

IRRADIATION EFFECTS ON THE PHYSICAL CHARACTERISTICS OF SEWAGE SLUDGE

*Myun-Joo Lee, Jae-Kwang Lee, Dae-Hyun Yoo, Kang-Ho**

Korea Atomic Energy Research Institute

**Chungnam National University, Korea*

ABSTRACT

The radiation effects on the physical characteristic of the sewage sludge were studied in order to obtain information which will be used for study on the enhancement of the sludge's dewaterability. Water contents, capillary suction time, zeta potential, irradiation dose, sludge acidity, total solid concentration, sludge particle size and microbiology before and after irradiation were investigated. Irradiation gave an effect on physical characteristics sludge. Water content in sludge cake could be reduced by irradiation at the dose of 10kGy.

KEY WORDS

Irradiation, capillary suction time, dewaterability, pH, sewage sludge, total solid, zeta potential, microorganism, particle size

INTRODUCTION

The volume of sludge is increasing rapidly on a yearly basis and desirable treatment of sewage sludge is a sensitive issue. Minimization of sludge cake is an important factor among the sludge treatment technologies. Scientists have vigorously studied the safe and reliable treatment of sewage sludge and reducing sludge cake volume^{1, 2, 3}. Generation of sewage sludge has been increased year by year by about 10% in Korea since 1998 (Table 1)⁴. It was a serious problem to certainly treat sewage sludge. Statistics of sludge in Korea showed that the ocean dump of sludge has been increased dramatically, whereas the landfill has been reduced and the incineration plays a minor role in managing it. However, direct landfill or ocean dump will be inhibited by regulation from the Korean government in the near future.

The characterization of physical characteristics of sludge is very important in term of study on reduction of water content in sludge cake. Water fraction in sludge can be divided into four groups from their characteristics; (1) Free water is not associated with and not influenced by the suspended particles. (2) Interstitial water trapped in the crevices and interstitial spaces of the flocs and organisms by the capillary force. (3) Vicinal water is the multiple layers of water molecules held tightly to the particle surface by hydrogen bonding (4) Water of hydration is the water chemically bound to the particles and removable only by the expenditure of thermal energy⁵. The surface bound water was only a minor contributor to the water content of sludge cake while interstitial water was the main constituent to the water in sludge cakes. A major component of interstitial water could be the water held by the osmotic pressure within sludge flocs². Several mechanical dehydration processes have been used to reduce water in sludge, which includes a filter press, a belt press and a screw decanter etc. Unfortunately, mechanical dewatering cannot remove water in sludge with a higher bonding energy than the free water, which includes interstitial water, vicinal water and bound water and it can only remove free water. Moreover some of the free water

might bind with sludge particles after mechanical dehydration because of hydrophilicity of the solid fraction. The binding energy of free water is 0.28kJ/kg water and that of bound water including surface and intracellular water is higher than 5kJ/kg water. Hence more than 5kJ/kg water of energy must be needed to remove the bound water⁶.

Here we investigated the effect of irradiation on several factors which may have close link with sludge dewaterability. Several researchers have recently studied the radiation technology to reduce water in sludge cake^{2, 7} but most of the radiation processes have been focused on eliminating the organic and biological contaminants of sludge^{8, 9, 10, 11}. Therefore we carried out the fundamental study on radiation effects based on enhancement of sludge dewaterability and evaluated the physical characteristics of sludge affecting dehydration.

Table 1. Generation and treatment of sewage sludge in Korea
unit : ton

Year	Total	Reuse	Landfill	Incineration	Ocean Dump	etc	Carrying Forward
1998	1447170	34466	792828	20947	552188	12647	34095
1999	1593001	80293	640515	33350	820135	8	18698
2000	1741371	88101	439099	93163	1118453	923	1633
2001	1902410	118339	229082	138440	1390779	20376	5394

MATERIALS AND METHODS

Materials and instruments

Digested sludge was supplied from the W-sewage treatment plant in Daejeon, Korea. The TS (total solid) content of sludge was about 4%(w/w). All samples were poured into a flat glass tray (Pyrex. Co. U.S.A.) with a thickness below 5mm and then irradiated at the electron beam dose rate of 0~50kGy for a few seconds. The electron accelerator (1.5MeV) was used from EB Tech. Co. in Korea. Acidity of sludge was adjusted at the pH 5, 7 and 9 respectively by using sulfuric acid and sodium hydroxide at the reagent grade and pH was measured by Orion 720A with a Ross combination pH electrode.

