Disinfection of Total Coli-forms in the Effluent from Municipal Wastewater Plant with Electron Beam

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Abstract. Electron beam has introduced to investigate the effect of radiation on the disinfection of coli-forms in the effluent from the municipal wastewater treatment plant. Unchlorinated secondary effluent was irradiated at different dose of 0.2 – 1.0 kGy with 1 MeV, 40kW electron accelerator. It is observed that nearly 100% reduction in E-Coli. and total coli-forms were achieved with a dose of 0.8kGy. Even with the lower dose of 0.2kGy, the E-Coli. and total coli-forms were successfully inactivated to the level of the new guideline for discharged effluent that has been effective from 2003 in Korea. Based on the data obtained in the experiments, industrial scale plant was designed with 0.2 kGy for the flow rate of 100,000m^3 effluent per day. The overall cost for plant construction is approximately 4.0~4.5M$, and the operation cost is around 1M$/yr. This is quite reasonable when compared to other advanced oxidation techniques such as Ozonation, UV techniques etc..

1. Introduction

Population growth and declining fresh water supplies need for clean water and it is one of the critical challenges for the 21st century. Because of the increasing levels and complexity of polluted effluents from municipalities; current wastewater treatment technologies are often not successful for the reclamation of effluents. Significant progress has been made in technical approaches to produce reliable sources of quality water by wastewater reclamation technologies, offering the possibility of a new water source for various beneficial uses. Advanced wastewater treatment is essential in the treatment of municipal wastewater to protect public health and to meet water quality criteria for aquatic environment, water recycling and reuse. Especially when reclaimed wastewater applications have a potential route for human exposure, disinfection is absolutely essential and a disinfection step for removal or inactivation of pathogenic organisms will be then the final treatment. Among the possible water treatment alternatives radiation processing, a very effective form of energy use, can degrade toxic organic compounds and biological contaminants.

Radiation disinfection of effluent from municipal wastewater plant for reclamation has been successfully demonstrated by a number of researchers. Researches showed that inactivation of fecal coli-forms in secondary effluents from municipal wastewater plant can be obtained with doses less than 1 kGy. While conventional disinfectants are adversely affected by the water matrix, radiation processing for bacteria inactivation is generally unaffected by the matrix. Therefore radiation processing has a clear advantage over the existing methods for municipal wastewater disinfection. Radiation processing for wastewater disinfection would be technically much easier than application of the conventional processes.

Average annual rainfall in Korea is around 1,270mm and is about 30% more than that of the world (973mm), but it varies too much with season and area to control for withdrawal. By considering the high population density (3rd in the world), the annual rainfall per capita is decreased to only 1/11 (3,000ton/yr/man) of the world average. (FIG. 1) And even worse, 2/3 of those rainfalls are concentrated in 2 or 3 months in summer and hence only 24% of rainfall could be accessible for human uses. Demand for fresh water increases gradually with industrialization and urbanization, but the supply has limitations in increasing. (See TABLE I)

