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40 Title: IMPROVED DISINFECTION EFFICIENCY OF WASTEWATER TREATMENT

41 Abstract: Disclosed herein is an improved wastewater treatment system and methods that synergistically integrate at least two different modes of disinfecting wastewater. Embodiments of the invention provide an unexpected efficiency of ridding wastewater of pathogens with much lower, and in turn, less expensive dosages, than could be achieve with either mode of disinfecting alone. Embodiments of the invention achieve a more efficient and less costly means of obtaining class A or class B biosolids.
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BACKGROUND

Biosolids are created through the treatment of domestic wastewater generated from sewage treatment facilities. The treatment of biosolids can actually begin before the wastewater reaches the sewage treatment plant. In many larger wastewater treatment systems, pre-treatment regulations require that industrial facilities pre-treat their wastewater to remove many hazardous contaminants before it is sent to a wastewater treatment plant. Wastewater treatment facilities monitor incoming wastewater streams to ensure their recyclability and compatibility with the treatment plant process.

Once the wastewater reaches the plant, the sewage goes through physical, chemical and biological processes which clean the wastewater and remove the solids. The wastewater treatment processes sanitize wastewater solids to control pathogens (disease-causing organisms, such as certain bacteria, viruses and parasites) and other organisms capable of transporting disease.

The federal biosolids rule is contained in 40 CFR Part 503. Biosolids that are to be land applied must meet these strict regulations and quality standards. The Part 503 rule governing the use and disposal of biosolids contain numerical limits, for metals in biosolids, pathogen reduction standards, site restriction, crop harvesting restrictions and monitoring, record keeping and reporting requirements for land applied biosolids as well as similar requirements for biosolids that are surface disposed or incinerated. Most recently, standards have been proposed to include requirements in the Part 503 Rule that limit the concentration of dioxin and dioxin like compounds in biosolids to ensure safe land application.

Biosolids are used to fertilize fields for raising crops. Agricultural use of biosolids, that meet strict quality criteria and application rates, have been
shown to produce significant improvements in crop growth and yield. Nutrients found in biosolids, such as nitrogen, phosphorus and potassium and trace elements such as calcium, copper, iron, magnesium, manganese, sulfur and zinc, are necessary for crop production and growth. The use of biosolids reduces the farmer's production costs and replenishes the organic matter that has been depleted over time. The organic matter improves soil structure by increasing the soil's ability to absorb and store moisture.

There are different rules for different classes of biosolids. Class A biosolids contain no detectible levels of certain pathogens, such as enteric virus or Helminth ova, and low levels of fecal coliform bacteria, which may or may not be pathogenic. Class A biosolids that meet strict vector attraction reduction requirements and low levels metals contents, only have to apply for permits to ensure that these very tough standards have been met. Class B biosolids are treated but still contain detectible levels of pathogens. There are buffer requirements, public access, and crop harvesting restrictions for virtually all forms of Class B biosolids.

Nutrient management planning ensures that the appropriate quantity and quality of biosolids are land applied to the farmland. The biosolids application is specifically calculated to match the nutrient uptake requirements of the particular crop. Nutrient management technicians work with the farm community to assure proper land application and nutrient control.

For biosolids to be categorized as Class A with respect to pathogens, they must meet one of six criteria:

1. Time and temperature requirements based on percentage of solids in the material.
2. pH adjustment accompanied by high temperature and solids drying.
3. Monitoring of enteric viruses and helminths after a treatment process to ensure below-detection concentrations.
4. Monitoring of enteric viruses and helminths in the biosolids at the time they are distributed or applied to land.
5. Treatment by a process for the further reduction of pathogens (PFRP).
8. Treatment in a process deemed equivalent to a PFRP. There are seven processes that are designated PFRPs for Class A biosolids: (a) composting with minimum time and temperature conditions, (b) heat drying with specified temperature and moisture conditions, (c) high-temperature heat treatment (no moisture content condition), (d) thermophilic aerobic digestion at specified time and temperature, (e) beta irradiation at specified dosage, (f) gamma irradiation at specified dosage, and (g) pasteurization. As with Class B biosolids, the EPA's Pathogen Equivalency Committee (PEC) has the authority to recommend to permit authorities that additional processes be designated PFRP. As of October 1999, nine additional processes were granted PFRP status by PEC (EPA 1999).

