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Evaluating the Effectiveness of Alum and Banana Peel Powder Combination as a Coagulant for the Surface Water Treatment

[1]Sanskriti, [2]Bedatrayee Saha

[1]M. Tech. Research Scholar, Civil Department, J.N. Government Engineering College, Sundernagar (H.P.), 175018, India
[2]Assistant Professor, Civil Department, J.N. Government Engineering College, Sundernagar (H.P.), 175018, India

***Abstract* - Chemical coagulants when used in water treatment led to reduction in pH level of water, large amount of sludge production and environmental pollution. Also, chemical coagulants have high cost. To reduce the excessive use of chemical coagulants and the cost of surface water treatment, Alum and Banana peel powder (BPP) combination was used in different proportions as an alternative of chemical coagulants in this research. The comparison of removal efficiencies of turbidity, iron, copper, nitrate, TDS and TSS between the Alum and BPP combination at different proportions was done to find out the best proportion for their combination. It was observed that highest iron and copper removal efficiencies of 99.38% and 99.39% respectively were obtained when Alum and BPP used at 75% and 25% proportion, respectively. Highest turbidity, nitrate, TDS and TSS removal efficiencies of 99.77%, 97.61%, 68.42% and 99.46% respectively were obtained when Alum and BPP used at 100% and 0% proportion. It was found that the cost of surface water treatment using Alum individually was 0.12 ₹/L and for combination of Alum with BPP at proportion 75% and 25%, respectively was 0.09 ₹/L. The cost of surface water treatment reduced by 25% when Alum and BPP combination was used as a coagulantat proportion of 75%:25%.**

***Keywords**:* Alum, Banana peel powder, Surface water treatment, Removal efficiencies, Turbidity, Iron, Nitrate, TDS, Cost Analysis.

I. INTRODUCTION

Water is a fundamental necessity for all living organisms. In the last 100 years, there has been 600% rise in water use worldwide [1]. According to World Bank, about 2.2 billion people had not access to safely managed drinking water in 2022. According to UNEP, 1.8 billion people will be living in regions with absolute water scarcity and two- thirds of the world's population could be living under water stressed condition by 2025. Rising population, increasing urbanization, expansion in industrial and agricultural activities has increased freshwater consumption, causing severe freshwater scarcity in several parts of the world. By 2050, almost 4.8-5.7 billion people can face water scarcity in their area [2].

Wastewater generation and water pollution issues, have been also increased in the past few years. Many toxic metals such as Arsenic, Cadmium, Iron, Lead, Mercury, copper and Nickel are present in wastewater which can be hazardous to public health and environment [3]. Many micro-organisms like *Salmonella typhimurium*, *Vibrio cholerae*, *G. intestinales* and *E. coli* are present in untreated raw water and wastewater which causes diseases such as typhoid, cholera, diarrhea, jaundice, hepatitis A, amoebiasis and dysentery [4, 5].

Coagulation and flocculation process is the most commonly used treatment method for water and wastewater treatment worldwide. Coagulation is done by using chemical and natural coagulants. From many decades, all over the world chemical coagulants are being most commonly used in water treatment plants [6]. But chemical coagulants have many disadvantages.

Chemical coagulants are non-biodegradable, produce toxic chemical sludge, cause environmental pollution, badly affect human health and have high costs [7]. Alum or Aluminium Sulphate ($Al_2(SO_4)_3.18\ H_2O$) is the most commonly used chemical coagulant in water treatment worldwide [8,9]. Residual aluminium in alum treated water causes serious health issues such as the Alzheimer's disease [10]. Excessive amount of residual aluminium present in water can also cause impaired concentration, short term memory loss, interstitial pneumonia, pulmonary alveolar proteinosis, granulomas, granulomatosis, toxic myocarditis, granulomatous enteritis, inflammatory bowel diseases, anemia, dementia, autism, osteomalacia, oligospermia, infertility, hepatorenal disease, breast cancer and cyst[11, 12].It was found that by using Alum, pH of water get reduced due to which water becomes acidic [13, 14, 15]. Due to low pH of water, corrosion of plumbing pipes and leaching of metals occurs which makes the water toxic [16].

