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Review Article

Chemical Coagulation: An Effective Treatment Technique for Industrial Wastewater

Aijaz PANHWAR[a*], Aftab KANDHRO[b], Sofia QAISAR[a]. Mudasir GORAR[c], Eidal SARGANI[d], Humaira KHAN[e]

[a] *PCSIR Laboratories Complex, Karachi, PAKISTAN*

[b] *M.A. Kazi Institute of Chemistry, University of Sindh Jamshoro, PAKISTAN*

[c] *Government Degree College Mehar District Dadu, Sindh, PAKISTAN*

[d] *Government Degree College Malir Cantonment, Karachi PAKISTAN*

[e] *M. A. Kazi Institute of Chemistry, University of Sindh, Jamshoro, PAKISTAN*

(*): Corresponding author, aijazap@yahoo.com

ABSTRACT

Industrial sector is a backbone of the economy throughout the world. Despite that there are a lot of benefits; such as development of urbanization, major contributor in economy's growth is sign of industrial development. There are a lot of adverse effects on environment including depletion and damage of our natural and precious resources. Textile, cement, paper and pulp, sugarcane, food, pharmaceuticals, chemical, paint and other industries are largest consumers of the freshwater; for meeting the requirements of industrial production requirement for the industrial sector for their production. As a result the discharged huge amount of water in form of highly polluted water, this is a great threat to our ecosystem. The unplanned industrialization is a prime responsible for degradation of environment. If industrial wastewater is not properly treated instantly, it may create foulest and septic conditions in adjacent parts of the industrial areas. The discharges acute poisonous wastewater by different industries is responsible for reduction of penetration in crops, and severely affects aquatic life. There are many treatment techniques such as coagulation, adsorption, membrane, biological etc. by different research studies disclosed that coagulation with different chemicals alum, ferric chloride, lime, PACl, PVA and ferrous sulphate are very effective for remove of pollution. The industrial wastewater creates several problems such as health problems, aquatic life including water pollution. In this paper reviews the chemical coagulation treatment technologies for industrial wastewater.

RESEARCH ARTICLE

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INTRODUCTION

Water is a most vital and valuable source for all living organisms and also important role in environment. Decontaminated water is an important requirement for all living organisms including human beings. Wastewater may be considered as wealth, if we use it after treatment properly; due to utilization of treated wastewater we can increase agricultural production to tide over the hunger in world. otherside it seems a biggest problem of future not only in developing countries but it will affect in developed world by industrial development and rapid growth of population. Industrial wastewater has becomes environmental and health threat to urban populated areas as well it is assets if properly treated (Drechsel *et al.*, 2015; UN Water, 2015). Over the years, the industrial wastewater has been a cause of pollution due to rapid urbanization; industrial revolution and luxury life style are the main factors. Now a day, an estimated 80% of global industrial saline wastewater is discharging without proper treatment into the environment. Industrial wastewater is a gateway to environmental degradation and diseases by contaminated water. Industrial wastewater is defined as waste generated by manufacturing or industrial processes. Natural waters may be more contaminated by the discharge of industrial waste by different industries. Wastewater word is used for the mixture by industries, municipal and agriculture actions. It comprises biological, chemical and physical pollutants. Unregulated and indiscriminate discharge of industrial pollution is the greatest threat and is degrading the environment of the vicinity areas. Harmful compounds in wastewater may extremely interrupt marine ecosystems. The wastewater chunks the photosynthesis process which is basic need for plants. There is a major role of industrial wastewater for soil and water bodies polluting within the nearby areas; and also equally responsible for the contamination of canals, groundwater, other water resources as well as coastal line areas. Textile, sugarcane, leather, pulp and paper, cement, paint, tannery, chemical industries, food processing, packaging, ghee, fertilizer, pesticides, petroleum refineries, pharmaceuticals, rubber, thermal power houses (electricity generation), mainly plants by coal fire, are a main cause of industrial saline wastewater. Among these almost all industries are responsible for discharge of wastewater without any prior treatment, with significant levels of pollutants and metals such as chromium, mercury lead, and cadmium as well as selenium, arsenic, and nitrates and nitrites. Pollutants in industrial saline wastewater can be removed, converted or broken down during the treatment process. Industrial saline wastewater treatment is not an easy and affordable way to remove pollutants from wastewater especially in developing countries. It requires huge amount/budget for proper treatment to fulfill the mandatory requirements set by regulatory authorities. Around 80% of wastewater is released to the environment with none prior treatment, ultimately resulting in a rising worsening of overall water quality with harmful impacts on human similarly as ecosystems (UN WWAP, 2017). How does wastewater affect the environment; waterways are generally most at risk to the harmful effects of wastewater. Textile industry is one of the largest industrial sectors. It boosts the economic development worldwide (Ghaly *et al.*, 2014). The industry is responsible for generation of around one-fifth of industrial saline wastewater pollution throughout the world; using around twenty thousand chemicals which are highly toxic, used to make clothes and ultimately discharge without proper treatment, into environment. Textile sector is consumer of freshwater as compared to other industries.