The goal of the treatment processes to achieve Class A biosolids is to reduce pathogen densities to below the following detection limits for these organisms: less than 1000 colony forming units (cfu) per 1 g of total solids (dry weight basis) for fecal coliform or less than 3 most probable number (MPN) per 4 g of total solids for Salmonella sp.; and less than 1 plaque-forming unit (PFU) per 4 g of total solids for enteric viruses; and less than one viable helminth ova per 4 g of total solids.

An estimated 1.47 billion persons are infected with the intestinal parasitic worm Ascaris lumbricoides, making it the third most common human infection. Adult Ascaris worms, measuring up to 12 in. in length, parasitize the intestinal tract of their host, competing for nutrition and potentially causing a range of other complications. Currently, an estimated 1.5 million children suffer from Ascaris infections that will result in permanent growth retardation, even if the infection is cured. Ascariasis is transmitted by eggs, which are excreted by infected individuals. During most types of wastewater treatment, Ascaris eggs are concentrated in the sludge by sedimentation, and this sludge must be treated prior to disposal or land application. The highest incidence of ascariasis occurs in regions with warm climates and poor sanitation, but even in the United States the concentration of eggs in wastewater sludge is high enough to significant problem. In addition to Ascaris, there are other
Helminths present in biosolids, such as *Toxocara*. *Toxocariasis* is also a cause of significant morbidity in the U.S. and other countries, especially among children. Radiation has been tested for treating sewage sludge. The effectiveness of using radiation in reducing pathogens is dependent upon the radiation dose and the type of radiation. The EPA guidelines for using radiation require that sewage sludge be treated with at least 1 megarad (10 kilogram). This dosage is required to effectively treat sludge so as to sufficiently reduce bacteria, helminth ova, and viruses. While irradiation of sludge is known to work to reduce pathogens, the use of irradiation intrinsically possesses certain disadvantages. For example, generating the doses needed requires expensive equipment, not only to generate the radiation but also to implement the shielding and processes necessary to protect the operators of the system. It also requires a substantial energy cost to run the system. For these and other reasons, there are relatively few wastewater treatment plants that use radiation for treating sewage sludge.

SUMMARY

The inventors have developed a new system and method of treating wastewater that is quick and efficient, and that reduces start-up and operational costs, while achieving biosolids that meet Class A standards. According to one embodiment, the invention pertains to a method of treating solids containing wastewater sample that involves administering a dosage of chlorine dioxide to achieve 30-300 mg/L of ClO₂ in the sample. In typical embodiments, the solid content of the solids containing wastewater sample is 5 percent or less. A dosage of 500-9000 Gy is coadministered before dewatering, or can be administered following dewatering of the wastewater sludge to produce a treated biosolids cake. In the first instance, i.e., prior to dewatering, the solid content of the solids containing wastewater sample is 5 percent or less. In the second instance, i.e., post dewatering, the solids content of the biosolids cake can be from 12 to 30%.

In a specific embodiment, the solids containing wastewater sample is waste activated sludge (WAS) containing between 1-3 percent solids. WAS is a solid containing wastewater sample that has been subjected to biological
treatment and/or clarification. Biological treatment involves the removal of biosolids dissociated nutrients. Clarification involves the separation of an effluent component that contains a negligible amount of biosolids (e.g., < 1%) and a biosolids containing component. Biological treatment is typically conducted by an oxidation ditch or a sequential batch reactor. The term "coadministering" or "coadministered" means that the ClO₂ is administered to the solids containing wastewater sample before, during or after the administration of the radiation dosage.