Capillary suction time (CST) was measured to estimate the sludge filterability and dewaterability by using the Type 304B Capillary Suction Timer (Triton Electronics Ltd. UK). 3mL of sludge sample was poured into the stainless funnel (L=1.8cm, Φ =5mm). Then the time for the filtrate wetting the CST paper (Triton Electronics Ltd. UK) was measured.

The surface properties of sludge were analyzed by measuring zeta potential of sludge. Zeta potential was measured by using ZetaPlus (Brookhaven Instrument Co. U.S.A.) when irradiated at 0, 6, 10, 20 and 30kGy respectively. 100 μ L of sludge was diluted into 5mL of ultra-pure water and vigorously shaken. The sample was poured into the cell and zeta potential was measured.

Sludge TS was controlled by a centrifuge at 1,000rpm and then discarded 8mL and 16mL of the supernatant from the 50mL P.P centrifuge bottle (Nalgene Co. U.S.A.) respectively. Water content of sludge cake was measured to evaluate the sludge dewaterability before and after irradiation by a centrifuge at the relative centrifugal force of 1,200, 3,700 and 12000 gauss for 20min respectively. The water content of sludge was measured by following the Standard method 2540¹² after a centrifuge. All the solutions were prepared by Milli-Q ultra-pure water (18.3 M Ω -cm).

RESULTS AND DISCUSSION

Water fraction

Water fraction in the sludge cake was dramatically reduced by about 10% (w/w) after irradiation at a maximum dose of 20kGy (Figure.1). It suggests that a high energy of radiation might cause the disruption of the sludge particles into smaller ones, which induces the removal of the interstitial water from the sludge.

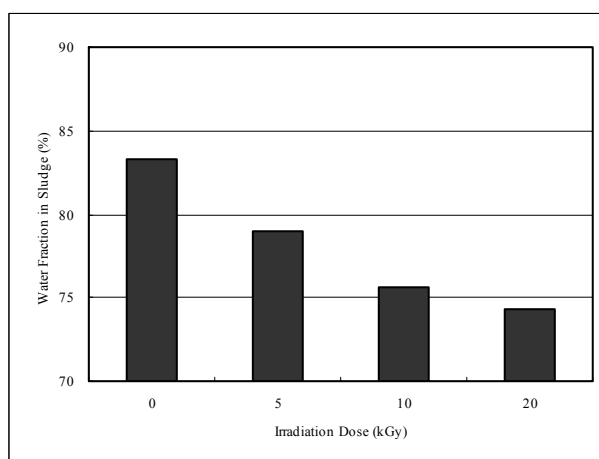


Figure 1. Water fraction of sludge cake with irradiation dose

CST value

Results of the CST test are shown in Figure 2. CST of raw sludge measured was 434sec and largely reduced at 170, 171 and 166 sec after irradiation at the dose of 3, 6 and 10kGy respectively. It means that the filterability and dewaterability of sludge was enhanced after irradiation because the radiation could destroy the sludge particles

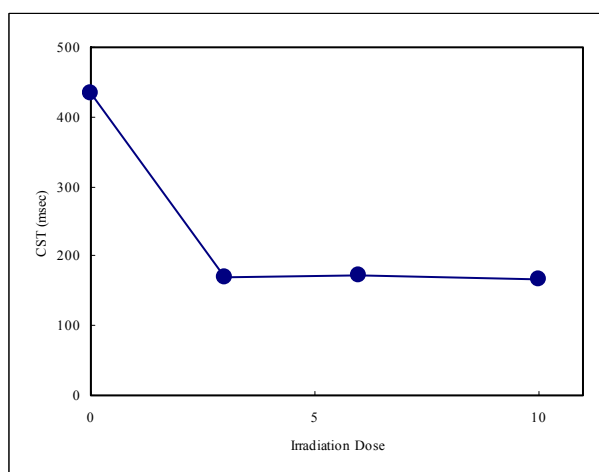


Figure 2. Capillary suction time of sludge with irradiation dose

Zeta potential

The zeta potential is calculated from the solution conditions and the electrical mobility and may be used as measures of dispersion stability¹⁶. The zeta potential of

