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Research Paper

Valorisation of a bioflocculant and hydroxyapatites as coagulation-flocculation adjuvants in wastewater treatment of the steppe in the wilaya of Saida (Algeria)

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ABSTRACT

Pollution caused by wastewater is a serious problem in Algeria. This pollution has certainly harmful effects on the environment. In order to reduce the bad effects of these pollutants, many wastewater treatment processes, mainly physico chemical are implemented, In this case, the method most used is the physical-chemical coagulation-flocculation process. The procedure is based on the use of aluminium and iron salts alone or in combination with the use of two flocculants; the first one is a biodegradable natural bioflocculant *Opuntia cactus* juice, and the second is the synthetic hydroxyapatite; to treat waste water collected at the entrance of the treatment plant, in the town of Saida. The flocculants were characterized using Fourier transform infrared spectroscopy, The influence of various experimental parameters, such as the amounts of coagulants and flocculants used, pH, turbidity, COD and BOD_5, was investigated. The coagulation—flocculation jar tests of wastewater reveal that ferric chloride, containing a mass of 0.3 g hydroxyapatite is the most effective adjuvant in clarifying the wastewater, with turbidity equal to 98.16%. In the presence of the two bioflocculants, *Opuntia cactus* juice and aluminum sulphate, with a dose of 0.2 g, flocculation is good, with turbidity equal to 95.61%. The examination of the main parameters studied during the flocculation tests shows that the degree of pollution decreases, this is confirmed by the COD and the turbidity values. Analysis of these results suggests the use of these flocculants in wastewater treatment.

1. Introduction

The question of the wastewater treatment took on an increasing importance at the beginning of the seventies, considering the general concern expressed all around the world about the growing problem of the pollution of the human environment, the atmosphere, the rivers, the lakes, the oceans, and groundwater by the urban, agricultural, and industrial wastes (Balamane-Zizi and Ait-Amar, 2012). A variety of treatment technologies are available with different degree of success to control and minimize water pollution (Lofrano, 2012; De Gisi et al., 2016), such as adsorption, oxidation, chemical precipitation, etc. Each has its merits and limitations in application (Gao et al., 2007). But, these procedures have not been widely used due to high cost, formation of hazardous by products and intensive energy requirement (Hai et al., 2007). The best immediate option is to use simple and relatively cost effective point-of-use (POU) technologies such as coagulation.

The coagulation-flocculation is a process commonly used for the treatment of raw water and in particular wastewater treatment, this technique is relatively low in cost, robust and environmentally benign.

The process of coagulation-flocculation aims to grow the colloidal particles by destabilization of suspended particles then the formation of flocs by adsorption and aggregation. The formed flocs will be decanted and thereafter filtered (Hayek and Newesely, 1963). Its application includes removal of dissolved chemical species and turbidity from water via addition of conventional chemical-based coagulants, such as iron or sulfate, iron chloride or aluminum sulfate are often used in the first operation (Tchobanoglous et al., 2003; Ayeche, 2012; Anon, 2013). Aluminum sulfate under optimal conditions, can achieve between 90% and 99% efficiency on removing microorganisms (Tchobanoglous et al., 2003). Also, the flocculation process requires addition of some chemical products, such as polyacrylamide or the sulfate polyferric.

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In the literature a number of coagulant–flocculants of vegetable, animal or micro-organism sources used in the treatment of natural and waste waters exist., some reports describe natural coagulants from *Nirmali seed* and *maize mesquite bean* and *Cactus latifaria Cassia angustifolia seed* and different leguminose species. Nevertheless, the material which has recently received the greatest degree of attention is the *seed of Moringa oleifera* indigenous to Sudan. The water extract of M. *oleifera seeds* compares quite favourably with aluminium salt (Kadouche et al., 2012a). The *Moringaoleifera* certainly is the most studied by the scientific community since these coagulant properties have been recognized (Yin, 2010). Since 1999, the coagulation ability of the *cactus* is highlighted (Diaz et al., 1999), and the different species of *Opuntia*, reserved to Habitin human food, fodder, medicine and cosmetics, Saenz et al. and Miller et al. have aroused the interest of researchers in the field of the water treatments (Saenz et al., 2004; Miller et al., 2008). Jing Dong Zhang et al. have seen the turbidity of the water decreased from 104 NTU to less than 5 NTU using powder of *Opuntia ficus Indica* (Zhang et al., 2006). Abid et al. have used the juice of *cactus* of this same species to eliminate heavy metals in industrial effluents, and the rate of reduction of chromium (VI) has exceeded 99.5% while the turbidity has decreased from 100 NTU to 2 NTU (Abid et al., 2009). Barka et al. have used the cladodes of the *cactus Opuntia ficus Indica* as biosorbant to eliminate the methylene blue from the waters (Barka et al., 2013). The chitosan and the xanthan are the only animal materials studied for the water treatments (Kadouche et al., 2012a,b; Zemmouri et al., 2012).

