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WATER TREATMENT PLANT SLUDGE CHARACTERIZATION, RECOVERY OF COAGULANT AND ITS REUSE

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Abstract

In the purification of water, conventional coagulants are mostly used, which produces large quantity of sludge. Therefore, the possibilities of sludge volume reduction, recovery of chemicals and their reuse as coagulant in the treatment of water and wastewater need to be explore. The objective of the study is to determine the physio-chemical characteristics of sludge obtained from water treatment plant and to investigate the regeneration of chemicals from WTS as coagulant for its re-use in wastewater treatment plants. WTS was collected from the Delhi Jal Board's water treatment plant (Chandrawal Water Works, New Delhi) which uses poly aluminum chloride (PAC) as coagulant in water treatment plant. The physio-chemical property of water treatment sludge was determined by using advance techniques such as Scanning Electron Microscope (SEM), Energy-Dispersive X-Ray Diffraction (ED-XRD), Fourier Transform Infrared Spectroscopy (FTIR). The sludge characteristic showed that it contains maximum amount of SiO_2 at 67.75% .The other oxides observed by ED-XRD method in sludge samples were Al_2O_3 (16.76%), Fe_2O_3 (5.52%) and MgO (3.33%). The analysis results of WTS also showed the presence of different trace metals such as Ni (21.97mg/kg), Cu (38.31mg/kg), Zn (83.08 mg/kg), As (18.00 mg/kg), Rb (136.26 mg/ kg), Sr (68.41mg/kg), Ba (485.94 mg/kg),and Pb (24.00 mg/kg) determined by ED –XRD. The WTS collected was acidified with different normality of sulfuric acid from 1N to 4N to produce chemical as a regenerated coagulant. The sludge acidified by 3N H_2SO_4 was found to be an optimum condition for regeneration of coagulant. The regenerated coagulant of relatively high dose of 25 ml solution with 3N sludge acidification, when used to treat 1liter of synthetic dairy wastewater, produced better turbidity removal efficiency found at about 94%. Thus, regenerated coagulant has the potential to substitute the conventional coagulant used in the water purification. This approach provides reuse potential of WTS and thus minimizes disposal cost, environmental damage, and health risk. This strategy of sludge management would achieve the economic, social, and environmental sustainability.

Keywords - *coagulation-flocculation, Water Treatment, Sludge, Regenerated coagulant, SEM, ED-XRD, FTIR, XRD,*

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1. INTRODUCTION

In the purification of surface water, coagulation-flocculation process is mostly used for the removal of turbidity and other impurities. A large quantity of water treatment sludge (WTS) is generated which is presently being disposed of indiscriminately particularly in the developing countries. Such practices cause contamination of surface and groundwater resources. This is a serious problem requiring attention to adopt a sound environmental management for waste / sludge disposal to minimizes adverse impact on environment and socio-economic conditions arising due to unsystematic disposal. A sustainable sludge management, therefore, requires possibility of minimizing sludge generation or whatever generated is reused, and recycled. Such strategy must be explored for recovery of chemicals as by- products from WTS which can be re-used in the treatment of water and wastewater.

Coagulants based on Aluminum salts are commonly used for coagulation purposes. WTS contains considerable portions of aluminum hydroxide precipitate. The sludge has been utilized for many constructive purposes. Application of WTS has been used for water and wastewater treatment processes. Lowest recovery of Aluminum from WTS was achieved at pH 1 to 3 and maximum recovery at pH 2.5. It fund that at maximum pH of 2.5, the recovery of aluminum salt from the sludge, produced from the river water treatment plant, was max. It was suggested that the coagulant recovery from water treatment sludge is depended on different pH in coagulation process and advised coagulation to be carried out within pH range 6.5to 8.5 and recovery of chemicals from sludge as regenerated coagulant in the pH range of pH 1.5 to 2.5. To obtain lowest pH 1.5, highly alkaline sludge is required whereas a typical coagulation process take place at optimal pH conditions (pH 6.6)

WTS quality generally depend on the quality of raw water, the treatment technology and chemical used as coagulant in coagulation process. Generally, the groundwater having stable quality produce lower amount of sludge. However, in case of surface water treatment, it has been observed a wide variation in waste generation (sludge) such as quality and quantity due to variation in the raw water quality as well as quantity of coagulant required in the treatment processes.

