SLUDGE TREATMENT TECHNOLOGIES

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Contents

Summary

Sewage sludge is generated as a result of treating municipal wastewater to remove organic and inorganic impurities from dilute solutions. The treatment results in concentrating the impurities into a smaller volume of liquid, called sludge. The main processes involve sludge stabilisation, dewatering and incineration. The major objective of stabilisation is to make the sludge less odorous and putrescible, and to reduce the pathogenic organisms. The processes of stabilisation include aerobic digestion, anaerobic digestion, thermo-chemical treatment and chemical treatment. Dewatering of sludge plays a crucial role, both operationally and economically, particularly when the methods of disposal involve landfill disposal or heat treatment combined with subsequent disposal of the residues. There are different types of dewatering processes namely cntrifugal dewatering, centripress, centridry, belt filter dewatering, chamber filter press, membrane chamber filter press. Incineration of sludge is becoming an acceptable treatment alternative, due to a high volume reduction, possible energy recovery, and some toxic destruction or reduction. This option is gaining more attention with the advent of proper air pollution control devices and highly effective flue gas cleaning systems.

1. Introduction

Sewage sludge is generated as a result of treating municipal wastewater to remove organic and inorganic impurities from dilute solutions. The treatment results in concentrating the impurities into a smaller volume of liquid, called sludge. Normally sewage sludge is a mixture of primary sludge from primary clarifier and biological sludge from biological treatment units. If the treatment process includes tertiary

treatment, then sewage sludge may also include tertiary sludge. Thus, sewage sludge is the concentrated form of impurities extracted from domestic wastewater, in the attempt to improve the quality of the effluent. The proper management of sludge during its disposal holds the key for the success of any wastewater treatment operation.
Dumping has been the most common disposal method for sewage sludge. However, this practice is limited due to lack of dumping sites, problems in handling, increasing costs and government regulations. These have provided the impetus for new methods in sewage sludge management. Whereas in the past locally organised disposal practices have been sufficient, requirements for future sludge management will demand more regional management concepts.

Depending on the specific local and regional situations, sewage sludge management and disposal options can be broadly categorised into the following:

- Disposal without any treatment
- Disposal after treatment
- Utilisation for recycle and reuse of nutrients and other resources, with or without treatment

The disposal of sewage sludge without any treatment is more suited to land fill disposal. There are plenty of treatment options available, which depend mainly on the ultimate disposal goal. By far, the most desirable option for management of sewage sludge is to utilise it as a resource so that the nutrient and other resources, which are the constituents of sludge, will be recycled. The most important treatment processes are sludge stabilisation, dewatering, incineration, composting, and drying.

2. Sludge Stabilisation

The major objectives of stabilisation are to make the sludge less odorous and putrescible, and to reduce the pathogenic organisms. Primary processes of stabilisation are aerobic digestion, anaerobic digestion, thermo-chemical treatment and chemical treatment. Application of thermo-chemical stabilisation is very limited. The application of aerobic digestion, which uses extended aeration process for stabilisation until now, has also been limited to small and medium size treatment plants, due to its energy-intensive nature.

Wet oxidation also is one of the aerobic sludge digestion process in which the sludge is oxidized in a deep shaft reactor. In this process, organic and partly inorganic compounds get oxidized in a 1250 cm deep tube reactor at temperatures up to 280^{o}C and a pressure of 8.5-11 MPa under injection of pure oxygen. The products remaining from the oxidation process are the process gas and a suspension with water and solids. The process gas undergoes catalytic post-oxidation for treatment for carbon monoxide and hydrocarbons. The suspension gets dewatered in a chamber filter press with the process water being treated in a multiple stage wastewater treatment plant i.e., biological wastewater treatment for nitrification/denitrification. The sludge cake, which contains very low concentrations of organic matter at 10-25% gets disposed off to landfill sites. The disadvantages in this process are the geo-technical reliability and the operation and maintenance security with limited access to the process.

The most practiced process for stabilisation has been anaerobic digestion. During anaerobic digestion, the sludge is stabilised through biological degradation of complex organic substances in the absence of free oxygen. Typically, 25-45% of the raw sludge solids are destroyed during anaerobic digestion through conversion to methane, carbon dioxide, water and soluble organic material. Most commonly, anaerobic digesters are operated between the mesophilic temperature range of 32-35^{o}C. Thermophilic digestion operating in the range of 50-60^{o}C has high efficiency, but require a high-energy input. The recommended average detention time for conventional anaerobic mesophilic digesters is 20-30 days and for high rate digesters, it ranges from 15-20 days. The detention time for thermophilic digesters, on the other hand, is 3-5 days. The major advantages of anaerobic digestion process include;

- A 25-45% reduction in the volume of sludge,
- Generation of methane rich biogas, which can be used as a fuel, and
- Inactivation of pathogens
- The disadvantages are;
- High capital cost requirement, and
- Sensitivity of anaerobic micro-organisms to environmental conditions

Aerobic composting is a method of sludge stabilisation in which sludge organics are decomposed by the micro-organisms in the presence of oxygen. The result of sludge composting is a humus like product that can be used, for example, as a soil amendment, for erosion control, as mulch, or other soil like products. The types of sludge that can be composted include both digested and undigested primary and secondary sludge. Composting can be practiced only for sludge or a mixture of sludge with municipal solid waste.

