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Plant-Based Flocculants: Alternative Materials to Synthetic Polymers for Sludge Dewatering

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Abstract

The use of conventional organic or inorganic synthetic chemicals in sludge dewatering process is currently leading to new concerns. Worrying issues are related to the pollution of the environment and the risks for human heath caused by the generation of large quantity of sludge containing residual metal ions and toxic residual organic monomers. Plants such as okra, cactus, moringa and aloe showed their ability in enhancing sludge dewaterability. Interestingly, the utilization of plant-based materials produce nontoxic and biodegradable sludge, and represent a sustainable strategy to substitute chemicals in sludge processing.

Keywords: Sludge dewatering; Natural flocculants; Plant-based flocculant; Synthetic chemicals

Introduction

Sludge is the by-product generated by wastewater treatment processes. Because of the increase of the population and the intensification of the industrialization, the produced sludge is constantly increasing, causing various environmental problems associated to its disposal. Due to its high water content, sludge must be dewatered. The dewatering procedure decreases the sludge volume by reducing its water content. This process reduces the difficulties related to sludge handling (storage, transport and stabilization) and improves the efficiency of its post-treatment. Several factors including sludge characteristics (composition, particle size, surface charge, the extracellular polymeric substances, etc.) control the dewatering process [1,2]. Mainly, the presence of polysaccharides and hydrophilic proteins are responsible of sludge high water content making difficult the sludge dewatering process [3]. Physical (microwave, ultra-sonic, freeze–thaw, thermal, etc.) [4], chemical (addition of flocculants, coagulants, acids, alkalis, etc.) [5], and biological (using enzyme) [6] methods were applied in sludge dewatering processes. Among these methods, the flocculation using synthetic chemicals is the commonly used method for many benefits such as the low cost, the high efficacy and the easy procedure [7]. Various chemicals were used in the coagulation/flocculation process of wastewater treatment and in sludge dewatering. Organic (polyacrylic acid, polyacrylamide, etc.) and inorganic (polyaluminum sulphate and polyaluminum chloride) synthetic polymers are the most common used polymers in sludge dewatering. However, their use are linked to many environmental and human risks due to the toxicity of residual monomers of organic polymers and residual metal ions [8]. Traces of aluminum causes various diseases (carcinogenic, genotoxic, Alzheimer's diseases, etc.) and acrylamide monomers are reported to be carcinogenic [9,10]. Because of the disadvantages of conventional synthetic flocculants, natural materials should be used as a substitute in sludge dewatering. The literature reported the use of plant-based flocculants, animal-based flocculants, and microbial-based flocculants. Plant-based flocculants are biodegradable, safe and renewable, which are suitable for sustainable development. Various plants such as okra, cactus, moringa and aloe were used to prepare flocculants to dewater sludge form different origins. The efficiency of sludge dewatering were evaluated by measuring various parameters (moisture content, dry solids, specific resistance to filtration, capillary suction time, settling velocity, etc.) [11-14].

Okra (*Abelmoschus esculentus*)

Okra is a commercial plant belonging to the family of Malvaceae and originated from Ethiopia. Its cultivation is spread all over the world and is used in human nutrition and in medicine [15]. For sludge dewatering, an aqueous flocculant extracted with water from okra was tested to dewater kaolin sludge. This

preparation allowed 45-50% of water recovery at a dosage of 175 mg/L. The water recovery was reduced (to 30-40%) while using dried flocculant at a dosage of 150 mg/L [16]. To the best of our knowledge, only this study was reported in the literature. Therefore, more investigations are needed to test okra-based flocculant efficiency on sludge collected various origins (municipal, industrial, etc.) and under various operating conditions.

Cactus (*Opuntia ficus Indica*)

Cactus is a plant belonging to the family of Cactaceae. Is originated from arid and semi-arid zones and many species are found in many regions over the world (South America, North Africa, Australia, Asia, etc.). Because of its composition, cactus are used in many industrial sectors (food, pharmaceutical, environmental, etc.) [17]. As reported for okra, only one study reported the use of cactus juice preparation to dewater municipal wastewater sludge [18]. Interestingly, at a dosage of 0.4 g/Kg, the cactus-based flocculant allowed good performances of dewatering with specific resistance to filtration of 0.13×10^{12} m/Kg, dryness of filtration cake of 20.5% and filtrate turbidity of 2.5 NTU. These values are comparable to that reported for synthetic polymers (Chimfloc C4346, Sedipur NF 102, Sedipu AF 400, $FeCl_3$, and $Al2(SO^4)_3$) [18]. These results approved the effectiveness of cactus juice in wastewater treatment as reported in the literature [19].

Aloe (*Aloe vera*)

Aloe vera belongs to Asphodelaceae (Liliaceae) family, and is found mainly in the dry regions of America, Asia, Europe and Africa. *Alwo* vera is used mainly in cosmetology and medicine [20]. Interestingly, *Aloe vera* was applied for the treatment of wastewater containing various pollutants (dyes, metals, turbidity, etc.) [21]. In the sludge dewatering, the gel of Aleo vera leaves allowed an enhancement of the sludge settling rate (22.72%) and an effective solid-liquid separation. However, these results were obtained for municipal wastewater sludge [22]. Therefore, more experiments are needed to confirm the capability of Aleo vera gel to dewater various sludge types and to be compared to chemicals polymers.

Moringa (*Moringa oleifera*)

Moringa oleifera belongs to Moringaceae family, and is found in South Asia. Moringa oleifera is used in many sectors (food industry, medicine, water treatment, aquaculture, polymer production, etc.) [23]. In the field of sludge dewatering, a limit number of studies reported the use of Moringa [24-28]. Different preparations (powder and water extract) of Moringa seeds were tested for municipal activated sludge. For example, the powdered bioflocculant allowed the reduction of specific resistance to filtration (reduction rate of 44.44 %) and the capillary suction time (reduction rate of 17.64%) [25]. Moreover, the salted water extract showed higher performance in term of specific resistance to filtration (reduction rate of 56.52%) and capillary suction time (reduction rate of 18.96%). The obtained performance are comparable to that reported for the cationic polyacrylamide Zetag 7653 [25]. In the same context, the moringa seeds free of oil could increase the ability of sludge dewatarability [29].

Conclusion

The production of flocculants using plants is a useful alternative to synthetic polymers. This strategy may reduce health and environmental risks. However, more investigation are needed to decide about the large scale application. The obtained results should be verified for sludge from various origins (industrial and municipal). Moreover, the flocculation performance should be optimized take into consideration the operating condition ((pH, dosage, mixing speed, etc.), the sludge characteristics (origin and composition) and the bioflocculant preparation. Also, is very important to understand the flocculation mechanisms for each plant-based flocculant

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