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Turbidity Reduction and Eco-friendly Sludge Disposal in Water Treatment Plants

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ABSTRACT

Plankton and other microscopic colloids are tiny particles that are suspended in water and cause turbidity, which causes the water to seem murky or opaque. These particles are too unstable and light to settle or be naturally eliminated. These details contribute to water turbidity and pose some stability. During the process of purifying raw water, all water treatment Plants (WTPs) produce waste/residue known as water treatment sludge (WTS). The majority of the sludge's chemical components include silica, alumina, ferric oxide, lime, and many heavy metals. The surface water treatment technique included coagulation, flocculation, sedimentation, and filtration to remove colloidal and suspended particles from raw water. The sludge obtained from the WTP located at Kekri (Rajasthan), India is being investigated for its physical and chemical properties. About 60% of the sand contained in the sludge is found in the 155-60 grain size range. Additionally, nutrient reduction of soil due to contamination and runoff can be minimized or rounded out by wastewater treatment or the removal of heavy metals from water solutions. To develop water-safe and appealing sludge management solutions, the efficiency of aluminum sulfate and poly aluminum chloride was assessed at different coagulant doses in the study. To make water safe and appealing for human consumption, numerous purification procedures are employed from a variety of sources. Sludge bricks are acceptable to high temperatures in the furnace and have better compressive strength than clay bricks.

INTRODUCTION

Water is the other term of life, and it is unquestionably the most important natural resource. The availability of clean and safe water is a key problem in many undeveloped and developing countries. Each year, diarrhea brought on by tainted water, claims the lives of more than 6 million people. In developing nations, importing chemicals for water treatment is expensive. (Ghebremichael 2004, Gomes 2005). In water treatment facilities, a flocculation treatment procedure, in which colloidal in water are destabilized so that they may coalesce and be physically removed, can reduce turbidity efficiently. To achieve consistently high coagulation effectiveness, conventional coagulants used in large-scale water treatment rely on water pH and accurate dosages such as aluminum sulfate, ferric sulfate, and ferric chloride salts. Sludge that is clotted with the use of metal salts includes leftover metals that must be carefully disposed of to avoid polluting the environment. Safe and appealing water may be made using a variety of techniques. Method selection is based on factors such as raw water quality and seasonal variations in turbidity, both of which are problematic when dealing with surface water (Connachie et al. 1999). Traditional coagulation factors have many drawbacks that restrict their utility in household water treatment. Poly aluminum chloride is one of the most common coagulants for water and wastewater treatment. Polyaluminium chloride contains about 70% Al, with an aluminum concentration of 0.35 $Mol.L^{-1}$ (Deng et al. 2015). Coagulation flocculation therapy may be broken down into two distinct steps, each of which must be followed sequentially. Destabilization of colloidal suspensions and solutions is the initial step in this process, known as coagulation, and its primary goal is the overthrow of stability-promoting factors. The so-called coagulant is used in this process, which involves the use of a suitable chemical. The inducement of destabilized particles to come together, establish contact, and therefore form huge agglomerates, is referred to as flocculation in the second subprocess. Gravity-settling coagulation normally completes in a relatively short time (approximately 10s), whereas flocculation happens usually for 20-45 minutes. It is a widespread practice, notably in Greece, the intensification of particle aggregation (Bratby 2006).

Coagulation, flocculation, sedimentation, filtration, and disinfection are often used in the treatment of drinking water. When it comes to liquid-solid separation, the coagulation and flocculation processes are vital (Yokselen & Gregory 2004, Sudhob et al. 2015). Mostly, optimizing the coagulation/flocculation and subsequent filtration and solid-liquid separation processes may remove all organic and suspended matter to a level below water quality limits, allowing for efficient use of sewage and sludge in soil (Khan & Thiem 2008, Fotoki & Oguntowokan 2012).

Almost 11.80 billion cubic meters of water would be needed in 2050, according to the Indian government's planning commission. In a typical water treatment facility, sludge is generated at a rate of 1.0 million tons per year (Bourgeois et al. 2004). India's waste-to-energy plants (WTPs) generate enormous amounts of waste each day. Due to a lack of sludge management practices, the majority of WTPs in India release their filters' backwash water and sludge into nearby drains, polluting the water supply with colloidal and suspended contaminants found in the sludge. Wet sludge typically has a moisture level exceeding 80 WTZ percent (WHO 2011).

