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Research article

Characterization of water treatment sludge and its reuse as coagulant

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A R T I C L E I N F O

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A B S T R A C T

Coagulation-flocculation process results in the generation of large volume of waste or residue, known as water treatment sludge (WTS), in the purification of surface water for potable supplies. Sustainable management of the inevitable waste requires careful attention from the plant operators and sludge managers. In this study, WTS produced with the optimum alum dose of 30 ml/L at the laboratory scale has been treated with sulphuric acid to bring forth a product known as sludge reagent product (SRP). The performance of SRP is evaluated for its efficiency in removing the colloidal suspensions from the Yamuna river water over wide pH range of 2–13. 1% sludge acidified with sulphuric acid of normality 2.5 at the rate of 0.05 ml/ml sludge has been observed as the optimum condition for preparing SRP from WTS. The percentage turbidity removal is greater at higher pH value and increases with increasing the dosage of SRP. The optimum SRP dosage of 8 ml/L in the pH range of 6–8 performed well in removing the colloidal suspension and other impurities from the Yamuna water. The quality of treated water met the prescribed standards for most of the quality parameters. Thus, SRP has the potential to substitute the conventional coagulants partially or completely in the water treatment process, depending on the quality needed at the users end.

1. Introduction

The conventional water treatment flow chart involves the process of coagulation, flocculation, sedimentation, filtration and disinfection in a series to treat the surface water for drinking purpose. Coagulation is an essential component of the treatment scheme and primarily aimed at destabilizing the colloidal particles, causing turbidity in the raw water. Coagulation process could be considered as one of the most typical physicochemical processes used in water treatments due to its easy operation, relatively simple design and low energy consumption (Teh and Wu, 2014). The destabilized colloidal particles are agglomerated into larger aggregates which get settled efficiently in the sedimentation process or further removed in the subsequent filtration process (Teh et al., 2016).

Aluminum salts (e.g. $Al_2(SO_4)_3 \cdot 18H_2O$) or Iron salts (e.g. $FeCl_3 \cdot 6H_2O$, $FeCl_2$, $FeSO_4 \cdot 7H_2O$) are commonly used as coagulants (Sales et al., 2011). Aluminum sulphate or alum ($Al_2(SO_4)_3 \cdot 18H_2O$) is the most widely used coagulant in the world for drinking water treatment (Edzwald, 1993). Alum gets hydrolysed in water to form aluminum hydroxide, and the colloidal and suspended impurities present in the water are removed by charge neutralization, sweep floc mechanism and adsorption onto hydroxide precipitates (Trinh and Kang, 2011). In fact, the coagulation process results in the production of voluminous sludge known as water treatment sludge (WTS) or water treatment residual (WTR) that poses difficulty in handling and disposal to environmental engineers. In general, sludge from water treatment plants are dumped directly into nearby hydric bodies. However, it is not a proper solution as it may leads to undesirable formation of mud deposits and contamination of the receiving water bodies due to the chemical products used in the treatment (Monteiro et al., 2008). Other alternatives for sludge disposal, currently practiced in the world are incineration, land application and landfilling, considering these sludge as non-toxic (Babatunde and Zhao, 2007; Makris and O'Connor, 2007; Shak and Wu, 2015). In India and many developing countries these Water treatment sludge discharged directly into downstream side of the river or disposed into nearby stream which ultimately meet the downstream river. Such practice adversely affects the water quality and aquatic life (Muisa et al., 2011). However, with the realization of adverse environmental impacts and public awareness, it is likely that stringent regulations would be implemented soon.

Recently, several studies have focused on beneficial reuses of

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WTS for sustainable and economical sludge management. Chu, (2001); Guan et al., (2005); Jangkorn et al., (2011) directly utilized WTS as a coagulant in the wastewater treatment and reported excellent results. Guan et al., (2005) observed that the insoluble aluminum hydroxide of WTS can be utilized as a coagulant in the primary sewage treatment that would rationalize the treatment of water in sludge deposition. Regeneration of the coagulants from WTS and further reuse in water and wastewater treatment could also provide environmental and cost benefits. In a typical primary treatment of wastewater Xu et al., (2009) achieved 96% and 53% reduction in turbidity and COD respectively, by using recovered coagulant. In recent years, four methods such as acidification, basification, ion exchanging, and membranes have been employed for the coagulant recovery from WTS. Acid digestion process is the high efficiency and low cost method for the coagulant recovery; it is also the most investigated process at laboratory, pilot-scale, and plant level (Prakash and Sengupta, 2003; Xu et al., 2009).