Aerobic composting depends on several operational parameters, which include oxygen availability within the compost, moisture content, temperature, and biodegradable volatile solid content of the compose. For adequate air supply, composting systems use methods of forced aeration, addition of bulking agents such as rice straw, wood chips, saw dust etc. or turning of pile. The composting of sludge can be carried out within a reactor (in-vessel system) or in the open (non-reactor system). During decomposition of volatile organics the temperature produced within the compost ranging from 50-70^{o}C. At this high temperature, moisture is evaporated and pathogenic organisms in the compost are inactivated. The temperature must be maintained for a minimum duration of time in order to be effective in destroying pathogens.

3. Sludge Dewatering

The mechanical dewatering of sludge plays a crucial role, both operationally and economically, particularly when the methods of disposal involve landfill disposal or heat treatment combined with the subsequent disposal of the residues. The dewatering process significantly increases the solid content and reduces the volume of sludge. The makes the sludge treatment process more competitive as a reduction in volume leads to a smaller amount for any subsequent treatment processes and transportation. This is particularly so when thermal treatment is part of the sludge treatment process. Factors affecting dewaterability of sludge are:

- Catchment area and general sewerage treatment scheme.
- Efficiency of screening and grit removal processes during treatment.
- Sludge load and carbon:nitrogen:phosphorus ratio.
- Detention time in secondary clarifier.
- Type and efficiency of the sludge stabilisation process adopted.
- Dry solids (DS) content of sludge.

DS content of sludge is basically used as the indicator for efficiency of dewatering processes. DS is measured as solids concentration on dry weight basis. General classification of dewaterability based on DS is presented in Table 1

Dewaterability	**Percentage of dry solids**
Good	26 - 30
Sufficient to medium	22 - 26
Bad	8 - 22

Table 1 Sludge dewaterability classification

There are different types of dewatering processes such as,

- Centrifugal dewatering
- Centripress
- Centridry
- Belt Filter Dewatering
- Chamber Filter Press
- Membrane Chamber Filter Press

Centrifugal dewatering is a process by which centrifugal force is applied to bring about the separation of solids from the liquid in the sludge. Dewatering is accomplished through clarification and solids compaction.

In the Centripress process, clarification and compaction of sediments occur simultaneously. This system has been developed with the aim of combining the well-known principle of continuously operated centrifuges with the dewatering performance achieved by filter presses. It can achieve dewatered sludge DS concentration of between 20-40%.

Centridry is the combination of several dewatering steps in one continuous, compact, enclosed process and is an improvement over the centripress technology. Here, the dewatered sludge is further dried by heated air resulting in DS concentration of 60-90%. The heated air is generated using a number of alternative fuels depending on what is available at a particular site.

Belt filters employ single or double moving belts made of woven synthetic fibre to dewater sludge continuously. The belt passes over and between rollers to exert increasing pressure on the sludge as it moves between the belts. A high pressure belt filters can achieve a DS concentration of 20-35%, by application of pressure upto

1500KPa.

The chamber filter press consists of series of parallel plates, each fitted with filter cloth and rigidly held together in a structural frame. The sludge is pumped at high pressure in between the plate packs and the plates are compressed by a hydraulic closing device, thereby dewatering the sludge.

In membrane chamber filter presses, sludge holding chambers are formed by filter cloth on one side and a membrane plate on the other side. The filter presses can achieve a DS efficiency of 25-40%.

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Bibliography

Alt, C., (1982). On the prediction of capacities and efficiencies of continuous decanter centrifuges, in Harnessing Theory for Practical Application, 3rd World Filtration Congress, Downington, Pa, 1982, 364. [This paper presents technical and operational details of continuous decanter centrifuges]

Alt, C. (1989). Centrifuges for Sludge Treatment, Cp 14 in Water Wastewater and Sludge Filtration, by Vigneswaran, S., and Ben Aim, R., CRC Press, Boca Raton, Florida, 1989. [This chapter presents all the technical and operational details of centrifuges with data from operating plants.]

Alt, C., and Gosele, (1982). W., Einsatzkriterien fur Dekanter, Chem. Ing. Tech., 5, 425, 1982. [This paper presents the diagram of the solid ball centrifuge.]

