IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Review of Granular Biomass Application in Sewage Treatment

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Abstract.
The treatment of urban sewage is done by using activated biomass in the biological stage of the treatment at most of the sewage treatment plant. This method is developed log back and being used worldwide. During the last two decades granular biomass technology has immerged out to be far better process on cost, performance, low energy consumption and low foot print. This article reviews both the process and present a comparative data highlighting improvement demonstrated by granular sludge process over the activated sludge process. The review study refers to the full-scale operational plants that apply granular biomass in sewage treatment and highlight benefits of granular sludge technology over activated sludge technology.

Keywords: Activated biomass, Granular Biomass, Sewage,

1. Introduction

Sewage treatment at urban area is becoming challenge with intensive urbanization. The treatment obligation has been brought into legislative compliance in India and is being implemented using various treatment methods. This paper focuses on two biological treatment process technologies,

1.1 Activated biomass (sludge)
1.2 Granular biomass (Sludge)

Both the biomass are applied in biological treatment of sewage treatment.

There is sewage treatment plant guideline issued by central public health & environmental engineering organization (CPHEEO) and Karnataka State pollution control board on activated sludge treatment process, these guide lines have been referred to review present practices being followed across India.

The future practice of improved technology that supersede present practice is identified and reviewed through various research papers and through study of few operational plants in India.

2. SEWAGE TREATMENT PLANT PRESENT PRACTICE

The typical arrangement of sewage treatment plant consists of primary treatment using bar screen, oil and grease trap, equalization tank, these are the physical treatment process to remove floating impurities from the waste water and equalize the shock loading. The secondary treatment is a biological process that removal organic contaminants from the waste water through biological oxidation, the resultant sludge is removed and recovered as organic manure and treated effluent is passed on to the tertiary treatment for further filtration to removal suspended impurities and disinfection through chlorination.

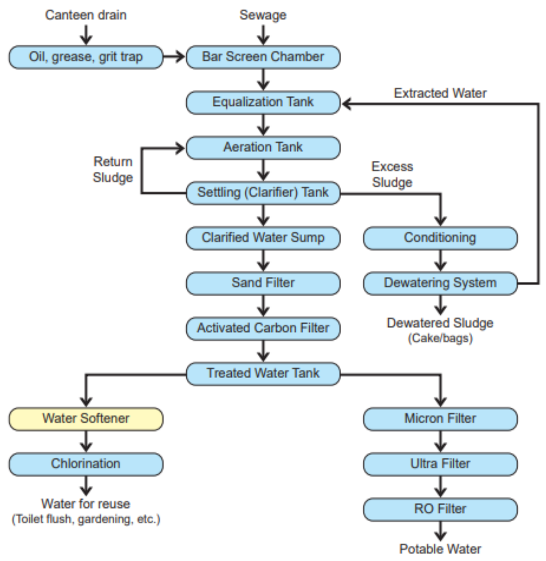

Fig. 1 block diagram showing typical arrangement of STP
(reference: STP guide Karnataka state pollution control board)

In this review study, focus is limited to secondary treatment process involving activated sludge process of treatment in the sewage treatment plant.

3. ACTIVATED SLUDGE PROCESS

The activated sludge process in a sewage treatment plant typically consists of aeration tank, secondary clarifier and return sludge pumps. The aeration tank is fitted with surface aerator or diffused aeration system for continuous operation to supply air to maintain dissolved oxygen for biological oxidation of organic impurities in waste water. The biomass along with waste water is carried over to secondary clarifier under gravity for separation of waste water and biomass. The settled biomass is transferred back from secondary clarifier to the aeration tank using slurry pump. The excess sludge is drained out from the system to sludge drying beds or to sludge dewatering mechanism.

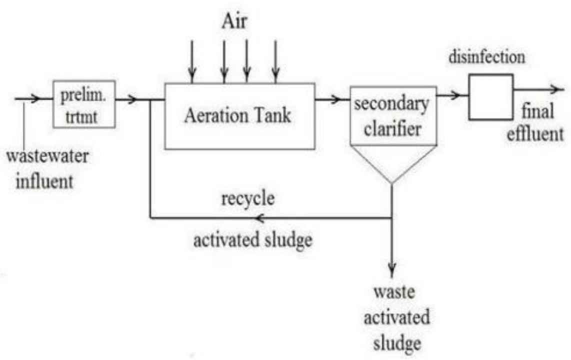

Fig 2 The typical arrangement of activated sludge treatment process is shown as:
(Shreya and Vishal 2018,)

This process of activated sludge is widely used in sewage treatment across country in India. A summary of STP using activated sludge process in various part of Delhi is presented below:

