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A REVIEW OF PHOSPHATE REMOVAL TECHNIQUES FROM SEWAGE WASTE WATER.

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Abstract - *It is observed that Phosphate is seen in the sewage samples in the industry and reduction of it is required. Removing Phosphorus (P) from domestic wastewater is largely done to reduce the risk of eutrophication in any water that the wastewater will be released into. Phosphorous being a nutrient can be recovered from the waste water and put to good use like in fertilizers. There are different technologies that are being used to achieve the removal of P-content from sewage like – Physical, Chemical, Biological and Ion Exchange amongst others. These technologies are used as per the scale of treatment plant and the amount of P-content removal to be achieved. This article reviews the different P-removal technology options studied by different researchers all over the world.*

Key Words: **Phosphate removal, Coagulation, Chemical Precipitation, Ion Exchange, Biological recovery.**

1.INTRODUCTION

Phosphorous is found in the sewage samples at varied concentrations and in different forms like orthophosphate, polyphosphate, organic phosphate, etc. It is introduced in the sewage streams from sources like Human Excreta, food waste from canteens, detergents, soaps and hand wash used in bathrooms, etc. Excessive amount of Phosphate in treated sewage may lead to Eutrophication which is a serious concern in the ecology. Strict measures must be taken at source level to reduce the introduction of Phosphorous in the sewage system. By combining all the source control measures by adapting to the conditions, it is possible to reduce the load of Phosphorous.

Phosphorous can be removed from the sewage using different techniques like chemical precipitation, biological removal technique, etc. Out of which the biological method has less efficiency of removal as compared to chemical precipitation. Various chemical agents like Alum, PAC, $FeCl_3$, etc. are being practiced on a wider range. The removal of Phosphorous can be carried out by chemical or biological method or by combining both of them to achieve maximum removal efficiency.

Different studies nationally and internationally have been carried out to remove the Phosphorous element from the sewage water using chemical precipitation. Some studies also explored the avenues of selective ion exchange in order to reduce the Phosphorous content. Ion exchange has proven to be highly efficient in P-removal but in turn is cost extensive. Even different studies have been carried out related to the Biological Phosphorous Removal (BPR) where Phosphate Accumulation Organisms (PAO) is employed to do the job.

2. REMOVAL TECHNOLOGIES

Phosphorous removal from wastewater can be done using physico-chemical methods, biological treatment, and/or combinations of both to achieve maximum reduction in the concentration levels.

2.1 Physical – Chemical Methods

These methods have been in practice for a long period of time and have proved efficient in many systems. While generally trustworthy and efficient, these procedures do have some drawbacks. They may affect other characteristics of the system and may require additional steps in order to normalize. Most widely used Physical – Chemical method is of Precipitation using Chemical Dosages. Chemicals like Alum, PAC, $FeCl_3$ are used frequently. The efficiency of the removal using these chemicals is dependent on various factors like – dosage quantity, original phosphorous content, system kinetics, etc. This method of chemical precipitation leads to generation of sludge. The removed P-content is present in this sludge and hence it requires proper disposal. Sludge management plays vital role if this method is used.

The precipitation of Phosphorous from the sewage is under study and further improvements need to be done in finding out the dosages by not disturbing the system and its characteristics. Other physical methods of P-removal include filtration, adsorption absorption, ion exchange. All these methods are being used in the field but not that frequently.

2.2 Biological Methods

Biological Phosphate removal has been under study for many years. However, it has not proven efficient as compared to the physic-chemical processes due to its fluctuating performance. Study along the lines of

Phosphorus-accumulating organisms (PAO) are also being carried out by different researchers. Enhanced Biological Phosphorous Removal (EBPR) is considered to be a cost effective and environmentally sustainable option to the chemical precipitation method of Phosphorous removal.

2.3 Absorption Methods

Removal of Phosphorous through filtration using active media is carried out. Different absorption media is used like naturally available- Limestone/Bauxite or other material like steel slag, fly ash, etc. Phosphate is removed via direct absorption on the active media. Due to its cost expensiveness, this method is used on a small scale.