sludge is indicated in Figure 3. Zeta potential was increased by 1 ~ 4mV when irradiated at 6, 10, 20 and 30kGy respectively. A high positive or negative zeta potential means that the particles are stable and hard to coagulate. A low positive or negative zeta potential means that the particles are unstable and easy to coagulate. When sludge was irradiated, viscous polymers of sludge could be disrupted and it would induce the lower negative zeta potential than that of unirradiated one. The reduced repulsive force between particles induces the effective dehydration of sludge after irradiation.

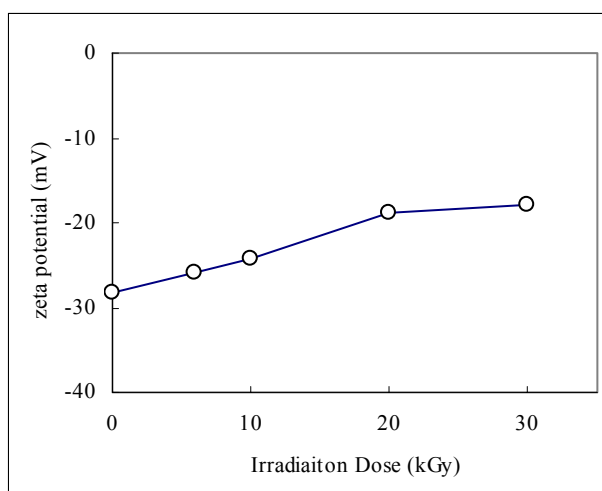


Figure 3. Zeta potential of sludge with irradiation dose

Sludge particle size

Particle size of the sludge was decreased according to the increase of the irradiation dose (Figure 4). This could be confirmed by SEM analysis (Figure 5). The sludge particle size was mainly distributed in around size of 20 μm after irradiation dose with 20 kGy while it was distributed in around size of 20 μm in case of unirradiation.

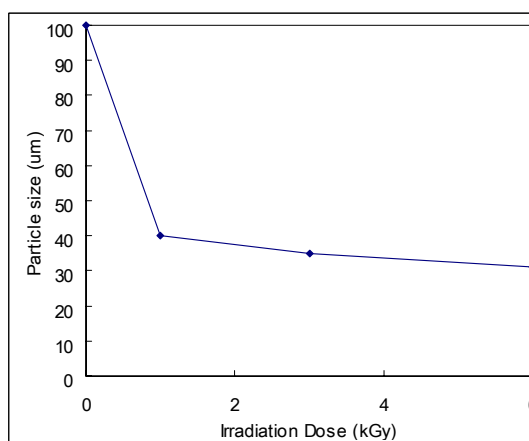


Figure 4. Sludge particle size reduction with irradiation

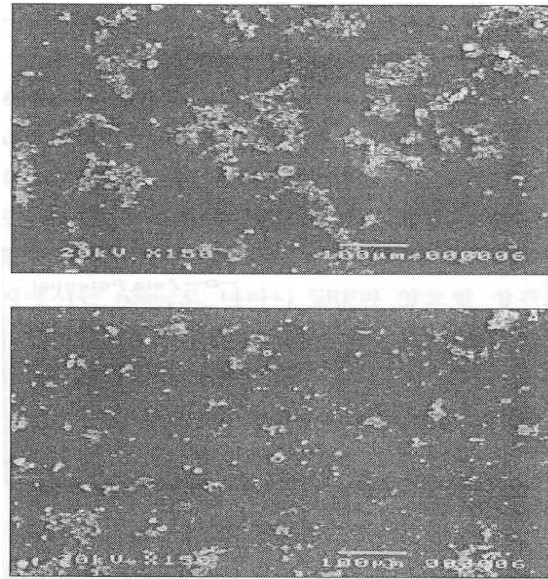


Figure 5. SEM results of particle size before(upper) and after irradiation(lower)