Discharging the water treatment sludge into the environment is not a viable alternative, thus it is necessary to develop a more eco-friendly, sustainable, and cost-effective solution. Other nations' WTS studies have shown parallels between the physio-chemical features of the sludge from the 132 MLD and 142 MLD treatment plants in Kekri, Rajasthan. These characteristics allow WTS to be used effectively in the brick-making process (Chiang et al. 2009, Huage et al. 2005). With these properties, WTS may be used to make bricks and cementitious materials, and light aggregate in a constructive way (Chiang et. al. 2009, Hong et al. 2013). Cation recovery and reuse in wastewater treatment plants as a coagulant to absorb phosphorus, hydrogen sulfurate, and boron fluorides percolate glyphosate and arsenate, lead, and selenium buffer is another feasible solution to the sludge discharge problem (Eliott & Dempser 1999). The technology will be explored to lessen the burden of safe sludge disposal while also optimizing expenses.

MATERIALS AND METHODS

For turbidity reduction from the surface (Raw) water, alum [Al_2 $(SO_4)_2$] and poly aluminum chloride are used in the coagulation-flocculation process in the water treatment plants of Kekri (Rajasthan). The source of surface water was the Bisalpur Dam in Deoli Tehsil of Tonk District (Rajasthan) India. Water from the Bisalpur dam is pumped to the Thadoli Intermediate Boosting Station, then raw water is pumped through the main pipeline rising from Thadoli to Kekri, receiving at the inlet point of water treatment plants at Kekri of 142 MLD and 132 MLD capacity. A Jar testing was conducted for finding the optimum dose of poly aluminum chloride, having good water solubility and for wider pH range of surface water. The optimal PAC doses are needed to produce adequate coagulant in the pH range of 6.5-7.5. Coagulant alum is often used to coagulate drinking water in traditional water treatment systems and also used with lime to neutralize the acidic nature of water, but it has many drawbacks, including the creation of significant amounts of waste materials and is also restricted for the coagulation process in the pH range of just 6.5-8. Compared to alum application, poly aluminum chloride application delivers superior quality treated water when carried out according to the prescribed process conditions. When applied in the right concentration, poly aluminum chloride enhances the coagulation process in traditional water treatment and lowers the pH of the finished water. During the first interview with the Kekri water treatment plant's management, the mixing speed and duration, and the maximum contact time utilized in regular Jar testing (Fig. 1) were learned.

Fig. 1: Flocculator model for Jar Testing.

Raw Water Sampling and Preparation

Raw water as received at the inlet of 142 MLD and 132 MLD water treatment facility at Kekri was sent for the Jar testing as shown in Fig. 1 and subsequent analysis was done to estimate the optimum dosage of poly aluminum chloride of medium basicity necessary for coagulation-flocculation in a conventional type water treatment plant. Further, the samples were taken in clean and sealed containers.

Jar Testing

The impact of pH fluctuations on coagulation was studied by conducting a series of Jar flocculation experiments at predetermined pH levels. For flocculation, the jars were first mixed quickly to ensure rapid coagulant mixing, and then slowly to ensure proper flocculation. These two different mixing rates make up a mixing speed pair. The flocculation model of jar testing consists of six jars each of 1-liter capacity. Five jars out of six were used for the testing. The flocculation jars were filled with raw water and 5 consecutive doses of PAC were administered to each jar to sustain concentrations of 20 mg.L^{-1}, 25 mg.L^{-1}, 30 mg.L^{-1}, 35 mg.L^{-1} and 40 mg.L^{-1} respectively at an increasing concentration of 5 mg.L^{-1} of PAC. The speed of the stirrers in the individual jars was 180 rpm for 5 minutes, then 10 minutes of gentle stirring. When the allotted time for mixing was over, the samples were allowed to stand for 15 minutes. A total of three samples of contaminated water from each Jar of supernatants have been taken with the help of a syringe and a meter. The experiment was done five times in total to assure high accuracy, and the average water quality parameter values were computed. The turbidity reduction was studied from March 2021 to June 18th, 2021 as shown in Table 1.

Sludge Testing

To remove the colloidal and suspended impurities from the sludge produced during the clarification and flocculation process in the clarifiers of Bisalpur dam surface water, poly aluminum chloride (PAC) of medium basicity is used as a coagulant. Sludge in beds of drying WTP employs percolated drying bed water for further treatment, and samples that have been dehydrated are sent to the lab for physical and chemical examination.