According to another embodiment the invention pertains to a wastewater treatment system that includes a headworks for receiving raw sewage wastewater having biosolids and a biological treatment station that is in fluid communication with said headworks. The system also includes a clarifier in fluid communication with the headworks for concentrating biosolids from the raw sewage wastewater. In a typical embodiment, the clarifier is in fluid communication with and downstream of the biological treatment station. Once the raw sewage wastewater has been subjected to biological treatment and clarification, the biosolids sample is considered to be waste activated sludge (WAS). Typically, the WAS contains anywhere from 0.5 to 5 percent biosolids. In a specific embodiment, the biosolids content of the WAS is 1-3 percent. The system also includes a first conduit for transporting WAS away from the clarifier. The oxidant addition is associated with the first conduit so as to deliver a predetermined dosage of chlorine dioxide, or other oxidant (e.g. to the WAS in the first conduit). A radiation source can be associated with this first conduit so as to deliver a predetermined dosage of radiation to this same treatment stream. In another embodiment, the oxidant addition is associated with the first conduit, and the radiation source is associated with a second conduit after the biosolids sample is dewatered to produce a biosolids cake. The system is equipped with a chlorine dioxide source associated with the conduit so as to deliver a predetermined dosage of chlorine dioxide. The predetermined dosages of the radiation and chlorine dioxide are such that the WAS is considered to meet either class A or class B standards with respect to pathogen content. Following radiation and chlorine dioxide treatment, the WAS is considered to be a treated biosolids sample. Optionally, the system also includes a dewatering device (e.g., a belt filter press or centrifuge device)
in fluid communication with the first conduit for further removing water from the treated biosolid sample. Moreover, the system optionally includes a second conduit for transporting the concentrated treated biosolid sample from the dewatering device.

The inventors have made the unexpected surprising discovery that radiation and chlorine dioxide work synergistically together so as to allow much lower dosages of each. It is known that the dose of radiation needed to meet EPA requirements of disinfection is 10 kGy. This dosage has been shown to inactivate Helminth ova (Ascaris), enteric virus (e.g., poliovirus) and fecal coliform bacteria to Class A standards (<1, <1 and <1,000, respectively). The inventors have discovered that it is possible to lower Helminth ova to Class A standards by using only 1000 Gy (1/10th of a kilogram) or lower, however the lower dosage of radiation can be insufficient to lower enteric virus content. Conversely, the inventors have discovered that dosages of chlorine dioxide in excess of 1000 mg/L are not sufficient to inactivate helminth ova in biosolids. However, chlorine dioxide is quite effective at lowering viral and bacterial content of biosolids. In light of these discoveries, the inventors have developed a new process of treating WAS that utilizes low dosages of radiation (500-9000Gy) and low dosages of chlorine dioxide (50-300 mg/l, or any integers therein, concentration of treated sample) at a contact time sufficient to reduce the chlorine dioxide, which in turn achieves biosolids meeting Class A standards. Embodiments of the invention substantially decrease the set up and operational costs of producing Class A or Class B biosolids from primary or secondary wastewater.

Alternatively, depending on the configuration of a particular wastewater treatment facility, the process can be used to treat digested sludge, i.e., sludge that has been treated in an anaerobic or aerobic digester, to produce class A biosolids. In a specific embodiment, primary wastewater, i.e., wastewater not subjected to biological treatment, is transported directly to a digester to produce digested sludge. The digested sludge is then subjected to an oxidant treatment zone and an irradiation treatment zone to produce pathogen reduced sludge. The pathogen reduced sludge can then be subject
to dewatering and/or disposed of properly. In another embodiment, primary or secondary sludge can be subjected to an oxidant treatment zone prior to digestion, and an irradiation treatment zone after dewatering. Secondary sludge is sludge that has undergone biological treatment.

In a specific embodiment, the dosages of radiation that are used in combination with oxidant treatment are 800-6000 Gy, or any integer in between. In a more specific embodiment, the dosages of radiation used are 900-5000 Gy. Even more specifically, the dosages are 1000-4000 Gy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic of a wastewater treatment system that utilizes radiation producing component and a chlorine dioxide generating device.

FIG. 2 shows a cross-sectional view of a radiation emitter embodiment that is positioned adjacent to a WAS conduit.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

