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OPG-Oxygenic Photo Granules A Modern Effective & Economical Way for Aerobic Treatment in ETP: A Review

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Abstract:
Race to a more developed nation had started a few decades back uprising the tremendous industrial growth thus resulting in the exploit of resources as we are running to attain this goal, we need to be aware that we are completely avoiding the fact that for tomorrow also we need these resources. Thus, there occurs a need for more convenient method for that. waste water treatment is a highly energy intensive process in here we are reviewing how the OPG can bring about a change for this and how much it can bring forward. In this review we are looking forward on OPG aka Oxygenic Photogranules a modern way as a replacement to the highly energy consuming Aeration tank process we will be looking forward how much these will result in terms of efficiency and economically. These OPG can alter the current system of using aeration tank i.e., producing the oxygen and diffusing for the degradation with a much safer way that is OPG which will produce the Oxygen required for this process and thus lowering the running cost. In this review we will look forward how they will give a change.

INTRODUCTION

From the early stage since the human development the waste water treatment and their disposal have been one of the foreseen things. It is strictly required and mandatory for the proper treatment and disposal of this waste water. With the development and introduction of new industries along with the rapidly increasing population has been playing a unique growth in this generation of increasing waste water production. The usual methods which were being employed rightly at here has been really energy intensive process and with the increase in the population along with the high energy demand this has been continued to give a negative impact to the human kind and thus emerges a situation demanding a new post-modern method for the treatment of waste water which is meant to be energy efficient along more effective compared to the conventional methods. As of now the plants evolve in the traditional methods of using the aeration tanks as a source of the secondary treatment which we are aware that this is a high energy consuming process we know that most of the energy evolved in the ETP are consumed at this step. Studies have been conducting to the introduction of a new treatment method which should be reliable along with more energy efficient and possessing more efficiency than that of the present technologies right now and

hence the biological treatment have been given more and more importance as they are economically more friendly and thus lowering the energy consumption. Among them microbial granulation has been found out to be having more efficiency and thus many research has been conducted to produce a new alternative for aeration treatment using these biological methods. Due to the natural characteristics, they have been continued to show promising results in the process. Among them OPG aka Oxygenic Photo granules are the latest additions to the group. As being a microbial granule, they are able to deliver a more effective impact both economically and in terms of efficiency also. OPG can produce oxygen through the lining outer layer of cyanobacteria through photosynthesis and may push the diversity of microorganisms to an extreme by providing a steep redox gradient across the granule diameter as demonstrated for the microbial mats. The oxygen thus produced through the photosynthesis can be used for the organic matter decomposition which are usually achieved through costly aeration techniques [(Wikipedia, n.d.)]. Successful cultivation of these OPG with a specific period of life has been carried out at many parts of the world by the completely achieving this we can make use of this at most of the ETP which are currently working with the aeration methods as a method of biological treatment. OPG are dense spherical granules which can work without the external aeration and consumes more carbon dioxides thus offering a greener working method [(Muhammed, 2021)]. With the introduction of OPG we can achieve a more economical way by reducing both the capital and working costs as these are found out to be the best way of biological treatment.

1. ETP

Effluent treatment plant (ETP) is one of the unavoidable parts in an industry they are solely the one working for the biological treatment of the waste water that has been producing in the industry and responsible for the reduction of the contaminants. Mainly inside the ETP the waste water is being treated as 3 Stages which are named primary secondary and tertiary treatment. In which each stages comprises different stages of treatment and of different qualities of treatment? Among them the primary treatment usually comprises of the case filtration whereas the secondary considers up of the chemical as well as the biological treatment and the tertiary usually comprises of the ultrafiltration thus allowing for the later reuse of the waste water. A typically ETP is being listed below

