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Performance Study of SBR with the Evaluation of Recovering Phosphorous and Nitrogen from Domestic Wastewater in Puducherry Region

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Abstract*— For the growth of plants and the production of crops, phosphorus and nitrogen are crucial. While nitrogen is limited in soils, it is abundant (78%) in the atmosphere as gas that is exceedingly steady and non-reactive N2.Whereas, the last few decades; there has been a growing awareness of the finite nature of phosphorus resources, as well as the significance of phosphorus recovery. In plants, phosphorus is a limiting factor. As a result, it is a significant component of fertilizers. Fertilizer industry processes the major part of the mined phosphate rock. Because phosphorus is non -renewable, it is critical to ensure that the amount of phosphorus fertilizer available in the future is sufficient to ensure a stable supply of food for the world's growing population. Nitrogen and phosphorus have emerged as major contributors to the eutrophication of receiving waterways. As a result, more rigorous environmental laws are implemented to reduce their discharges, generating an urgent need. There is a need for technical methods to improve nutrient removal and nutrient recovery in the current secondary wastewater treatment plants, removal (WWTPs). The obtained test result of 'N' and 'P' which are outlet chlorinated samples 9.6mg/l and 1.6mg/l. Hence the need for nutrient recovery, the strain on reactive nitrogen and phosphorus production is reduced, resulting less nitrogen and phosphorus entering the environment that is reactive. It could result in greater fertilizers use and less negative environmental impact. The Nation's total consumption of Phosphorous in all sector are 8808.99 Million Kg /year has been estimated. The study results of the cost comparison between struvite fertilizer and conventional fertilizer show that struvite fertilizer is more affordable than other conventional fertilizer.

***Index Terms*— EBPR, Nitrogen, Nitrification & De-nitrification, Phosphorous, SBR and Struvite.**

I. INTRODUCTION

Plant development and crop production require nitrogen and phosphorus. While nitrogen is abundant in the atmosphere (78%) in the highly stable and insoluble form N2 gas, it is scarce in soils. Nitrogen is fixed in reactive forms like amino acids, nitrate, and ammonia to make it more portable and available in soils.Phosphorus is non-renewable, it is critical to ensure that the amount of phosphorus fertilizer available in the future is sufficient to ensure a stable supply of food for the world's growing population. Fertilizer industry processes the major part of the mined phosphate rock. Today, some phosphorus is recycled. Phosphorus-containing waste streams that can be reused as phosphorus fertilizers include animal manure, household organic waste, and wastewater sludge. However, many fertilizers in the globe come from phosphorus mines, where finite stocks of phosphorus are removed from the ground to be utilised as mineral phosphorus fertilizer or by the phosphorus industry in some other application. Furthermore, phosphorus is employed in the production of products such as detergents and medications.

Each year, 2% of the reactive nitrogen that is added to the atmosphere globally escapes as N2O, which warms the planet and thins the ozone layer, and 12% as NOx and NH3, which have different impacts on the atmosphere. The eutrophication of receiving streams has been mostly attributed to the elements nitrogen and phosphorus. The pressure on activated nitrogen and phosphorus production is reduced as a result of nutrient recovery, resulting in less activated nitrogen and phosphorus entering the environment. As a result, fertiliser will be utilized more efficiently, and the environmental impact would indeed be reduced.

The process of Enhanced Biological Phosphorus Removal (EBPR), a crucial technique for "P" recovery. Recovery of phosphorus from domestic wastewater, can minimise the problem outbursts on phosphate rocks about 15% to 20%. To efficiently recover struvite, soluble "p" is required. While recovery often occurs via precipitation as struvite, phosphorus release can also be accomplished utilising thermochemical or biochemical techniques [1].The Crystallization of Struvite to Remove Phosphorus from Wastewater. They looked into a number of different techniques, including stirred tank reactors, air-agitated and fluidized bed reactors, as possible struvite recovery designs. One of the most viable options for removing phosphorus and recovering it as struvite is fluidized bed reactors. According to test findings, this approach can recover "P" by more than 70% [2]. They suggest on optimum duration on single phase. It can remove and obtain low nutrient concentration like piggery wastewater – with COD (Chemical Oxygen Demand), nitrogen, phosphorus removals higher than 98%. This plant has been in operation for almost a year [3].