3.1.1 STP based on activated sludge process

The data on activated sludge treatment processes applied at various part of Delhi for treatment of sewage is gathered and presented below:

Table 1. STP treatment process at Delhi (Ref.: CPHEEO manual 2013),

	Name of the STP's	Capacity (MLD)
1	Coronation Pillar STP's (3 STPs)	45.46, 45.46, 90.92
2	Ghitorni	22.73
3	Keshopur (3 STP's)	54.55 90.92 181.84
4	Kondli (3 STP's)	45.46 113.65 45.46
5	Mehrauli STP	22.73
6	Najafgarh STP	22.73
7	Nilothi STP	181.84
8	Narela STP	45.46
9	Okhla (5 STP's)	54.55 72.73 136.38 168.20 204.57
10	Papankalan STP	90.92
11	Rithala STP's Old	181.84
12	Rohini STP	68.19
13	Yamuna Vihar (2 STP's)	45.46 45.46
14	Vasant Kunj STP's	10.00

Based on above table, it is evident that activated sludge treatment is the most common treatment process adopted in India.

A case study published by ResearchGate on STP at Delawas Jaipur (Sharma et. al., March 2020) confirm to use activated sludge technology with sludge recycling through secondary clarifier and sludge recycling pumps.

In China similar activated sludge system with arrangement of biomass recycling is used (Bingqin et. al., 06.07.2022,)

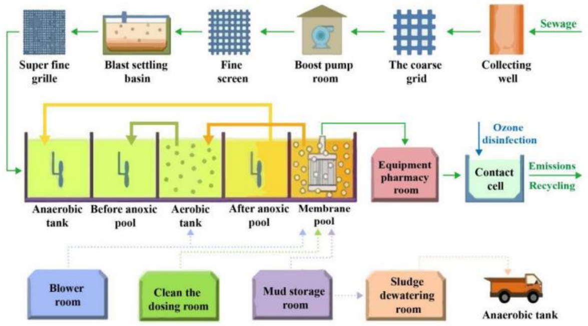

Fig 3. A typical STP system in China, confirming present scenario at global level. (Bingqin et. al., 06.07.2022,)

Activated sludge (AS) process is still widely employed globally, though not sustainable in terms of large land foot print, higher cost and complex designs for biological nutrient removal (Naancharaiah et al, 2019).

3.1.2 Activated sludge process limitation

Due to loose microbial structure and poor settling properties activated sludge, secondary clarifier is essential to separate biomass from the treated waste water. The major drawback of conventional activated sludge process is large the foot print requirement, due to flat reactor and large clarifier for gravity separation. The associated capital cost, complex process design and high energy cost for recirculation of biomass and waste water are also the disadvantages of conventional activated sludge process (Nancharaiah et al., 2019)

In last two decades it became possible to address sludge separation issue by engineering the microbial community in the form of a compact and dense aerobic granular sludge (GS) which is becoming a standard for future of aerobic waste water treatment.

4. GRANUAL SLUDGE PROCESS

Granular activated sludge has gained increasing interest due to its potential in treating wastewater in a compact and efficient way. It is well-established that activated sludge can form granules under certain environmental conditions such as batch-wise operation, high hydrodynamic shear forces, and short settling time which select for dense microbial aggregates. Aerobic granules with stable structure and functionality have been obtained with a range of different wastewaters seeded with different sources of sludge at different operational conditions, but the microbial communities developed differed substantially (Britt-Marie Wilén et al, 2018)

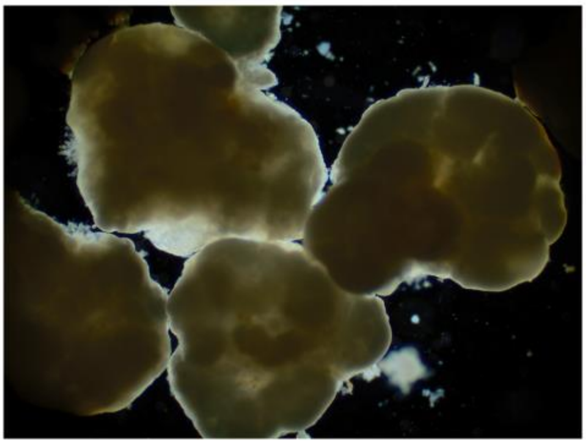

Photo 1 Light microscopy image of granular sludge
(Britt-Marie Wilén et al, 2018)