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The water treatment sludge (WTS) produced in the water treatment plants constitutes organic and inorganic matter. The physical, chemical and biological characteristics of WTS generally varies. The poly- disperse suspension with a wide range of rough disperse or even colloidal particles are present in the WTS. The turbidity in terms of dispersed or colloidal particles present in raw water are agglomerated and settled down by the coagulants. Therefore, chemicals used in coagulation process frequently create a considerable part of the sludge. The common used coagulants are aluminum salts ferric salts, and ferrous iron salts. The WTS generated also consists of changeable nature and concentrations of organics, inorganics, suspended solids, coagulant products and trace elements.

The composition of WTS states that oxide of silica was the major constituent. In the water treatment, mostly Al based or Fe based composition has been found in WTS while physicochemical analysis which contains heavy metalsin trace. The variation in presence of oxide percentage also observed due to variation in raw water quality, composition of coagulants, water treatment technology and treated water quality. In general, SiO_2foundsasmajor portion of the sludge and followed by Al_2O_3 and Fe_2O_3. Other oxides such as CaO, MgO, Na_2O, K_2O, P_2O_5 and TiO_2 were found in small percentage. The percentage metals were carried along with surface water and/or as impurities in the coagulants which get concentrated in sludge during the treatment process. Present study was undertaken to (i) determine the physio-chemical characteristics of water treatment sludge collected from a water treatment plant, (ii) the WTS was used to investigate the optimum condition for maximum recovery or regeneration of chemicals as coagulant for reuse, and (iii) the regenerated coagulants was reused to examine the treatability of dairy wastewater for removal of turbidity- a case of sustainable sludge management.

2. MATERIALS AND METHOD

In present the study, WTS was collected from the Delhi Jal Board's water treatment plant. The name of the plant is Chandrawal Water Treatment Plant located in west Delhi which uses poly aluminum chloride (PAC) as coagulant. The physio-chemical property of water treatment sludge (WTS) was investigated by using Scanning Electron Microscope (SEM), Energy-Dispersive X-Ray Diffraction (ED-XRD), Fourier Transform Infrared Spectroscopy (FTIR), and X-Ray Powder Diffraction (XRD) methods.

The chemical composition of the sludge surface morphology was studied by scanning electron microscope (SEM) using Jeol model JSM 6510 LV equipment coupled with energy dispersive spectroscopy. The elemental analysis of water treatment sludge was carried out using ED-XRF setup involving a low power (100 W) tungsten anode X-ray tube (Kevex, 50 kV, 2.0 mA, water cooled) as source of excitation. The X-ray tube was operated at 35 kV and 1.7 mA. The Fourier transform infrared (FTIR) spectroscopic analysis of sample was carried out using VERTEX 70V instrument. FTIR scans were performed in KBr chamber at frequencies from 4000 to 400 per cm and spectral resolution of 4 per cm. X-ray powder diffraction (XRD) was used for rapid phase identification of a crystalline material.