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Natural coagulants have become popular in past few years due to their advantages over chemical coagulants. Natural coagulants are biodegradable, eco-friendly, less toxic, produce less sludge, have low costs and they are safe for human health [17.18]. *Moringa oleifera* [19], nirmali seeds [20], papaya seeds [21], watermelon seeds [22], aloe vera gel [23]and banana peels [24, 25, 26] are some of the natural coagulants used in recent studies. The application of Banana peel as a coagulant in treatment of water has emerged as a prominent area of research. The coagulation efficiency of banana peels has been improved in various studies by either chemically modifying them or mixing them with other coagulants [27]. Biopolymers such as pectin, cellulose, lignin and hemicelluloses are present in banana peels, along with functional groups like hydroxyl and carboxyl [28], which attach to pollutants through chelation, complexation, coordination and hydrogen bonding [29]. Polysaccharides like pectin present in banana peels support coagulation process by enabling particle aggregation of suspended particles and impurities. Polyphenols present in banana peels acts as effective agents in removal of heavy metals from wastewater [30].

In this research paper, the potential of the combination of Alum and BPP at different proportions in the treatment of surface water has been explored. The reduction in the cost of surface water treatment by using combination of Alum and BPP has also been investigated.

II. LITERATURE SURVEY

Chong and Kiew compared the capability of Banana peel bio-flocculant and Alum for water clarification. Banana peel bio-flocculant and Alum both were used in doses of 50 mL, 100 ml, 150 mL, 150 mL and 250 mL. Effect of pH, doses of Alum and Banana peel bio-flocculent, temperature and initial wastewater turbidity on the turbidity removal efficiency was investigated. Highest turbidity removal efficiency was observed at pH 12, dose of 150 mL, temperature of 30°C and when initial turbidity was greater than 500 NTU for Banana peel bio-flocculant. Highest turbidity removal efficiency was observed at pH 12, dose of 150 mL, temperature of 25°C and when initial turbidity was greater than 500 NTU for Alum. The potential of Alum and Banana peel bio-flocculant combination at different percentages ratios of 100:0, 80:20, 60:40, 50:50, 40:60, 20:80 and 0:100, respectively was also investigated. The results showed that the best turbidity removal efficiency was 94.13% when Banana peel bio-flocculant and Alum was used at ratio of 50:50 [31].

Lau and Kiew examined the efficiency of Banana peel as bio-flocculant at different extraction method, different extraction time, different microwave power and different doses for the turbidity removal. Results showed that as compare to Conventional heating extraction (CHE), Microwave Assisted Extraction (MAE) was more effective extraction method. The optimum extraction time, microwave power and dose for Banana peel bio-flocculant was 30 seconds, low microwave power and 5g/100 ml distilled water, respectively. The potential of Banana peel bio-flocculant as coagulant aid to alum was also explored. Banana peel bio-flocculant and Alum was used in combination at different percentages ratios of 0:100, 20:80, 40:60, 50:50, 60:40, 80:20, 100:0 respectively. The findings showed that highest turbidity removal was 99.22% which was obtained when Alum and Banana peel powder bio-flocculant was used at ratio of 100:0 [32].

Asharuddin *et al*. analysed the effect of dose of Alum, Cassava peel starch (CPS) and ratios of their combination, pH, slow mixing speed and settling time on the turbidity removal efficiencies. Alum dose was varied from 5 mg/L to 30 mg/L and CPS dose was varied from 100 mg/L to 600 mg/L. Highest turbidity removal efficiency of 85.20% and 29.20% was achieved when 15 mg/L of Alum and 200 mg/L of CPS dose was used, respectively. Highest turbidity removal efficiency of 90.32% was obtained when Alum and CPS was used in combination in ratio of 50%:50% which was equivalent to 7.5 mg/L:100 mg/L of Alum:CPS. The pH levels were adjusted between 2 to 11. Optimum turbidity removal was achieved at pH 7, pH 2 and pH 9 when Alum, CPS used alone and in combination, respectively. Slow mixing speed and settling time was varied from 0 to 50 rpm and 10 to 122 minutes, respectively. The best turbidity removal efficiencies for Alum, CPS and ratios of their combination were accomplished at slow mixing speed of 10 rpm and settling time of 30 minutes [33].

