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Feasibility of using coagulation for treatment of wastewater generated from a Kuwaiti tiles industry

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Abstract

Tile industry wastewater is known to contain a high concentration of total suspended solids (TSS) and turbidity resulting from the various raw materials. In the present study, the effectiveness of coagulation process on turbidity and TSS removal from a Kuwait ceramic tile industry wastewater was examined using $FeCl_2 \cdot 6H_2O$ as a coagulant. The experiments were conducted using jar tests to determine the optimum dosages of coagulant, optimum pH, and settling time period. It was found that the coagulant dosage and medium pH greatly affect the efficiency of coagulation process. An increase in coagulant dosage from 10 to 50 mg/L gradually increased the efficiency of turbidity removal from 95.6% to 99.5%. The efficiency of the coagulation process was also found to be dependent on pH and higher pH favored the efficiency of turbidity removal. It was found that a medium pH of 10, 1 h settling time period, and 50 g/L of coagulant dosage are the optimum process conditions to achieve almost complete removal of turbidity (99.5%) and TSS (99.8%). This study concluded that coagulation may be a useful primary wastewater treatment process for the tiles industry wastewater.

Keywords: Coagulation, wastewater, iron chloride, tiles industry, turbidity

1. Introduction

Most of the middle-eastern countries, including Kuwait, are characterized by severe arid climatic conditions and have very limited annual rainfall of about 110 mm/yr [1]. The fresh water availability is extremely limited and majority of fresh water supplies in these countries come from scarce groundwater resources. The Kuwait has one of the highest per capita water consumption and lowest level of renewable international fresh water resources per capita in the world [2]. The rapid infrastructure development and population growth in Kuwait is expected to exert severe pressure on the limited groundwater reserves. In this context, potential reuse of treated wastewater is considered as an important element of water resource development and management.

Among a number of manufacturing sectors, ceramic tile manufacturing is an industry which typically requires a large quantity of energy while producing both liquid and solid wastes [3]. There are about 75 ceramic and tile factories in Kuwait that make various types of tiles for different needs such as residential and commercial uses. These tiles industries produce wastewater, though no concrete data is available on the quantity of wastewater discharged from these industries. The ceramic industry wastewater is known to contain high amount of suspended and total solids besides dissolved cations such as Ca, Fe, Zn, Cd, B, etc. [4, 5]. This wastewater is discharged untreated to the environment and hence pose a serious threat to the ecosystem. Therefore, the environmental management of these tiles industry in Kuwait is becoming very crucial. Ironically, treatment of ceramic industry wastewater has got little attention worldwide and limited studies have been reported in the literature. These reported studies also focused mainly on the treatment of organics through biological processes [6] or removal of metallic ions [4]. The studies on removal of solids and associated turbidity from ceramic tiles industry have rarely been reported. The situation is grimmer with respect to Kuwait as no information on the quantity and quality of wastewater discharged from these industries exist. The studies on the possible treatment option of ceramic and tiles industry wastewater generated in Kuwait are completely absent. Present study is probably the first attempt to conduct a detailed analysis of the wastewater generated from tiles industry in Kuwait. Moreover, application of a physicochemical process in treatment of tiles industry wastewater has been reported.

In the present study, the wastewater generated from a tiles factory located in the Sabhan district of Kuwait was chosen for the study. A physicochemical treatment consisting of coagulation and flocculation was applied to find the effectiveness of the process in treatment of tile industry wastewater. As efficiency of coagulation/flocculation process is highly dependent on medium pH, coagulant dosage and settling time, the effect of these process parameters were assessed to find the optimum operating conditions resulting in best quality of effluent. The present study demonstrates the implementation of a sustainable physicochemical process to reduce the pollution load of the tile industry to the environment, and illustrates an effective and innovative approach which can be effectively implemented in similar industry worldwide.

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2. Materials and Methods

2.1 Wastewater sample

The wastewater sample in the present study was procured from a small tile manufacturing company located in the Sabhan district of Kuwait. The company has been manufacturing floor tiles of the international grade and produces significant quantities of wastewater. The wastewater was analyzed for total suspended solids (TSS), total dissolved solids (TDS), pH, conductivity, turbidity, alkalinity, chloride, sulfate, hardness, Ca^{++}, Mg^{++}, COD, and BOD using standard analytical methods [7]. The results of the physicochemical analysis are provided in Table 1.