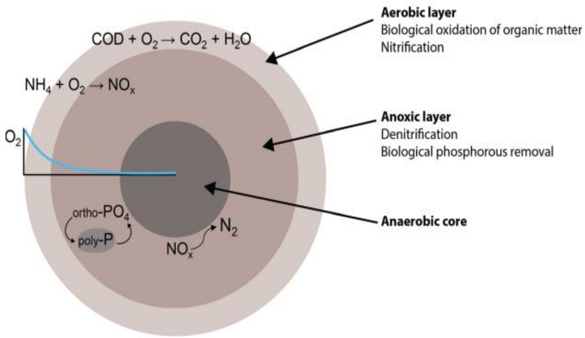

Fig 4 Schematic drawing of anaerobic granule with the different conversion processes for organic material, nitrogen and phosphorous, taking place within the different redox zone. (Britt-Marie Wilén et al, 2018)

The layered aerobic and anaerobic zones with in the granule as shown above allows simultaneous process to take place in the granular biomass like phosphorous reduction, nitrification and denitrification. (© 2017 Aqua-Aerobic Systems, Inc, Bulletin #991 10/17)

SVI_5 comparison of aerobic granular sludge (left) and conventional activated sludge (right)

Photo 2: Settling property comparison of granular sludge left with activated sludge right,
(© 2017 Aqua-Aerobic Systems, Inc, Bulletin #991 10/17)

The granular biomass has excellent settling properties, the comparison data is presented in photo 2, with respect to activated sludge.

Due to this fast-settling properties of granular sludge, the process of fill and draw, aeration and settling is achieved in one tank described below:

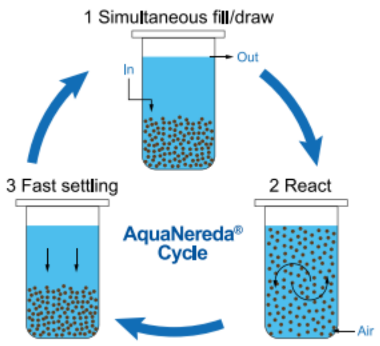

Fig 5: Nereda cycle of operation in a single tank

(© 2017 Aqua-Aerobic Systems, Inc, Bulletin #991 10/17)

4.1.1 Study of full scale STP based on granular sludge process

In India two plants have been identified that are applying granular sludge technology for field study and following data were collected:

Plant 1 location: Village Ratanpur, near Bhopal, for treatment of resident hostel sewage along with effluent of canteen with installed capacity of 25 KLD,

Photo 3: 25 KLD STP based on granular sludge process (courtesy M/s Shreyans Energy P Ltd)

Plant 2 location: Village Chhan, near Bhopal, for treatment of resident hostel and staff quarter sewage along with canteen effluent capacity 35 KLD.

Photo 4 : 35 KLD STP based on granular sludge process (courtesy M/s Shreyans Energy P Ltd)

Above both the STPs are using granular sludge process for treatment and recycling of sewage and carrying out entire treatment process in single tank and eliminating use of secondary clarifier and sludge recycling pumps.

4.1.2 Granular sludge process description in a single tank

The influent is collected in underground tank and from this tank submersible pump transfer it to bioreactor in four batches. Each batch has 6 Hrs as cycle time and the break-up of 6 hour is:

- Feeding 01:20 (HH:MM) (Fill and draw taking place simultaneously)
- Solenoid valve operation 00:10 (HH:MM)
- Aeration 04:00 (HH:MM)
- Settling 00:30 (HH:MM)
- Effluent recycling 01:20 (HH:MM)(taking place simultaneously with feeding operation)

Feeding: During feeding period of 01:20 (HH:MM) submersible pump shall remain ON and transfer influent @ 7.5 M3/hr into the reactor. This operation of pump takes place on auto through either a timer or programme with flexibility of changing the setting duration as well as defining start and stop time.

There are two pumps, the auto controller has provision to choose either of the pumps, the arrangement is for one working and one standby..

A condition may arrive that there is less influent in the collection tank and submersible pump may get off due to OFF command from low level float switch

Solenoid valve operation: During solenoid valve operation period of 00:10 (HH:MM) valve shall remain ON, after 10 minutes valve gets OFF. This activity ensures low liquid level in the aeration tank than the overflow nozzle so as to avoid sludge carryover during aeration stage, as liquid level increases due to compressed air displacement and this level increase is compensated in the preceding stage by maintaining low liquid level though solenoid valve opening and transfer of effluent from reactor under gravity to treated effluent sump.

Aeration: The aeration is achieved through roots air blower, driven through 3 HP motor with VFD. The blower starts after the completion of feeding cycle just after the SOV closes as per step 2. The blower duration operation is fixed as 4 Hr, after this period of operation it stops on auto. However there is provision to run blower on manual as and when required.

