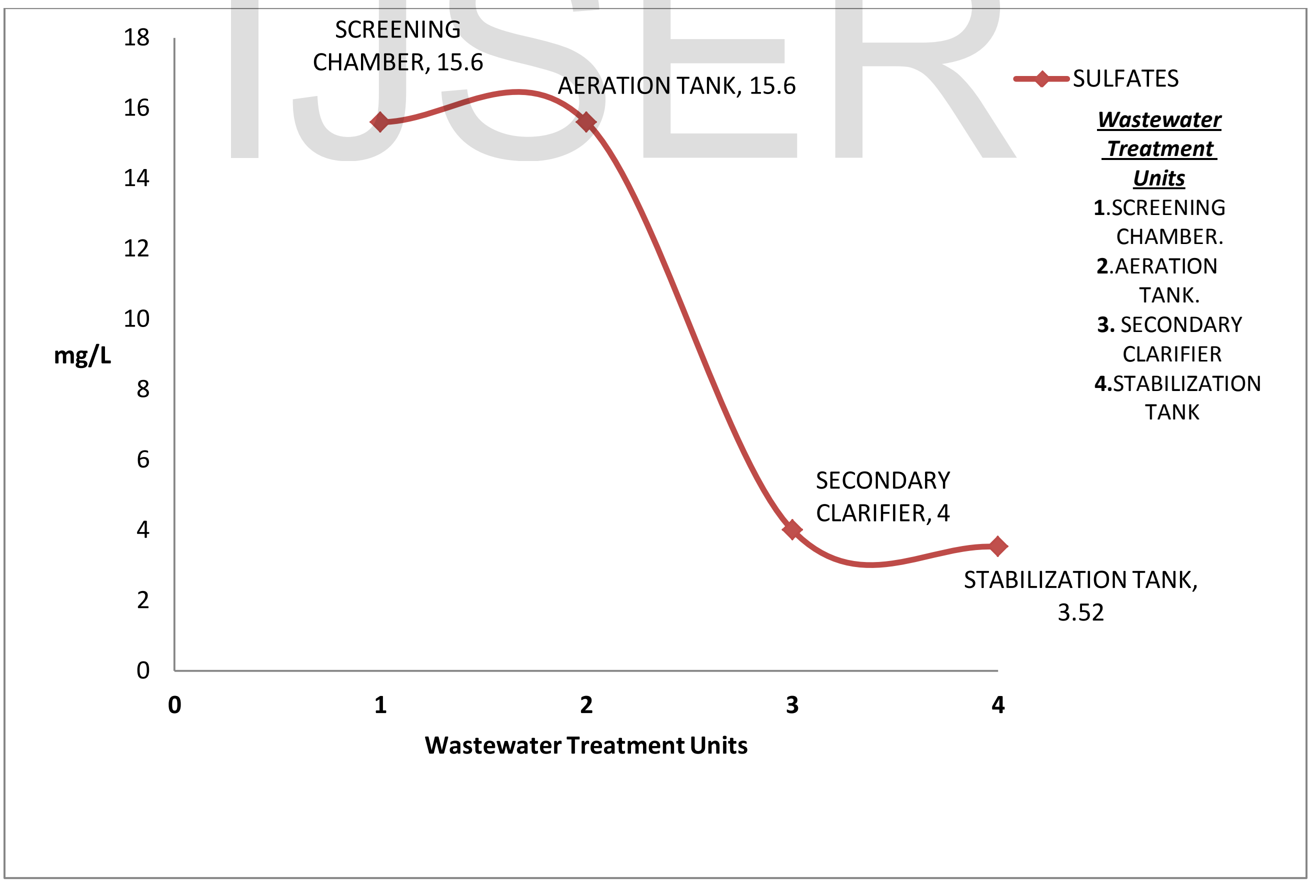


Figure 9: Graph of Unit wise sulfates Removal

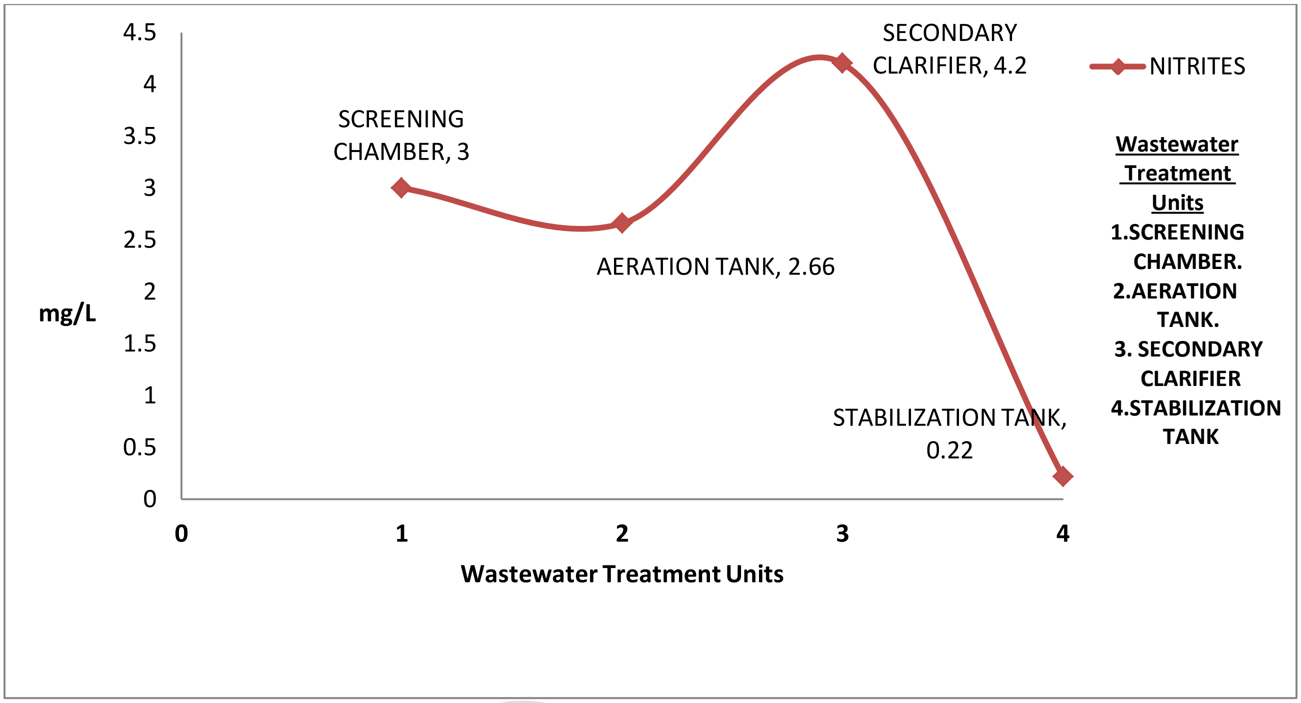


Figure 10: Graph of Unit wise Nitrites Removal

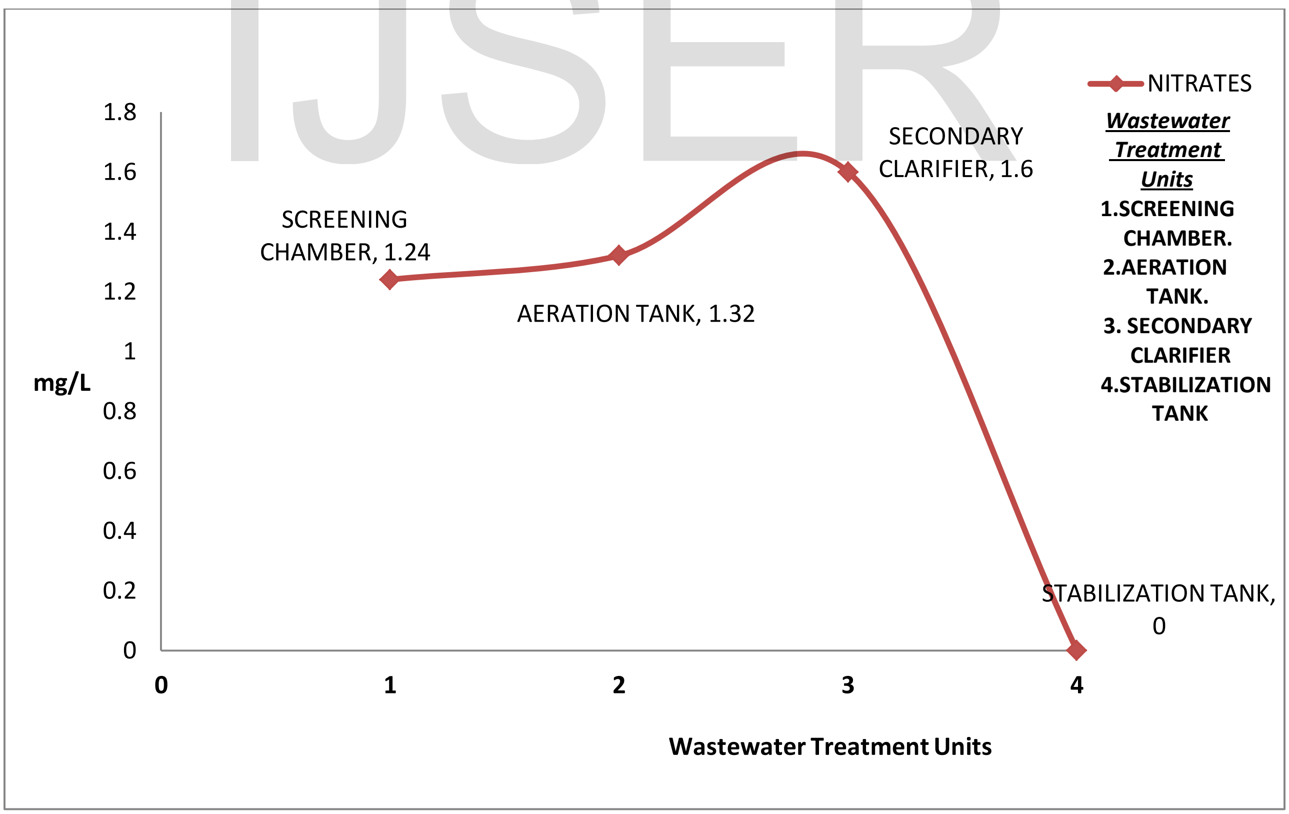


Figure 11: Graph of Unit wise Nitrates Removal

5. CONCLUSION

Based on the Study, the following conclusions can be drawn.

- ✓ The COD removal efficiency of WWTP was found to be 62.00%.
- ✓ The BOD_5 removal efficiency of WWTP was found to be 58.62%.
- ✓ The Total solid removal efficiency of WWTP was found to be 73.91%.
- ✓ The current results suggest that the treated effluent is complying with the standard values and can be used for irrigation.

The treated effluent water is found to meet the effluent discharge standards. In order to further improve the performance of the ETP, the following action plans are recommended. The above study recommended to following action plan for the resource recovery to make ETP sustainable for conservation of energy and water.

Based on results, we can conclude that the Treated Wastewater is used for Eco-plantation.

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