2.1 Wastewater Preparation, Sludge Collection, and their Characteristics

For the preparation of Synthetic dairy wastewater (SDW), 7ml milk (full creammanufactured by Mother Dairy Fruits and Vegetable Ltd.) in one-liter distilled water and added onegram of kaolin ($H_2Al_2Si_2O$ $8H_2O$) (laboratory Grade) powder and mixed to get a uniform solution. For the experimental works, SDW were prepared freshly whenever required to kept composition constant during study. SDW was prepared as per the standard methods. The SDW sample was analyzed for pH, colloidal suspension removal in terms of turbidity, and other parameters as per the prescribed standard method of APHA

2.2 Recovery or Regeneration of Coagulant from Water Treatment Sludge (WTS)

The WTS collected was acidified with different normality of H_2SO_4 at 1.0 N to 4 N (interval of 0.5N) at a ratio of 0**.02** ml H_2SO_4 /ml of sludge i.e. for the experimental purpose 100 ml sludge was mixed with 2ml H_2SO_4 of different normality. A varying conc. of product in solution as regenerated coagulant are produced with varying volume from 5 ml to 30ml and normality and the same solution used to treat 1liter SDW for its turbidity removal.

2.3 Performance Evaluation

The efficiency performance of regenerated coagulant prepared in the laboratory has been evaluated for removal of colloidal suspension from synthetic dairy wastewater. Jar tests have been performed to simulate a conventional coagulation/ flocculation process. 1000 ml SDW sample was placed in a standard jar test apparatus. The variable dosage of regenerated coagulant of different normality was added in six Jars then 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 were kept undisturbed forabout 20 – 25 min. to settle down the flocs and then supernatants are taken for determining the extent of turbidity removal. The batch experiments have been carried out at neutral pH condition.

3. RESULTS AND DISCUSSION

3.1 SDW Characteristics

Analysis of SDW water was carried out which showed it is a little acidic in the range of pH of 6.2-6.8 but higher in COD at 1250 mg/l. the presence of colloidal suspension in terms of turbidity was 372 NTU and TSS wasmeasured 348 mg/l, with TDS at 1187 mg/L. The SDW contains total solids at about 1535 mg/l.

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The experimental observation showed thathigher coagulant dose was found to settle down the colloidal suspension. Similar observations were observed by other which suggested that a higher dose of different coagulants were used for treatment of water. To avoid such problems i.e. the use of higher dose of coagulant, kaolin powder was added to the SDW to make the solution uniform and lower the requirement of coagulant dose. This may help increased adsorption of colloids present in water on the large surface area of kaolin particles.

3.2 WTS Chemical Characteristics or Composition

XRD analysis of WTS was carried out for chemical composition as shown in Table 1 and Fig. No 1.The presence of SiO_2 and Al_2O_3 in WTS were found to be present at 67.75% and 16.76 % as a major constituent. The other oxides including Fe_2O_3 were in small quantity as shown in Table 1.Thepoly- aluminum chloride (PAC) is used in the water treatment plant, the WTS contains the higher percentage of aluminum. The oxides of silica, iron and others shown in XRD (Table 1, Fig No 1) are due to the impurities present in raw water and conventional coagulant used in raw water purification. The acidification of WTS regenerated aluminum and iron which acts as coagulant for its reuse in the treatment of synthetic dairy wastewater. The trace element analysis of WTS as shown in Table 1 was carried by ED –XRD These metals along with other oxides were present in raw water and conventional coagulate as impurities, and get accumulated in WTS. These heavy metals contaminate environment and cause risk to public health if it is not properly utilized or disposed. This is because many metals exceed the regulatory requirement of waste disposal notified by the ministry of Environment Govt. of India.

Table 1: Composition of WTS with trace elements

Composition	% W/W	Elements	mg/kg
SiO_2	67.75	Ni	21.97
Al_2O_3	16.76	Cu	38.31
Fe_2O_3	5.52	Zn	83.08
MgO	3.33	Ga	13.48
K_2O	3.03	As	18.00
CaO	2.37	Rb	136.26
TiO_2	0.51	Sr	68.41
MnO	0.09	Ba	485.94
Cl	0.30	Pb	24.00

3.3 Physico-Chemical Characterization

(i) There is no sharp characteristic diffraction peaks was observed during the X-ray diffraction (XRD) analysis (Fig No 1) of sludge showed ,it showing thepoorly ordered particles, having no distinct shape or form and suggesting that the crystalline Al(OH)3 phase is absent within alum sludge.