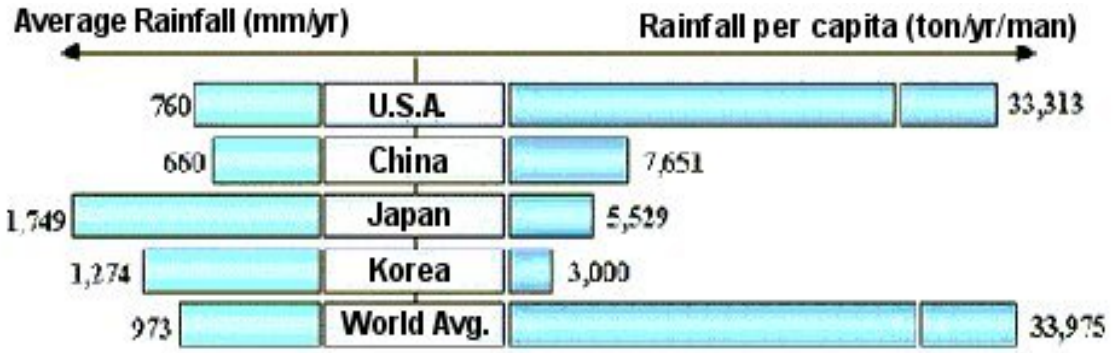

FIG.1. Comparison of rainfalls in some countries

The treatment of municipal wastewater for reclamation to industries or agricultural purposes becomes a more important subject in the field of Water Resources Management. Nation-wide in Korea, over 200 sewage disposal plants are in operation and they treat up to 20 million tons of sewages per day which covers 80% of total discharged and 95% from the main streams in the country. Most of those existing municipal sewage disposal plants are equipped with conventional biological methods with the digestion of activated sludges, which are efficient to remove suspended solids and organic matters. However, those methods have limitations in removing nitrates and phosphates that used to be the nutrient of algae formation as well as in decreasing the number of microorganisms in effluent. For the re-use of such effluent to industries or irrigation, not only the colour, odour, and residual organics are important, but the numbers of microorganisms are also important. In Korea, starting from the 2003, new guideline of governmental authorities has been effective to control the numbers of E-coli in the effluent from sewage plants less than 3,000 numbers in 1 ml. Therefore, advanced technologies to control the microorganisms as well as to remove, colour, odour etc. are required on the economical basis. Among the many new technologies, radiation treatment is the most promising method in both economical and technical evaluation. The treatment of municipal wastewater with electron beam is actively studied in EB TECH Co.. An electron accelerator of energy 1 MeV is used in experiments. Applied doses in the experiments were measured with an ordinary or modified Fricke dosimeter and dichromatic dosimetry system.

2. Continuous Flow Irradiation Experiments

To observe the applicability of electron beam treatment for disinfection of the effluent from municipal sewage treatment plant, the effectiveness of electron beam irradiation in the disinfection of wastewater and the improvement of the water quality were measured by determining the changes in organic matter as indicated by the measurement of BOD, COD and TOC. The experiments were conducted with 1MeV, 40kW electron accelerator at EB-TECH.CO., LTD in Korea. The absorbed doses for all of the experiments were in the region of 0.2kGy - 1.0kGy.

TABLE I : SUPPLY AND DEMAND OF FRESH WATER IN KOREA ($10^8 m^3$/year)

Year	1994	2001	2006	2011
Demand	29,901	33,640	34,991	36,652
Supply	32,219	34,290	34,541	34,655
Shortage	-	-	450	1,997