Ramal *et al.* investigated the effectiveness of Mallow’s Leaves Extracts (M.L.E) and Carob’s Pods Extracts (C.P.E) as coagulant aids along with Alum at different proportions to improve turbidity removal efficiency. Highest turbidity removal efficiencies of 97.265%, 51.175% and 31.12% were obtained at 30 mg/L Alum, 30 mg/L M.L.E and 25 mg/L C.P.E. dose, respectively. M.L.E. and C.P.E both were used in combination with Alum in percentages ratios of 100:0, 50:50. 40:60, 25:75 and 0:100, respectively. Highest turbidity removal efficiency of 97.72% was achieved using 75% of 30 mg/L Alum and 25% of 30 mg/L M.L.E. equivalent to 22.5 mg/L and 7.5 mg/L, respectively. Highest turbidity removal efficiency of 92.3% was obtained using 75% of 30 mg/L Alum and 25% of 30 mg/L C.P.E. equivalent to 22.5 mg/L and 7.5 mg/L, respectively. It was concluded that M.L.E. combination with Alum was more effective as compared to C.P.E. combination with Alum [34].

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III. MATERIALS & METHODS

3.1 Study area

Sundernagar is a town located in district Mandi in Himachal Pradesh, India. Longitude of Sundernagar is 76.88 ° E and its latitude is 31.53° N. According to Crop Research Substation Sundernagar, average annual rainfall in Sundernagar for the last ten years is 1200 mm out of which 80 percent is received during monsoon season. According to data collected from IPH department Sundernagar, rate of water supply in Sundernagar at present year 2025 is 135LPCD. Sources for water supply to household in Sundernagar are Sundernagar Lake, springs and tube wells. Sundernagar Lake is a man-made lake that is formed due to the water of Beas River being diverted from Pandoh, H.P. Due to the presence of several contaminants and poor quality of Sundernagar lake water, it is not fit for the drinking purposes. So, there is a need of water treatment of Sundernagar Lake. This study aims to find the optimum proportion of Alum and BPP when used in combination as a coagulant in treatment of Sundernagar lake water.

Figure 1: View of Sundernagar Lake, Himachal Pradesh

3.2 Sample collection

About 35 liters of water sample has been collected in prewashed and sterilized plastic containers in month of September in 2024 from Sundernagar lake.

3.3 Materials

(a) Alum procurement

Alum ofhigh-quality analytical grade of NICE brand was purchased from the market of Sundernagar.

(b) Preparation of BPP

The banana peels were collected from the local market of Sundernagar, Himachal Pradesh. The banana peels were cut into small pieces of length 5-6 cm and washed thoroughly with tap water to remove any external dirt. The washed pieces of banana peels were oven-dried for 24 hours at 105°C [35].The dried banana peels were grinded to fine powder using domestic common blender. Then this powder of banana peel was sieved through 150 µm sieve [31]. The BPP was then stored in airtight plastic container.

(a) (b) (c) (d) (e)

Figure 2: Preparation of BPP (a) Banana peels (b) Banana peels pieces of length 6 cm (c) Dried pieces of Banana peels (d) Sieving the powder obtained after grinding through 150 µm sieve (e) BPP

3.2 Coagulation-flocculation by using chemical & natural coagulants

To perform coagulation-flocculation tests, laboratory jar testing apparatus Phipps & Bird (PB – 900) with six paddles had been used. 1000 mL of Sundernagar lake water was filled in six glass beakers. Alum was added in dosages of 20 mg/L, 40 mg/L and 100 mg/L [36, 37]. BPP was added in dosages of 400 mg/L, 700 mg/L and 1000 mg/L [38]. The rapid mixing of these mixtures in beakers was done at speed of 200 rpm for 2 minutes, followed by slow mixing at speed of 40 rpm for 20 minutes. The settling time of 60 minutes was given for the sedimentation of all mixtures in the beakers. The samples for testing after sedimentation are collected with a micropipette from 20 mm beneath the surface of water without disturbing the sediments at the bottom [39].