2.2 Chemicals

Iron chloride or ferric chloride ($FeCl_2.6H_2O$, Merck) was used as a coagulant in the present study. 1 M NaOH and 1 M HNO_3 solutions were used for pH adjustments and pH was measured using a pH meter. The laboratory deionized water was used for preparation of chemicals to avoid probable interference of any elements in water with turbidity removal. Before analyzing the turbidity, a calibration curve of the turbidity versus kaolin concentration was made and results were expressed in the form of Nephelometric turbidity units (NTU).

2.3. Jar Test Experiments

2.3.1 Effect of coagulant dosage

To find out the effect of coagulants dosage Jar test were conducted. Jar test is the most widely used method for performing coagulation study. A conventional Jar test apparatus was used in the experiments for coagulating the highly turbid tiles industry wastewater. Jar tests were carried out under batch mode of operation, accommodating a series of six beakers having paddles. The objective of the jar test was to determine the optimum dose at which a coagulant should be introduced to this wastewater. The test procedure was conducted by filling beakers with 1 L of the wastewater to be treated, after measuring pH, turbidity, TDS, TSS etc. The pH value of the individual beakers was adjusted and coagulant was added to each beaker. Ferric chloride ($FeCl_2.6H_2O$) was used as a coagulant with concentrations of 10, 20, 30 40, and 50 mg/L. The mixed wastewater of the beakers was mixed at high speed (100 rpm) for 1 min followed by a lower speed (40 rpm) for 3 min. The process is stopped for one hour to allow flocs to precipitate and separate from the water. Samples are collected from the supernatant and analyzed to measure the effectiveness of each coagulant dosage. The effectiveness is determined by the reduction in the turbidity of wastewater samples at each coagulants dosage. All jar tests were conducted at room temperature as low temperature is known to have an adverse effect on the kinetics of coagulation and flocculation.

2.3.2 Effect of pH

To find out the optimum pH for conducting Jar test, experiments were conducted using 1 L of wastewater sample and using Ferric chloride ($FeCl_2.6H_2O$) as a coagulant. The experiments were conducted by varying the pHs of 6, 7, 8, 9, and 10, while keeping other variables (coagulant concentration-50 mg/L and settling time-1h) constant. The experiments were conducted using the method described above. At the end of experiments, samples were collected from the supernatant and analyzed to measure the effectiveness of each pHs. The effectiveness is determined by the reduction in the turbidity of wastewater samples at each pH conditions.

2.3.3 Effect of settling time

Jar tests to study the effect of settling time on reduction of turbidity were conducted using 1 L of wastewater samples. The experiments were conducted at three settling time intervals of 30, 60, 90, 120, and 180 mins to find out the optimum settling time. The coagulant concentration added was 50 mg/L, whereas settling time period was 1h. At the end of experiments, supernatant was analyzed to measure the effectiveness of each settling time.

3. Results and discussions

3.1 Physicochemical characteristic of the wastewater

The physicochemical characteristics (Table 1) of the wastewater used in the present study suggested that it is highly contaminated with in-organics (e.g. Ca^{++}, Cl^-, TSS, TDS, conductivity and alkalinity) and violate the Kuwait Environmental Public Authority (KEPA) proposed standards for industrial discharge to Sewer [8]. Results also suggested that the concentrations of TSS, TDS, alkalinity, and pH, hardness, Ca^{++} and Cl^- are significantly higher than the acceptable ranges set by (KEPA), while COD, BOD, Mg and SO_4 concentrations are within the acceptable ranges. In Table 1, it is evident that TSS concentration of the wastewater stream is about 26350 mg/L which is about 90 times higher than the permissible by KEPA. Also, turbidity level is about 270 times of that set by KEPA. This undoubtedly confirms that the wastewater stream coming out of the factory is heavily contaminated with inorganic suspended solids. The presence of high colloidal and suspended solids along with turbidity in ceramic and tile industry wastewater has been reported in earlier studies [4, 5, 9, 10].

