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Application of food waste leachate to a municipal solid waste incinerator for reduction of NOx emission and ammonia water consumption

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ABSTRACT
This study investigates the possibility of applying food waste leachate to a municipal solid waste incinerator in order to effectively dispose of the material and to reduce the environmental impact. The spray positions and the quantity of the food waste leachate in municipal solid waste incinerator were adjusted to examine the stability of the process and the environmental effect. The rear of the first combustion chamber was found to be the desirable location for an environmental perspective in this study. At a food waste leachate injection rate of 2 m^3/h, the concentration of the emitted NOx decreased from 130 ppm to 40 ppm. The consumption of ammonia water was reduced by about 36% after adding the food waste leachate. The inclusion of the food waste leachate to the municipal incinerator also increased the amount of steam that was produced. The results of this research indicated that a positive outcome can be expected in terms of diversifying the treatment options for food waste leachate. The results also provide guidance for institutional framework to manage the incineration of the food waste leachate.

Keywords: Food waste leachate, Incinerator, Municipal solid waste, NOx reduction

1. Introduction

In Korea, it is forbidden to disposal of organic waste, including food waste, in landfills and oceans. Food waste is separately collected to encourage beneficial uses [1-4]. However, the treatment of food waste for such use results in a large amount of food waste leachate (FWL) to be discharged. Although FWL should also be disposed of effectively, more cost-effective methods need to be developed for its final disposal. An option to FWL treatment involves using a municipal solid waste incinerator on the assumption that co-combustion would reduce the overall environmental impact.

Furthermore, the NOx originating from the municipal solid waste (MSW) incineration is a notable, air pollutant from the combustion process itself, and it is released through the stack with the flue-gas. NOx originates from diverse combustion mechanisms [5-9]. Without flue-gas cleaning, the MSW that is incinerated may release more than 1 kg of NOx/ton and will significantly contribute to the overall environmental impact of the incineration plant [10-12]. In general, a flue-gas cleaning system is employed selective non-catalytic reduction (SNCR) brought about by adding ammonia water for NOx reduction of the flue [6, 7]. SNCR is one of the most promising technologies to reduce NOx output [8, 9]. It has been already used in practice for combustion systems where the decomposition of NOx gives rise to desired reactions with NH_3 to form N_2 and H_2O as follows [13-15]:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \quad (1)$$

$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O \quad (2)$$

$$6NO + 4NH_3 \rightarrow 5N_2 + 6H_2O \quad (3)$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O \quad (4)$$

$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O \quad (5)$$

The ammonia that is injected is proportional to the ammonia dosage and the NOx-emission through the stack is inversely proportional to the ammonia dosage. Therefore, further efforts to rid

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the flue-gas of NOx will result in an increase in the ammonia released to the environment [11-15], and as a result, the overall environmental impact can be calculated as the environmental impact from the decrease in the NOx-emission plus the environmental impact from the increase in the ammonia that is injected [6, 7, 15-18]. The environmental impact associated with production of ammonia as well as the energy necessary to run the SNCR-process should be considered when determining the overall impact.

This study addresses some of the challenges related to the MSW incinerator process where FWL is injected. The two goals are (i) to remove the FWL through incineration, and (ii) to replace and reduce the amount of ammonia water used with the FWL. In this paper, we provide a comparison of the NOx emission form an MSW incinerator of an actual plant by injecting FWL and ammonia water in the SNCR system.

2. Materials and Methods

2.1. MSW Incinerator

An alternative method to dispose of the FWL was investigated by evaluating the potential for using an incineration treatment. Fig. 1 shows the schematics of the municipal solid waste incinerator plant that was considered in this study. The plant includes two furnaces and incinerates approximately 90 tons of MSW per day. This study considered an incinerator consisting of one furnace with SNCR flue-gas cleaning systems. All data regarding the incinerator and the flue-gas cleaning system were obtained from the MSW incinerator in Y city, South of Korea.