The physical characteristics of the sludge samples, including pH and moisture content, were assessed in line with the Indian Standard. In addition, to determine the volatile matter, ash concentration, and ignition loss, the sample was heated in a muffle furnace as shown in Fig. 2.

Further, sieve analysis and hydrometer analysis have been used to examine the grain size distribution of the dried sludge sample. The energy dispersive x-ray technique and Florence (ED-XRF) technique were used to examine the

Table 1: Turbidity of raw water in water treatment plants Kekri at dose 30 mg.L^{-1}.

Date	142 MLD water treatment plant					132 MLD water treatment plant				
	Raw water Turbidity	Clarifier flocculator turbidity	Filter bed out let turbidity	CWR water turbidity	% Re-moval of turbidity	Raw water Turbidity	Clarifier flocculator turbidity	Filter bed out let turbidity	CWR water turbidity	% removal of turbidity
03/03/2021	4.97	2.68	1.77	1.10	79.87	4.92	4.70	2.05	1.79	61.91
10/03/2021	5.12	2.45	1.29	1.09	78.71	5.60	4.85	2.17	1.82	69.75
17/03/2021	5.26	2.68	1.32	1.18	77.56	4.86	4.45	2.20	1.66	66.59
24/03/2021	5.30	2.21	1.38	1.19	77.54	4.49	4.02	2.05	1.66	72.42
31/03/2021	4.80	2.96	1.23	1.20	75.00	5.18	4.46	1.43	1.23	72.42
07/04/2021	4.86	2.84	1.51	1.36	70.81	5.37	4.24	1.65	1.45	72.99
14/04/2021	5.75	2.29	1.16	1.09	81.04	5.30	4.99	2.49	1.47	72.26
21/04/2021	6.27	3.57	1.69	1.57	74.69	6.22	4.12	3.10	1.50	75.56
28/04/2021	6.13	2.98	1.56	1.42	76.83	5.67	4.11	3.08	1.51	73.36
06/05/2021	6.27	2.98	1.87	1.70	72.88	6.25	3.95	1.78	1.73	72.25
13/05/2021	5.20	2.51	1.61	1.52	70.69	5.05	3.85	1.70	1.50	70.29
20/05/2021	5.53	2.85	1.69	1.35	75.58	4.92	4.12	1.54	1.46	69.70
27/05/2021	7.67	3.35	2.04	1.95	74.57	7.10	5.50	2.31	2.22	70.14
04/06/2021	7.92	3.27	2.10	1.52	80.80	8.45	5.54	2.30	2.13	74.79
11/06/2021	7.25	3.47	2.20	2.13	70.62	7.10	5.10	2.15	2.05	71.12
18/06/2021	6.62	2.76	1.85	1.69	74.47	6.57	5.31	2.10	1.96	70.16

Fig. 2: Muffle furnace.

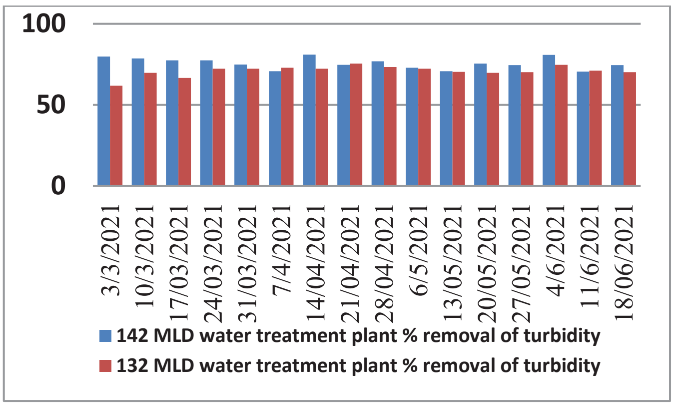

Fig. 3: Comparative bar chart of turbidity removal % of 142 and 132 MLD WTP.

principal chemical components of dry sludge, while trace elements are identified by using the wavelength X-Ray Florence (WD XRF) technique.