Table 1: Physicochemical properties of wastewater sample

Parameter	Unit	Lab Results	KEPA standards for industrial discharge to Sewer (Parson, 2002)
pH	--	12.8	6-8
Conductivity	μS/cm	7975	--

TSS	mg/L	26,350	300
TDS	mg/L	4800	1500
COD	mg/L	22.9	750
BOD	mg/L	0.27	500
Turbidity	NTU	13,610	50
Alkalinity	mg/L	3600	--
Chloride	mg/L	1203	--
Hardness	mg/L	119.4	--
Ca	mg/L	44.9	--
Mg	mg/L	1.77	--

3.2 Effect of coagulant dosage

The residual turbidities and total suspended solids of the wastewater at different coagulant dosages (10-50 mg/L) measured after the completion of tests are provided in Fig. 1 and Fig. 2 respectively. The turbidity and TSS of the feed wastewater was 13,610 NTU and 26,350 mg/L, respectively. As observed from Fig. 1, the residual turbidity of the supernatant water at 10 mg/L coagulant dosage was 600 NTU, whereas it decreased gradually with an increase in coagulant concentrations. The residual NTU was 480 at 20 mg/L coagulant dosage, and about 70 NTU at 50 mg/L coagulant dosage. This shows that high concentration of coagulant favors the removal of turbidity and about 99.5% of the turbidity was removed at this coagulant dosage compared to 95.6% at 10 mg/L dose. The reason for this can be explained by the fact that at higher coagulation dosages, an increase in the possibility of particle-particle collision during mixing exist which led to the higher removal of turbidity. Generally, iron salts are rapidly hydrolyzed in water to give cationic species, which can be absorbed by negatively charged suspended particles and neutralize their charge. During the reaction particles are destabilized, so that flocculation can occur and led to removal of turbidity. The results obtained in the study are in agreement with earlier study conducted with water which suggested that high coagulant concentration favor the coagulation efficiency [11]. As a result of turbidity reduction, a significant reduction in the TSS was also observed at all coagulant concentrations, though residual TSS was lowest at highest coagulant concentrations. About 99.8% of the TSS was removed at 10 mg/L of coagulant concentration, whereas it increased marginal to 99.9% at 50 mg/L of coagulant dosage. The results suggested that 50 g/L is an optimum coagulant concentration for efficient removal of turbidity and TSS.

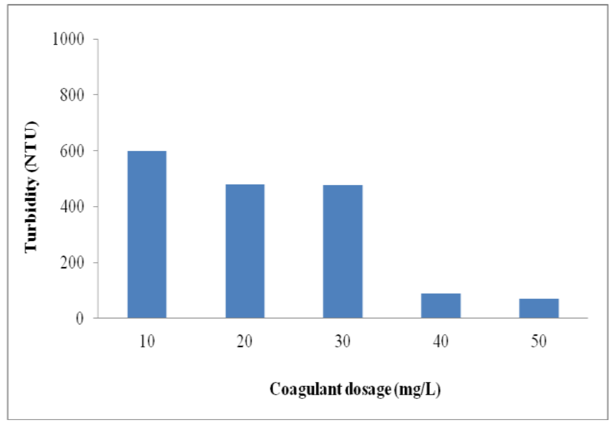

Fig. 1 Residual turbidity of treated wastewater at different coagulant dosage

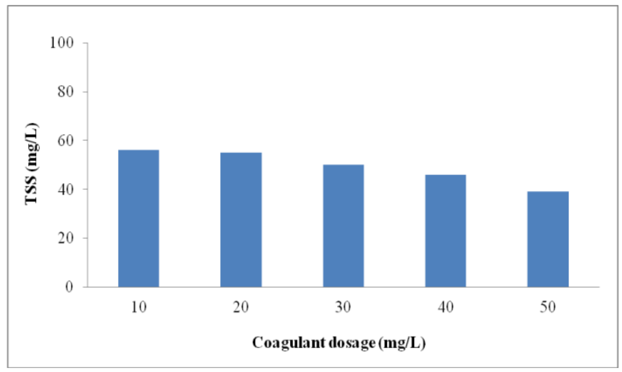

Fig. 2 Residual TSS of treated wastewater at different coagukant dosage

3.3 Effect of medium pH

The residual turbidities, total suspended solids and total dissolved solids of the wastewater at different pH values (pH 6, 8, and 10) measured after the sedimentation tests are provided in Figs. 3 and Fig. 4 respectively. The experiments on effect of medium pH were not carried out at pH values lower than 6 due to the solubilization of natural tile powders in acidic medium. As observed from Fig 3, the residual turbidity of the supernatant water at medium pH 6 was 108 NTU, whereas it decreased gradually with an increase in pHs. The residual NTU was 58 at pH 8, and about 15 NTU at pH 10. This shows that high pH favors the coagulations and about 99.8% of the turbidity was removed at this pH. The reason for this can be explained by the adsorption of matter solids onto preformed ferric hydroxide flocs, followed by precipitation, at higher pH values.