The industry is also a biggest threat to the environment. Other side textile sector is a great contributor of economic development. Industrial saline wastewater is a main hurdle for growth of the textile industry. The wastewater is responsible for numerous complications such as health issues, and aquatic life in form of contamination of water (Isık and Sponza, 2006). Due to industrialization there is a prominently increasing pollution issues; a huge quantity of organic and industrial saline wastewater, the water and land is polluting gradually. It reduces sunlight, and disturbing photosynthesis process of aquatic plants (Zaharia *et al.*, 2009). The cement manufacturing industries are considered as one of the major environmental polluting industries in the world (Akeem, 2008). Sugarcane industry is also one of the biggest users of freshwater and responsible for addition of wastewater in environment. Wastewater generation by sugarcane industry is very hazard and threat to the environment, comprises of in high quantity of chemical oxygen demand (COD), biological oxygen demand (BOD), total dissolved solids (TDS), and Total suspended solids (TSS), which are mainly responsible for reduction of oxygen. If wastewater by industries is not treated at right time, it may create very worst conditions (foul smelling and septic condition) in vicinity of industrial areas. This toxic wastewater is also responsible for less penetration, and threat to crops and aquatic life (Zaharia *et al.*, 2009). The food and its allied packaging materials is around fifty percent of generated municipal solid waste (US EPA, 2014). The total generation of MSW in 2018 was 292.4 million tons, which was approximately 23.7 million tons more than the amount generated in 2017. This is an increase from the 268.7 million tons generated in 2017 and the 208.3 million tons in 1990 (US EPA, 2021). It is projected for millions ton of plastic made up of trillions of quantities swirling in oceans. Around 5% of the used plastic mass is noticeable on the surface; while the remaining is floating settled into the oceans (Winn, 2016; Thompson *et al.*, 2009; Khalil *et al.*, 2016; Nurul *et al.*, 2016).

CHEMICAL COAGULATION

Coagulation is used for the wastewater treatment around more than one century ago (Guven *et al.*, 2009). The chemical coagulation (conventional) is best method for removal of organic; if dose of the coagulant and adjustment of pH in optimal range. The increasing dose (more than use for turbidity removal) of the coagulant (alum) can achieve the best results for the removal of organic. Alum dose and pH are very important variables in industrial wastewater treatment process (Sahu and Chaudhary, 2013). Coagulation-flocculation is particularly employed for effective removal of colloidal sized particles. Aluminum salts are widely used as coagulants in water treatment process due to its effectiveness in removing a broad range of impurities, including colloidal particles and dissolved organic substances (Teh *et al.*, 2016; Zonoozi *et al.*, 2008). The alum as the coagulant is capable of achieving significant organic removal. The pH of the wastewater during coagulation has profound influences on the effectiveness of coagulation for organic removal. Organic removal is much better in slightly acidic condition. For water of higher organic content, the optimum pH is displaced to slightly more acidic values (Sahu, 2019); chemical coagulation (Sahu and Chaudhari, 2014), electrochemical treatment