2.4 Electrochemical Methods

Phosphorous recovery methods through electrochemical ways are broadly classified into two categories - processes using sacrificial anode and processed that use dimensionally stable anodes.[10] This method does not require chemical dosing, is cost friendly and non-complex. Recovery of Phosphate is easily carried out in this method for further usages.

3. LITERATURE REVIEW

Sawsan A. M. Mohammed et. al. (2009)[1] have carried out a study for removal of Phosphorous from waste water using coagulation. They carried out a series of Jar tests using different coagulants at studied their effects on the concentration of Phosphorous and its effect on pH. They also tried variations in the mixing speed and concluded that mixing speed is not relevant to the efficiency of Phosphorous removal. They have concluded that Phosphorous removal was found to be highly dependent on pH of the waste water. Through their tests and analysis, it can be seen that Phosphorous removal for highest (83%) for dosage of Alum (80mg/L) as compared to (60%) for dosage of Calcium Chloride (60mg/L). Finally they concluded that Alum proved to be more efficient in Phosphorous removal than Calcium Chloride.

Jong-Oh Kim et. al. (2013)[2] carried out a study to find out the factors that affect the removal of Phosphorous as pre-treatment for MBR (Membrane Bio-Reactor) based waste water treatment. For this study, waste water from 5 different treatment plants in Japan was collected. Coagulation experiments were carried out using a Jar Test Apparatus with two coagulants namely PAC (Poly Aluminum Chloride) and $FeCl_3$(Ferric Chloride). Parameters like pH, Alkalinity, Suspended Solids, Total Phosphorous, Total Organic Carbon, Total Nitrogen, Color, Turbidity, Zeta Potential and Metal ions were analyzed for raw waste water as well as filtered waste water. They studied the effect of dosage of PAC and $FeCl_3$ on coagulation, relation between Total Phosphorous removal and other characteristics of the waste water. They concluded that Total Phosphorous removal from raw waste water was seen more as compared to $FeCl_3$ than PAC, whereas, for filtered waste water, PAC was more effective. Finally, they concluded that chemical coagulation can be used as a pretreatment to remove the Total Phosphorous for MBR based treatment.

G. K. Luk (1999)[3] in his study has defined the objective of solving the problem of complex metal-phosphorous reactions and hydroxide reactions occurring in the coagulation process by carrying out standard jar tests. The chemicals chosen for study are Ferric Chloride ($FeCl^3$) and Alum ($Al_2(SO_4)_3$). He has also considered the effects of different field conditions, initial Phosphorous level, pH of waste water, dosage & removal efficiency. A series of Jar tests were carried out for known concentration of Phosphorous in the waste water using different dosages of coagulant. After the study, he has concluded that due to the presence of alkalinity in the sample, removal efficacy of Phosphorous is varied. He also concluded that Alum is more effective in Phosphorous removal than Ferric Chloride. But Ferric Chloride functions better in lower pH waste water.

Mina Nejad et. al. (2013)[4] carried out research to achieve the prescribed concentration limit for Phosphorous in treated municipal waste water. A combination of PAC and Bentonite Clay was used for coagulation. Samples were collected from different locations within the same waste water treatment plant like inlet, before primary and before secondary treatment. Along with the main objective of finding the best possible combination dosage and its efficiency, study of pH on removal efficiency of Orthophosphate was also carried out. Upon analysis, it was found that with increase in pH, the removal efficiency of Orthophosphate increased. Highest efficiency was observed at pH=10. Variation in coagulant performance can be seen due to other contaminants present in waste water. Increase in contaminant concentration resulted in decrease in removal efficiency of Orthophosphate.

Joshua T. Bunce et. al. (2018)[5] have carried out a comprehensive review of Phosphorous removal technologies and tried to find out their applicability to small scale domestic waste water treatment plants. They have stated that most of the technologies that are present right now cater only to the large scale waste water treatment plants and not for the small ones. They have explained different methods that are used presently for removal of Phosphorous like Physico-Chemical process; Adsorption through media, Ion exchange, Biological method like EBPR (Enhanced Biological Phosphorous Removal), Algae based hybrid systems, etc. In all of this, it is not feasible to apply the existing systems for small scale treatment plants and requires further research along the lines. The possible technology must satisfy two basic requirements of affordability and appropriateness. They have concluded that there is need for more research in this area and technologies which are reliable and have minimal operation and maintenance must be developed.