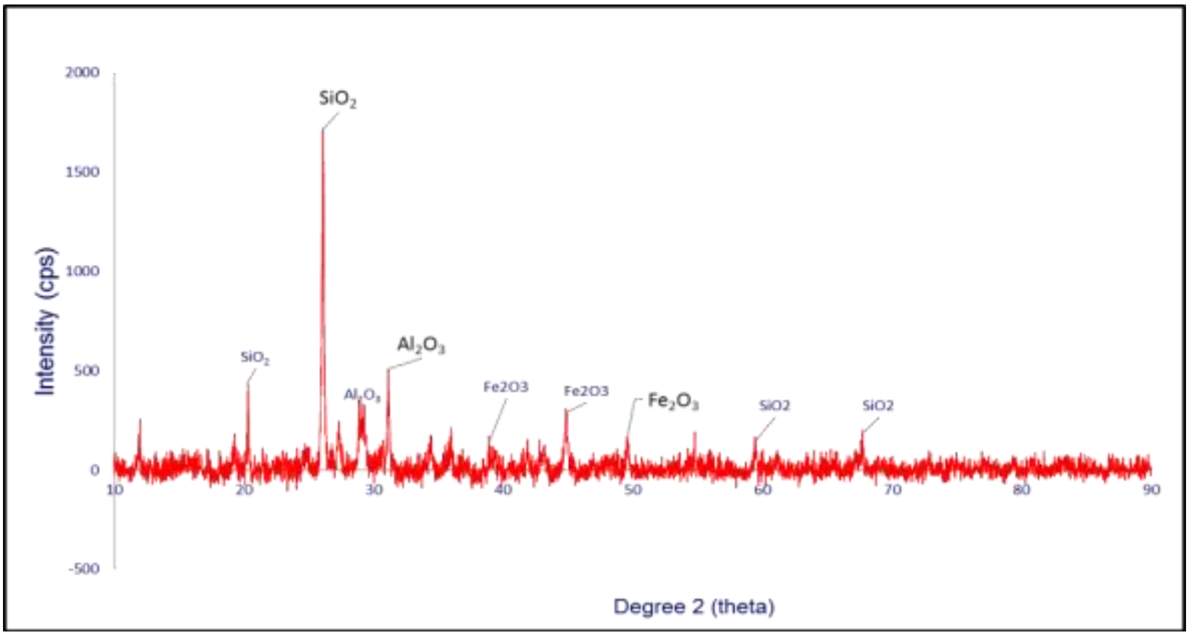

Fig 1: XRD analysis pattern of WTS

This gives an idea that alum sludge is amorphous in nature, silica (SiO_2) is one ofthe major crystalline phase present sludge. Similar findings also exhibited that silica (SiO_2) was the major crystalline solids recognized in numerous XRD analyses. The pure aluminum hydroxide as found by others exhibited a regular crystalline structure

(ii) while scanning electron microscope (SEM) of WTS as shown in Fig No 2 that there is no definite crystalline appearance was observed on surface of the sludge and therefore the sludge parade the amorphous nature.