(Sahu and Chaudhari, 2015). (Noppakhun and Thunyalux, 2016) used different coagulants ($Al_2(SO_4)_3.18H_2O$), Polyaluminum chloride (PACl), Ferric chloride hexahydrate; and ferric sulfate hepta hydrate for removal of pollutants such as color by $FeCl_3$, turbidity by Alum, $FeCl_3$ and $Fe_2(SO_4)_3$. Coagulation is considerably affected by pH changes and results in a significant removal of colored impurities (Tchamango *et al.*, 2010). Aluminum is easily available economically fit and highly efficient as compared to other metals for industrial effluent and drinking water treatment (Moussa *et al.*, 2017) reported that Alum shows decrease of COD and color reduction as compared to aluminum chloride which showed much reductions of ferrous sulfate. Coagulation and flocculation are usually followed by sedimentation, filtration and disinfection. The problems with this treatment process include poor % recovery, operational issues, arbitrary guidelines and dependency on various operational parameters (Holt *et al.*, 2002). Samsuddin *et al.* (2019) used alum, ferric chloride and Polyaluminum chloride (PACl) for selection of suitable coagulant. The optimum condition of the coagulant (pH, coagulant dosage, fast mixing speed) was determined by using Design Expert software. Results showed that alum can be used to effectively for removal of COD and TSS at high dosage. Polyaluminum chloride (PACl) allows formation of floc faster compared to other coagulant as it has high positive electrical charge so it can neutralize the charges of the colloidal easily and reduce the repellent between particles thus allows the particles to form larger flocs (Poddar and Sahu, 2017). By using PACl, percentage of COD that can be removed was much better and same for TSS removal (Aziz *et al.*, 2017). The most suitable coagulant was determined based on its efficiency to reduce COD and TSS in the wastewater at different dosages. By using alum and PACl as coagulant, the percentage of turbidity can be removed effectively (Ghafari *et al.*, 2010). $FeCl_3$ and alum has high percentage of turbidity removal at high dosage and achieved the reduction target. In contrast, PACl shows decreasing of percentage of turbidity removal at high dosage and did not achieve the target. This reduction may be due to charge reversal and re-stabilization of colloidal particles by reason of overdosing (Radhi and Borghei, 2017). By using PACl, the percentage of TSS removal was remarkable (Sahu, 2013; Aziz *et al.*, 2017). Similarly, 100% of TSS can be removed by using alum as coagulant. This removal is more than a percentage removal achieved by (Sahu, 2013; Alkaya and Demirer, 2011). In this case, PACl is the most efficient in removing TSS in the wastewater since it can reduce the same amount of TSS as alum at low dosage. In contrast, $FeCl_3$ gives less efficient result of TSS removal (Sahu, 2013). In chemical coagulation the alum, polyaluminum chloride, ferric chloride, polyvinyl alcohol and ferrous sulphate are effective for the reduction biochemical oxygen demand, chemical oxygen demand, suspended solids and oil & grease (Panhwar and Bhutto, 2020; Panhwar *et al.*, 2021).

Coagulants

Almost chemical coagulants are iron based or aluminum based chemicals, which can change the magnetic charge of particles in the water causing them to attract instead of repel each other. Arsenic, organic matter, chemical phosphorus, and pathogens are removed by chemical coagulants effectively.

pH Control

The control of pH adds acidic or basic chemicals to the wastewater, thereby allowing hydroxide ions to bond with heavy metals and precipitate out of the solution. In addition, greater acidity will kill bacteria and organic compounds by breaking them down at a cellular level.