Microorganisms

Microorganisms went from an active state to an inactive state. This means that irradiation of the sludge is very effective for the sterilization of the microorganism. In according to figure 7 and 8 reduction of bacteria and *E.coli* in sludge was rapidly carried out with irradiation dose. Within irradiation dose of 3 kGy large portion of microorganisms became inactive and figure 6 showed evidence on destruction of *E.coli* by irradiation.

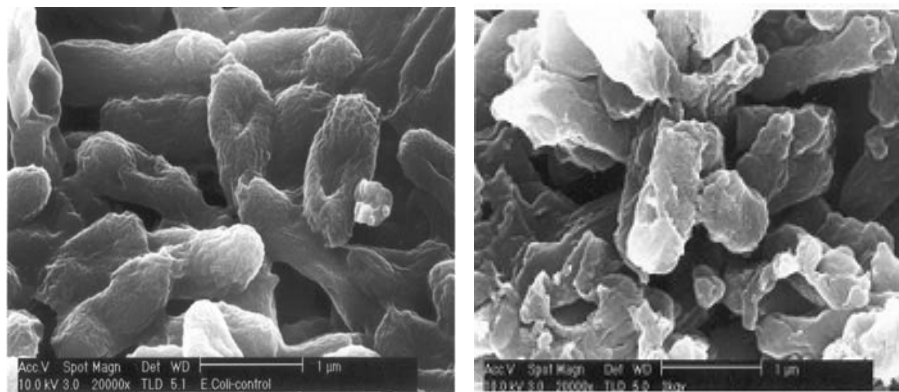


Figure 6. SEM results on destruction of *E.Coli* before(left) and after 3 kGy of irradiation dose(right)

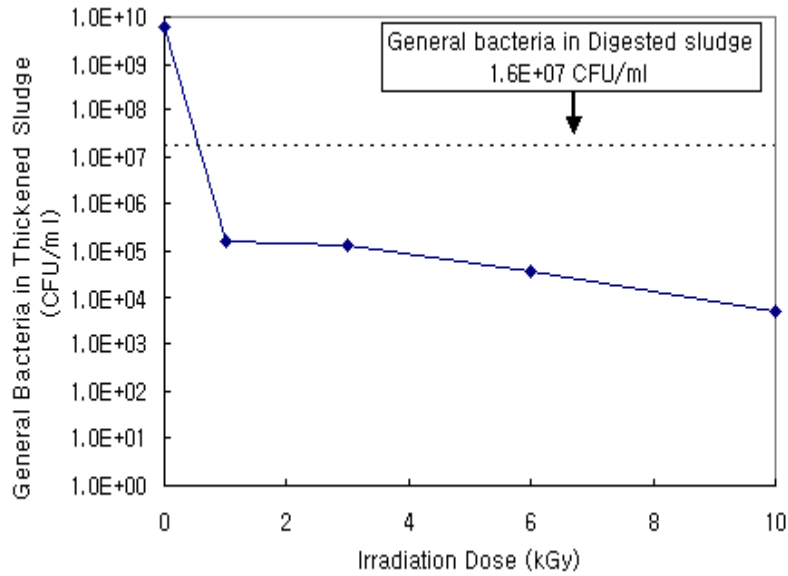


Figure 7. Reduction of colony forming unit of bacteria in sludge with irradiation dose