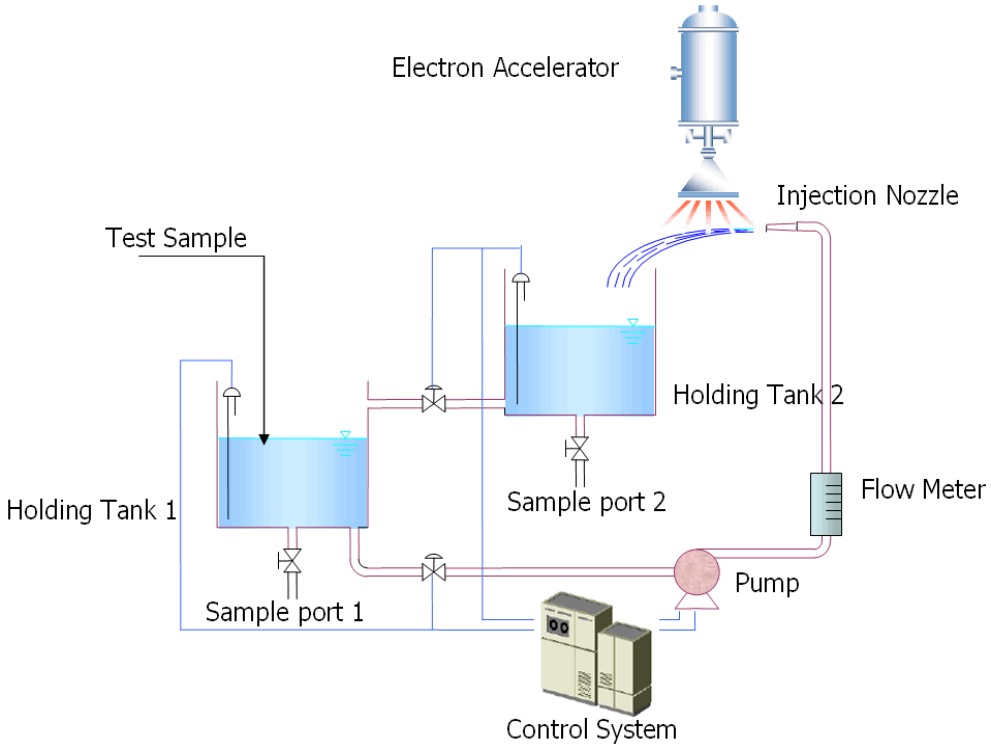

FIG. 2 Schematic diagram of experimental apparatus

The effluent used for this research was supplied from the Daejeon Municipal Wastewater Treatment Plant, and the effluent is taken after the activated sludge treatment - just prior to discharge. Estimates of E-Coil. and total coli-forms of bacteria were determined by the membrane filter procedures EPA Method. After Irradiation, the change of characteristics in effluent was measured as BOD and COD, EPA standard method. Fig. 2 shows the bench scale electron beam irradiation system used in this research.

3. Results and Discussion

It is observed that nearly 100% of E-Coli. and total coli-forms were inactivated with a dose of 0.8kGy. Even with the lower dose of 0.2kGy, the E-Coli. and total coli-forms were successfully inactivated to the level of the guideline for effluent discharge. (See FIG. 3) Besides disinfection of total coli-forms, approximately 50% of removal in biochemical oxygen demand (BOD) was pronounced at a dose of 0.2kGy. More than 20% removal in suspended solids (SS) and turbidity was also observed at a dose of 1.0kGy.

TABLE II: CHRACTERISTICS OF SECONDARY EFFLUENT FROM MUNICIPAL PLANT

Parameters	Max.	Min.	Aver.
	2002. 7. 8 – 2002. 9. 6 (40day)		
BOD (mg/l)	21.2	7.2	10.1
COD (mg/l)	14.8	8.8	10.8
SS (mg/l)	12.8	1.7	5.6
E-coli (CFU/ml)	14,000	800	4,200
Total coli-forms (CFU/ml)	820,000	140,000	440,000