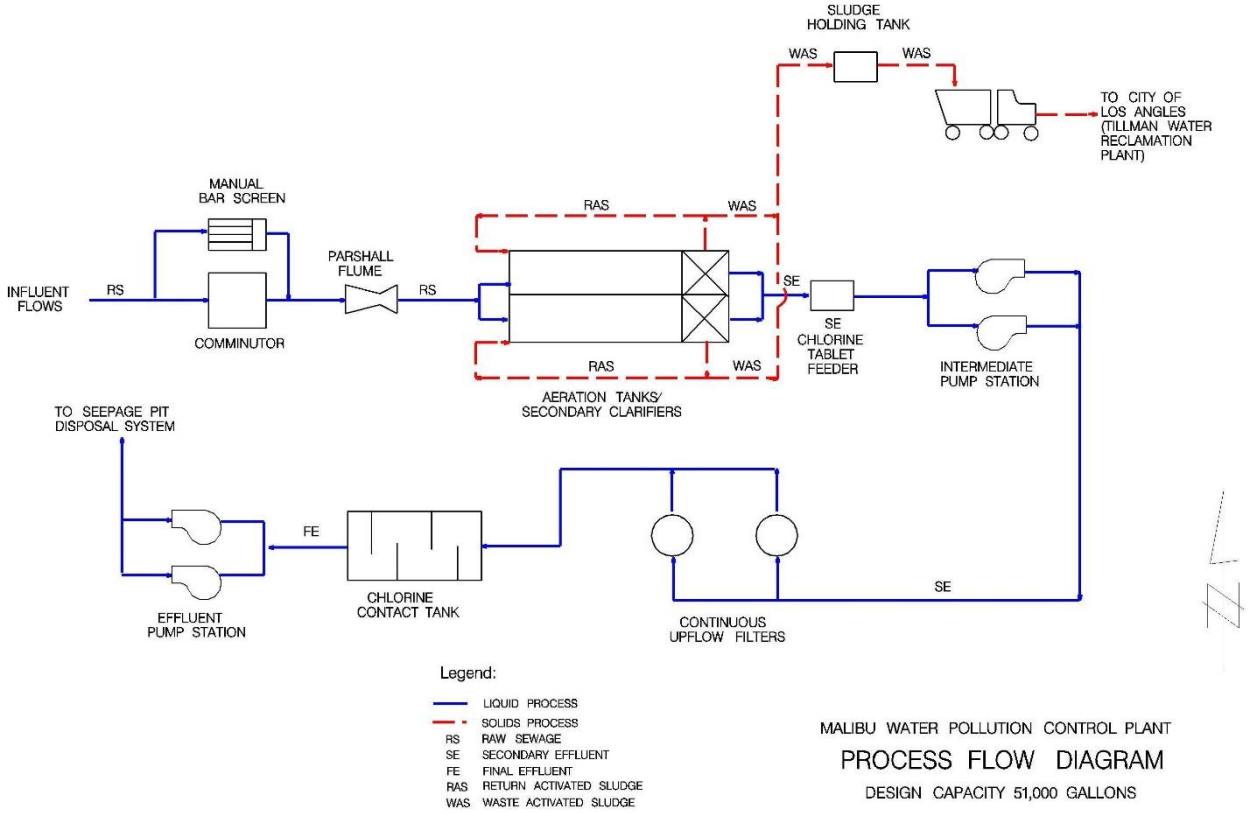


Figure 1. Conventional waste water treatment plant.

The above figure will give an idea about the basic operational units of a typical ETP and as visible from these that the secondary treatment is the most important stage which is being considered among these and since they are being carried out with utmost care. Due to these reasons among all the secondary treatment is the one which consumes a lot in terms of economic aspects. The studies have evidently proved that about the 70% of the total working cost in a typical ETP is being consumed at these steps and also the 60% of the total working capital is being consumed by these parts of the plant. Thus, the need for higher energy arises exponentially with a rise to our growth thus exploiting the Mother Nature for this need of ours.