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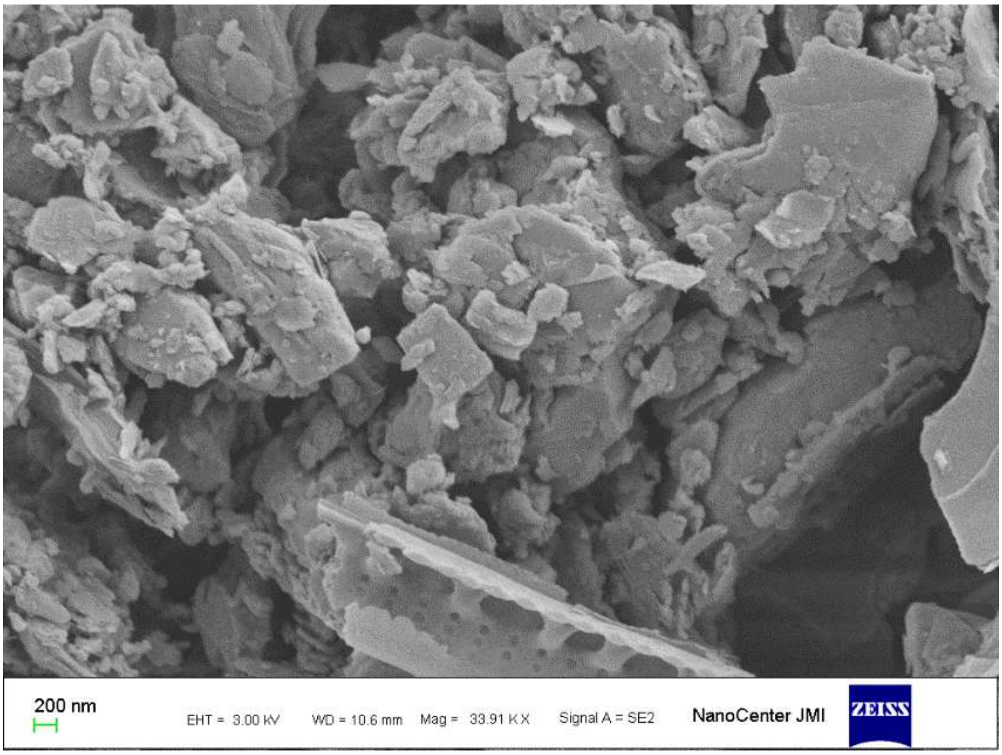

Fig 2: SEM micrograph of WTS at 200 nm distance and Magnification 33.91 KX.

Such observations were made in others which pointed that the sludge surface is highly porous structure having total micro-pore volumes in case of Al and Fe WTS were 0.042 and 0.012cm3/g respectively. The amorphous and porous nature of Al and Fe hydroxides makes the sludge surface sites more adsorptive in nature for majority of anions.

(iii) The FTIR Spectra of WTS collected for the recovery of coagulant for reuse in wastewater treatment, is shown in Fig No 3.