Henderson, R. T., Schultz, S. T., Itnyre, M. (1999). Centrifuges Versus Belt Presses in San Bernardino, California." 1999 WEF/AWWA Joint Residuals and Biosolids Management Conference: Strategic Networking for the 21st Century. Charlotte, NC. [This paper provides the operational conditions of centrifuges and belt press.]

Hooton, J. A. and Thomas, C. M., (1969). Filter Presses, in Process Engineering Technique Evaluation-Filtration, Suttle, H. K., Ed., Morgan-Grampian Publishers, Kent, England, 1969, 11.

Ireland, J. S. and Balchunas, B. M. (1998). High-Speed, High-Solids Centrifuges: Sorting Through Mechanical Features, Manufacturers' Claims, and Owners' Opinions. Water Environment & Technology, Vol. 10, Num. 10, October 1998, pp. 32-38. [This paper provides the various centrifuge manufacturers and the operational conditions of centrifuges.]

Jones, B. R. S., (1956). Vacuum sludge filtration II. Prediction on filter performance, Sewage Ind. Wastes, 28, 1103, 1956. [This paper provides the operational conditions and performance of vacuum sludge filtration.]

Kemp, J. S. (1997). Just the Facts on Dewatering Systems: A Review of the Features of Three Mechanical Dewatering Technologies. Water Environment & Technology. Vol. 9, Num. 12, December 1997. [This paper provides a detailed review of mechanical dewatering technologies.]

Leber, R. S. and Garvey, D. (2000). Centrifuge or Belt Press? Odour Control May Be a Pivotal Factor." WEF 14th Annual Residuals and Biosolids Management Conference. 27th Feb-1 March, 2000, Boston. [This paper provides the operational conditions of centrifuges and belt press.]

Moir, D. N., (1982). Selecting batch filters, Chem. Eng., 89, 47, 1982. [This is a practical paper giving rational ways of selecting filters for dewatering.]

Spinosa, L., (1986). Design and operation of dewatering equipment. in: Proceedings of the Course Notes at 4th World Filtration Congress, Ostend, 1986. [This course notes gives extensive details on the design and operation of the three different dewatering techniques discussed in this chapter.]

Sugaya, K., (1987). Private communication, Ishigaki Mechanical Industry Co., Tokyo, 1987. [This gives information on the pressure filter used in Ishigaki Mechanical Industry Co., Tokyo.]

Treffry-Goatley, K., Buchan, M. I., Rencken, G. E., Vortman, W. J., Buckley, C. A. (1987). The dewatering of sludges using a tubular filter press, Desalination, Volume 67, December 1987, pp. 467-479. [This paper provides the details on a prototype tubular filter press plant designed to dewater sludge from a treatment plant for surface water.]

US EPA (2000). Biosolids Technology Fact Sheet Centrifuge Thickening and Dewatering. United States Environmental Protection Agency, Office of Water Washington, D.C., EPA 832-F-00-053, September 2000. [This paper provides the Various centrifuge manufacturers and the operational conditions of centrifuges and belt presses.]

Vigneswaran, S., and Ben Aim, R., (1989). Water Wastewater and Sludge Filtration, CRC Press, Boca Raton, Florida, 1989. [This book presents all the technical and operational details of different filtration technologies used in wastewater and sludge treatment.]

Wakeman, R. J., (2007). Separation technologies for sludge dewatering, Journal of Hazardous Materials 144 (2007) 614-619. [This paper presents the separation technologies for sludge dewatering with details on operating parameters and performances.]

Water Environment Federation, (1992). Operation and maintenance of sludge dewatering systems: manual of practice no. OM-8, 1992. [This document provides all the details on operation and maintenance of all three sludge dewatering systems discussed in this chapter.]

Biographical Sketches

Dr S. Vigneswaran has been working on water and wastewater treatment and reuse related research since 1976. During the last twenty years, he has made significant contributions in physico-chemical water treatment related processes such as filtration, flocculation, membrane-filtration and adsorption. His research activities both on new processes development and mathematical modeling are well documented in reputed international journals such as Water Research, American Institute of Chemical Engineers Journal, Chemical Engineering Science, Journal of American Society of Civil Engineers, and Journal of Membrane Science. He has also been involved in a number of consulting activities in this field in Australia, Indonesia, France, Korea, and Thailand through various national and international agencies. He has authored two books in this field at the invitation of CRC press, USA, and has published more than 230 papers in journals and conference's proceedings. Currently a Professor of the Environmental Engineering Group at the University of Technology, Sydney, he was the founding Head of and the founding Co-ordinator of the University Key Research Strength Program in Water and Waste Management. He is coordinating the Urban Water Cycle and Water and Environmental Management of the newly established Research Institutes on Water and Environmental Resources Management and Nano-scale Technology respectively.

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