RESULTS AND DISCUSSION

The turbidity removal percentage at 142 MLD and 132 MLD WTP has been analyzed as shown in Fig. 3. The best dose of PAC is found to be 30 ppm ($mg.L^{-1}$) to lower the quantity of turbidity in raw water at Kekri (Rajasthan) treatment facilities for the jar testing that conducted from 3rd March to 18th June 2021. The turbidity in clear water was measured only weekly for the samples of both the water treatment plants. The removal of turbidity of 142 MLD and 132 MLD was measured and it was found to be a maximum of 81.04% on 14/04/2021 and 75.56% on 21/04/2021 of turbidity removal rate respectively from both the water treatment plant. The turbidity removal average capacity in 142 MLD and 132 MLD at Kekri was found to be 75.32% and 70.08% respectively. The trend of turbidity removal efficiency of 142 MLD filter plant is more than that of 132 MLD water treatment plant. The trend of the turbidity reduction potential of the 142 MLD water treatment plant is 1.0 NTU and it fulfills the Indian standard code 10500-2012 of the acceptable limit of 1.00 NTU. Whereas, the turbidity reduction potential of 132 MLD water treatments is more than 1.0 NTU. However, it is more than the acceptable limit but less than 5.0 NTU, the permissible limit of turbidity as per the Indian Standard. Both the water treatment plant was found to be satisfactory in turbidity reduction within the permissible limits, i.e., the range below 5.0 NTU.

Sludge Disposal

Turbidity and coagulant-added sludge found during the water treatment are collected as sludge samples by the process of conduction tests at water treatment plants, in Kekri. Acidity (pH 6.82), moisture content, and volatile matter (volatile matter level of 2.65%) were identified in the sludge. The ash level found in sludge is 84.55%, which indicates its inorganic nature whereas the loss of ignition is found to be 8.39%. The physical characteristics of the sludge are given in Table 2.

In this present work, the sludge obtained from the WTP is used for making bricks. In the process of brick fabrication, the quantity of Portland cement grade 43 was mixed in the ratio of 1:6, 1:5, 1:4, and 1:3 with dry sludge, and the standard size of brick was constructed. The bricks made from cement and sludge are then kept in submerged water for 7 days and cured with water for 21 days. In the laboratory, the compressive strength of bricks was tested by a universal testing machine. Bricks constructed of sludge and cement were shown to have a stronger compressive strength than that made from clay soil. The chemical composition of the sludge contains silica dioxide (SiO_2)-52.74%, aluminum oxide (Al_2O_3)-14.61%, ferric oxide (Fe_2O_3)-5.13%, calcium oxide (CaO)-5.02% and potassium oxide (K_2O)-3.41%. Silicon dioxide (SiO_2) possesses the same set of properties as silica. It can be translucent to gray, crystalline, unscented, or an amorphous solid. Its melting point is 1713°C, while its boiling point is 3265°C. The density was found to be 2.64 $g.cm^{-3}$ and it is soluble in acid as well as in water. Silicon is a hard, dark gray solid with a metallic sheen and has an octahedral crystalline structure. Aluminum oxide (Al_2O_3) is an insert, tasteless, white amorphous substance that is extensively used in industrial ceramics. Ferric oxide (Fe_2O_3) comes from the electrodes used in an electric conductivity (EC) system. Calcium oxide (CaO), also known as lime or more especially quick lime; is a white or grayish whole solid, widely used for desulfurization. Spray-dried sludge is added to the clay at a rate of 20% of the dry weight of the clay. The compressive strength was increased from 9.0 to 10.2 MPa by lowering the drying time by 20% and by adding 20% of the dried sludge to the mixture.

Effects of Waste Sludges on Compressive Strength

The compressive strength of the bricks has a significant role in deciding their utility. Typically, porosity affects compressive strength. It was discovered that the compressive strength of the bricks rapidly decreased as the amount of water treatment sludge in the mixture increased. Additionally, it was found that the compressive strength of the bricks made from different four ratios increased as the curing days increased. The specimen showed a compressive strength of 7.5 MPa and 9.3 MPa on the 7^{th} and 28^{th} days respectively after the addition of 5% of sand in the mixture with the replacement of 5% of the sludge. This was done using a mixture of cement and sand in a ratio of 1:4. However, when the sludge concentration went up, the bricks' compressive strength decreased. For instance, for control mortar and bricks containing 3, 5, 7, 10, 15, 20, and 40% of waste treatment sludge, the strength developed for the mixtures was 7.5, 8.0, 5.43, 4.63, 4.13, 2.56, and 0.47 MPa respectively. After 28 days, brick combinations with the same water-to-cement ratio had strengths of 9.67, 10.37, 5.7, 4.77, 4.77, 4.30, 2.57, 1.63,

Table 2: Physical characteristics of the sludge.