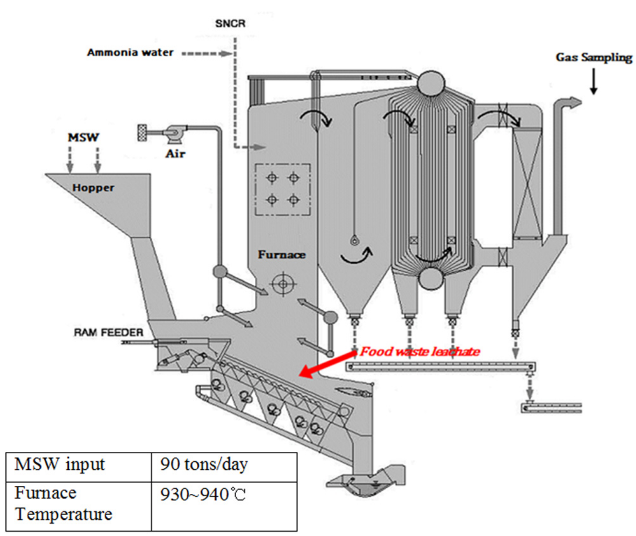

Fig. 1. Schematics of the municipal solid waste (MSW) incinerator with a selective non-catalytic reduction (SNCR) system including an food waste leachate (FWL) input point.

2.2. Materials

The input position and the quantity of the FWL were adjusted to determine the effect that FWL injection dosage had on NOx reduction in the incineration process. The FWL consisted of 87.1% moisture content, 11.8% combustible matter, 1.1% ash, 49.8% carbon content, 4% nitrogen content, and a high heating value (HHV) of 5,232 kcal/kg, 420 ppm of NH_3-N were present in the FWL, as shown in Table 1. This ammonia in the FWL will have effects in reducing NOx released in the MSW incinerator.

Table 1. Characteristics of the Food Waste Leachate

Parameter	Value
Ultimate analysis (%)	
Moisture content	87.1
Combustible	11.8
Ash	1.1
Proximate analysis (%)	
C	49.8
H	6.59
O	26.5
N	4
S	0.23
High heating value (kcal/kg)	5,232
BOD_5 (mg/L)	94,800
COD (mg/L)	117,000
SS (mg/L)	27,900
NH_3-N (mg/L)	752
T-N (mg/L)	3,380
T-P (mg/L)	653
n-Hexane (mg/L)	11,700

2.3 Experimental Details

The relationship between the ammonia injection dosage, the ammonia slip and the NOx removal in the flue-gas cleaning system were investigated in a full-scale MSW furnace incinerator. The relationship between the ammonia injection dosage, the FWL injection dosage, and the NOx removal in the flue-gas cleaning system was determined. The furnace temperature was determined by using an automatic monitoring system. The NOx concentration of flue-gas was determined by using the Optima 7 handheld multigas analyzer.

3. Results and Discussion

3.1. NOx Reduction Through the Spray Injection of FWL

Different combustion conditions in the incinerator, including the ammonia injection dosage, ammonia slip and ammonia injected with the FWL, will affect the amount of NOx concentration and the furnace temperature. First, the FWL injection disturbed the combustion reaction in the MSW incinerator. Table 2 shows a comparison of the effect that the injection conditions of the ammonia and FWL dosage had on the NOx emission and furnace temperature. Ammonia water is commonly used in an SNCR system to reduce NOx emissions [6, 7], as in this research. Instead of the ammonia water, the ammonia (NH_4) in the FWL reacted to reduce the NOx emission. Without ammonia (just an injection of water at 1.5 m^3/h), approximately 131 ppm of NOx were observed.

Table 2. Comparison of the NOx Reduction

Injection	Quantity	Furnace temperature (˚C)	NOx (ppm)
Water	1.5 m^3/h	931 ± 30	131
Ammonia water	24 L/h	942 ± 12	30
Ammonia water	12 L/h	941 ± 15	60
Food waste leachate	2 m^3/h	920 ± 20	44
Food waste leachate	1 m^3/h	925 ± 16	104

The addition of ammonia water could reduce the NOx emission down to approximately 30 ppm with an injection of 24 L/h of ammonia. When FWL was injected at 2 m^3/h, the concentrations of NOx emissions were reduced to approximately 44 ppm, which was similar as that achieved when ammonia water was injected at a rate of 24 L/h. Furthermore, the FWL injection did not have an effect on the operating temperature of the MSW incinerator, which further provides guidance for an institutional framework.