According to the findings from this publication, the average eradication rates for COD, TN, and TP were 93.52, 88.31, and 97.56%, respectively[4]. Phase length and influent distribution optimization are crucial factors in this study's findings, which demonstrate that they are critical for high nutrient removal (88%, 93%, and 99% of carbon, nitrogen, and phosphorus, respectively) [5]. In this work, the fundamental relationships between effective sludge age, recycling ratio, and cycle time were examined in order to provide design parameters. After 0.7 hours of mixing, SNO is reduced in the summer and anaerobic conditions develop [6].

Findings indicate that at least two different microbial communities, an LPO (lactic acid producing organism) and a PAO(Polyphosphate Accumulating Organism), were responsible for the EBPR with glucose supply. At pH 6.9, 1 C mmol of glucose generated approximately 0.42 C mmol of PHAs, whereas 0.12 P mmol of phosphate was released during the anaerobic stage. [7]. According to the test results, Pseudomonas strains that were isolated from sludges for the purpose of eliminating phosphorus were also identified as regular PAO and dominant species to the entire microbial population. [8].

Nitritation may be gradually raised to a stable 80% nitritation from the initial 40% nitrite. According to the test findings, there was a mean nitrogen elimination of 84% when TKN at the effluent level of 6.4 mg/N Land remained in the effluent [9]. The effectiveness of ammonium removal and the rate of nitrite buildup were 94.12% and 83.54%, respectively. Nitrospira, the sole nitrite-oxidizing bacterium in the system, and Nitrosomonas, the ammonium-oxidizing bacterium with 83% of the total results from 16S rRNA (ribosomal ribonucleic acid) high-throughput sequencing [10]. From microbes, EPS (Extracellular Polymeric Substances), and inorganic precipitates, the (TP) Total P of EBPR-AGS (Aerobic Granular Sludge) was determined to be 73.7%, 17.6%, and 5.3-6.4%, respectively [11]. The systems for biological nitrogen removal and recovery from wastewater, including microalgal growth and a variety of bio nitrogen removal processes such nitrification, denitrification, and anaerobic ammonium oxidation (anammox). According to the study, it is important to regulate external factors including pH, temp, sunlight, oxygenation, and co2 in order to promote the growth of microalgae and, as a response, effective wastewater treatment [12].

According to the findings, this facility may go from chemical precipitation to bio precipitation, followed by mineral precipitation, with only minor structural adjustments. Phosphorous recovery might be important, either as struvite or, most sustainable, as calcium phosphate, a mineral with fertilizer properties. The latter would be around one order of magnitude less expensive than the former [13].

The removal rates for SCOD (Soluble Chemical Oxygen Demand), N-NH4 + (60%) and TSS (Total Suspended Solids) (70%) and VSS (Volatile Suspended Solids)(80%) are 83%, 70%, and 70%, respectively . The average F/M (Food/Microbe) ratio was 0.2 gCOD/gVSSd. The existence of Bacteria domains such as Nitrosomonas spp., Nitrobacter spp., Nitrospira, and C. "Accumulibacter" cluster was determined by analysing the microbial community [14]. In a single tank, the SBR completes equilibrium, biological treatment, and secondary clarification using a timed control sequence. The findings for removing 98.4% of the biochemical oxygen demand [15].

The Metropolitan Region of São Paulo in Brazil, where they discussed on the different process, economic feasibility of that region and the recovered ‘P’ are distributed to fertilizer sector as struvite product. The test results reveal that 38.0 metric tonnes per day of struvite granules are produced and 5.3 metric tonnes per day of phosphorus are recovered [16]. The study compares on 19 technologies with the conventional one Sewage sludge ash is among the most viable Phosphorous resource, with recovery efficiency of 60–90% in comparison to wastewater P, when the costs of "P" recovery are evaluated [17]. According to this study, 100 m3 of sewage wastewater may crystallized 1 kilogramme of struvite for a cost of $0.07 (Australian Dollar) per kg or a profit of $0.74 (Australian Dollar) per kg [18].

