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Formaldehyde and acetaldehyde emissions from waste wood combustion power plant, South Korea

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ABSTRACT

Formaldehyde (CH_2O) and acetaldehyde (CH_3CHO) emission from the waste wood combustion plan recognized as one of the major cause of degrading air quality. In this research, we present the obtained result from formaldehyde and acetaldehyde concentration generated by wood combustion plants at three cities, Iksan, Gunsan and Asan, South Korea which are represents some of the industry leaders in region. Totally six points were selected around the combustion power plants to provide data on the areas within zones and agglomerations where the highest and lowest concentrations of formaldehyde and acetaldehyde occur during the sampling day. High performance liquid chromatography analyzer (HPLC) was used to measure the aldehydes values in the collected samples. The average emission of CH_2O calculated on the basis emission in sampling day have been found 5.9 at Iksan , 3.32 in Gunsan and 3.62 ppb in Asan while the CH_3CHO value as measured 2.82, 1.44 and 1.91ppb.

Introduction

In relation to measure the amount of the direct formal dehydeand acetaldehyde emission generated from the waste wood combustion power plant in South Korea, this research was undertaken. Measurement of this aldehydes were carried out at 3 waste wood combustion plants in Gunsan, Asan and Iksan city in 25 of July 2010.

The combustion of waste wood to generate district heat and power in manufacturing process that have access to this energy source is increasing. By-products from logging operations, wood residues from manufacturing such as lumber, furniture, pallets, and paper, burnable solid wastes that would otherwise go to landfills are all sources of low-cost wood-waste fuel. Waste wood burning represents the largest source of air pollution in many rural areas of developing countries (Larson et al.1993). The ever increasing the concern about the effects of gas emission from wood combustion process around the residual area put the pressure on government to take adequate measurements to monitor and control the volume of these pollutants.

Collected waste from wood-based panels manufacturing such as medium density fiberboard (MDF) and oriented strand board (OSB) is one of the main fuel sources for combustion power plant in South Korea. Wood panels are usually manufactured by bonding the small pieces of wood with adhesive materials like Urea-formaldehyde (UF), phenol formaldehyde (PF) resin and melamine-urea-formald- ehyde (MUF) (Yinping et al. 2012). Emitted aldehyde compounds such as formaldehyde and acetaldehyde gases from the combustion process has become one of the major causes of degrading air quality followed by negative effect on human comfort, health and productivity.

Urea-formaldehyde (UF) resin is the most commonly used adhesive due to its good performance and low cost, while the phenol formaldehyde (PF) resin and melamine-urea-formaldehyde (MUF) is the second and third most use in wood-based panel industry (Park et al. 2008;Tang et al. 2009).

Formaldehyde has been classified as a carcinogen that can cause nasopharyngeal cancer in human (IARC.2004). Watery eyes; burning sensations of the eyes, nose, and throat; coughing; wheezing; nausea; and skin irritation are well known as the other effect of formaldehyde when the concentration of this compound in air exceeding 0.1ppm. Acetaldehyde is classified as possibly/probably carcinogenic to humans, by IARC/ US EPA, based on the observation of dose-dependent tumor incidence in inhalation bioassays in rats and hamsters. There is very little evidence that inhalation of aldehyde vapors causes asthma, a small number of studies have shown that inhalation of acetaldehyde vapor may induce bronchoconstriction and potentiate non-specific bronchial responsiveness in some asthmatic patients. Many studies have been conducted to measure and predict the concentration of acetaldehyde and formaldehyde emission from waste wood combustion process and it has again become consider of this particulate research.

Temperature in the combustion zone was found to be the most important parameter affecting the combustion process and associated air pollutants. The amounts of air pollutants will be minimal at combustion zone temperatures greater than 1100 °F (Prakash et al. 2007). Emitted aldehydes from incomplete combustion in fireplaces and woodstoves (below 1100°F) to atmosphere would be degraded through photo oxidation and oxidation by the hydroxyl radical. The main product of photo oxidation in the presence of NOx is peroxy acetylnitrate which causes eye irritations at very low concentrations of only a few parts per billion and also irritates the respiratory system.