Date	PAC dose in WTP ($mg.L^{-1}$)	Moisture (%)	Volatile matter (%)	Ash content (%)	Loss of ignition (%)
03/03/2021	30	0.85	2.66	84.66	8.26
10/03/2021	30	0.84	2.65	84.64	8.39
17/03/2021	30	0.91	2.65	84.50	8.40
24/03/2021	30	0.90	2.65	84.55	8.30
31/03/2021	30	0.90	2.65	84.44	8.41
07/04/2021	30	0.90	2.65	84.55	8.46
14/04/2021	30	0.87	2.65	84.55	8.47
21/04/2021	30	0.86	2.67	84.55	8.39
28/04/2021	30	0.85	2.64	84.55	8.39
06/05/2021	30	0.85	2.65	84.55	8.39
13/05/2021	30	0.86	2.64	84.55	8.39
20/05/2021	30	0.89	2.64	84.55	8.39
27/05/2021	30	0.89	2.64	84.55	8.41
04/06/2021	30	0.90	2.65	84.55	8.35
11/06/2021	30	0.86	2.64	84.55	8.35
18/06/2021	30	0.85	2.64	84.55	8.39
Average			2.65	84.55	8.39

Fig. 4: Photograph of Sludge Bricks and Red Colour Bricks.

and 0.6 MPa. Here, the final compressive strength of the brick was taken as the arithmetical mean of the compressive strength of 5 bricks. Compressive strength is taken as ($C_O = P/A$) . Here, P is an applied axial load on the brick at the uniform rate of 140 kg.cm^{-2} per minute. A water adsorption test has been carried out for sludge bricks as per I S Code 1077-1970 and it was found to be 9.04% which is less than the prescribed limit of 25%. Adsorption percentage is given by the formula as, $W = \frac{(W_2 - W_1)}{W_1} \times 100\ \%$. Where, W_1 is dry weight and W_2 is the weight after immersion in water for 24 hours. In another formation, sludge bricks have been made with the mortar in a ratio of 1:4, and 5-part of sludge are mixed and then the compressive strength was measured. It was found to be 10.37 N/mm^2. Water absorption of these bricks was found to be 8.10%, which is well below the permissible limit of 25% as per the I S Code 1077-1970 and the brick efflorescence was found to be nil. Further, these bricks were found better in performance as compared with the red color bricks as shown in Fig. 4. The compressive strength of the red color bricks or building bricks lies within 3.5 MPa which is less as compared with the sludge bricks and the water absorption capacity of these red color bricks is up to 20% which is higher than that of the sludge bricks. Therefore, the sludge bricks have better performance than the red color bricks in a wide range of applications.

A sludge brick has high corrosion endurance, and high-temperature stability and its coefficient of thermal expansion at 25-1000°C are found to be 8.210^{-6}/°C. It also provides insulation in different types of applications.

CONCLUSIONS

By using the available coagulant poly aluminum chloride (PAC), significant improvement in the reduction of turbidity and coliform has been observed in the raw water of Bisalpur dam. The maximum turbidity reduction was found in the highly turbid water after dosing poly aluminum chloride (PAC). It has been observed that highly turbid water having 5.97 & 7.92 NTU reduced to 1.09 & 1.52 NTU respectively in 142 MLD water treatment plants and turbid water having 5.18 & 4.92 NTU reduced to 1.23 & 1.46 NTU respectively in 132 MLD water treatment plant. The maximum turbidity removal reduction of up to 81.04% was found in 142 MLD WTP on 14th April 2021 and up to 75.56% was found in 132 MLD WTP on 21st April 2021. Therefore, 142 MLD WTP has good turbidity removal in comparison to 132 MLD WTP.

Water treatment sludge produced at Kekri, India WTP is composed of 55% fine sand, 26% silt, and 19% clay. Sustainable growth necessitates the creation of effective sludge management services. An environmentally friendly method of disposing of construction and building sludge might be recycling. The government may make money by using sludge in the construction business and benefit from its positive environmental effects. Every part of sludge may be recycled by the formation of bricks for the construction of buildings and furnaces also. Sludge bricks had better compressive strength than the clay and soil red bricks and were also found light in weight. Bricks were successfully produced in this research work from the sludges of water treatment plants. Utilizing the sludge as brick formation reduced the adverse impact on the environmental pollution caused by the sludge. Sludge bricks are acceptable to high temperatures in a furnace and have better compressive strength than clay and soil bricks.

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