King et al., (1975) found that aluminum recovery from the alum sludge could be achieved at lower pH ranging between 1 and 3 and pH value of 2.5 accounted for maximum recovery. Xu et al., (2009) also reported an optimum pH of 2.5 for the recovery of coagulant from the sludge produced in river water treatment. Additionally, Masides et al., (1988) pointed that the coagulant recovery pH range is somewhat depended on the pH of the coagulation process and advised coagulation within pH range 6.5–8.5 and recovery ranging from pH 1.5 to 2.5 for a treatment plant operated with coagulant recovery process. Highly alkaline sludge required lowering of pH to 1.5 whereas a typical coagulation process at pH 6.6 and recovery at pH 2.5 gave the maximum profitable level of coagulants recovery from alum sludge.

In the present study, a different approach of WTS utilization has been investigated. The sludge produced from natural turbid water through the process of coagulation/flocculation by alum, has been chemically treated with acid to bring forth a product known as sludge reagent product (SRP). The produced SRP is directly used as a coagulant and the performance of SRP as a coagulant for the removal of colloidal suspensions from the Yamuna water is evaluated under variable conditions. The main objective of the study is to produce sludge from the coagulation/flocculation of river Yamuna water by using optimum dose of conventional coagulant, characterize the sludge and then prepare SRP from the produced sludge. Then, the SRP is used as a coagulant and its efficiency in the removal of suspended colloids at variable pH has been evaluated.

2. Materials and methods

2.1. Quality of water samples

Three grab samples have been collected from the river Yamuna at different locations. These samples are composited and preserved in non-adsorbing PVC containers. Then, the composited raw water samples of river Yamuna have been analyzed for physical, chemical and biological water quality parameters as per procedure explained in Standard Methods for Examination Water and Wastewater (APHA, 1998).

2.2. Determination of optimum coagulant dose

The alum reagent of 1000 mg/L (1 ml of alum reagent is equivalent to 1 mg alum) has been prepared. Thereafter, this alum reagent is used as a coagulant for the removal of colloidal suspensions from the collected water sample in batch operations. The conventional jar test apparatus has been used for the determination of optimum coagulant dose. The doses of alum reagent ranging from 10 ml/L to 35 ml/L with an increment of 5 ml/L have been added. A flash/rapid mixing for 2 min and a slow mixing for 30 min is carried out. Thereafter, jars have been kept standstill for 20 min to settle down the flocs. The supernatant from each jar has been taken out and tested for turbidity through Nephelo turbidity meter.

2.3. Sludge characterization

The sludge produced in the jar having optimum coagulant dose has been separated using separatory funnels. Then, the sludge obtained, is analyzed for physiochemical properties. pH and solid content of the sludge are measured according to Standard Methods for Examination Water and Wastewater (APHA, 1998). The chemical composition of the sludge and surface morphology of the sludge have been analyzed by scanning electron microscopy, SEM, using a Jeol model JSM 6510 LV equipment coupled with energy dispersive spectroscopy, EDS, facility.

The Fourier transform infrared (FTIR) analysis is carried out using VERTEX 70V instrument. FTIR scans are performed in KBr chamber at frequencies from 4000 to 400 per cm and spectral resolution of 4 per cm.

2.4. Preparation of SRP from sludge

The obtained sludge is treated with variable normality of H_2SO_4 (0.5 N, 1.0 N, 1.5 N, 2.0 N, 2.5 N and 3.0 N) ranging from 0.02 ml/ml to 0.12 ml/ml of sludge with an increment of 0.02 ml/ml for acidification of sludge. The optimum normality and dose of H_2SO_4 found in this process has been selected for preparing SRP from the sludge. The appropriate sludge concentration for the preparation of SRP has been decided experimentally by varying the concentrations of sludge starting from 0.5% to 3.5%. The sludge concentration and normality of acid which gave maximum turbidity removal is chosen to produce SRP and then it is used as a coagulant for the treatment of Yamuna water in this study.

2.5. Performance evaluation

The performance of SRP prepared in the laboratory has been evaluated for its efficiency in removing colloidal suspension from untreated water samples collected from river Yamuna. The removal efficiency has been observed over a wide range of pH from 2 to 13. Jar tests have been performed to simulate a conventional coagulation/flocculation process. Six jars containing 1000 ml water sample have been placed in a standard jar test apparatus and pH of the water samples are lowered by using H_2SO_4 or increased by using NaOH for attaining the desired pH level. After adding the SRP dose, a flash mixing of 2 min is provided to achieve the coagulation process followed by slow mixing for 30 min to flocculate the colloidal suspension during flocculation process. Thereafter, jars have been kept standstill for 20 min to settle down the flocs and then supernatants are taken for determining the turbidity removal. The batch experiments have been carried out for each pH condition at variable dosage of SRP. The optimum dose of SRP and the optimum alum dose found in the present study have been applied individually to treat the collected Yamuna water and the results of various water quality parameters have been compared.

3. Results and discussion

3.1. Quality of water samples

The composited raw water samples of river Yamuna have been analyzed for various water quality parameters and the results are presented in Table 1. Total dissolved solids, turbidity, pH, alkalinity, total hardness present in the raw water samples are below the