A) Properties of medium density fiberboard

Medium density fiberboard (MDF) is fiber composite material comprising of refined wood fiber, adhesive (UF, PF and MUF), process additives and a minor amount of wax. The most promising annual plant waste materials for manufacturing MDF

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are wheat and rice straw (Halvarsson et al. 2008). Main chemical components of wood and straw materials are cellulose, hemicelluloses and lignin(Markessini et al. 1997).Physical and chemical fractionation analysis of the MDF and Straw board are given inTable 1.

Table 1. Physical and chemical fractionation analysis of MDF and Straw board (Zygarlicke et al., 1999, Sumin et al., 2004)

Physicochemical properties Wt%	MDF	Straw Board
Proximate analysis	5.8	6.70
Moisture Content	83.19	72.73
Volatile Matter	10.43	12.74
Fixed Carbon	0.58	7.83
Ash		
Ultimate Analysis,	5.79	5.65
Hydrogen	43.44	40.77
Carbon	3.93	1.24
Nitrogen	46.15	0.15
Oxygen	0.58	7.83
Ash	5.8	6.70
Urea formaldehyde (JIS A 5908) (DIN EN 120)	7.05(ppm/panel) 12.1(mg/100 g panel)	
Melamine–formaldehyde (JIS A 5908)	0.6(ppm/panel) 2.88(mg/100 g panel)	

(JIS A 5908, Japanese standard method of determining formaldehyde emission with desiccators, (DIN EN 120) European Committee for Standardization (1991) method using the perforator value was used as the typical standard methods.)

MEV formaldehyde performance standards

The acceptable levels of formaldehydes emission from industrials stacks have been continuously reduce in past decade in South Korea. South Korea ministry of environment (MEV) announced in January2010 that it had settled the suit by agreeing to implement performance standard for formaldehyde exposure from variety of industrial stacks by the mean concentration <10 ppm. (Air pollutants control act, article 15).

Experimental methods

The purpose of this section is to describe the analytical method which selected to measure, and monitor the concentration of formaldehyde and acetaldehyde during the sampling period.

Ambient air sampling

Formaldehyde/acetaldehyde was sampled using C18 resin cartridges (Sep-Pak Classic from Waters) coated with 2, 4-dinitrophenylhydrazine (DNPH). DNPH was purified by recrystallization and checked by high-performance liquid chromatography (HPLC). The aldehydes were trapped by reaction with DNPH in the cartridges forming the corresponding stable 2,4dinitrophenylhydrazonederivatives (Sergio, 2005).

Analytical method

F0ormaldehyde (and other aldehydes and ketones) can be determined by several chromatographic methods. Many of the analytical methods used for environmental samples are the methods approved by federal agencies and organizations such as EPA. EPA has published methods using dinitrophenylhydrazine (DNPH) derivatization followed by liquid chromatography that have been used in this research. The EPA methods have been published for air (Formaldehyde EPA TO-5 and TO-11).Laboratory analysis in this study were carried out by using High performance liquid chromatography analyzer (HPLC) model (UV730D/CTS30/SP930D).

Sampling location

The sampling pointswere sited to be representative of air quality in a surrounding area. Totally six points were selected inside the area of combustion power plants to provide the highest and lowest concentrations of formaldehyde and acetaldehyde occur during the sampling period.The number of sampling points for measurement determined based on accounted emission densities, and likely distribution patterns of ambient air pollution. Figure 1 shows the location of selected sampling points

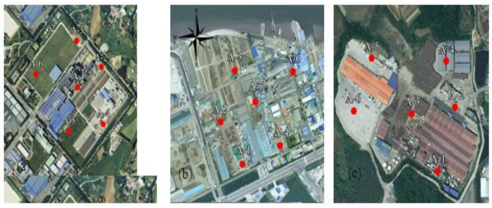

Fig. 1 Locations of six sampling points (A-1 to A-6) inside the combustion power plants area, a) Iksan, b) Gunsan, c) Asan.(A-1, source of pollution)

Result and discussion

Wood combustion plants

Table 2 shows the type and total amount of waste wood which used as fuel in 3 studied waste wood power units in South Korea which are represents some of the industry leaders in region. Fluidized bed combustion (FBC) is an established technology for generating heat and power in these plants.

