Paper ID: ICMIME2024_168

Enhancing Wastewater Treatment with ZnO-Based Organic Polymerized Coagulants: A Modern Approach to an Effective Solution for Wastewater Treatment

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Abstract

The research and development of effective and environmentally friendly methods for wastewater treatment has been the center of many studies in recent years due to growing worldwide concerns about water contamination. This work addresses developing and applying a polymerized coagulant based on zinc oxide (ZnO) as a novel wastewater treatment technique. Conventional coagulants often have trouble effectively eliminating various pollutants in municipal and industrial wastewater. Zinc oxide (ZnO), recognized for its powerful adsorption capacities, antibacterial characteristics, and chemical durability, is combined with a polymer matrix to increase its coagulant effectiveness. Starch extracted from various plants and vegetables has been utilized to synthesize organic polymer. In the quest for cleaner water, coagulation often combined with flocculation represents a critical phase that guarantees the reduction of environmental risks and the preservation of public health. Several jar tests were used to evaluate the coagulant's effectiveness on a range of wastewater samples, including those containing organic contaminants, colors, and heavy metals. Before and after treatment, many parameters were evaluated, including turbidity, chemical oxygen demand (COD), and the concentration of certain pollutants. The ZnO-based polymerized coagulant outperformed other coagulants in terms of performance, removing turbidity at a higher rate. The research also addressed the causes behind the better performance, attributing it to the combined impacts of the large surface area of ZnO nanoparticles and the higher flocculation capabilities of the polymer matrix. The harmful bacteria in treated water decreased as a result of Zinc Oxide's antimicrobial qualities. With the goal to improve and evaluate the useful utilization of this innovative coagulant, future research should concentrate on optimizing the synthesis process, increasing production, and performing comprehensive field experiments.

Keywords: Coagulant, polymer, Zinc-Oxide nanoparticle, turbidity, TDS.

1. Introduction

The treatment of wastewater plays a vital role in maintaining environmental sustainability, supporting sustainable water usage, and protecting public health. It makes sure that potentially harmful contaminants, such as bacteria, chemicals, and organic debris, are taken out of water before it is recycled or returned to natural water bodies. Furthermore, treated wastewater may be recycled for industrial uses, agricultural irrigation, and in some situations, drinkable water, all of which contribute to the preservation of freshwater supplies. Water scarcity is becoming a worldwide problem, and a safe and dependable water supply for present and future generations depends on efficient wastewater treatment[1]. Organic debris, bacteria, chemicals, and heavy metals are all common components of wastewater, and if they are not adequately treated, they may pose serious dangers to the environment and public health. Together, physical, chemical, and biological treatment procedures eliminate or neutralize these dangerous materials. Thus, wastewater that has been cleaned may be safely dumped into natural water bodies, used for irrigation, or even further cleansed for further uses[2]. We can lessen pollution, preserve fresh water, and promote the health of people and the environment by properly processing wastewater. Before sewage or industrial effluent is discharged back into the environment, pollutants must be removed via the vital process of wastewater treatment[3]. Ensuring the sustainability of water supplies, safeguarding ecosystems, and preserving public health all depend on this process. Public health and environmental sustainability depend on efficient wastewater treatment, especially as the world's population and industrial output continue to rise[4]. The increasingly complex pollutants present in wastewater, such as heavy metals, organic contaminants, and microplastics, are often too complicated for traditional treatment techniques to handle. This has fueled the hunt for more sophisticated and effective technology. Naturally occurring polysaccharide starch has gained popularity

as an eco-friendly and efficient coagulant for treating wastewater. Starch, which is derived from sustainable plant sources including potatoes, corn, maize, and cassava, provides a greener option to traditional synthetic coagulants like polyacrylamides and aluminum sulfate. Because of its non-toxic properties and biodegradability, it is a desirable choice for enterprises looking to lessen their environmental impact without sacrificing treatment efficacy[5]. In order to neutralize the negatively charged particles in the water and encourage the aggregation of suspended particles into bigger flocs, starch derivatives, especially cationic starch are used. Then, sedimentation, filtration, or flotation may be used to more readily remove these flocs. Because modified starch is made from renewable resources, is non-toxic, and biodegradable, it is advantageous to utilize it as a coagulant[6].
To improve its coagulation and flocculation properties, starch may be chemically altered or used in its natural state in wastewater treatment. Because starch molecules have hydroxyl groups, they may undergo chemical changes like cationization, which makes them more attractive to negatively charged wastewater particles. The charges on suspended particles may be balanced by cationic starch, which promotes particle aggregation and eventual elimination. Clearer effluent is produced as a result of this method's efficient reduction of turbidity, organic matter, and other contaminants in the water[7]. The adaptability of starch as a coagulant is one of its main benefits. It may be used on a variety of wastewater kinds, such as municipal sewage, agricultural runoff, and industrial effluents[8].