3.2. MSW Incinerator Operation

Figs. 2 and 3 show the results of operating the MSW incinerator with and without FWL injection. The MSW incinerator usually processed 90 tons/day, and the ammonia water is injected in the SNCR system to decrease the NOx emission. Ammonia water had been injected at 14.3 L/h, which was the basis for the fundamental operation of the MSW incinerator. When the MSW incinerator operated with ammonia water, as shown Fig. 2, the NOx emission could not be reduced beyond 40 ppm of NOx, and the NOx emission was generally of approximately 76 ppm (between 62 and 78 ppm). When, 2 m^3/h of FWL were injected in the MSW incinerator with 14.3 L/h of ammonia water, the NOx emission decreased to approximately 27 ppm (as shown Fig. 3). The ammonia components consiste of 420 ppm of NH_4-N in FWL, as shown in Table 1, which substitute the ammonia water agent in the incinerator [8, 13-15]. This FWL that is injected for removal can therefore reduce the

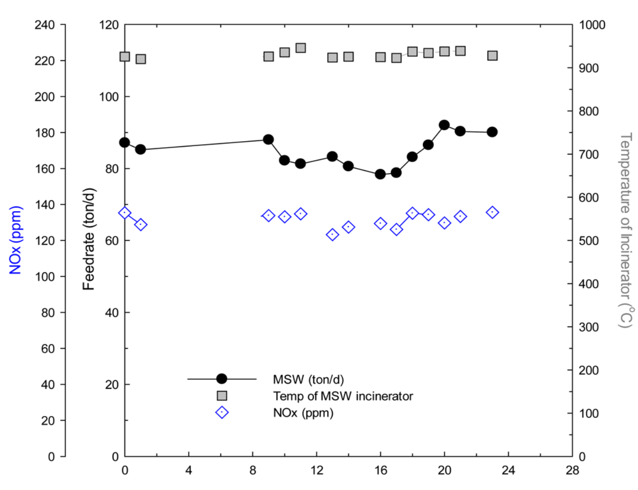

Fig. 2. The result obtained when of operating the municipal solid waste (MSW) incinerator without food waste leachate (FWL) (14.3 L/h of ammonia water injected).

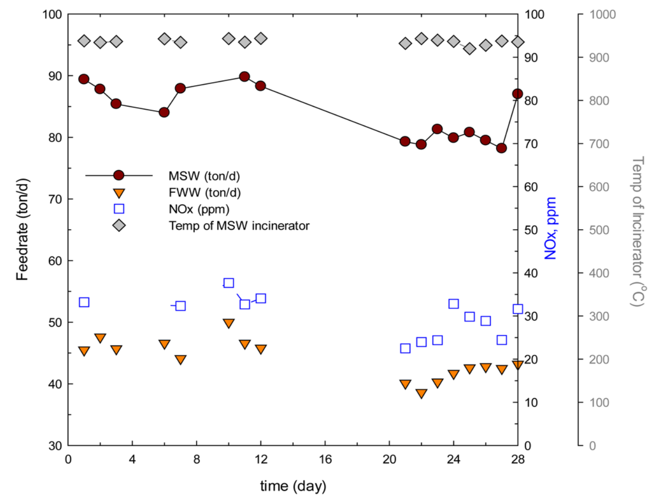

Fig. 3. The result obtained when operating the municipal solid waste (MSW) incinerator with food waste leachate (FWL) (14.3L/h of ammonia water injected).