The planning and proper design should be done for LCA of nutrient recovery. The review on 65 LCA (Life Cycle Assessment) shows the multi functionality, fertilizer offset accounting, contaminant accounting, and inventory and method transparency [19]. The findings indicate that treatment with Struvite Aerobic Granular Sludge Anammox (SGA) was more expensive than conventional methods and had less of an impact. [20].

Cyclic Activation Sludge Treatment Process, often known as C-TECH, is a forthcoming version sequential batch reactor technique. It gives the maximum level of treatment effectiveness possible in a solitary biological mechanism.. C-Tech uses 50% less power to achieve 6 times better outlet characteristics. C-Tech uses half the land area of other traditional technologies, saving money on land purchases. C-Tech is completely automated and computer controlled. It does not necessitate continuous operator attention. The plant may be controlled from anywhere in the globe via the Internet. C-Tech uses stainless steel for all underwater metal parts. This results in significantly longer plant life and lower maintenance costs. It has an equalization capacity built in to handle peak loads [21].

The main complexes and free ions found in the struvite system include Mg OH+, MgH2PO4+, MgHPO4, MgPO4-, H3PO4, H2PO4-, HPO42-, NH3, NH4+, Mg2+, and PO43-. According to the results of the thermodynamic modelling, struvite precipitation starts in a supersaturated solution, and supersaturation is dependent on the solution's composition (total magnesium, ammonium, and phosphate), as well as its pH level [22]. Several factors influence struvite precipitation, including pH, Mg2+, PO43-, and NH4+ concentrations, and the presence of other interfering ions such as calcium

(Ca2+)[23].The pH of for struvite precipitation has been well confirmed to be 8.0-10.7[24]. At the moment, the phosphorus recovery methods that depend on the precipitation of phosphoric minerals from leachates or sludge are the most often used. Struvites, hydroxyapatites, or calcium phosphates can precipitate as phosphoric minerals. It is an assortment of the most popular phosphorus recovery techniques. [25].

While efforts are being made to mitigate biological nutrient from the municipal waste water is accumulated in the water body and causes eutrophication of water bodies. The approach presented here recovery of the biological nutrients in order to boost up the fertilizer application. The study's objectives are to monitor the effectiveness of the Kanaganeri Sewage Treatment Plant's SBR (Sequencing Batch Reactor), to evaluate the phosphorous production, consumption, and demand, as well as to estimate national consumption of 'P', to estimate the cost comparison between the production of struvite and conventional fertilizer. Therefore, the study experimentally examined sample testing from Kanaganeri Sewage Treatment Plant, evaluating its effectiveness for sustainable wastewater treatment, Puducherry's and India's yearly uptake of Phosphorous from Sewage Treatment Plant, estimation of Nation's total phosphorous consumption in all sectors in the year 2020-2021, and cost comparison between the production of struvite and conventional fertilizer.

II. MATERIALS AND METHODS

Study Area

17MLD Kanaganeri Sewage Treatment Plant (STP) which is located at Kanganeri Lake, Kathirkamam, Puducherry. It has SBR and is currently being upgraded by C-Tech [Cyclic Activated Sludge Technology], It is equivalent to the Activated Sludge Process and the next-generation SBR. Fill-Aeration Sequences, Aeration Sequences, and Settle Sequences are the C-Tech processes. The treatment facility additionally includes bio-phosphorous removal, cocurrent nitrification and denitrification, and effluent withdrawal by decanting [26].

Fig. 1- Kanaganeri Sewage Treatment Plant

Fig.2- Kanaganeri Sewage Treatment Plant interior elevation

Preliminary Test

pH

Regardless of whether treatment is physical/chemical, biological, or bothBeing a chemical component of the wastewater, pH has a direct influence on how well it can be treated. It is essential to treatment since it contributes so significantly to the wastewater's composition. To ensure that the process runs smoothly and to provide the appropriate conditions for the necessary chemical or microbiological reactions, pH levels must be managed.