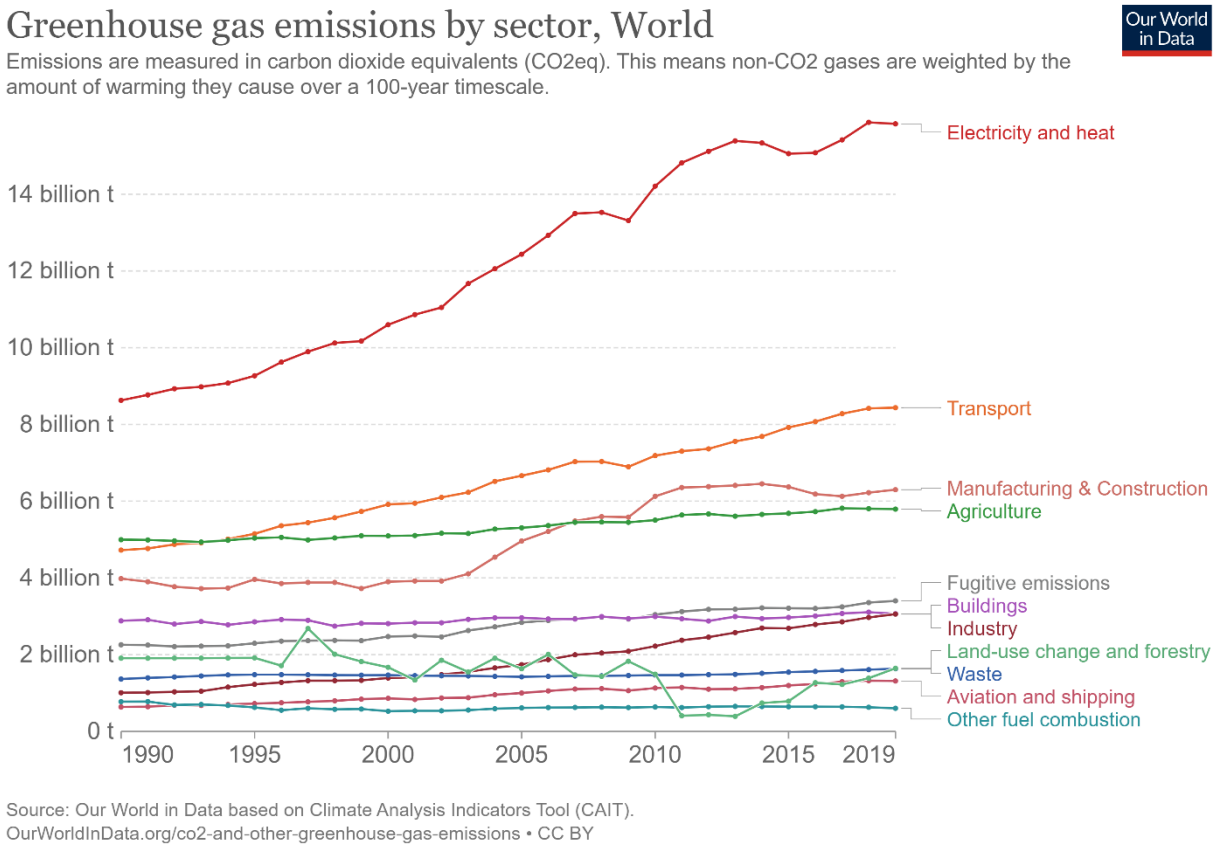


Figure 2. Graphical representation of the greenhouse gas emission from industries (Google Images, n.d.)

The graph shows the after effects. How much we are affecting the environment on our race for the industrial growth. In this modern world the stoppage of new industries or the current is unthinkable only known way will be following an alternative path which can benefit us as well as the Mother Nature

On the growing economic aspects of the world, it is a sure need to find a professional solution for these problems and for a green and economical working in these fields as evident we can see that if we were able to bring about a change then we can be able to save a fortune amount by providing a greener environmental aspect and it is where the ETP will come forward as a modern solution for these.

A study has been conducted in a typical ETP plant localized at Ambalathara Thiruvananthapuram. This will serve as a comparable medium for all the working plants out there. For a proper working of the usual method that is aeration tank which is being believed to do the most of the biological as well as chemical treatment 3 motor were being worked continuously which includes 2 20HP and 1 5 HP which enables the diffusion of the produced oxygen and thus maxing the whole process work effortlessly. So, in short, we can say that these are unavoidable part of the effluent treatment plant and these are the one which is consuming the 70% of the total energy put forward. Study has been conducted at this point and to make use of the microbial treatment methods available and thus making a green and economical method.

