

SLUDGE DEWATERING WITH DUAL POLYMER CONDITIONING

This application is a PCT application that claims priority to Chinese Application Serial No. 201110344579x, filed October 25, 2011, the disclosure of which is herein incorporated by
5 reference in its entirety.

FIELD OF THE INVENTION

The disclosure pertains to a composition and method for assisting dewatering of sludge.

BACKGROUND

10 A large amount of sludge is generated in the activated sludge process for treating sewage and industrial wastewater. Currently, sludge treatment cost accounts for 25–45% of the operational cost for a typical wastewater treatment plant (“WWTP”). This cost is expected to keep rising with the increasing cost of landfill and incineration, especially in countries and areas
15 with limited land space. Even after the dewatering process, a typical sludge contains a significant amount of water (70–85% by weight). Such high water content increases sludge disposal cost considerably, and as a result it is highly desirable for WWTPs to improve dewatering efficiency as much as possible.

In the dewatering process, sludge is usually conditioned using a cationic polyacrylamide-
20 based polymer (flocculant). The conditioned sludge is then dewatered by a physical process such as centrifuge, belt press, or filter press. Flocculants can cause colloids and other suspended particles to aggregate and thus improve the sedimentation rate and filterability of the sludge.

Accordingly, there is a need for improved dewatering of sludge. Desirably, the improved dewatering of the sludge will result in cheaper disposal cost of the sludge.

SUMMARY

25 Flocculation is a key step for sludge dewatering. The present disclosure provides an improved flocculation process by incorporating a dual polymer conditioning program. In addition to the polymeric flocculant, a polymeric coagulant is also applied to the sludge to
30 enhance flocculation efficiency. Compared to the traditional flocculant-only conditioning, this

dual polymer conditioning method can allow for the removal of more water from sludge, and thus lower the sludge disposal cost, such as that of a WWTP.

As such, the present disclosure is directed toward a method of treating a sludge. The sludge comprises water. The method comprises: providing the sludge; mixing a polymeric
5 coagulant with the sludge to form a coagulated sludge; mixing a cationic flocculant with the coagulated sludge to form a flocculated coagulated sludge; and removing at least a portion of the water from the flocculated coagulated sludge. The polymeric coagulant comprises a copolymer of epichlorohydrin and dimethylamine ("Epi-DMA"), a homopolymer of diallyldimethylammonium chloride ("polyDADMAC"), or a combination of the two.

10 In an aspect, there is provided a method of treating a water-containing sludge, the method comprising: providing the water-containing sludge; mixing a polymeric coagulant selected from the group consisting of a copolymer of epichlorohydrin and dimethylamine, a homopolymer of diallyldimethylammonium chloride, and a combination thereof, with the sludge thereby producing a coagulated sludge; mixing a cationic flocculant with the coagulated sludge thereby
15 producing a flocculated coagulated sludge; removing at least a portion of the water from the flocculated coagulated sludge.

In another aspect, there is provided a method of treating a water-containing sludge, the method comprising: providing the water-containing sludge; mixing a polymeric coagulant selected from the group consisting of a copolymer of epichlorohydrin and dimethylamine, a
20 homopolymer of diallyldimethylammonium chloride, and a combination thereof, with the sludge thereby producing a coagulated sludge; mixing a cationic flocculant with the coagulated sludge thereby producing a flocculated coagulated sludge; removing at least a portion of the water from the flocculated coagulated sludge; wherein the polymeric coagulant comprises an epichlorohydrin and dimethylamine that is cross-linked by a cross-linking agent selected from
25 the group consisting of ammonia, primary amines, alkylene diamines of from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, and a combination thereof; wherein the polymeric coagulant has a molecular weight in the range of one hundred thousand Daltons to three million Daltons; and wherein the polymeric coagulant is mixed with the sludge at a concentration of greater than 10 ppm but less than 800 ppm by weight.

30 These and other features and advantages of the present disclosure will be apparent from the following detailed description, in conjunction with the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The benefits and advantages of the present disclosure will become more readily apparent to those of ordinary skill in the relevant art after reviewing the following detailed description and accompanying drawings, wherein:

FIG. 1 is a graphical illustration of the results of Example 1; and

FIG. 2 is a graphical illustration of the results of Example 2.

DETAILED DESCRIPTION OF THE INVENTION/PREFERRED EMBODIMENT

While the present disclosure is susceptible of embodiment in various forms, there will hereinafter be described a presently preferred embodiment with the understanding that the present disclosure is to be considered an exemplification of the disclosure and is not intended to limit the disclosure to the specific embodiment illustrated.

