Sludge Hygienization Plant with Electron Beam

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1. Introduction

The sludge resulting from municipal wastewater treatment can be used as a soil conditioner. However, it contains bacteria and other micro-organisms, and should be disinfected prior to use. Ionizing Radiation has the ability to inactivate the pathogens with a very high degree of reliability. Accelerated electrons interact with matters, thus causing cell death.

Digested sludge from municipal wastewater treatment plant has been used directly for agriculture in Israel, however, owing to the infection by pathogenic micro-organisms, the sludge must be processed to reduce the number of pathogens, and the radiation is the solution.

An industrial scale plant with the capacity to treat 5 m^3 of dewatered sludge per hour (18% solid contents) with 10 kGy has been planned in municipal wastewater treatment facility Bet Shemesh. This plant will be equipped with an electron accelerator (1.5MeV, 20kW) and handling facilities, and is expected to be more economical than other sludge disposal processes, such as incineration, lime stabilization, etc.

2. Experimental Methods

2.1 Pilot Scale Sludge Treatment

Continuous electron beam irradiation of sludge cake under electron accelerator was developed with sludge handling system. The electron accelerator used in this experiment was transformer-rectifier type high-voltage electron accelerator ELV-8 (EB Tech Co., Ltd.). Its maximum accelerating voltage and beam current were 2.5MeV and 40mA, respectively.

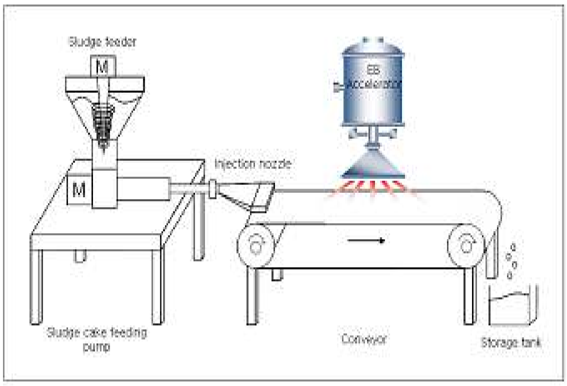

Fig. 1. Pilot electron beam irradiation system for sludge treatment, with the maximum feed rate of 500 kg/h.

Continuous electron beam irradiation system of sludge cake is shown in Fig. 1. The sludge cake is transferred through the flat nozzle from sludge hopper to irradiation conveyor belt made of thin stainless steel mesh, and spread to desired thickness. This system was setup under the scan horn of electron accelerator in the irradiation room. The width of the nozzle was 20-40cm and sludge thickness was adjusted to be 3-5mm. The maximum feed rate of sludge is 500 kg/h.

2.2 Dose Measurement

The absorbed dose distribution at conveyor surface was measured with a commercial CTA dosimeter. The stacked CTA film was fixed on moving conveyor under the scan horn and irradiated at various beam energies. After irradiation, absorbed doses of the film were then measured with UV Spectrophotometer at a wave length of 280nm. To evaluate the radiation dose of the sludge sample, the dose calculation program (base on the same film dosimeter) was used.

2.3 Microbial Test

A various methods based on U.S. EPA and other standards for measuring bacteria and micro-organisms were used in the laboratory. Survival fraction of total coliform, fecal coliform, E. coli and Salmonella were the indices of hygienization effects after irradiation. As a hedge against this uncertainty, in addition to using the EPA's "most probable number" (MPN) technique, composted samples were also examined under a different cultural method specifically for E. coli by plating on MUG agar.

Low MPN of fecal coliform (<1000 MPN per gram dry solids), very low MPN of Salmonella (<3 MPN per 4 g solids) and a negative result for E.coli (at a detection limit of 1 cell/25 g solids) will be interpreted as a sign of a very hygienic sludge.