3. OPG-Oxygenic photo granules

Studies have been conducted through ages for the use of a microbial techniques in the effluent treatment plant. It was mainly during the early 2000 and late 1900 believed to the first discovery of the OPG it was during that time that the activated sludge that was found on the windows of the laboratory on exposure to the sunlight after times started to give a spherical form and found to have the properties of cyanobacteria and later on studies were being done and thus give rise to the discovery of OPG aka oxygenic photo granules. It was during the 2011 Park and Dolan first observed the transformation of activated sludge into oxygenic photo granules. In 1980's anaerobic granular sludge was applied in an up flow anaerobic sludge blanket (UASB). (Wikipedia, n.d.)

Among all these available options OPG was considered to be the most fascinating one found out till date. A large number of studies were conducted in relations to the static cultivation of OPG's. They have received much attention recently due to the advantage that their application can bring in relation to waste water treatment. Their major attraction is being considered as their ability to combine the nitrification/denitrification process with oxygen production with the help of the photosynthesis by making them a probable solution for the costly mechanical aeration techniques. (German Smetana, 2023) (Muhammed, 2021)

Oxygenic photo granules are composed of a driven community of microorganisms including cyanobacteria, green sulfur bacteria, purple bacteria and diatoms. they usually represent a light driven process for wastewater treatment, developed based on photo granulation of filamentous cyanobacteria unlike all the other process requiring the air lift or up flow-based mixing, the OPG's do not require aeration. They are capable of removing the organic as well as the inorganic pollutants simultaneously producing the oxygen through photosynthesis. They are usually comprised of layers of matter formed in the shape of the granules as well as in thick sheets or forms as based upon the condition at which they had been cultivated. They are being highly occupied with the diff kind and variety of the microorganisms occupying different layers with the granule structure. Efficient removal of the pollutants as oxygen is produced in outer layers and aerobic degradation of the organic matters occurs in the inner layers. About 90% of the COD is being able to be removed along with the achievement of 95% of the NH3--N

They make combined nitrification and denitrification and phosphorous removal in single stage biomass. The studies conducted in the different parts of the worlds have shown that by doing the proper maintenance and management techniques employed correctly we can be able to achieve the life of about 3-6 years simply.

Maintenance techniques	Management technique
Granular size and morphology	PH levels and nutrient supply
Oxygen production & consumption	removal of excess biomass from the system
Pollutant removal efficiency	necessary to rejuvenate/adding fresh
Microbial community driven techniques (DNA and FISH)	microbial inoculation/ adjusting of HRT