Furthermore, the compatibility of starch-based coagulants with other treatment methods, such as sedimentation and filtration, increases their effectiveness in integrated treatment systems. The use of starch fits with the increasing need for environmentally friendly water treatment technology, even if it may not yet completely replace conventional coagulants. The efficacy of starch-based coagulants is still being enhanced by research and development, which makes them a viable instrument for implementing more environmentally friendly wastewater treatment techniques[9].
ZnO-based organic polymerized coagulants are one of the most promising recent developments. They provide improved coagulation, adsorption, and photocatalytic capabilities, making them a contemporary option. Because of its well-known special photocatalytic abilities and environmental friendliness, zinc oxide (ZnO) is a great option to use in wastewater treatment procedures. ZnO may improve the removal of a variety of pollutants, such as suspended particles, dissolved organic matter, and pathogens when mixed with organic polymerized coagulants. The total effectiveness of the flocculation and coagulation processes is increased by this synergistic combination, producing wastewater treatment results that are more efficient and long-lasting. Research on the use of sophisticated nanotechnology and natural materials in wastewater treatment has increased recently due to the growing need for economical and ecologically friendly solutions. One method that shows promise is the combination of potato-derived starch with zinc oxide (ZnO) nanoparticles to produce a novel coagulant for wastewater treatment[10]. This ZnO-based starch coagulant is an innovative combination of bio-based polymers and nanotechnology, using the complementing qualities of both materials to provide an environmentally friendly and very efficient way to remove contaminants from polluted water. Due to their potent photocatalytic capabilities, high adsorption capacity, and antibacterial activity, zinc oxide (ZnO) nanoparticles have attracted interest. Because of these qualities, zinc oxide (ZnO) is a great option to deal with a variety of contaminants, such as viruses, heavy metals, organic pollutants, and even microplastics, which are becoming more and more common in wastewater. Through a process known as photocatalysis, in which ZnO nanoparticles absorb UV light and produce reactive oxygen species capable of disassembling complex pollutants into simpler, less hazardous chemicals, the use of ZnO in wastewater treatment improves the breakdown of organic pollutants[11]. On the other hand, because of its distinct physical and chemical characteristics, potato starch is a plentiful, renewable, and biodegradable polymer that is extensively employed in a variety of sectors. Amylose and amylopectin, the two primary polysaccharides that make up starch, have the ability to establish hydrogen bonds with other molecules, which gives it the ability to function as a coagulant or flocculant[12]. Potato starch, when altered, has a remarkable capacity to absorb contaminants, including heavy metals, colors, and suspended particles. It is a more environmentally friendly substitute for synthetic polymers in wastewater treatment procedures due to its low toxicity and renewable nature[13].

2. Materials

ZnO, Potato, Corn, iodine solution (KI)

3. Method

Extraction of Starch

After a number of mechanical and chemical procedures, the particles of starch were isolated in order to extract the starch polymer from potatoes. There were many phases involved in separating the starch molecules from the potato cells during the relatively simple process of extracting starch from potatoes. To start, carefully, the potatoes

were washed to get rid of any dirt or contaminants. After being cleaned, the potatoes were peeled, grated, or ground coarsely to liberate the starch and break down the cell walls. In order to release the starch, potatoes were first carefully cleaned, peeled, and grated. To separate the fibrous material from the liquid containing starch, the grated potatoes were combined with water to create a slurry, which was then run through a fine screen[14]. The larger starch particles sank to the bottom of the liquid and produced sediment when it was allowed to settle. A slurry was made by combining the shredded potato mass with water, which aids in separating the starch granules from the potato fibers. To separate the fibrous particles from the liquid holding the starch, the slurry was next filtered or strained, often via a fine screen or cheesecloth. After several hours, the liquid was collected and left to settle. During that time, the heavier starch granules sink to the bottom and produce a layer of white sediment[15]. The starch is in the bottom of the container after the clear liquid on top is carefully decanted or siphoned off. After that, the gathered starch was repeatedly washed with clean water to get rid of any leftover contaminants. To get rid of contaminants and soluble substances like sugars and proteins, this silt was continuously washed with water. This procedure was continued until the water was clear. Ultimately, the wet starch was dried using low heat in an oven or dryer, or by letting it air dry. After the starch had completely dried, it was crushed into a fine powder. After the starch had been cleaned, it was gathered, dried with air or low heat, and crushed into a fine powder. Polymerized amylose and amylopectin chains make up this powdered starch[16].

Collection of ZnO

The authentic ZnO powder was collected from a local chemical shop situated in Khulna. It was tested in the Chemical Engineering Lab in KUET.