Wood burning power station at Iksan city with the maximum capacity of 8.33 tons/hr established in 1991. The waste wood fuel feed consist of 1500 kg fibers, saw dust and sander dust, 5417 MDF scrap and bark wood ,1050 kg of recycled waste wood and 800 kg of Oak wood per hour. Combustion gas temperatures in the combustion boiler are reported with an average of 900^{o}C. This plant holds the distinction of having the two boilers with the low heat value (2.100-3000 Kcal/Kg) of other biomass-fired power plant. The online dates of the plan span about 20 years, from January 1991 until present.Sitting the plant in a residential neighborhood of a small city has caused a number of problems and extra expenses such as high taxes, local political involvement, and neighborhood complaints about odor and noise over the years.

Wood Combustion station at Asan city located in the area of 94,878m^{2} with maximum burning capacity of100 tons/day. This company starts working at 2005. Incineration facility currently holds an active period a total of 4.2 tons/hr of waste wood.

Biomass power plant located at Gunsan city is the third combustion plants which consider in this research, this company established in 1990 with area of 171.816 m^{2}. Medium density fiberboard (MDF) is amain product by this company. Existing combustion chamber hasmaximum burning capacity of 200 tons/day of wood waste.

Wind speed and direction

Air movements are key determinants of pollution concentrations because horizontal and vertical air flows influence the mixing and transport of air pollutant.Since pollutants are primarily dispersed downwind from sources; wind direction affects pollution concentrations (Youngkook, 2011). The frequencies for the wind direction in each cityduring the sampling period are illustrated in Figure 2.The prevailing wind directions in Asan, Gunsan and Iksan area was from the North and North westto South and South east in most of the time. Collected data from Asan station monthly and seasonal wind speed shows the highest wind speed was 3.8 m/s in this city while the lowest wind speed recorded as 0.6 in the area of Iksan.

Fig. 2 The frequencies for the wind direction in each city (25.July.2010).

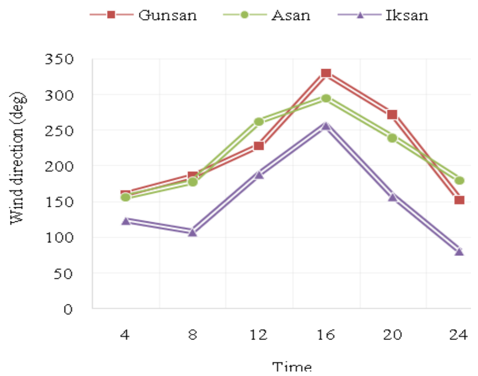

Table 2. Type and quantity of waste wood use at Asan , Gunsan and Iksan combustion plant

Type of wood	Asan		Gunsan		Iksan	
	(Tons/day)	(%)	(Tons/day)	(%)	(Tons/day)	(%)
MDF	46	46	73.5	36.8	130	65
Sawdust, wood flour	16.2	16	18	9.0		
Lang fiber	2.8	3.0	0.5	0.2	30	15
Waste board	6.0	6.0			20	10
Screening saw dust	14.2	15				
Bark wood	11.1	11	96	48		
Oak	3.7	3.0	12	6.0	20	10
Total	100	100	200	100	200	100

Acetaldehyde/Formaldehyde emission

Table 3 shows the average concentration of CH_2O and CH_3CHO during the sampling days. The samples were collected from 6 different points around each combustion plants at the same sampling and analytical condition. The given values are the average of 6 hour sampling. During the studied period, formaldehyde concentration was higher than the acetaldehyde in all selected locations.It is also observed that the highest CH_2O concentration (7.2ppb) measured at point A-1,Iksan city, while the minimum value (1.77 ppb) was found at point A-5 at Gunsan area.