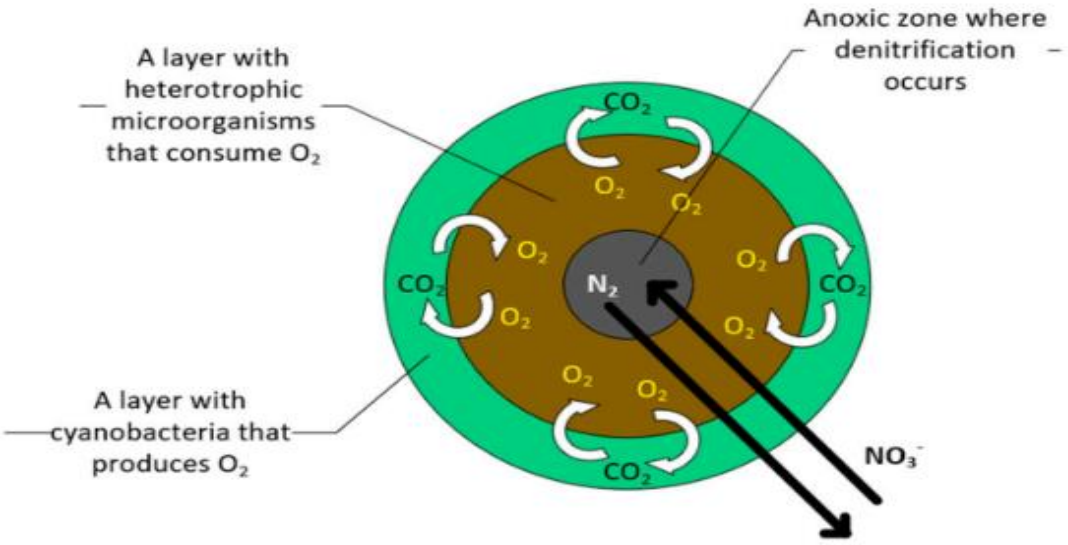


Figure 3. A typical OPG (German Smetana, 2023)

One of the primal reasons for choosing the OPG over all those existing and developing treatment methods is due to their irreplaceable advantages. The most fore seen advantage will include that these are one of the best options for a more sustainable way for the waste water treatment along which they need not to be aerated but will produce oxygen required for the process using the cyanobacteria lining over the outer half and also the center part of the OPG will take part in the nitrification as well as the denitrification process. The major part which we need to focus is that by saving the economic aspects we shouldn't let down the efficiency of the current scheme we should make sure that the efficiency is not lost but, in this case, the major advantage is that the efficiency is never lowered but increased which is one of the major advantages of the OPG.

4. Production of OPG

One of the major steps that has to be closely observed that should be the production of this OPG as we know that our primary aim was to make sure that the produced OPG should be of that value that is much desired and as well as compactible for a long-term use. As in studies it is observed that for a typical OPG after the life span of about 120 days a slight decrease in the hydraulic retention time being found out and it is found as negative feedback but in the later studies by providing a perfect condition for the OPG to be grown they tends to have a life much higher. By giving proper maintenance we can increase the life expectancy of the given OPG to a life span of about 3-6 years. Some studies have shown the longevity of them in the range of about 4 months to 4 years. We are expecting an average life expectancy for a period of 3 years. With the proper techniques the first aim should be to reach this particular specification.

As we mentioned earlier the production of OPG is usually being carried out at different stage mainly

- preparation of the growth medium
- inoculation
- incubation

- harvest

The activated sludge that was collected is the primarily used raw material for the production of the OPG. The basic idea which is implanted for the production of this OPG is that the activated sludge thus collected has to be stored in the glass vials or the reactors and later they need to be illuminated with sufficient light for the sufficient period for the proper growth of the OPG. As in this case the OPG need to be produced in a mass and thus the vials are not a viable option so that it is carried out in the proper reactors. In this case the photo sequencing batch reactor is the best viable option for us. (German Smetana, 2023) For the mass production the required volume of the photo sequencing batch reactor is being employed. The collected activated sludge of the preferred bio chemical characteristics are being filled inside the reactor. It is important to check the activated sludge way before their use that is the collected activated sludge has been having a BOD of 100-300mg/L and the COD of the value 250-500 mg/L. the lower the BOD and COD then less matter will be available for the production of the OPG and if a higher value of the BOD & COD will result in the excess oxygen demand (Muhammed, 2021). So, it is important to make sure of the raw material BOD & COD value and a time period of 90-120 days is being expected for the production of the OPG. As told earlier for the industrial use we need to make sure that the produced OPG would have the required time period and the HRT will not get reduced for that we need to make sure that the OPG produced should be healthy so we need to add nutrients to the raw materials. Studies have shown that the along with the water source we need to supply carbon, nitrogen, phosphorous and many trace minerals like iron magnesium and Sulphur. They are added along with the activated sludge. The carbon is being supplied in the form of the glucose about 2-5g/L and the nitrogen in the form of ammonium at about 0.2-0.5 g/L and phosphorous as phosphate at a rate of 0.02-0.05 g/L. along with these they are added with a trace amount of the minerals and thus treated activated sludge is being taken inside the reactors and is being illuminated (German Smetana, 2023). At first it was believed that a high light source will result in the better yield later it was found during the studies that a light source is only required for the above-mentioned operation. The high intensity of light didn't have any role. The total suspended solids (TSS) will be with in the 12.5 g/L. the 90% of success is being found at a high ammonium rate. The presence of the filamentous cyanobacteria is also a crucial part. The cyanobacterium of the origin Oscillatoria's form a dense outer photo layer outside the produced OPG (German Smetana, 2023). Oscillatoria to the synthetic media in the ratio of 3.6-14.4 (Oscillatoria to AS solids in mg wet mass) was associate with an increase in the cultivation success. They are being left in the P-SBR and after the growth period the OPG should have a definite shape that is indestructible by small forces and should be able to retain the shape on shaking of them. If they are able to do so they are considered as a successful cultivation. The above mentioned are considered as the basics steps that has been followed at the stages of production of OPG. For getting a much better result and the OPG that are being able to give a life expectancy of more than 3 years all those things need to be considered. By the production of the OPG of that life will be only considered as a successful cultivation (Muhammed, 2021)