Ying Zhao et. al.(2014)[6] have carried out a study wherein they recycled the chemical sludge along with fresh coagulant to improve the removal efficiency of Phosphate. They carried out a pilot lab test to study different parameters like ration of recycled sludge, operating conditions and removal mechanism. The idea for this study has been attributed to the fresh chemical costs and problems raised due to disposal of chemical sludge generated. They have created synthetic waste water containing known concentration of Phosphate. Ratio of chemical and recycled sludge is considered to be important. From the analysis results, it was found that removal efficiency increase when the ratio of recycled sludge was between 15-20%. Also mixing and aging time of the recycled sludge has a significant effect on removal of Phosphate.

Stainslaw M. Rybicki et. al. (2022)[7] has reviewed various Phosphorous removal technologies from municipal waste water. He has also discussed history of Phosphorous removal technologies and the difficulties and operating problems faced by the same. He has also briefly explained the electrolytic method of Phosphorous removal where electricity is used for coagulation. Other methods like Crystallization, Magnetic Separation and Adsorption is also explained in short. Along with those, few methods of Biological nature like Multiphase Biological reactors and Sequential Batch Reactor has been explained. Finally he has concluded that in future the technology used for Phosphorous should be such that, the Phosphorous can be used as a fertilizer.

C. Kazadi Mbamba et. al. (2019)[8] carried out a research study which focused on optimizing the operational aspects of a MBR pilot plant using Iron based chemical dosing for Phosphorous removal. The pilot plant operates on the mechanism of precipitation, adsorption and co-precipitation. The study also showed that environmental factors such as pH as well as operational conditions such as Fe/P molar ratios contributed to the variation in Phosphate concentration. Dosing at 3 different points in the plant was carried out – at pre-aeration tank before primary clarifier, in aerobic tank and before membrane tanks. The research study had good results which depicted closer to 5-10% relevancy in pilot plant and reality.. The study demonstrated that the integrated model was suitable enough for biological nutrient and Phosphorous removal through Iron precipitation. They also concluded that the reaction showed a slow dynamic response which may be likely due to factors like dissolution, Oxidation of Iron, Precipitation of Fe-P compounds, adsorption and co-precipitation processes.

Viola Somogyi et. al. (2022) [9] have carried out an experimental research for recovery of Phosphorous from waste water using Red Mud. The researchers have created a synthetic waste water of known Phosphorous concentration. A highly alkaline Red Mud, treated with gypsum and Carbon Dioxide was used for experiments. Red Mud treatment was carried out on different waste waters like synthetic waste water, poultry effluent, spiked effluent from Municipal waste water treatment plant and leachate generated from Landfill. The Red Mud dosages for given concentration of synthetic waste water were found to achieve 90% removal efficiency (at alkaline pH). A relationship between Red Mud, HCL, Conductivity and remaining Phosphate was established. Similar experiments were carried out with remaining waste water and leachate and their respective results were discussed. They have concluded their research by stating the importance of finding the optimal dosage of alkaline adsorbent (Red Mud) and neutralizing agent (HCL) to achieve optimal pH for Phosphorous removal. Applied dosages were capable enough to remove all the Phosphorous from waste water and achieve stricter limiting values. Increase in Red Mud dosages does not equate to increase in cost but pH setting would increase the cost significantly.