The higher formaldehyde concentrations obtained from this city compare with other area were expected. Combustion power plant located at Iksan has a maximum capacity of around 200tons/day of waste wood which more than 60% of total waste consist of MDF materials, higher formaldehyde concentrations is referred to primary emissions from the stack of this company. This assumption is supported by the obtained result from concentration of formaldehyde at the stack; the highest value estimated as 1125ppb.

AS can be observed from Table 1 urea formaldehyde concentration, 12.1mg/100g in MDF panel reported in previously experiments. Combustion power plant at Iksan city uses 5.5 tons of waste MDF per hour. Simple calculation can estimate the concentration of formaldehyde by 4545mg in 5.5 tons.High temperature at combustion zone with an average of 900°C found to be the most important factor which reduces the value ofaldehydes in combustion process. This assumption is confirmed by the low concentration of formaldehyde 1125ppb released from the stack compare with actual amount, 4545g in the waste materials.

Collected data from different locations at Gunsan indicates, for formaldehyde, a maximum 4.87 ppb at point A-1 and the minimum at point A-5(1.77 ppb) while in Asan the highest concentration of fomaldehyde recorded at point A-1 (5.26 ppb) and lowest was 2.5 at point A-6.

The ambient concentration of acetaldehyde ranged at Iksan from 1.88 to 4.04, in Asan was lower from 1.51 to 2.84 and Gunsan shows from not detected to 2.36 ppb. In general, it can be assumed that, the emission value of CH_3CHO from industrials plant in studied area was almost similar and the concentration of emission was not clearly different.

Conclusions

The importance in South Korean context of the estimation of released pollutant from industrial power plant in environmental impact assessment has become increasingly concern to some public and private sectors. This research presents the result from correlation between the formaldehyde and acetaldehyde content in adhesive materials in wood-base panels manufacturing process and emission rate from wood combustion power plant which used waste wood as fuel source. Obtained result from analyzing the collected atmospheric air samples in 3 different cities of South Korea indicates:

- The emission rate of the formaldehyde at the area of Gunsan, Iksan and Asan city is nearly unchanged compare to the result from other studies but the obtained concentration of acetaldehyde in these cities are is relatively lower than other cases.
- Currently, the South Korea regulation requires emission limits of <10 ppm of formaldehyde from actual industrial stack. The obtained result in this research shows the highest emission value of 1125 ppb of formaldehyde from the industrial stacks in selected cities which were much lower than standard limit.
- The low level concentration of the acetaldehyde emission obtained from the combustion power plant in this research can be confirm this hypothesis that waste wood (biomass) can be consider as greenhouse gas neutral energy source to generate district heat and power in manufacturing process.

Table 3. Ambient formaldehyde and acetaldehyde concentration (ppb) at different locations of selected cities

Location (City)	Sampling Point	formaldehyde	acetaldehyde
(Gunsan)			
	A-1	4.87	2.6
	A-2	3.51	2.11
	A-3	3.84	2.36
	A-4	3.47	1.62
	A-5	1.77	N.D
	A-6	2.46	N.D
	Average	3.32	1.44
(Asan)			
	A-1	5.26	2.84
	A-2	3.9	1.63
	A-3	2.92	1.51
	A-4	4.07	1.72
	A-5	3.08	2.05
	A-6	2.5	1.72
	Average	3.62	1.91
(Iksan)			
	A-1	7.2	4.04
	A-2	5.6	2.25
	A-3	5.43	2.09
	A-4	5.37	2.85
	A-5	4.6	3.82
	A-6	3.62	1.88
	Average	5.9	2.82

Acknowledgements

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