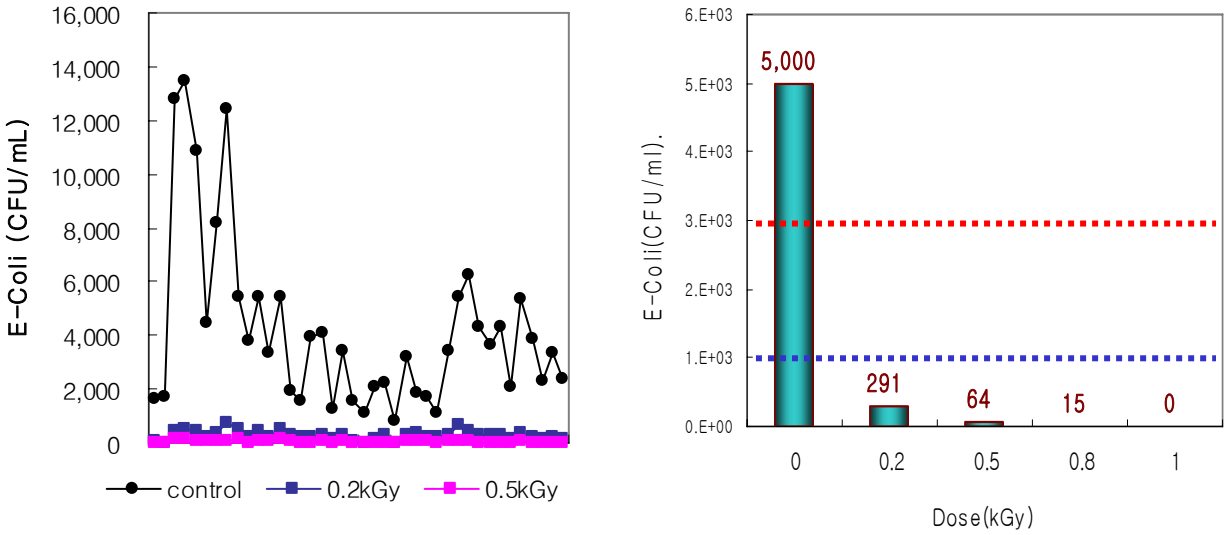

FIG. 3 Disinfection of E-Coli. with different doses

Radiation processing for effluent reclamation represents a true alternative to chemical and UV treatment. As compared to chemical disinfection it proved to be a clean technology without formation of hazardous by-products; as compared to UV irradiation electron beam irradiation is technically much more simple, almost insensitive to color, suspended solids or gas bubbles in the effluent stream, and moreover, to effluent composition and fouling characteristics, respectively. It needs considerably less maintenance and is very easy to control.

4. Economical Estimation of Commercial Plant

Based on the data obtained in the laboratory experiments, the suitable doses are determined as around 0.2 kGy for the flow rate of 100,000m^3 effluent per day. Therefore, accelerator with the power of 400kW is applied for economies and compactness of the plant. Cost for high power accelerator is around 2.0~2.5M$ and building, piping, other equipment and construction works could be estimated 1.0~1.5M$. Even by considering the additional cost for tax, insurance and documentation as 0.5M$, the overall cost for plant construction is approximately 4.0~4.5M$ as is stipulated in TABLE III. This doesn't include cost for land, R & D and cost for the authority approval. Expected construction period includes 11 months in civil and installation works and 3 months for trial operation.

TABLE III: CONSTRUCTION COST OF INDUSTRIAL PLANT (UNIT: M$)

	Cost	Remarks
Accelerator - 1MeV, 400kW, double window	2.0~2.5	Cost for Land, R&D, Approval from Authorities are not included
Water reactor & other Raw Material	1.0~1.5	
Installation cost – welding/piping/inspection etc.		
Design		
Shield Room & Construction works		
Others - transportation, tax, insurance etc.	0.5	
Total	4.0~4.5	~ 4M$

TABLE IV: ECONOMIC EVALUATION OF INDUSTRIAL PLANT (UNIT: k$)

Items		Addition of E-beam	Remarks
Operation Cost	Invest (k$)	(4,000)	
	Interest	320	8%
	Depreciation	200	20yrs
	Electricity	336	800kW
	Labour, etc.	100	3 shift
Total cost		956	~ 1M$/yr

To estimate the operation cost, the electricity consumption is estimated for accelerator with 500kW (80% efficiency) and other equipment in additional 300kW to the total of 800kW. Based on the year round operation (8400hr/yr), it costs 336,000$/yr when the cost of electricity (kWh) was assumed to be 0.05$. The labour cost is calculated 3-shift with one additional operator and is approximately 100,000$/yr. Thus, the actual operation cost for 100,000m^3/day plants is 436,000$/yr and if we consider the interest and depreciation of investment, the cost comes up to around 1M$/yr. It is approximately 0.12$/$m^3$ for construction and 0.03$/$m^3$/yr for operation of above re-use plant, and is inexpensive compared to other advanced oxidation techniques such as Ozonation, UV techniques etc..

5. Conclusion

Radiation disinfection appears to be an alternative method to replace traditional chlorination method of treating effluent from municipal plant. This would improve the economics of the disinfection process and would also reduce the residual organics.

It is observed that nearly 100% reduction in E-Coli. and total coli-forms were achieved with a dose of 0.8kGy. Even with the lower dose of 0.2kGy, the E-Coli. and total coli-forms were successfully inactivated to the level of the new guideline (less than 3,000 numbers in 1 ml) for discharged effluent that has been effective from 2003 in Korea.

Construction cost for the plant of 100,000m^3/day is around 4.0~4.5M$ and operation cost is around 1M$/yr. It is quite reasonable when compared to other advanced oxidation techniques.

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