Mahamalage Kusumitha Pereraa et. al. (2019) [10] have carried out a review on technologies that are used for recovering nutrients from waste water. Available technologies are reviewed by them on basis of waste water characteristics, effluent discharge limits, recovery goals, constraints on chemical dosage, scale and size of treatment plants, operational ease and applicability along with the energy requirements for per unit nutrient recovery. Methods like Ion exchange, magnetic micro-absorption, reactive filtration, urine separation, Struvite precipitation, Electro-dialysis, chemical precipitation, biological P-recovery, algae harvesting and electrochemical P-recovery have been discussed in detail. They have also summarized pros and cons of all P-recovery technologies. Finally they have concluded their review by saying that Struvite and Electrochemical precipitation can be used for production of Fertilizers which require minimal post-processing. Also, processes like electrochemical precipitation, chemical precipitation and ion-exchange have relatively low maintenance and chemical requirements and are suitable for on-site applications. Only the adsorption technologies are capable enough to achieve the stringent requirements of Phosphorous concentration from effluent discharge.

4. CONCLUSIONS

The above research papers have examined the methods and technologies of Phosphorous removal from waste water and the need to do so. Different researchers have adopted different technologies to remove the P-content from waste water to avoid the ultimate discharge of Phosphorous in fresh water bodies which may lead to Eutrophication. Experimental setups and pilot studies have generated a good database for research in this field.

Key Points:

1. Removal of Phosphorous from waste water is the need of hour and due attention needs to be given for control of the same.

2. Chemical, Electrochemical, Filtration as well as Biological technologies have been developed for achieving stringent discharge standards.

3. Nutrient (Phosphorous) removal from waste water can be done to achieve goal like manufacturing of fertilizers.

4. As per the need, operational ease, cost incurred and on-site demands, suitable technology can be implemented.

In summary, this review highlights the available research in the field of Phosphorous removal from waste water. And how there is more need of research in this domain.

REFERENCES

[1] Mohammed, Sawsan and Shanshool, Haider (2009). Phosphorus removal from water and waste water by chemical precipitation using Alum and Calcium Chloride. *Iraqi J. Chem. Petrol. Eng.* 10. 35-42.

[2] Kim, JO., Chung, J. (2014) Implementing chemical precipitation as a pretreatment for phosphorus removal in membrane bioreactor-based municipal wastewater treatment plants. *KSCE J Civ Eng* 18, 956–963.

[3] G. K. Luk, (1999) Removal of phosphorus by metallic coagulation: An experimental aid to dose computations, *Transactions on Modelling and Simulation* vol. 21.

[4] Mina Hormozi Nejad, Afshin Takdastan, Nematollah Jaafarzadeh, Mehdi Ahmadi Mogadam and Nezamaddin Mengelizadeh (2013), Removal of Orthophosphate from municipal wastewater using chemical precipitation process in Ahvaz wastewater treatment plant, Iran, *Asian Journal of Chemistry*; Vol. 25, No. 5 Pg. No. 2565-2568.

[5] Bunce JT, Ndam E, Ofiteru ID, Moore A and Graham DW (2018) A review of phosphorus removal technologies and their applicability to small-scale domestic wastewater treatment systems. *Front. Environ. Sci.* 6:8.

[6] Xi, Beidou and Zhao, Ying and Zhang, Lie-yu and Xia, Xunfeng and Luan, Zhaokun and Peng, Xing and Lv, Wei. (2014). Return chemical sludge employed in enhancement of phosphate removal from wastewater. *Desalination and Water Treatment.*

[7]Rybicki, Stanisław. (2022). New technologies of phosphorus removal from wastewater.

[8] Mbamba, C.K., Lindblom, E., Flores-Alsina, X., Tait, S., Anderson, S., Saagi, R., Batstone, D.J., Gernaey, K.V., Jeppsson, U., (2019) Plant-wide model-based analysis of iron dosage strategies for chemical phosphorus removal in wastewater treatment systems, *Water Research*, https://doi.org/10.1016/j.watres.2019.01.048.

[9] Somogyi, V.; Pitás, V.; Berta, K.M.; Kurdi, R. (2022) Red Mud as Adsorbent to Recover Phosphorous From Wastewater Streams *Sustainability*, 14, 13202.https://doi.org/10.3390/su142013202

[10] Mahamalage Kusumitha Pereraa et. al. (2019) Technologies for Recovering Nutrients from Wastewater: A Critical Review, *Environmental Engineering Science*, DOI:10.1089/ees.2018.0436