3. Results and Discussions

3.1 Sludge Hygienization with Dose

The number of surviving coliforms and other micro-organisms were decreased almost exponentially with increasing radiation dose up to 3kGy, resulted in a reduction of 3 to 4 orders of magnitude in the total counts for coliforms and Salmonellae sp. whereas the fecal coliforms, and E-coli were reduced by 2 to 3 orders of magnitude. In case of 10kGy, the risks of pathogenic infection in the sludge were substantially eliminated. The required doses to reduce the number of coliforms to acceptable levels were ranged 5-10kGy, which was mostly dependent on the initial count. Therefore, based on the radio-sensitivity of coliforms which represented as a marker organism for disinfection, the adequate disinfection dose is around 5-10kGy. The dose is higher than that necessary for liquid sludge.

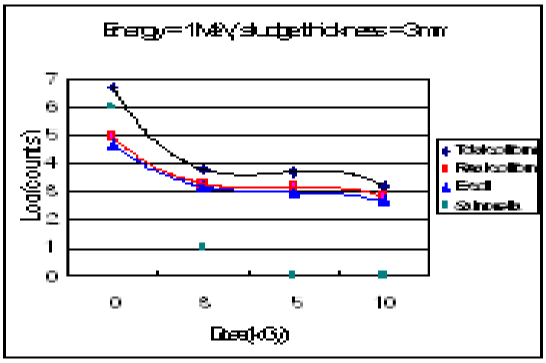

Fig. 2. Survival fraction of coliforms with different doses, 1MeV electron beam irradiation on 3mm thickness sludge.

3.2 Temperature Rise due to irradiation

In case of high-dose irradiation, the rate of heat accumulation is large and may often enhance the effect of radiation. However, the maximum dose used in this study was about 10kGy, which is equal to 2.4 cal per gram of sludge. When the specific heat of sludge is assumed to be around 1.0 cal/℃.g since the sludge contains 80% of water even after the dewatering process, and if all the absorbed energy were converted to heat, the temperature of sludge would rise by only 2.4℃, which would be unlikely to influence the disinfection efficiency.

4. Design of Industrial Scale Plant

4.1 Design parameters

Based on the experimental results, an industrial scale plant for Bet Shemesh municipal wastewater treatment facility in Israel was designed. This plant has the capacity of treating 800 tons/mon of dewatered sludge (5 m^3 per hour) with 10 kGy. It will be equipped with an electron accelerator (1.5MeV, 20kW) and conveyor-type sludge handling equipments with the nozzle of 4.2mm by 1200mm width.

4.2 Costs for Construction and Operation

The capital cost including electron accelerator, shield vault and handling equipments were calculated USD 1.7M. By considering the 10 years' depreciation with 5 % bank interest, salaries of operators and maintenance cost (1% of capital cost), and the annual operating cost will be USD 0.35M in total. It is approximately USD 7.2 for each ton of sludge.

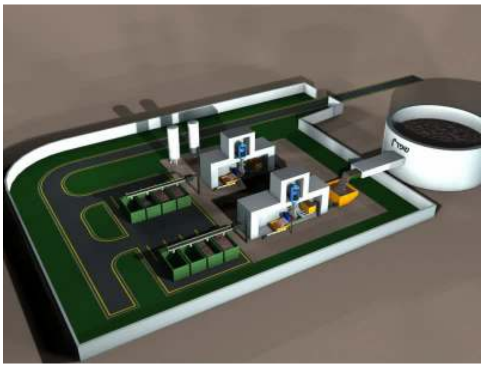

Fig. 3. Industrial plant designed for Bet Shemesh, Israel.

5. Conclusion

Electron beam was proved the ability to inactivate the pathogens with a very high degree of reliability and efficiency in pilot scale electron beam plant operation. The most coliforms and micro-organisms were observed to be disinfected around 5-10 kGy. The industrial plant designed for treating 800tons per month showed good economics and is expected to be more economical than other sludge disposal processes, such as incineration, lime stabilization, etc

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