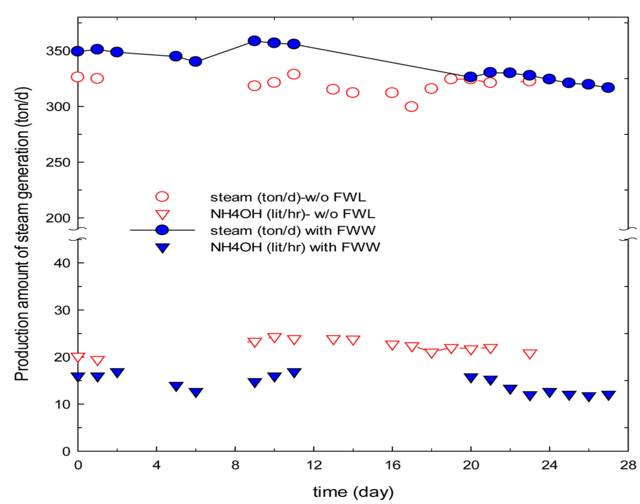

Fig. 4. Comparison of steam generation and ammonia water usage by injecting food waste leachate (FWL).

generation of NOx. As a result, FWL can be useful to replace ammonia water, especially since the operating conditions of the incinerator, such as the temperature and the stream generation (Fig. 4), were as those of other conditions, e.g., the heat loss remained below 13%. However, increasing FWL injection dosage will affect decreasing furnace temperature including emitting dioxin.

3.3. Reduction of Ammonium water Usage

The fundamental operation of an SNCR system for an MSW incinerator involves injecting 22.3 L/h of ammonia water to reduce NOx emission. The SNCR system could reduce NOx emission in flog-gas to less than 40 ppm. Injecting the FWL could help reduce ammonia water usage and could provide an option to remove FWL. The optimum condition to inject the FWL was of approximately 2m^3/h. The modified operation of the MWS incinerator with a 2 m^3/h injection of the FWL could reduce ammonia water

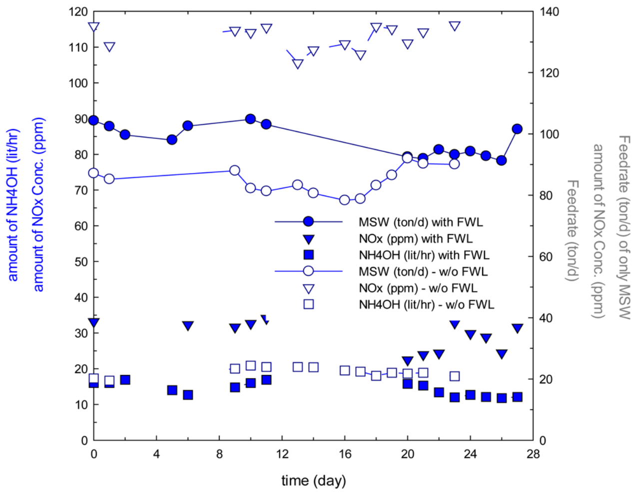

Fig. 5. Comparison of NOx reduction by injecting of ammonia water and food waste leachate (FWL).

usage from 22.3 L/h to 14.3 L/h (the savings efficiency for the ammonia water was of 35.9%) as shown in Fig. 5. NH_3-N injection dosage of FWL with ammonia water (NH_3-N concentration of FWL is 725 mg/L as shown in Table 1, NH_3-N content of 2 m^3 FWL is 1,450 g) can help to reduce ammonia water injection dosage. Furthermore, modifying the conditions of operation for the MWS incinerator, such as injecting FWL, did not have an effect on the other conditions, such as the incinerator temperature that remained at approximately 920°C and the steam generation that were similar to those without FWL (Fig. 4).

4. Conclusions

We confirmed the reduction in the concentration of NOx through a comparison of tests under several conditions. In addition, the increased in the rate of gas emissions and the rate of heat loss due to the input of FWL appeared to be of about l3% and 12%, respectively. The results of this research indicated that a positive outcome can be expected from diversifying the treatment options for FWL. Also, future research is necessary to the scientifically prove the reduction mechanism of NOx through the addition of the FWL and provide an institutional framework to manage the incineration of FWL.

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