Selection of Coagulant

Principally, there are four major categories of the coagulation as per application and nature; such as Aluminum salts (alum) Ferric and ferrous salts Lime Polymers Cationic Anionic and non-ionic polymers Natural (Kawamura, 1996; Sahu and Chaudhari, 2013). Before treatment of the industrial wastewater the selection of the coagulants is very crucial. There is a different work of coagulants in different quality parameter of wastewater. Many researchers have been reported on the effectiveness and optimal performance of different chemical coagulants (Table 1) for using in the treatment of industrial wastewater (Holt *et al.,* 2002).

Table 1. Use of different chemical coagulants for treatment of industrial wastewater.

S. No	Industries	Coagulant	Dosing	Optimum Alkalinity/ pH	Temp.	Max. Mixing/ rpm	Parameter	Rema
1	Sugar Industries	$(Al_2(SO_4)_3+FeSO_4)$and Aluminium salt $Al_2(SO4)$	5mg/l	7.1	nm	nm	COD	75% Redu
2	Pulp and paper	I- Calcium benoite + alum. II- polyaluminium chloride (PAC) as the chemical coagulant and bagasse fly ash (BFA). III- Poly-Aluminum Silicate-Chloride IV- aluminium chloride, poly aluminium chloride and copper sulphate	I-100 mg l^{-1}+ 200 mg l^{-1} II- 3 kg l^{-1} PAC, 2 kg for Fly. III- 40 mg l^{-1}. IV- PAC= 8 ml L^{-1} AlCl3=5ml l^{-1} CuSO4=5 ml l^{-1}	I-7 II-PAC= pH3 Fly ash =pH 4 III- pH-7 IV- PAC=pH5 AlCl3=pH4 CuSO4=pH6	I-nm II_nm III-nm IV- 18	I- 120. II-120. III-200. IV- flash-mixed	I- Color. II- Color and COD. III- Turbidity and COD IV- COD and Color	I-88% reduc II- C colou III- 9 91.12 IV- P % an 74 % colou COD 78 %
3	Textile	PAC	25mg/l	7	nm	100	COD, TDS and turbidity	90.17 93.47
4	Pharmacy	$FeSO_4$, $FeCl_3$, and alum	$FeSO_4$ (500 mg l^{-1}), $FeCl_3$, (500 mg l^{-1}), and alum (250 mg l^{-1}),	pH9	Nm	nm	COD, SS	24–2
5	Pesticides waste water	$FeSO_4$ and Al_2SO_4 with H_2O_2	2 mg+20 ml	pH=5.5	nm	120	COD	FeSO
6	Petroleum wastewater	PACl, $FeCl_3$	10mg l^{-1}	pH=7.5	nm	150	Color, COD	PAC= 72% color

CONCLUSION

Wastewater may be considered as wealth, if we use it after treatment properly; due to utilization of treated wastewater we can increase agricultural production to tide over the hunger in world. According to this study the recent developments elucidate that the physical treatment processes (primary treatment) has becomes an effective treatment technique and helpful before further treatment processes, which constitute the tertiary treatment. It would require the chemicals process only and time saving and treat huge quantity of water as compared to biological treatment which is time consuming. The same process used to produce water for re-use in industries and agriculture production. In chemical coagulation process the decontaminated process is very easy and time saving techniques and almost chemicals are easily available. It is an edge to this technique by adding or increasing dose of different chemical coagulants can improve the treatment efficiency for treatment of industrial wastewater. Due to this process the impressive results are achieved to reduce BOD, COD and suspended solids. It is feasible and affording treatment processes and well-known disposal procedure for discharge of industrial wastewater in freshwater bodies.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Aijaz Panhwar: Investigation, conceptualization, writing original draft.
Aftab Kandhro: Methodology, writing original draft.
Sofia Qaisar: Conceptualization
Mudasir Gorar: Review, and editing, references.
Eidal Sargani: Review, and editing, references.
Humaira Khan: Review, and editing, references.

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