A specific example of a wastewater treatment system for producing a Class A Biosolid sample is shown in FIG. 1. In this specific example, wastewater 108 first enters the headworks 110 and then is transferred to a biological treatment station 115. The biological treatment station 115 functions primarily to remove biosolid-dissociated nutrients (and a low percentage of biosolid-associated nutrients) in the wastewater to produce a nutrient-reduced wastewater sample 116. The nutrient-reduced wastewater sample 116 is transferred to a clarifier 120, where the nutrient-reduced wastewater sample 116 is separated into an effluent component 121 and a WAS component 122. The effluent component 121 is either returned to the headworks 110 or is discarded.
According to scheme I., the WAS component 122 is transported in a conduit 124 and subjected to an irradiation zone 123 and an oxidant treatment zone 125 that is fed by an on-site oxidant generator 127 in fluid communication with the oxidant treatment zone 125. The irradiation zone 123 includes a radiation producing device 129 that delivers ionizing radiation to the irradiation zone 125 thereby exposing radiation to a specific area of WAS in the conduit 124. The water content of the WAS 122 is between 0.5 to 5 percent solids. The conduit 124 may also include a settling tank 143 which is a device that enables decanting of water off the top from solids that have settle more toward the bottom. The settling tank assists in further concentrating the solids content of the WAS as desired. Following, oxidant treatment and irradiation treatment, the WAS 122 is transported to a dewatering device 140 (such as a belt filter press or centrifuge device) where more water is removed from the WAS to achieve a concentrated biosoioids sample 141 having 12-30 percent biosoioids. The, concentrated biosoioids sample achieved following the dewatering station 140 has reduced pathogen content and can be classified as Class A or Class B by set regulatory standards, which is dependent upon the dosages of oxidant and irradiation subjected to the WAS.

According to scheme III, WAS 122 is transported in conduit 124 and subjected only to the oxidant treatment zone 127. The WAS is then transported to the dewatering device 140 where further water is removed to achieve a concentrated biosoioids sample 141. Following dewatering, the biosoioids sample 141 is transported away from the dewatering device via conduit 185, where it is subjected to irradiation zone 183 in which ionizing radiation is delivered by radiation producing device 169. The conduit 165 may be a pipe, ditch, shunt or conveyor. As a result, the biosoioids sample 141 is sufficiently devoid of pathogens so as to be able to be classified as Class A or Class B biosoioids.

According to an alternative embodiment, scheme IV, raw wastewater is delivered to a digester 184, either prior or after biological treatment. The raw wastewater is treated in the digester 184 to produce digested sludge 192.
The digested sludge may have 0.5 to 5 percent biosolids. A conduit 184 transports digested sludge 192 away from the digester 184. The conduit 164 includes a oxidant treatment zone 155 and an irradiation treatment zone 153. An oxidant generator 157 and radiation producing device deliver the predetermined dosages to each the oxidant treatment zone 155 and the irradiation treatment zone 153, respectively. The digested sludge 192 is transported to a dewatering device 140, where further water is removed to obtain a concentrated biosolids sample 141 that may be classified as Class A or Class B biosolids.

FIG. 2 shows a cross-section of a conduit having a radiation emitter adjacent thereto. The conduit 124 is shown with WAS 122 passing therethrough. The radiation emitter 205 is positioned proximate to the conduit 124 to emit ionizing radiation 210 into a zone in the conduit 124. The conduit may be a closed pipe made of a radiation permeable material or a pipe having an exposed portion. An area at least partially surrounding the conduit 124 is shielded by shield 215 so as to prevent undesired escape of ionizing radiation 210 into the surrounding environment. The embodiment shown in FIG. 2 is not intended to be limiting. Those skilled in the art will appreciate that there are other configurations by which ionizing radiation can be administered to the wastewater sample in view of the teachings herein.

While one or more embodiments of the present invention have been shown and described herein, such embodiments are provided by way of example only. Variations, changes and substitutions may be made without departing from the invention herein. Accordingly, it is intended that the invention be limited only by the spirit and scope of the appended claims.
CLAIMS

What is claimed is:

1. A method of treating a solids containing wastewater sample that comprises administering a dosage of ClO$_2$ to the wastewater sample to achieve ClO$_2$ 50-300 mg/L in the wastewater sample and coadministering a dosage of ionizing radiation of 500-9000 Gy to the wastewater sample.

2. The method of claim 1, wherein the wastewater sample contains 5 percent or less solids.

3. The method of claim 1, wherein the wastewater sample contains 5 percent or less solids at the time of administration of the chlorine dioxide, and 12-30% during the administration of the radiation.

4. The method of claim 1, wherein the wastewater sample is waste activated sludge (WAS).

5. The method of claim 4, wherein the WAS contains 0.5-5 percent solids.

8. The method of claim 1, wherein the method further comprises obtaining a raw sewage wastewater sample; subjecting the raw sewage wastewater sample to a biological treatment to produce a biologically treated sample; subjecting the biologically treated sample to a clarifier to obtain an effluent sample and a waste activated sludge sample, wherein the waste activated sludge sample is subjected to said administering and coadministering steps.