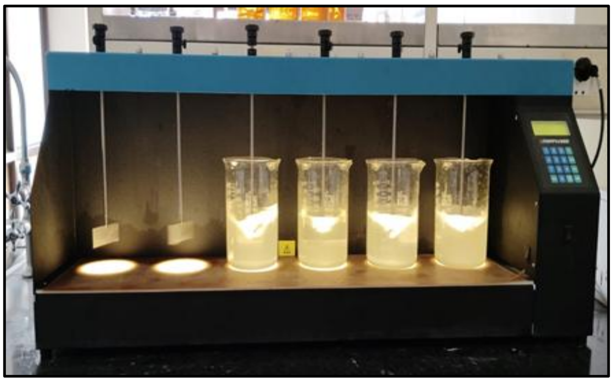

Figure 3: Jar test apparatus

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3.5 Methods of analysis

To evaluate the Sundernagar lake water parameters before and after the jar testing process, analytical equipments were used on its water samples before and after jar tests. Turbidity was measured using Turbiditimeter (EUTECH TN-100), TDS was measured using TDS meter (HANNA HI98301), TSS was measured using colorimeter (HACH DR 900) while iron, copper and nitrate concentrations were measured in Sundernagar lake water using UV spectrophotometer (Spectroquant Prove 300). Removal efficiencies of various response parameters such as turbidity, iron, copper, nitrate, TDS and TSS were determined using equation (1).

$$R\,\% = (Ci\text{-}Cf)/\,Ci \times 100 \qquad (1)$$

Where Ci and Cf are the initial and final values of each contaminant, respectively, and R is the response parameter removal efficiency [40].

3.6 Potential of coagulant formed by combination of Alum and BPP

To find out the optimum combination of Alum and BPP for the best turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies, the proportion of Alum to Banana peel powder was varied from 0 to 100% respectively. The performance of different proportions of combination of Alum to BPP at 0:100, 25:75, 50:50, 75:25 and 100:0 in percentages was investigated.

The procedure similar to section 2.5 was followed. The final turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies obtained under all proportions of combinations were compared to the 100% dosage of Alum and BPP, respectively.

IV. RESULTS AND DISCUSSIONS

4.1 Initial values of all parameters for raw water

The initial values of all water quality parameters of Sundernagar lake water such as turbidity, iron concentration, copper concentration, nitrate concentrations, TDS and TSS were found by performing various instruments before treatment. The initial turbidity, iron concentration, copper concentration, nitrate concentrations, TDS and TSS of raw Sundernagar lake water were 628 NTU, 4.88 mg/L, 4.95 mg/L, 29.3 mg/L, 190 mg/L and 371 mg/L, respectively. After finding out the initial values of all parameters, three different experimental setups were conducted to evaluate the impact of Alum and BPP when used individually and in combination as coagulants on turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies, respectively.

4.2 Effect of varying Alum dose

The dose of coagulant significantly influences the coagulation-flocculation process. Poor removal efficiency of contaminants can occur from both under dosing or overdosing. So, it is crucial to find the optimum dose of coagulant [41].

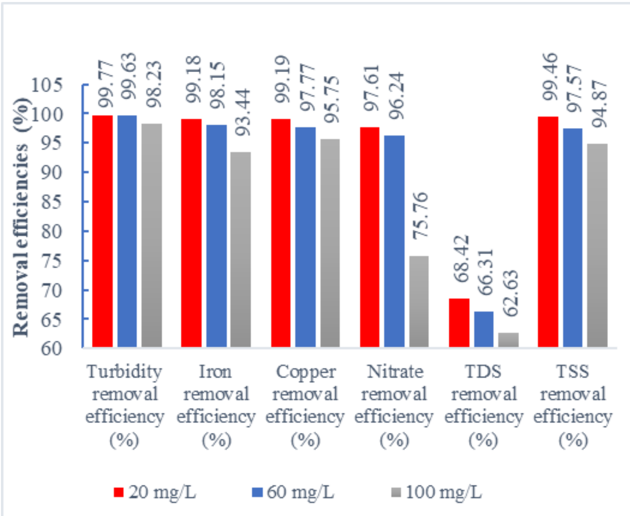

Figure 4: Effect of Alum dose on turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies (rapid mixing = 200 rpm for 1 minutes, slow mixing = 40 rpm for 20 minutes, settling time = 60 minutes)