Photo 5: Image of Granular Sludge during aeration phase

(Courtesy M/s Shreyans Energy P Ltd)

Settling: During the period of 00:30 (HH:MM) of settling, neither pump nor blower operates, all machine remains OFF.

Effluent recycling: This operation takes place simultaneously with feeding of influent, duration is fixed as 01:20 (HH:MM).

Both the above referred plants are in auto operation since following dates:

Ratanpur site: 5th Oct 2020

Chhan site: 12th March 2022

5. Results and discussions

Granular sludge STP data analysis, Ratanpur site capacity 25 KLD:

The STP installed at this site is operated on auto with no manual intervention, hence no operation data are available, however during commissioning temporary lab was set up to establish plant parameter and data documented during commissioning are reproduced.

Flow – 10 to 22 M3/d,

Influent data

pH – 7.5

COD – 298 to 560 mg/l

Treated effluent

pH – 8.5

COD – 42 to 90 mg/l

Biomass in the reactor was measured by cylinder settle method to evaluate % settlement, same is initially found after seeding cow dung and continuous aeration for 15 days

Initial biomass 5 to 10 % which grew to 18% over three weeks of observation.

Sludge settling characteristics

100 ML glass cylinder were used for determination of sludge settling characteristics and sample were drawn from 4 sampling points of the aeration reactor during aeration phase of the reactor and following sludge settlement photo taken with timer ON reading:

Sludge Settlement seen after 2 Minutes	
Sludge Settlement seen after 4 Minutes	
Sludge Settlement seen after 6 Minutes	
Sludge Settlement seen after 10 Minutes	
Sludge Settlement seen after 30 Minutes	

Photo 6: Sludge settlement with respect to time (Courtesy M/s Shreyans Energy P Ltd)

This is wonder to find that sludge got settled very fast, it has reached to more than 75% settlement in just 4 minutes. This fast-settling characteristics of the granular sludge given a great opportunity to redesign STPs and ETP and utilize this wonderful characteristic of granular sludge.

Organic loading rate

The organic loading rate calculated at across single tank reactor using granular sludge at STP Ratanpur site and found as 0.554 Kg of COD/M3/day. This is however is on lower side due to the less flow of 10 to 22 M3/d as against designed flow of 25 M3/d.

No COD measurement data were available from other site (Chhan), however the flow measured here is 35 M3/d, being operated at designed flow and here the biomass concentration noted is more 20%, this show a more healthy operation of the Chhan STP than Ratanpur STP. The organic load across Chann STP is therefore concluded more than as calculated for Ratanpur STP.

Oxygen supply interruption

The designed oxygen interruption in the STP process is described in the table below:

Operation processes at granule sludge STP site Chhan Bhopal			
1	2	3	4
feeding 1 hr 20 min	SOV on 10 min	Aeration 4 hrs	Settling 30 min
Withdrawal 1 hr 20 mi			
Cycling operation with cycle of operation of 6 Hr X Cyle in a day			
% of aeration duration in each cycle:4/6*100=66.67%			
Designed interruption in oxygen supply in each cycle of operation, that is sum of duration of operation 1, 2 and 4 = 2 hrs			

(Curtesy: Shreyans Energy P Ltd)

However during course of operation oxygen supply interruption found to be more than the designed interruptions at following incidences:

- Interruption in electricity supply to the plant
- Twin lobe air blower belt failure
- Twin lobe air blower lobe failure,

The STP at both the locations are having only one twin lobe blower and no standby blower is created due to capital cost control. But this had the risk of plant performance deterioration in the event of twin lobe air blower.

It is noticed that during above such un designed oxygen supply interruption, STP got stabilized quickly without need of external culture seeding for re-establishment of granular sludge volume within the reactor.

6. CONCLUSION

This review article concludes that granular sludge process in treatment of sewage treatment is far better than the existing practice of activated sludge process due to following advantages (Andreas et al,; Nancharaian et al, 2019; © 2017 Aqua-Aerobic Systems, Inc, Bulletin #991 10/17):

-MLSS permissible % as high as 8000 Mg/l, that is almost double the conventional activated sludge,

-Four times less space required compared to conventional activated sludge method.

-Energy saving upto 50%,

-Elimination of secondary clarifier, return sludge pumps and associated piping reduce capital cost,

-Robust structure of granule withstand fluctuation in pH, flow, Oxygen supply, chemical spike, salts and toxic shocks.

-Ease of operation with fully automated controls.

Above advantages are significant in terms of cost and quality along with ease of operation of sewage treatment plant.

The comparative data analysis revealed in this review study of both the technologies, that provides a strong recommendation to switch from activated sludge technology to the new technology that uses granular biomass process.

This granular sludge technology may lead the future of waste water treatment industry worldwide.

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