It should be further understood that the title of this section of this specification, namely, "Detailed Description of the Invention," relates to a requirement of the United States Patent Office, and does not imply, nor should be inferred to limit the subject matter disclosed herein.

The present disclosure is directed toward a method of using a composition of matter comprising an Epi-DMA or polyDADMAC, or a combination of the two. The Epi-DMA may be linear or cross-linked. If cross-linked, the cross-linked Epi-DMA may employ a cross-linking agent selected from the group consisting of ammonia, primary amines, alkylene diamines of

from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, and combinations thereof. In certain embodiments, the cross-linking agent is hexamethylenediamine. In certain embodiments, the Epi-DMA and/or polyDADMAC may have a molecular weight from one hundred thousand Daltons to three million Daltons. In certain embodiments, the molecular weight may be ranging from five hundred thousand Daltons to two million Daltons.

Sludge is a complex gel-like material that may consist of mineral particles, microorganisms, and other substances. Those having skill in the art will recognize that the disclosure pertains to sludge of any kind. One example of a sludge is the waste from waste water treatment plants ("WWTPs"). Two examples of WWTPs are municipal and industrial. The surface of sludge particles is usually negatively charged. In the conventional sludge conditioning, sludge is flocculated by polyacrylamide based cationic flocculants with molecular weight in the range of 5–15 million g/mol.

In this innovation, sludge is first treated by a polymeric coagulant, which is either Epi-DMA, polyDADMAC, or a combination of the two. If cross-linked Epi-DMA is selected, the cross-linking agent may be selected from the group consisting of ammonia, primary amines, alkylene diamines of from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, or a combination thereof. In certain embodiments, cross-linking agent is hexamethylenediamine. Hexamethylenediamine is also known by the names hexane-1,6-diamine; 1,6-diaminohexane; and 1,6-hexanediamine. In certain embodiments, the molecular weight range of the polymeric coagulant is from five hundred thousand to three million Daltons. The sludge may be a biological sludge, a primary sludge, or a mixture of biological and primary sludge.

Primary flocs are formed upon treatment of the coagulant. For example, the average particle size for a municipal sludge sample has increased from 37 μm to 185 μm after addition of 100 ppm of coagulant. The primary flocs are visible to naked eye, and they can be further flocculated by cationic flocculants before dewatering.

Optimal dosages of coagulant and flocculant vary from sludge to sludge and can be determined by jar tests. Due to reduced surface area and charge demand of the primary flocs, the optimal dosage of the flocculant in the dual polymer program can be 30–80% less than the flocculant only program if the same flocculant is applied.

The inventors have found that polymeric coagulants, and especially cross-linked Epi-DMA is particularly effective to treat sludge. While not wishing to be bound by this theory, it is believed that because the polymeric coagulant has a very high cationic charge density, it binds strongly to the surfaces of sludge particles. The smaller molecular weight of the coagulant is
5 believed to allow the coagulant molecules to penetrate deeper inside the sludge gel matrix. Although a traditional inorganic coagulant such as polyaluminum chloride shows similar effects, a polymeric coagulant of the present disclosure seems to cause the sludge particles to aggregate into primary flocs. The fully-formed flocs that are built from these primary flocs have a more compact structure and higher floc strength; as a result, higher sludge cake dryness can be
10 achieved upon dewatering.

In certain embodiments, the Epi-DMA is cross-linked by a cross-linking agent. The cross-linking agent may be selected from the group consisting of ammonia, primary amines, alkylene diamines of from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, and combinations thereof. In certain embodiments, the cross-linking
15 agent is hexamethylenediamine.

In certain embodiments, the polymeric coagulant is first added to the sludge. In certain embodiments, the polymeric coagulant may be added to a concentration of greater than 10 ppm but less than 800 ppm by weight. In certain embodiments, the overall concentration of the polymeric coagulant in the sludge is greater than 10 ppm but less than 800 ppm by weight.

20 In certain embodiments, the removing of the water from the flocculated sludge is performed by a physical process. Examples of physical processes include, but are not limited to, filtration and centrifugation. Persons of skill in the art of sludge treatment will readily recognize whether a process is a physical process within the meaning of the term.