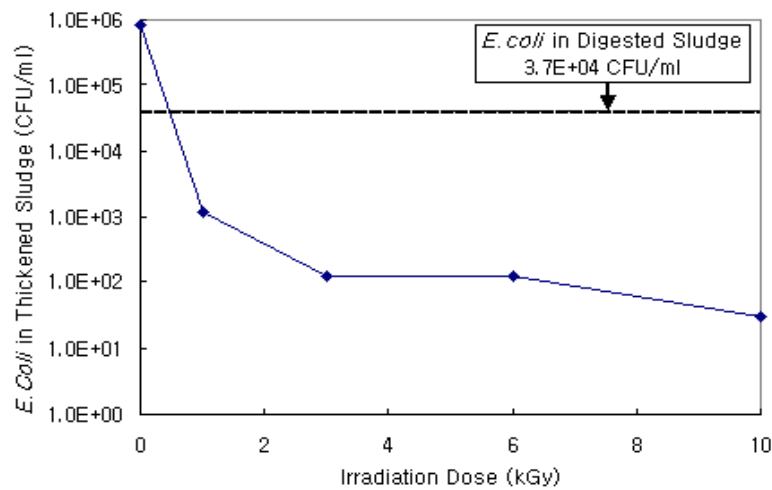


Figure 8. Reduction of colony forming unit of *E.coli* in sludge with irradiation dose

pH effect on sludge dewaterability

Acidity of raw sludge was pH6.8~7.1 and the pH drift after irradiation was not significant. The pH effect on dewaterability was examined to select the optimum condition for radiation pretreatment at pH 5.0, 7.0 and 9.0 (Figure 9). Water content was least at pH5.0 and increased little by little in accordance with a rising pH. Though the pH effect on sludge dewaterability was minor, low pH could reduce the water fraction in sludge after irradiation. It means that a drift of the surface charge of sludge at low pH can induce good coagulation efficiency.

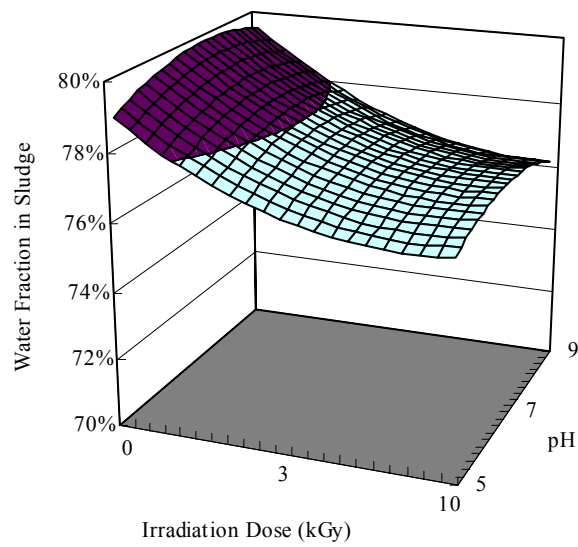


Figure 9. pH effect on dewaterability of sludge

TS effect on dewaterability of sludge

TS effect on dewaterability of sludge is shown in figure 10. TS effect was lesser than pH and irradiation dose, which means that variation of TS loads cannot cause a dewatering efficiency of the radiation.

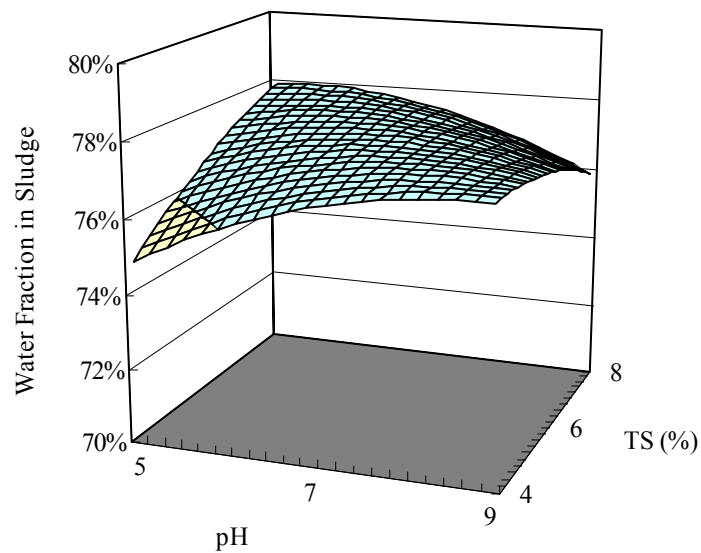


Figure 10. TS effect on dewaterability of sludge

CONCLUSIONS

Sludge dewaterability could be increased by 10% of the water content by induced 10 kGy of irradiation. Factors affecting sludge dewaterability were evaluated. Irradiation dose was key factor for dewaterability while pH and TS had relatively minor effects on the water content of sludge. This basic study will give a chance for the adoption of radiation technology for sludge treatment, which enhances sludge dewaterability.