Generally ferric chloride work as per below equation:

$2\ FeCl_3{\cdot}6H_2O + 3Ca(HCO_3)_2\ -\ 3\ CaCl_2 + 2\ Fe(OH)_3 + 6CO_2 + 12\ H_2O$

The insoluble ferric hydroxide, $Fe(OH)_3$, act as a gelatinous flocs that settles through the wastewater and sweep out the suspended material of wastewater.

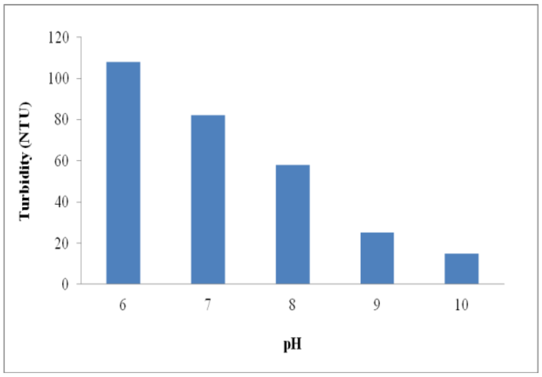

Fig. 3 Residual turbidity of treated wastewater at different medium pHs

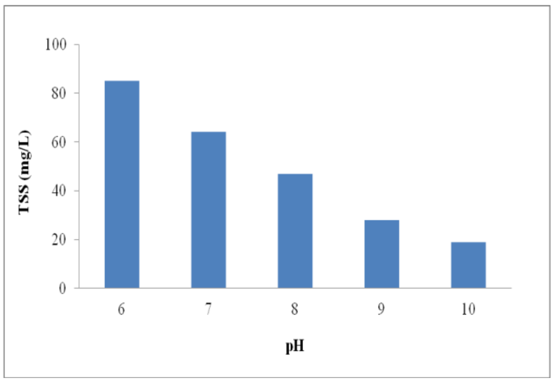

Fig. 4 Residual TSS of treated wastewater at different medium pHs

3.4 Effect of settling time

The residual turbidities and associated total suspended solids of the wastewater at different settling time period (30-180 mins) measured after the completion of tests are provided in Fig. 5 and Fig. 6 respectively. As results suggested that at every settling time period almost complete removal of turbidity and TSS was observed, though removal was maximum at highest settling time period. The residual turbidity of the supernatant water after 30 min settling period was about 180 NTU, whereas it decreased to about 15.5 at 1 h settling period. Beyond 1h settling period, there was only a slight decrease in residual turbidity and residual turbidity values were 10 NTU and 5.8 NTU, respectively at 2 and 3 h settling time period. This shows that 1h settling time is sufficient to remove the almost complete turbidity from the tile wastewater. Similarly, about 98.9% of the TSS was removed at 30 minutes settling time period, whereas almost 99.93% of TSS was removed at 1h settling period. The removal of TSS increased further marginally to 99.96% at 3h settling time. The settling time period used in the present study is in agreement with the reported range of between 30 and 120 minutes [12, 13]. As the concentration of suspended solids in the raw wastewater was considerably high, the destabilization of colloidal and suspended particles occurred due to the adsorption of strongly charged partially hydrolyzed ions at longer settling time period.

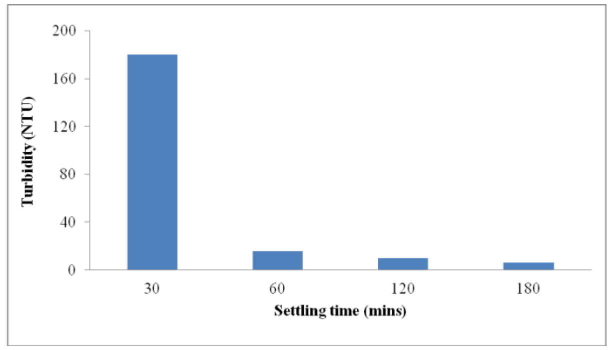

Fig. 5 Residual turbidity of treated wastewater at different settling time period