In certain embodiments, the flocculant is a cationic polymer. A particularly suitable
25 flocculant is based on polyacrylamide. The flocculant may be a cationic polymer made up of one or more cationic monomers. Examples of cationic monomers include monoallyl amine, diallyl amine, vinyl amine, dialkylaminoalkyl acrylates and methacrylates and their quaternary or acid salts, including, but not limited to, dimethylaminoethyl acrylate methyl chloride quaternary salt ("DMAEA-MCQ"), dimethylaminoethyl acrylate methyl sulfate quaternary salt,
30 dimethylaminoethyl acrylate benzyl chloride quaternary salt, dimethylaminoethyl acrylate sulfuric acid salt, dimethylaminoethyl acrylate hydrochloric acid salt, dimethylaminoethyl

methacrylate methyl chloride quaternary salt, dimethylaminoethyl methacrylate methyl sulfate quaternary salt, dimethylaminoethyl methacrylate benzyl chloride quaternary salt, dimethylaminoethyl methacrylate sulfuric acid salt, dimethylaminoethyl methacrylate hydrochloric acid salt, dialkylaminoalkylacrylamides or methacrylamides and their quaternary or acid salts such as acrylamidopropyltrimethylammonium chloride, dimethylaminopropyl acrylamide methyl sulfate quaternary salt, dimethylaminopropyl acrylamide sulfuric acid salt, dimethylaminopropyl acrylamide hydrochloric acid salt, methacrylamidopropyltrimethylammonium chloride, dimethylaminopropyl methacrylamide methyl sulfate quaternary salt, dimethylaminopropyl methacrylamide sulfuric acid salt, dimethylaminopropyl methacrylamide hydrochloric acid salt, diethylaminoethylacrylate, diethylaminoethylmethacrylate, diallyldiethylammonium chloride and diallyldimethyl ammonium chloride ("DADMAC"). Alkyl groups are generally C₁ to C₄ alkyl.

In certain embodiments, the polymeric coagulant and the sludge are pre-mixed prior to mixing the cationic flocculant.

In certain embodiments, the adding of the coagulant and/or flocculant is performed under mixing. However, other technologies may exist that will eliminate the need for the coagulant and/or flocculant to be added under mixing. Such a technology may be nozzles for dispersing such as Nalco PARETO Technology, available from Nalco Company, 1601 West Diehl Road, Naperville, Illinois 60563, USA, or other similar technologies.

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EXAMPLES

The following examples are given to allow better understanding of the disclosure. These examples are not to be construed as narrowing the scope of the disclosure beyond that of the language of the allowed claims.

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Example 1:

A sludge sample (2.1% total suspended solids ("TSS")) was taken from a municipal WWTP. The onsite dewatered sludge had a sludge cake solids content of 16.5 %. The cationic flocculant was selected from Nalco Core Shell® line of flocculants. The sludge sample and polymer solution were mixed by a jar tester, and the capillary suction time ("CST") of the conditioned sludge was recorded. The optimal polymer dosage was determined as the polymer

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concentration with the lowest CST value. The conditioned sludge was then dewatered in a laboratory filtration device which simulates industrial belt press equipment. The resulting sludge cake was dried at 105°C until a constant weight and solid content was analyzed. As can be seen from FIG. 1, the flocculant-only conditioning method had sludge cake solid around 16%, and the content was increased to around 19% with 133 ppm polymeric coagulant (a hexamethylenediamine cross-linked Epi-DMA having a molecular weight of approximately 1.5 million Daltons), and further increased to around 20% with 266 ppm coagulant. The optimal flocculant dosage is reduced from approximately 120–200 ppm, to 30–90 ppm. Total sludge volume reduction is about 16% at a 133-ppm coagulant concentration.

Example 2:

A sludge sample (3.7% TSS) was taken from an oil refinery WWTP. The onsite dewatered sludge had sludge cake solids content of 15.6%. The experimental protocol was similar to that of Example 1. As can be seen from FIG. 2, the coagulant plus flocculant program had a sludge cake solids content around 21%, which is 4–6% higher than the flocculant only program. The use of the coagulant plus flocculant yielded a sludge total volume reduction of about 20%.

All patents referred to herein, are hereby incorporated herein by reference, whether or not specifically done so within the text of this disclosure.

In the present disclosure, the words “a” or “an” are to be taken to include both the singular and the plural. Conversely, any reference to plural items shall, where appropriate, include the singular.