REFERENCES

- 1 SAWAI, T. YAMAZAKI, M. SHIMOKAWA, T. Improvement of sedimentation and dewatering of municipal sludge by radiation. *Radiation Physics and Chemistry* 1990, 35, (1-3), 465~468
- 2 LEE, C H. LIU, J C. Sludge dewaterability and floc structure in dual polymer conditioning. *Advances in Environmental Research* 2001, 5, 129~136
- 3 MIKKELSEN, L H. KEIDING, K. Physico-chemical characteristics of full scale sewage sludges with implications to dewatering. *Water Research* 2002, 36, 2451~2462
- 4 *Statistics of sewerage*. Ministry of Environment, Korea, 1998~2002
- 5 VESILIND, P A. The role of water in sludge dewatering. *Water Environment Research* 1994, 66, (1), 4~11
- 6 KOPP, J. DICHTL, N. Influence of the free water content on the dewaterability of sewage sludges. *Water Science and Technology*, 2001, 44, (10), 177~183
- 7 SHIN, K S. *Application of electron beam irradiation for effective wastewater sludge treatment*. Ph.D Thesis. Dep. Environmental Engineering. Chungnam Nat. Univ. Korea. 2002
- 8 BORRELY, S I. CRUZ, A C. DEL MASTRO, N L. SAMPA, M H O, SOMEISSARI, E S. Radiation processing of sewage and sludge ; a review. *Progress in Nuclear Energy* 1998, 33, (1), 3~21
- 9 CAPIZZI-BANAS, S. SCHWARTZBROD, J. Irradiation of *Ascaris* ova in sludge using an electron beam accelerator. *Water Research* 2001, 35, (9), 2256~2260
- 10 SHAMMA, M. AL-ADAWI, M A. The morphological changes of *Ascaris Lumbricoides* ova in sewage sludge water treated by gamma irradiation. *Radiation Physics and Chemistry*. 2002, 65, 277~279
- 11 LAFITTE-TROUGQUÉ, S. FORSTER, C F. The use of ultrasound and γ -irradiation as pre-treatments for the anaerobic digestion of waste activated sludge at mesophilic and thermophilic temperatures. *Bioresource Technology* 2002, 84, 113~118
- 12 CLESCERI, L S. GREENBERG, A E. EATON, A D. *Standard methods for the examination of water and wastewater* 20th edition. American Public Health Association, American Water Works Association, Water Environment Federation, Washington DC. USA. ISBN 0-87553-235-7. 1998
- 13 CHO, Y H. JEONG, C H. HAHN, P S. Sorption characteristics of ¹³⁷Cs onto clay minerals: effect of mineral structure and ionic strength. *J. Radioanalytical and Nuclear Chemistry* 1996, 205, (1), 33-43
- 14 LEE, J K. CHO, Y H. HAHN, P S. SEO, Y C. Adsorption of Cu²⁺ and Ni²⁺ at solution/mineral (goethite, kaolinite, montmorillonite) interface. *J. Korean Society of Environmental Engineers*, 1998, 20, (6), 831~840
- 15 TICKNOR, K V. CHO, Y H. Interaction of iodide and iodate with granitic fracture-filling minerals. *J. Radioanalytical and Nuclear Chemistry* 1990, 140, (1), 75~90
- 16 *Instruction manual for ZetaPlus, Zeta Potential Analyser*. Brookhaven

Instruments Corporation, 1992

17 LEE, M J. et al. *Development of a technique for environmental treatment by radiation*. KAERI/RR-2010/99 (Final Report), Korea Atomic Energy Institute. Korea. 2000

ACKNOWLEDGEMENTS

This project has been carried out under the Nuclear R&D Program by MOST of Korea