Combining of ZnO and polymerized Starch

The powders were first weighed out according to the necessary quantities before ZnO and starch powder were combined. To guarantee a homogenous mix, zinc oxide (ZnO) powder was added gradually to the starch powder while constant stirring was maintained. After that, the mixture was treated using a mechanical mixer or a mortar and pestle to get a finer, more consistent consistency. The powder was well mixed and then moved to a dry, clean container so it could be stored or used again. A well-integrated ZnO-starch powder that may be used in a variety of formulations or applications was the end product of this process[17].

Wastewater treatment procedure

The pond at KUET called Poddopukur is where the wastewater sample was taken. The ZnO-starch sample was mixed with the results of the turbidity, DO, ORP, pH, TDS, and hardness tests completed beforehand. The mixture was combined with an organic starch coagulant based on zinc oxide and left in a beaker for three hours. Since some material had gathered on the beaker's surface, the water was carefully transferred to another beaker. Three hours later, the required test was being conducted[18].

4. Result

Starch Identification test

Iodine test

A small quantity of the material was initially put in a clean test tube in order to detect starch using the iodine test. The sample was then given a few drops of iodine solution. To guarantee that the iodine and sample were well combined, the mixture was gently stirred. When the solution took on a deep blue or purple hue, signifying the creation of a starch iodine complex, the presence of starch was verified by color change observation. Starch was absent from the sample if there was no change in color.

$$\text{Starch (amylose)} + I_2 \rightarrow \text{Starch-}I_2 \text{ complex (blue/purple)} \quad (1)$$

Using a burette, a small amount of iodine solution was added to the test tube after a sample of starch had been obtained. The solution became deeply blue, indicating the presence of starch.

Turbidity test

Turbidity, which is a qualitative attribute caused by solid particles preventing light from passing through a water sample, is the technical word for a solution's cloudiness. The presence of suspended and scattered particles, such as clay, organic debris, silt, algae, and other microorganisms, is often indicated by turbidity. Turbidity is a manifestation of the optical characteristic that results in light being absorbed and dispersed inside the sample instead of being transmitted through it in a straight path. The opaqueness or milky coloring of turbid water in a

tiny, clear container, such as a drinking glass, is noticeable when held up to the light. Chemicals and potentially benign living organisms may adsorb on the colloidal substance that causes turbidity.

TDS Test :

The measurement of Total Dissolved Solids (TDS) in a wastewater sample was conducted using a standardized procedure. Initially, the wastewater sample was filtered to remove suspended solids. The filtered sample was then transferred into a pre-weighed evaporating dish. This dish was subsequently placed in an oven set at 103-105°C and was left to evaporate until all water content was removed. After drying, the dish was cooled in a desiccator to prevent moisture absorption, and its final weight was recorded. The TDS concentration was calculated by subtracting the initial weight of the dish from the final weight, representing the mass of dissolved solids present in the wastewater sample.

Table 1. Turbidity test observation data

Observation	Time (hour)	DO (mg/L)	Turbidity (NTU)
Waste	0	5.5	560
Clean	3	5.5	315

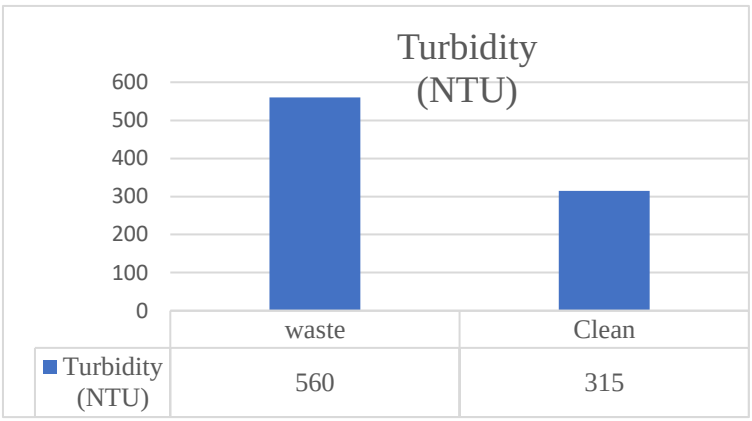


Fig. 1. Turbidity of wastewater and clean water

The turbidity value dropped. This showed that, in contrast to the wastewater sample, the water is pure. DO stands for Dissolved Oxygen, which was consistently present. After the ZnO-based starch coagulant was added, the other parameter changed. The hardness dropped from 103 ppm to 100. Both the total suspended solid (TSS) and total dissolved solids (TDS) dropped at the same time. The turbidity was the most crucial factor. Turbidity drops to a value of 315 NTU. It suggests that the water was becoming cleaner. Even if the whole treatment process was not completed with 100% precision, a respectable degree of success was attained.