5. Calculation of number of OPG

For completing the proper study, we have collected some data about the present scenario in the ET plant working with the traditional aeration method. For the given study we have selected the Milma Plant Ambalathara Thiruvananthapuram at where 750m^3 of waste water has to be treated daily. The waste water thus produced is being collected to study about their characteristics. And from thus obtained data the calculations are done to have a better understanding about replacing it up with OPG.

COD of waste water	2400 mg/L
BOD of waste water	1200 mg/L
Treatment efficiency	>90%
Hydraulic retention time	24 hrs.
Organic loading rate	0.087

Characteristics of desired OPG

Density	1.260 g/cm^3
Settle velocity	36 m/hr.
Yield of OPG	0.5

(Muhammed, 2021)

5.1 Calculation of Organic removal;

COD remaining = COD of waste water × (1- Treatment efficiency)

=2400 mg/L× (1-0.9)

=240 mg/L

=0.240g/L

Similarly, BOD =120 mg/L

=0.120g/L

5.2 Calculation of biomass production;

COD biomass production = 240mg/L ÷ 0.5

= 480 mg/L

= 0.480 g/L

Similarly, BOD = 240 mg/L

= 0.240 g/L

5.3Calculation of required number of OPG;

Number of OPG =) $\frac{(\text{Organic loading rate} \times \text{waste water column}}{(biomass\ production \times HRT \times density \times settle\ velocity)}$

Organic loading rate = 0.000087g/g/day

≈ 0.000001g/g/sec

Number of OPG = $\frac{(0.000001 \times 1L)}{(0.480\ g/L \times 864000 sec \times 1.260 g/cm3 \times 0.01 m/s)}$

≈ 3

Hence for 1L of waste water, about 3-5 OPG are required.

6. Capital cost analysis

Amount of waste water that need to be treated per day is found that 750000 L and we are assuming that it was being treated in 6 equal shifts.

The volume of reactor = 750000/6= 12500

For each liter of waste water that need to be treated 3 OPG was required but for a higher performance we are taking 4 OPG for each liter

Total no of OPG = 12500*4 = 50000

Form the studies conducted it is proved that for the proper production of OPG

About 150 OPG we require 216 Wh (18 W led for 12 hrs. and remaining with 12 hrs. sunlight)

Energy consumed = $(\frac{216}{150}) * 50000 = 72000\ Wh$

Energy consumption per day = 36KWh

Thus for 100 days = 3600KWh

We are standardizing the cost of electricity as 5.8 Indian rupees per unit consumed

From this we can say that for the operational time of approximately 100 days it will costs us about 20880 Indian rupees. As we have mentioned we have that the average life expectancy expected is minimum 3 years.

If we are using the traditional aeration tank method from the details, we have gathered we will minimum require 3 motors those will be two 20HP motors and one 5HP motor. This is the minimum requirements and the average life of a motor is 15 years.