Fig. 3- pH meter

ELECTRICAL CONDUCTIVITY

TDS measurement takes a long time, and hence it's frequently calculated using electrical conductivity (EC), presuming that the majority of the dissolved solids are ionic species and that their concentration is low enough to provide a linear TDS-EC relationship: **TDS (mg/L) = k_e × EC (µS/cm)** where k_e is a constant of proportionality.

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Fig. 4- EC Meter

COD Test [Chemical Oxygen Demand]

The COD test is commonly used in liquid waste to infer the presence of organic molecules. It is measured in milligrammes or grammes per litre, which represents how much oxygen is used up for every litre of solution. The standard method for measuring COD in Part 5220 (COD), open reflux method [26] have been tested in laboratory and test results have been obtained and discussed.

Fig. 5- COD Test

BOD Test [Biochemical Oxygen Demand]

The term "biochemical oxygen demand" (BOD) refers to the total amount of oxygen that bacteria and other types of microbes will consume to decompose any organic matter that is present in the water. A BOD test can be used to assess how much oxygen is needed for an organic matter sample of water to degrade. The standard method for measuring BOD in Part 5210 (BOD (3rd day, 27 degree C)) [26] have been tested in laboratory and test results have been obtained and discussed.

Fig. 6- BOD TEST

Total Nitrogen

When the water is contaminated by sewage, nitrogen compounds can be found in the water and are indicative of organic contamination. Organic nitrogen, nitrite, nitrates, ammonia nitrogen, and this Organic nitrogen with free ammonia make up TKN. When analyzing soil, water, and wastewater chemically, organic nitrogen, ammonia, and ammonium are added together. For biological wastewater treatment, the TKN value (Total Kjeldahl Nitrogen), for instance, is crucial. To monitor the process and perhaps make adjustments, it must be determined throughout each phase of the purification of the wastewater process.The standard method for measuring ORGANIC Nitrogen in Part 4500-Norg, Macro-Kjeldahl Method (B) [26] have been tested in laboratory and test results have been obtained and discussed.

Fig. 7- Macro-Kjeldahl method-
(Total Kjeldahl Nitrogen Test)

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PHOSPHORUS TEST

To ensure public safety and safeguard the environment, phosphorus removal during wastewater treatment is crucial. The elimination of this nutrient from waste streams is essential for preventing eutrophication, a natural phenomenon that causes algal blooms. Numerous chemical forms of phosphorus, such as the phosphate ion (PO43-), are present in water, soil, and sediments. Orthophosphates and polyphosphates are examples of phosphates that can also take an inorganic or organic form (organically-bound phosphates). The standard method for measuring phosphorus in Part 4500-P PHOSPHORUS (C) [26] have been tested in laboratory and test results have been obtained and discussed.

Fig. : 8. PHOSPHORUS TEST

III. RESULTS AND DISSCUSSION

PRELIMINARY TEST RESULTS:

TABLE: 1. Kanaganeri Sewage Test Results

Sl. No	Test	Inlet Sample	Outlet Not Chlorinated Sample	Outlet Chlorinated Sample
1.	pH (no unit)	7.9	7.2	7.5
2.	TDS (mg/l)	1200 mg/l	650 mg/l	638 mg/l
3.	BOD [3^{rd}Day, 27^{o}c]	300 mg/l	10 mg/l	4 mg/l
4.	COD (mg/l)	435 mg/l	58 mg/l	50 mg/l
5.	Total Nitrogen (mg/l)	48 mg/l	10 mg/l	9.6 mg/l
6.	Phosphorous (mg/l)	8 mg/l	2 mg/l	1.6 mg/l

The 9 samples (Inlet Sample, Outlet Not Chlorinated sample, Outlet Chlorinated Sample) from 17MLD Kanaganeri Sewage Treatment Plant (STP) which is located at Kanganeri Lake, Kathirkamam, Puducherry had been tested and test result are tabulated above.