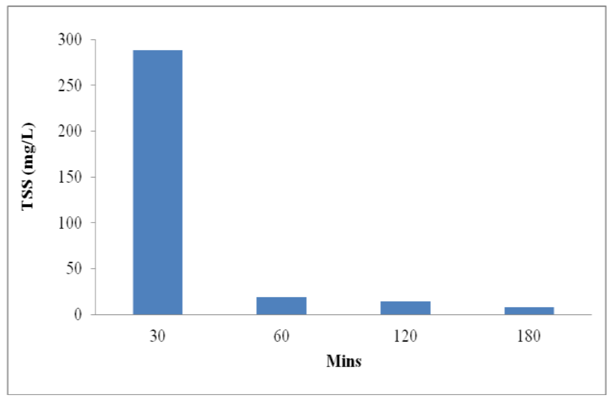

Fig. 6 Residual TSS of treated wastewater at different settling time period

4. Conclusions

The feasibility of coagulation process in removing the total suspended solids (TSS) and turbidity from ceramic tile industry wastewater was investigated. It was found that coagulation process employing $FeCl_2.6H_2O$ is an effective way to remove the turbidity from highly contaminated tiles industry wastewater. The results suggested that the coagulant dosage, medium pH and settling time period significantly affect the efficiency of coagulation process. The optimal coagulant concentration was found to be 50 g/L at which almost 99.5% of the turbidity and 99.9% of TSS were removed from the highly contaminated tiles industry wastewater. Overall, 1 h settling time period, medium pH 10, and 50 g/L of coagulant dosage were found to be the optimum conditions at which almost completer removal (99.8%) of turbidity and TSS can be observed. Our study suggested that coagulation using cheaper iron salt is an effective primary treatment process for the high turbid tiles industry wastewater.

References

[1] Al-Anzi, B., Abusam, A., Shahalam, A. (2012) Assessment of wastewater reuse in Kuwait and its impact on amounts of pollutants discharged into the sea. Journal of Environmental Protection, 3, 935-939.

[2] **http://www.oxfordenergy.org/wpcms/wp-content/uploads/2014/04/MEP-9.pdf**

[3] Albinoa, V., Kühtzb, S., Zhouc, C., Peng, G. (2005) Energy and materials use in Italian and Chinese tile manufacturers: a comparison using an Enterprise Input-Output model. In: International Input Output Association – 15th International Conference – Beijing – China.

[4] Elias, S.H., Mohamed, M., Anuar, A.N., Muda, K., Hassan, M.A. H.M., Othman, M.N., Chelliapan, S. (2014) IIOAB Journal, 5(1), 6-14.

[5] Fahiminia, M., Ardani, R., Hashemi, S., Alizadeh, S. (2013) Wastewater treatment of stone cutting industries by coagulation process. Archives of Hygiene Sciences, 2(1), 16-22.

[6] Dincer, A.R., Kargi, F. (2000). Characterization and biological treatment of ceramic industry wastewater. Bioprocess Engineering, 23, 209-212.

[7] APHA: American Public Health Association (2005) Standards methods for examination of water and wastewater', 21st edn; Washington DC.

[8] Parsons, "Kuwait Sanitary Master Plan" (2002) Parsons Engineering Science, Inc. and Gulf Consult, Kuwait.

[9] Khalid H. Khalil, Olfat H. Ibrahim, (2015) Enhancing ceramic industry effluent wastewater quality for reuse. International Journal of Engineering Research and Development, 11(11), 42-53.

[10] Kamaleddin Hosseinzadeh, Mehdi Ghayebzadeh, Mehdi Shahi, Mehdi Babrzadeh, Zargam Hossein, 2015 Polymer induced flocculation for treatment of a tile factory wastewater using polyacrylamide (PAM): optimization by response surface methodological analysis, Turkish Journal of Engineering and Technology, 2(4), 62-71.

[11] Asrafuzzaman, M., Fakhruddin, A.N.M., Hossain, M.A. (2011) Reduction of turbidity of water using locally available natural coagulants. ISRN Microbiology, 1-6.

[12] Amokrane, A., Comel, C., Veron, J. (1997) Landfill leachates pretreatment by coagulation-flocculation. Water Research, 31(11), 2775-2782.

[13] Connolly, R., Zhao, Y., Sun, G. & Allen, S. (2004) Removal of ammoniacal-nitrogen from an artificial landfill leachate in downflow reed beds. Process Biochemistry, 39, 1971-1976.

The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:
Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.
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