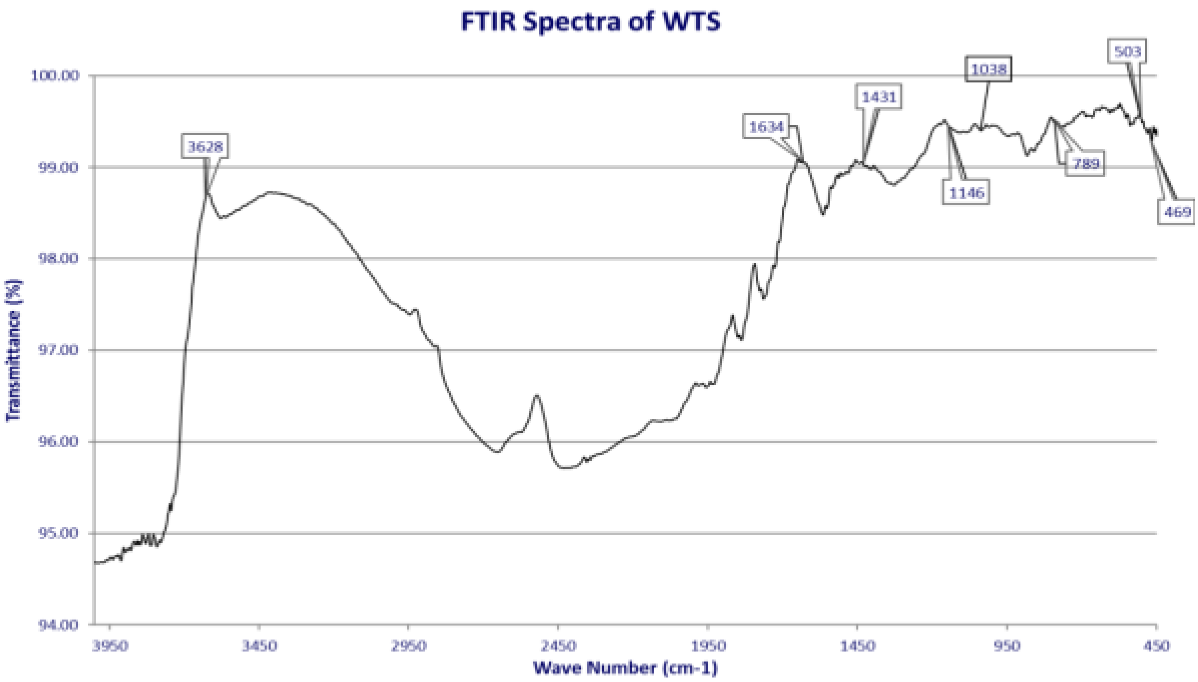

Fig 3: FTIR Spectra of WTS

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The bonded O-H stretching vibration can be detected between 3650 and 3200 cm^{-1}(anti symmetric and symmetric O-H stretching mode) and bending vibrations due to the H-O-H are between 1650 and 1600 cm^{-1}.Such observations in WTS samples obtained from other water treatment plants were similar. In the present case of WTS, the wide band at 3638 cm^{-1} could be assigned to the stretching vibration of O-H bonds while absorption band at 1634 cm^{-1} represents the bending vibration of H-O-H in water molecules chemically associated with $Al(OH)_3$. The stretching vibrations generated by the C-O groups in the carbonate appeared at around 431 cm^{-1}. This represented the carbonate associated with other metals present in WTS as impurities in river water. The bands at 1146, 1038 and 789 cm^{-1} correspond to the stretching vibrations of Si-O-Si in the quartz while bending vibration of O-Si-O appeared at 470 cm^{-1} in WTS. This corresponds to major constituent of silica in WTS.

3.4 Acidification of WTS

Acidification of WTS was carried out by H_2SO_4 to releases the aluminum and iron from the sludge matrix which act as regenerated coagulating agent and used for removal of turbidity from water and wastewater. Such process of recovery of coagulants was studied earlier by acidification of sludge and applied in the wastewater treatment. Variable dosage of WTS acidified with different normality of H_2SO_4 wasusedto treat 1 liter of dairy waste water for turbidity removal. The results are plotted in Fig No 4 which showed that with increasing H2SO4 normality from 1N to 3N, the turbidity removal also increased.