Table 2. Observed data of different tests for both waste and clean water

Sample	pH	Hardness (ppm)	Conductivity (ms)	DO (mg/L)	Turbidity (NTU)	Salt%	ORP (mV)	TDS (mg/L)	TSS (mg/L)
waste	7.7	103	2.08	5.5	560	0.12	62	300	600
Clean	7.4	100	1.96	5.5	315	0.10	97	400	300

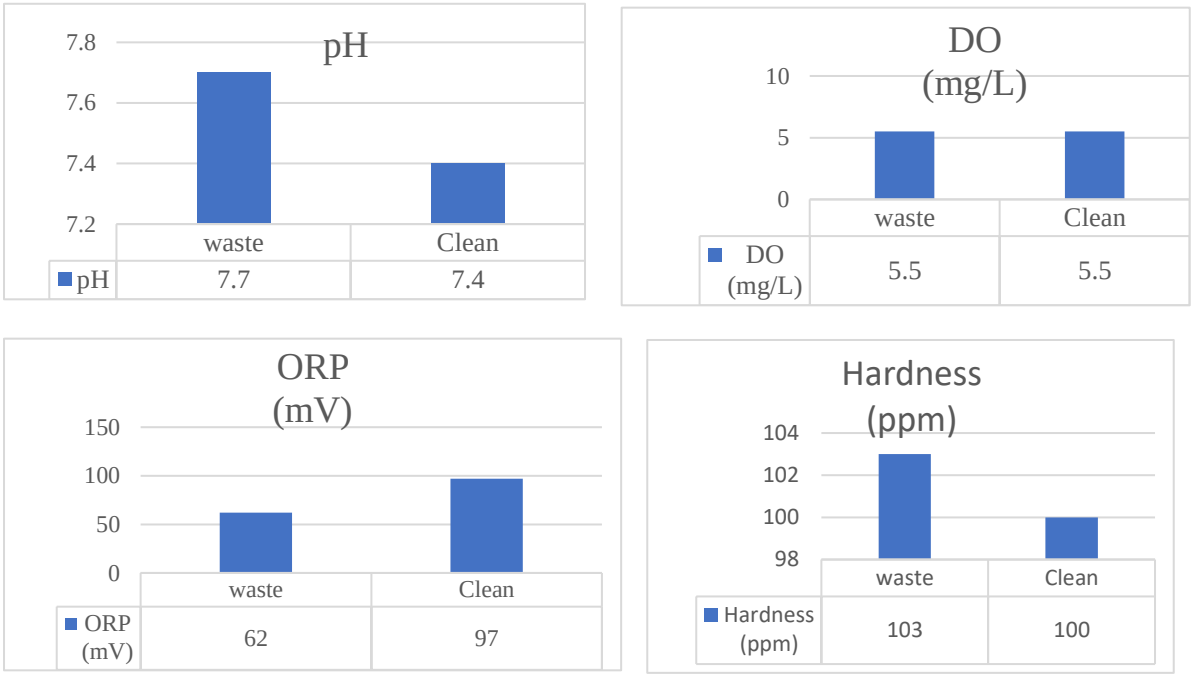


Fig 2. Observed data comparison for different test



Fig 3. Sample water, Turbidity meter, Water quality meter.



Fig 4. Poddopukur, KUET

5. Discussion

The creation of potato-derived ZnO-based starch coagulants is an important step in the realm of environmentally friendly wastewater treatment. This hybrid coagulant provides a cutting-edge and practical way to deal with a variety of water contaminants by fusing the potent photocatalytic capabilities of ZnO nanoparticles with the natural flocculating qualities of potato starch. The utilization of organic polymerized coagulants based on zinc oxide (ZnO) signifies a significant progression in wastewater treatment approaches. Compared to older techniques, this contemporary strategy provides more efficacy in eliminating pollutants, such as organic debris, heavy metals, and viruses. Higher water quality and less environmental impact are achieved by the enhancement of coagulation-flocculation processes through the integration of ZnO nanoparticles with organic polymers. These coagulants also show great promise for large-scale use since they are inexpensive, simple to produce, and flexible enough to work with a variety of wastewater sources. These materials will probably be improved with additional research and development in this area, making them even more effective and eco-friendly. ZnO-based organic polymerized coagulants are a viable approach to sustainable wastewater treatment as the world's need for clean water keeps growing. Its advantages for the environment biodegradability, renewability, and the ability to recover nanoparticles make it a viable instrument for managing wastewater more sustainably and producing cleaner water. Green wastewater treatment methods may rely heavily on ZnO-based starch coagulants in the future with more investigation and refinement.

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