PHOSPHATE UPTAKE FROM SEWAGE

In India there are 1469 STP [Sewage Treatment Plant] and having the installed capacity of 31841MLD [Million Liters per Day] [27]. If we recovered 70% of inlet Phosphorous which is 8(mg/L) which shows 65.08 Million Kg of Phosphorous per year (2022).If we recovered the inlet Phosphorous from 30 years of now which contributes 1.952Billion Kg of Phosphorous (2052). Similarly in Puducherry, the no. of STP is 3 and Total sewage capacity is 51MLD[27]. If we recovered 70% of inlet Phosphorous which is 8(mg/L) which shows 1,04,244 kg/year of ‘P’ in (2022) and Phosphorous from 30 years of now which contributes 31.27 Lakhs Kg of Phosphorous (2052). This has been clearly represented in the below mentioned fig.9.

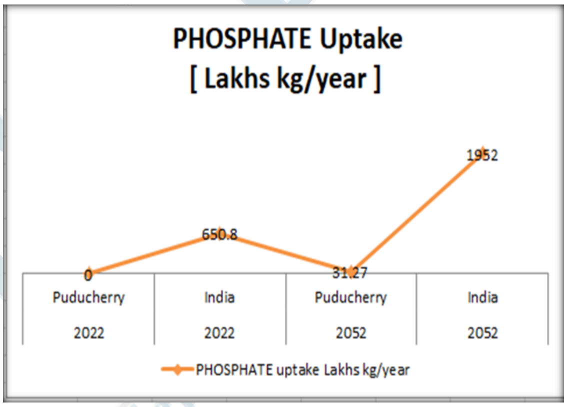

Fig. 9-Phosphate Uptake from Sewage

FERTILIZER NEEDS IN INDIA

India is the world's second largest fertilizer user (urea accounting for more than two-thirds of total fertilizer consumption) and the third largest producer of nitrogenous fertilizers (China and the US rank before India). India's population of 1.42 billion people today means that in 2022, there will be a huge demand for fertilizer, amounting to 21.80 billion kg. When the population reaches 1.64 billion after 30 years, there will be a significant demand for fertilizer, with 25.53 billion kg needed in 2052.

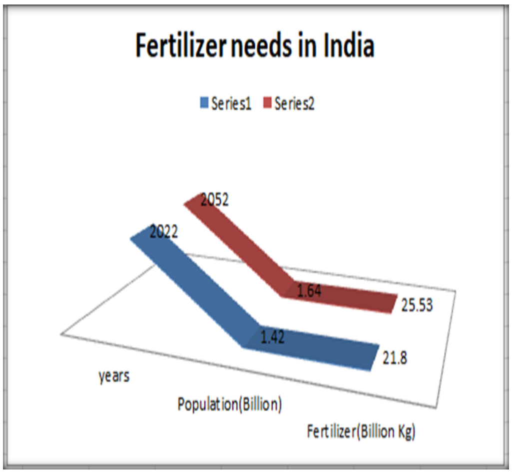

Fig. 10- Fertilizer Needs in India

COST ANALYSIS OF FERTILIZER IN INDIA

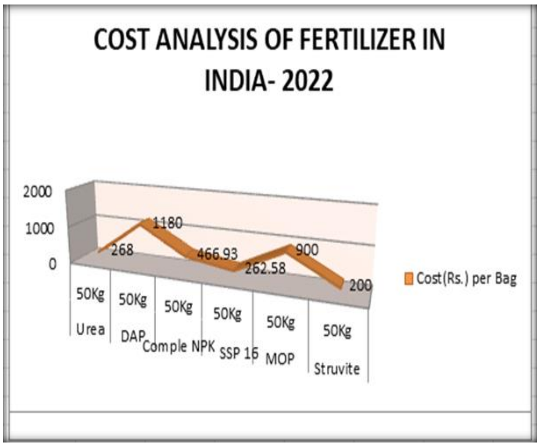

Fig. 11- Cost Analysis Of Fertilizer In India and the cost comparison between the production of struvite and conventional fertilizer.