Comparing the installation cost of two methods

6.1 OPG

Since the average life is 3 years, we need to replace it totally five times to get the life of 15 years, so the installation costs = 20880*5 ~ 110000 Indian rupees

For the 230 tubes it will cost about 23000 rupees

So, in short for OPG the total capital cost for a life span of 15 years will be 133000 Indian rupees

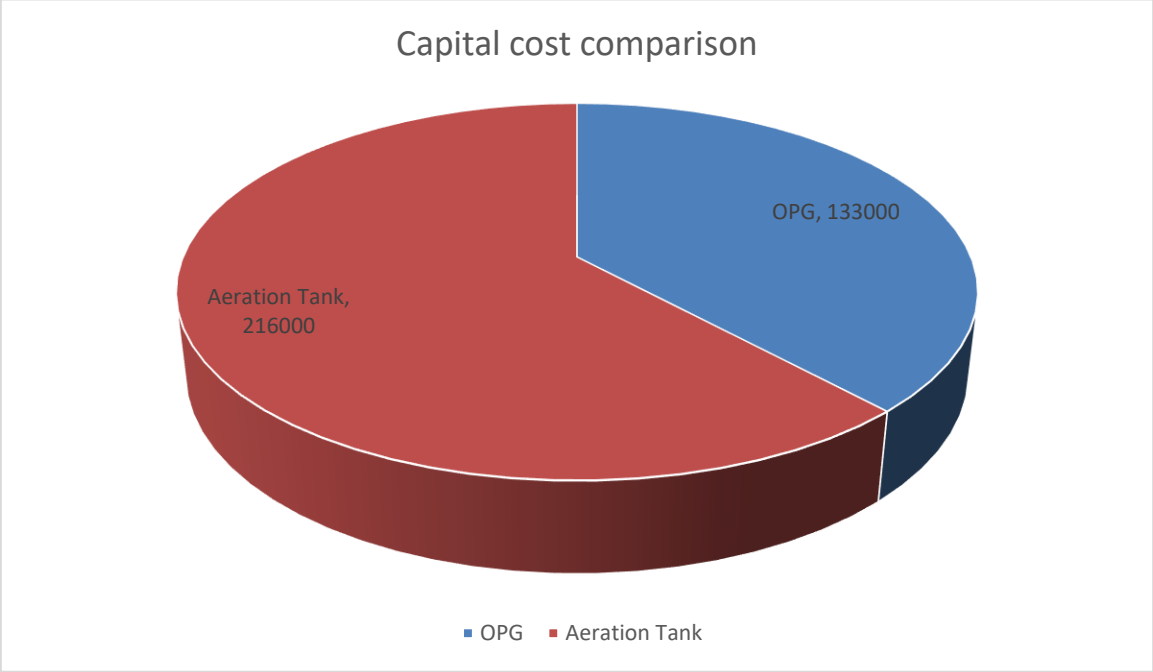
6.2 Aeration tank

Cost of 20 HP motors (Kirloskar 3 phase 20 HP 4 pole) = 2*90000 = 180000

Cost of 5 HP motors (Kirloskar 5 HP Monoblock pump) = 36000

Total cost by Aeration method = 216000 Indian rupees.

We are saving 40 % of the previous method.



By comparing we can see that the operational cost of the OPG will be 38.43% lower compared to that of the conventional aeration tank process.

7. Running cost analysis

As we know that the major energy consumption occurs during the running of the plant at this stage, we are comparing how much energy OPG can help us to save on comparing them with the traditional aeration tank methods.

7.1 Using OPG

Since within the aeration tank itself we can introduce the OPG and use them for the treatment process without using the mechanical motors and the surface area of the tank was being found about 65m^2 and during the night time itself they need to be illuminated with light since at that time the sunlight cannot be provided and hence from this we can possibly say that there need to be illuminated with about 6.4 Klux light (German Smetana, 2023) for make happen the photosynthesis and for this process total lamination required will be 65*6.4= 416

The total power required = $\frac{\text{total flux requirement}}{\text{luminous efficiency}}$ = 416/100=4.16KWh

From this we can say that total no of tubes require at this point will be 4160/18 =230 tubes. (Assumed using 18W tubes for this process)