According to experimental data, the best Alum dose to treat Sundernagar lake water was 20 mg/L. It is evident from Figure 4 that at Alum dose = 20 mg/L, slow stirring speed = 40 rpm and settling time = 60 rpm, the removal efficiency of turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies were 99.77%, 99.18%, 99.19%, 97.61%, 68.42% and 99.46% respectively. The increase in Alum dose beyond 20 mg/L led to the decrease in turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies due to overdosing. Overdosing contributed to the destabilization of colloidal particles which leads to less floc formation and charge reversal process. This observation supports earlier findings of researches where coagulant dose beyond optimum value led to reduction of removal efficiencies of contaminants [31, 32, 33].

4.3 Effect of varying BPP dose

BPP is very light and fibrous [42]. When more BPP dose is added to water, then more fibers of BPP float on water. The thick layer of these fibers blocks the active functional groups like hydroxyl and carboxyl which remove impurities, from interacting with colloidal particles of contaminants like iron, copper and nitrate leading to reduced coagulation. At high concentrations, BPP particles tend to clump together rather than spreading uniformly. This limits the effective surface

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areaexposed for adsorption and flocculation, which reduces the removal efficiency of all parameters [43]. At high dose of BPP removal efficiencies of all parameters decreases due to overdosing [38].

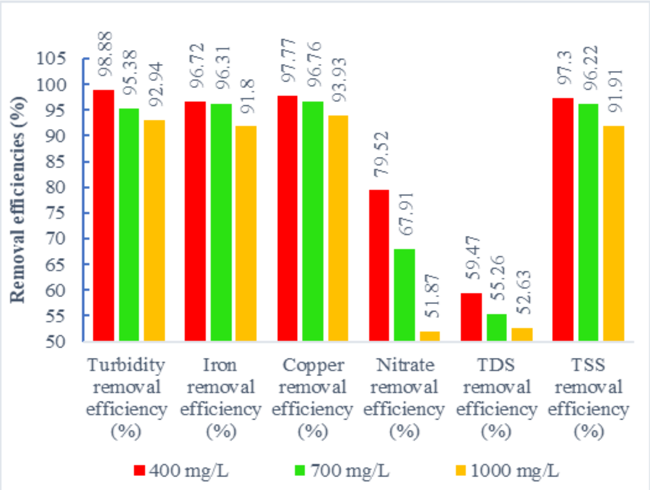

Figure 5: Effect of Banana peel powder dose on turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies (rapid mixing = 200 rpm for 1 minutes, slow mixing = 40 rpm for 20 minutes, settling time = 60 minutes)

According to experimental data, shown in figure 5, the best BPP dose to treat Sundernagar lake water was 400 mg/L. At BPP dose = 400 mg/L, slow stirring speed = 40 rpm and settling time = 60 rpm, the turbidity removal efficiency, iron removal efficiency, copper removal efficiency, nitrate removal efficiency, TDS removal efficiency and TSS removal efficiency were 98.88 %, 96.72%, 97.77%, 79.52%, 59.47% and 97.30% respectively.