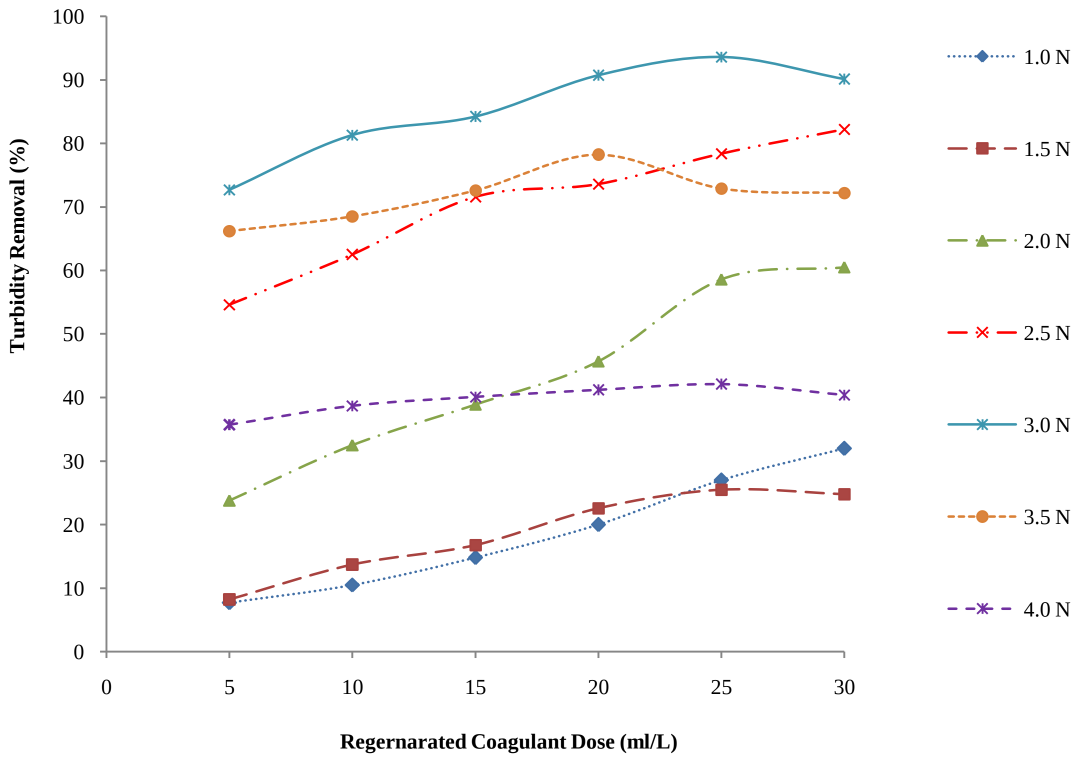

Fig 4: Turbidity removal with variable normality and different doses of regenerated coagulant from WTS

However, the turbidity of wastewater decreased when WTS was acidified with more than 3N H_2SO_4. The decreased in turbidity may be due to dissolution of Al- flocs at lower pH which adversely affected the coagulation process.Therefore, WTS acidification above 3 N of the medium was found less efficient in removing colloidal suspension from SDW (Fig No 4). The 3N acidification of WTS with higher dose at 25 ml per liter SDW found as optimum condition showing a highest turbidity removal at 93.6%. The trend of turbidity removal was high at all the dosage of 3N acidified WTS (Fig No 4). At such an optimum conditions the Al-flocs relatively pre-dominant and adsorb more colloidal particle may be due to the availability of more adsorptive sites on aluminum hydroxide flocs. It provides good settle-ability of colloidal particles and reduces turbidity. Hence, it can be summarized from the present study that regenerated coagulant could be potential source to utilize and treat the wastewater. This reduces the volume of WTS and save the disposal cost and minimizes environmental and public health risk.

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4. CONCLUSION

Current practice of sludge disposal poses danger to the environment and community health. The reuse of WTS offers both economic and environmental sustainability. Prior characterizations of sludge in terms of its physic-chemical properties are necessary for better reuse and recycle as a safe disposal alternatives.

WTS application in water /wastewater treatment will provide some significant chemical savings through resource recovery, re-use, and sludge volume reduction. However, it is unlikely that the setup a wastewater treatment plant would close to a water treatment plants,but it could be a workable option overcoming long distances and high costs. Currently, the developing and many developed countries have introduced specific legislation related to the sound management WTS with focus on waste reduction and reuses guidelines. Ministry of Environment, New Delhi emphasized the need of waste minimization-waste reuse and recycling in the policy Statement for Abatement of pollution,1992 and in E(P) Act 1986.

Regenerated coagulant recovered from WTS after 3N H2SO4 acidification and using its higher dose of 25 ml per liter of dairy wastewaterperformed better, as compare to acidified sludge of other normality, and achieved maximum turbidity removal efficiency of 94 % at neutral pH value. Hence, it can be concluded from the present study that regenerated coagulant could be possibly utilized to treat any wastewater. In particular, the reuse of water treatment sludge for treatment of dairy wastewater provides beneficial utilization and sustainable approach of WTS disposal.

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