Almendárez et al. (Almendárez, 2004) showed the effectiveness of the *Cochifloc* polymeric coagulant on waters of Lake "Piedras Azules" in Managua. In that study, the authors compared turbidity removal after applying the polymer *Cochifloc,* aluminum sulphate, ferric chloride, and *Quimifloc* (a synthetic polymer). They showed that the effectiveness of turbidity removal of *Cochifloc* was superior, achieving 91%. Vázquez et al. (Vázquez., 1994) performed coagulation tests on samples of domestic wastewater using *nopal* as a natural coagulant, and combining it with aluminum sulphate as coagulation mediator. Using the natural coagulant individually, results show a turbidity removal of 58%, total suspended solids (TSS) removal of 33.4%, and COD removal of 37.5%. When aluminum sulphate was applied, the results for turbidity, SST and COD were 92%, 95.6% and 50%, respectively. Suárez et al. (Suárez and Navia., 2007) found that thermal water produced significantly better removals, and had a better economic performance for the Advanced Primary Treatment (APT) than those achieved with ferric chloride. Furthermore, Guzmán et al. (Guzmán and García., 2012) reported the use of plant origin natural coagulants to remove turbidity and color from untreated sewage water. Yin et al. (Yin, 2010) found that most plant extracts used for removal of turbidity in water are efficient, and produce less sludge compared to aluminum sulphate.

The use of natural coagulant-flocculants will promote more biodegradable sludges at the end of the process. Finally, the coagulation-flocculation capabilities of all these natural products will be compared with the use of $FeCl_3$, a chemical coagulant very frequently used in wastewater treatment. It is important to remark that no synthetic polymer will be added after $FeCl_3$ addition. This fact would seem disadvantageous for $FeCl_3$, but it has been reported that the use of a synthetic polymers can promote additional COD removals of around 10–15% to that obtained with only $FeCl_3$ (Mijaylova et al., 1996).

As part of the present study, we focused on the valorization of the plant *Opuntia cactus*, or *Cactus ficus-indica*, which grows in the town of Saida (Algeria). The *cactus*, which belongs to the genus *Opuntia*, is originally from the arid and semi-arid regions of Mexico. It was one of the food bases for the indigenous populations. It was introduced in southern Spain after Columbus's first expedition to the New World. Thereafter, it was spread throughout the Mediterranean Basin by the Spanish conquerors in the 16th and 17th century (Bouzoubaa et al., 2016; Hoffman, 1995). Cactus also knows a renewed interest in several countries due to its ecological role, environmental and socio-economic: the fight against erosion and desertification, and fruit production fodder (Bouzoubaa et al., 2016; Bouzoubaâ et al., 2014). It is a succulent xerophytic plant, capable of storing large amounts of water and does not pose any health risks to human beings. The main advantages of using natural plant-based flocculants as water treatment material are apparent; they are cost-effective, unlikely to produce treated water with highly biodegradable. Usage of plant based coagulants provides environmental benefits and numerous lab-scale studies have proven that they are technically feasible for small-scale (Kadouche et al., 2012a).

Furthermore, many inorganic materials are successfully used to remove specific undesirable contaminants present in many wastewater treatment systems, including agricultural, municipal, industrial, and nuclear wastewaters (Rajec et al., 1996). Some of those potential materials used as adsorbents include activated carbon, metallic oxides and oxyhydroxides, carbonates, and calcined phosphates (Feng et al., 2010). Calcined phosphate compounds, recently have shown considerable promise to play an important role in environmental remediation, due to their chemical, surface, and structural properties (Anandan and Janakiram, 2012).

Hydroxyapatites have also shown their effectiveness in retaining various pollutant species from polluted waters or soils. Thus, metal cations such as Cu^{2+}, Zn^{2+} (Chen et al., 1997; Corami et al., 2007). Moreover, the effectiveness of chitosan produced from shrimp waste to flocculate turbid suspensions produced from the previous treatment is evaluated. However, the use of hydroxyapatite, as an adsorbent, generates turbid suspensions which are hardly settleable; Kadouche et al. evaluated the effectiveness of chitosane to flocculate the hydroxyapatite turbid suspensions (Kadouche et al., 2012b). Hence the idea to investigate the applicability of hydroxyapatites due to their surface characteristics; these are calcium phosphates that exist in some phosphate rocks, but especially in teeth and bone tissue of animals.

In this context, this research aims to study the appropriateness of use of the two flocculants, *Opuntia cactus* and hydroxyapatite, in wastewater coagulation-flocculation in the wastewater treatment plant (WWTP) of Saida (Algeria). Wastewater treatment is evaluated by using the jar-test, from the measurements of residual turbidity, COD and BOD_5. In order to reach the goal we have set ourselves, it seemed to us essential to carry out prior physicochemical analyses of the wastewater in the WWTP of Saida. The experimental study consists in assessing the results of physicochemical analyses of wastewater before and after treatment.

2. Materials & methods

2.1. Presentation of the treatment plant "STEP" of the city of Saida

The treatment plant of the wilaya of Saida is located in the northwest part of town near the river Saida at the town Rebahia (Fig. 1), with an area of 11.47 ha, with a capacity of 150 000 equivalent/capita, it is designed to treat daily 30,000 m^3 of urban sewage and industrial biologically, the proposed treatment process is biological treatment using activated sludge at low load (Anon, 2013). Currently, the collection system connected to the treatment plant from administrative center is unitary and the outcome of different collectors is done by gravity (Anon, 2013). Pollution received by the station head would come from urban domestic waste and some industrial discharge.