India is a top importer of urea and other soil nutrients required to feed its massive agriculture industry, which employs approximately 60% of the country's workers and accounts for 15% of the country's $2.7 trillion economy. So, various fertilizer industries started to produce their products to meet the demand for fertilizer. There emerges the cost variation in products and wide range of product marketed. This causes the depletion of non- renewable sources mined phosphate rocks.

The total production of phosphorite/rock phosphate is at 1,400 thousand tons in 2019-20. In India total rock phosphate mines are **7**[28].The cost comparison between the production of struvite and conventional fertilizer, 1 kg of struvite (Struvite (Magnesium Ammonium Phosphate) is the product from Phosphorous recovery) is **Rs. 200**. Thereby suggesting struvite is economical than commercial fertilizer (Urea, Diammonium Phosphate (DAP), Single Super Phosphate (SSP), Muriate of Potash (MOP) and other Complex fertilizers and NPK Fertilizers (Fertilizers having different grades of Nitrogen (N), Phosphorus (P), and Potassium (K)).

INDIA'S PHOSPHATE CONSUMPTION DATA

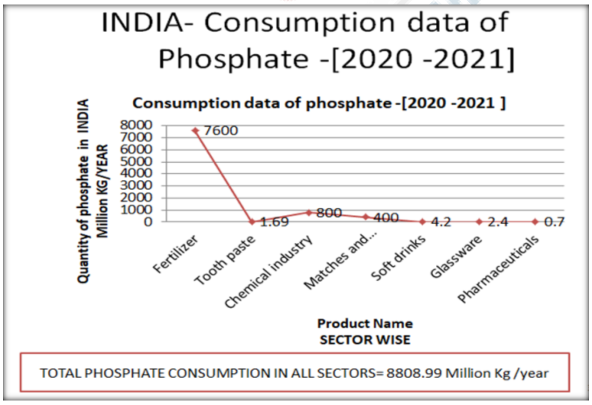

Fig. 12-India's Total Phosphorous consumption in all sectors.

The demand for phosphorus has been rising quickly every day. Phosphorus has been a primary component of many commercial products in a variety of industries, including the following: Soft drinks, animal feed, fertilizer, detergents, pesticides, pharmaceuticals, Toothpaste, glass, photographic films, matches, fireworks, military smokescreens, incendiary bombs etc. Thus **India's Total Phosphorous consumption in all sectors is 8808.99 Million Kg /year.**

IV. CONCLUSIONS

- The test carried out for three different sample inlet, outlet before chlorination, and outlet after chlorination from kanaganeri STP and results are obtained. The testing results showed that the optimal amounts of nitrogen and phosphorus are within the permitted range, preventing eutrophication.
- Phosphorous fertilizer consumption is **7.6 billion kilograms** of "P," whereas imports and production combined cannot full fill the **1.42 billion people's need for 'P.'** In order to compensate the Phosphate demand, from **1469 STP** if we recover 'P' we will get **65.08 M Kg/ year** of phosphorous for India.
- The total amount of phosphorous consumed in India each year is **8808.99 Million Kg**. The resource "P" should be recovered in a sustainable manner in order to meet the needs. One promising strategy for recovering "P" is through wastewater.
- The study results of the cost comparison between struvite fertilizer and conventional fertilizer show that **struvite fertilizer is more affordable** than other conventional fertilizer.

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RESEARCH WORK – Worked on BIOHYDROGEN - GREEN ENERGY Drive - Startups & Prototype - PTU - Team Students & Scholars,
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RESEARCH WORK- NATION'S 'VISION for 2047'- 'New INDIA'- RESEARCH to Futuristic TECHNOLOGY [1] BIOHYDROGEN - GREEN ENERGY Drive - Startups & Prototype - PTU - Team Students & Scholars - TECHNOLOGY TRANFER to Commercialization [2] Startups in Water Process Technology [3] Startups in Waste Water Process technology [4] Biomass to Biomethane & Biohydrogen [5] Carbon Sequestration and Climate Change Mitigation .

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