All ranges and parameters disclosed herein are understood to encompass any and all subranges assumed and subsumed therein, and every number between the endpoints. For example, a stated range of “1 to 10” should be considered to include any and all subranges between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges beginning with a minimum value of 1 or more (*e.g.*, 1 to 6.1), and ending with a maximum value of 10 or less (*e.g.*, 2.3 to 9.4, 3 to 8, 4 to 7), and finally to each number 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 contained within the range.

From the foregoing it will be observed that numerous modifications and variations can be

effectuated without departing from the true spirit and scope of the novel concepts of the present disclosure. It is to be understood that no limitation with respect to the illustrated specific embodiments or examples is intended or should be inferred. The disclosure is intended to cover by the appended claims all such modifications as fall within the scope of the claims.

CLAIMS

We claim:

1. A method of treating a water-containing sludge, the method comprising:
 - providing the water-containing sludge;
 - mixing a polymeric coagulant selected from the group consisting of a copolymer of epichlorohydrin and dimethylamine, a homopolymer of diallyldimethylammonium chloride, and a combination thereof, with the sludge thereby producing a coagulated sludge;
 - mixing a cationic flocculant with the coagulated sludge thereby producing a flocculated coagulated sludge;
 - removing at least a portion of the water from the flocculated coagulated sludge.
2. The method of claim 1, wherein the polymeric coagulant comprises an epichlorohydrin and dimethylamine that is cross-linked by a cross-linking agent.
3. The method of claim 2, wherein the cross-linking agent is selected from the group consisting of ammonia, primary amines, alkylene diamines of from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, and a combination thereof.
4. The method of claim 3, wherein the cross-linking agent comprises an alkylene diamine of from 2 to 6 carbon atoms.
5. The method of claim 4, wherein the alkylene diamine of from 2 to 6 carbon atoms is hexamethylenediamine.
6. The method of claim 1, wherein the polymeric coagulant has a molecular weight in the range of one hundred thousand Daltons to three million Daltons.
7. The method of claim 1, wherein the polymeric coagulant is mixed with the sludge at a concentration of greater than 10 ppm but less than 800 ppm by weight.
8. The method of claim 1, wherein the removing the water is performed by a physical process.

9. The method of claim 8, wherein the physical process is selected from the group consisting of filtration, centrifugation, and combinations thereof.
10. The method of claim 1, wherein the polymeric coagulant and the sludge are pre-mixed prior to mixing the cationic flocculant.
11. The method of claim 1, wherein the sludge comprises a biological sludge, a primary sludge or a mixture of biological and primary sludge.
12. The method of claim 1, wherein the cationic flocculant comprises a polyacrylamide-based cationic polymer.
13. A method of treating a water-containing sludge, the method comprising:
 - providing the water-containing sludge;
 - mixing a polymeric coagulant selected from the group consisting of a copolymer of epichlorohydrin and dimethylamine, a homopolymer of diallyldimethylammonium chloride, and a combination thereof, with the sludge thereby producing a coagulated sludge;
 - mixing a cationic flocculant with the coagulated sludge thereby producing a flocculated coagulated sludge;
 - removing at least a portion of the water from the flocculated coagulated sludge;
 wherein the polymeric coagulant comprises an epichlorohydrin and dimethylamine that is cross-linked by a cross-linking agent selected from the group consisting of ammonia, primary amines, alkylene diamines of from 2 to 6 carbon atoms, polypropylenepolyamines, polyethylenepolyamines, and a combination thereof;
 wherein the polymeric coagulant has a molecular weight in the range of one hundred thousand Daltons to three million Daltons; and
 wherein the polymeric coagulant is mixed with the sludge at a concentration of greater than 10 ppm but less than 800 ppm by weight.

14. The method of claim 13, wherein the cross-linking agent comprises an alkylene diamine of from 2 to 6 carbon atoms.
15. The method of claim 14, wherein the alkylene diamine of from 2 to 6 carbon atoms is hexamethylenediamine.
16. The method of claim 13, wherein the removing the water is performed by a physical process.
17. The method of claim 16, wherein the physical process is selected from the group consisting of filtration, centrifugation, and combinations thereof.
18. The method of claim 13, wherein the polymeric coagulant and the sludge are pre-mixed prior to mixing the cationic flocculant.
19. The method of claim 13, wherein the sludge comprises a biological sludge, a primary sludge or a mixture of biological and primary sludge.
20. The method of claim 13, wherein the cationic flocculant comprises a polyacrylamide-based cationic polymer.