So, the 230 tubes will consume about 230*18=4140W

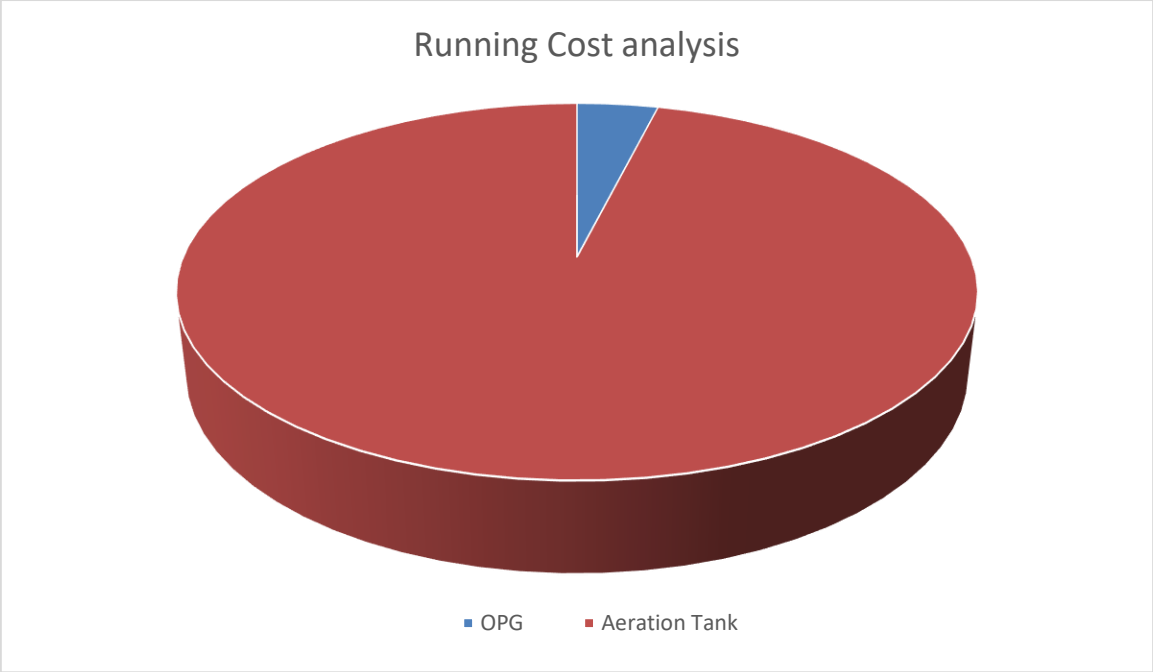
When worked for about 8hrs to accompany the sunlight 4.140*8=33.12 units will be consumed

7.2 Aeration method

The two 20 HP motors itself will be 745.7*20*24*2 = 716KWh

And a 5HP will cost about 5*745.7*24= 90 KWh

So, the total power consuming per day will be 816 KWh



The chart itself will speak for the need of OPG in the present scenario

8. CONCLUSION

In the given work we have gone through a detailed study about the OPG. We have gone through the possible outcomes which it can bring up on the field of the ETP and moreover about its advantages and in the industrial approach. How they are advantageous in terms of the economics and efficiency too from all these things this is evident that how much we will be saving by contributing to the nature as well us to our upcoming generation. The OPG will be a perfect replacement as we are able to save in terms of the installation cost and as well as in the terms of the running costs that too without compromising in the treatment efficiency. By doing proper research we will be thus able to develop OPG which will be able withstand even more time and thus improved life expectancy will surely result in the economic stability as well. It is really a compromising as treatment of wastewater using OPGs is done in plot scale which upon scaling up will leads us one step towards sustainability. By incorporating OPG on a scale wide enough thus we will be able to attain an energy efficient as well as sustainable process. Results obtained thus far shows that by continuing long enough we will be able to produce OPG which will be much more efficient and economical way of waste water treatment. The values itself will show that how much we will be able to save if we are able to change towards the OPG and each day we are saving our money as well as the mother nature

Thus, in short, we can say that by the advancement in science we can simply bring more changes to the production of OPG thus attaining more and more efficient methods which is more economical also much safer to our mother nature.

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