4.4 Effect of varying Alum and BPP proportions when used in combination

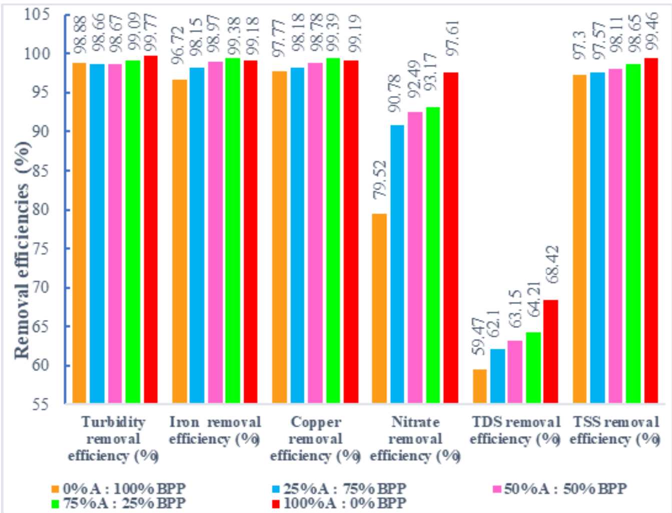

Figure 6: Effect of Alum and BPP combination in different proportions on turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies (rapid mixing = 200 rpm for 1 minutes, slow mixing = 40 rpm for 20 minutes, settling time = 60 minutes)

According to experimental data which is depicted in figure 6, best iron and copper removal efficiencies were obtained when 75% Alum and 25%BPP was used while best turbidity, nitrate, TDS and TSS removal efficiencies were obtained when 100% Alum and 0 % BPP was used, at stirring speed of 40 rpm and settling time 60 minutes. When Alum was used 75% and BPP was used 25%, then iron and copper removal efficiencies were 99.385% and 99.393 % respectively. When 100% Alum and 0%BPP was used, then turbidity, nitrate, TDS and TSS removal efficiencies are 99.77%, 97.61%, 68.42% and 99.46% respectively.

4.5 Cost of Sundernagar lake water treatment by combination of Alum and BPP as a coagulant

The optimum dose of Alum was 20 mg/L = 0.20 g/L and optimum dose of BPP was 400 mg/L = 4.00 g/L when used individually whereas the optimum dose of Alum was 75% of 20 mg/L = 0.15 g/L and optimum dose of BPP was 25% of 400 mg/L = 1 g/L when used in combination for the treatment of Sundernagar lake water. Cost of 1 gram Alum was 0.6 ₹ while the cost of 1gram BPP was 0 ₹. By multiplying optimum dose by cost of coagulant per gram, the total cost for the treatment of Sundernagar lake was calculated in rupees per litre. Therefore, the total cost of Sundernagar lake water treatment using Alum and BPP individually was 0.12 ₹/L and 0 ₹/L respectively and for their combination was 0.09 ₹/L. Using Alum and BPP in combination reduced Sundernagar lake water treatment cost by 25% compared to treatment of its water with Alum alone.

V. CONCLUSION

From the results obtained in this research work, it was determined that the optimum dose of Alum and BPP required for the treatment of Sundernagar lake water was 20 mg/L and 400 mg/L, respectively when used individually. This study revealed that BPP had high turbidity, iron, copper, nitrate, TDS and TSS removal efficiencies almost near to the removal efficiencies of Alum. When Alum and BPP was used in proportion of 75%:25%, then highest iron and copper removal efficiencies of 99.385% and 99.393%, respectively were obtained. While highest turbidity, nitrate, TDS and TSS removal efficiencies of 99.77%, 97.61%, 68.42% and 99.46 % respectively were obtained when Alum and BPP was used in proportion of 100%:0%. The cost of treatment of Sundernagar lake water was 0.09 ₹/L, which was 25% less than the cost of water treatment by using Alum alone. High removal efficiencies and reduction in cost of the water treatment, suggested that the combination of Alum and BPP has great potential in treatment of surface water. Based on the findings of this research work, it can be concluded that the combination

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of Alum and BPP can be used as an alternative of chemical coagulants in treatment of surface water.

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AUTHORS BIOGRAPHY

Sanskriti, M. Tech. Research Scholar, Civil Department, Jawaharlal Nehru Government Engineering College, Sundernagar, Himachal Pradesh, India.

Bedatrayee Saha, Assistant Professor, Civil Department, Jawaharlal Nehru Government Engineering College, Sundernagar, Himachal Pradesh, India.

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