7. The method of claim 1, wherein said coadministering step comprises administering 900-6000 Gy to the wastewater sample.

8. The method of claim 1, wherein the administering step comprises administering 1000-5000 Gy.
9. The method of claim 1, wherein said radiation is any form of ionizing radiation.

10. The method of claim 9, wherein the ionizing radiation is gamma radiation, beta radiation, x-ray radiation and e-beam radiation.

11. A wastewater treatment system, said system comprising

   a first conduit for transporting a solids containing wastewater sample;

   a chlorine dioxide generating component in fluid communication with said first conduit so as to deliver a dosage of chlorine dioxide to chlorine dioxide zone said conduit, wherein said dosage of chlorine dioxide is such to achieve 50-300 mg/l chlorine dioxide in said wastewater solids sample in said chlorine dioxide zone; and

   a radiation producing device adjacent to said conduit so as to deliver a dosage of ionizing radiation to an irradiation zone in said conduit, wherein said radiation producing device delivers 500-9000 Gy of ionizing radiation to said irradiation zone.

12. The system of claim 11, further comprising a clarifier in fluid communication with said first conduit and upstream of said chlorine dioxide treatment zone and irradiation treatment zone, said clarifier concentrates solids in solid containing wastewater to produce a solids content of 0.5 to 5 percent.

13. The system of claim 12, further comprising a headworks in fluid communication with said clarifier and upstream thereof for filtering nonbiological debris from raw wastewater entering the same.

14. The system of claim 11, further comprising a biological treatment station in fluid communication with said headworks and clarifier, said biological treatment station removing nutrients from raw wastewater.
15. The system of claim 12, further comprising a settling tank in fluid communication with said conduit and upstream of said chlorine dioxide treatment and irradiation treatment zones, said settling tank assisting in further concentrating solids content of solids containing wastewater.

16. The system of claim 11 further comprising a dewatering device for further concentrating solids in solids containing wastewater, said dewatering device downstream of said chlorine dioxide treatment zone.

17. A wastewater treatment system, said system comprising

   a first conduit for transporting a solids containing wastewater sample;

   a chlorine dioxide generating component in fluid communication with said first conduit so as to deliver a dosage of chlorine dioxide to chlorine dioxide zone said conduit, wherein said dosage of chlorine dioxide is such to achieve 50-300 mg/l chlorine dioxide in said wastewater solids sample in said chlorine dioxide zone;

   a dewatering device for concentrating solids in said solids containing wastewater to produce a concentrated biosolids sample, said dewatering tank downstream of said chlorine dioxide treatment zone;

   a second conduit for transporting a concentrated biosolids sample from said dewatering device; and

   a radiation producing device adjacent to said second conduit so as to deliver a dosage of ionizing radiation to an irradiation zone in said conduit, wherein said radiation producing device delivers 500-9000 Gy of ionizing radiation to said irradiation zone.

18. The system of claim 17, wherein said second conduit is a pipe, ditch or conveyor belt.

19. The system of claim 17, wherein said wastewater solids sample comprises 0.5 to 5 percent solids and said concentrated biosolids sample comprises 12-30 percent solids.
20. The system of claim 12, further comprising a settling tank downstream of said clarifier but upstream of said chlorine dioxide treatment zone.

21. A method of treating a solids containing wastewater sample that comprises administering a dosage of any suitable chemical oxidant to the wastewater sample to achieve concentration of 50-300 mg/L in the wastewater sample and coadministering a dosage of ionizing radiation of 500-9000 Gy to the wastewater sample.

22. The method of 21, wherein said wastewater sample comprises primary sludge, secondary sludge or WAS.

23. The method of claim 22, further comprising subjecting said wastewater sample to digestion and to dewatering, wherein said administering step occurs prior to said digestion, and said coadministering step occurs after dewatering.

24. The method of claim 21, wherein said suitable chemical oxidant comprises chlorine dioxide, ozone, or sodium hypochlorite, or a combination thereof.

25. The method of claim 24, wherein said chemical oxidant is chlorine dioxide.