Characteristics of VOCs of Industrial Complex in Incheon Area

Ji Ye Yoo, Ji Young Kim, and Chan Jin Park

***Abstract*—The primary pollutants such as sulfur dioxide and carbon monoxide tend to be gradually improved due to promotion of fuel policy etc. However, secondary pollutants such as ozone and fine dust are getting worse. Hence, it is necessary to strengthen regulations on VOCs.**

Incheon city has located large industrial complexes such as export industrial complex, Namdong industrial complex, Incheon mechanical industrial complex, Incheon district industrial complex, Incheon casting industrial complex. These industrial complexes are mainly composed of large-scale manufacturing industries and chemical industries such as machinery, equipment, assembly metal, automobile, and primary metal. However, these industrial complexes are mixed with residential areas in the city center, and it is also a source of odor generation that can cause complaints by odor inducing substances and VOCs.

In this study, in order to it's investigate the general characteristics of the Namdong industrial complex and the present status of the odor complaints, and we analyzed VOCs items by using the data of photochemical pollutant measurement network operated in the vicinity of industrial complex, and measured the concentration emitted from the odor control facility of the Namdong Industrial Complex and the odor emission control to analyze the current situation.

***Index Terms*—VOCs, odor, industrial complex, Incheon.**

I. Introduction

Incheon City has been characterized by industrial integration due to favorable location conditions such as roads and harbors. Air pollution of various and complicated shapes is occurring. In particular, Located in southeast part of Incheon, Incheon Namdong Industrial Complex was completed in 1997. As the largest industrial complex in Incheon City, some cases of civil complaints are due to odor problems including air pollution are continuously appearing.

There are a variety of industries and companies in the Namdong Industrial Complex, and residential areas such as large-scale apartments are adjacent to each other, so the odor problem of the Namdong Industrial Complex is becoming very sensitive. Therefore, in order to solve the odor problem of Incheon Namdong Industrial Complex reasonably, it is necessary to identify the odorous substance emitted from the Namdong industrial complex and to identify the source of the main odor substance. Through this, countermeasures against major odor sources can be prepared and efficient management strategy can be derived.

Large-scale industrial complexes such as Namdong Industrial Complex are likely to generate odor and VOCs (volatile organic compounds) due to the characteristics of the industry, by discharging a large amount of volatile chemical substances. In recent years, it has been designated and managed as a odor management area, however, odor complaints are continuously occurring.

Exposure to volatile organic compounds (VOCs) occurs in the workplace. [1] They are also the most common accidental release in the outdoor environment. One study examined the blood of individuals living close to hazardous waste sites and found no difference in VOC levels between the exposed population and controls [2]. There are ongoing studies to look at citizens living near toxic waste sites in order to determine blood VOC levels and to follow them over time to detect potential adverse health effects [3]

In this study, in order to it's investigate the general characteristics of the Namdong industrial complex and the present status of the odor complaints, and to investigate the volatile organic chemical emission status among the odor inducing substances.

II. Math

The purpose of this study is to investigate the basic data such as the current status of odor induced emission facility and characteristics of odorous complaints at Namdong Industrial Complex. This can grasp the characteristics of odor generated in the Namdong Industrial Complex of Incheon City to the residential area, it can be confirmed separation of offensive odor source, so it will be utilized for monitoring and management of odors occurring in Namdong Industrial Complex in the future.

We investigated the ingredients of odor complaints in the Incheon area and divided it into 6 regions of the area for more effective analysis. And we analyzed VOCs items by using the data of photochemical pollutant measurement network operated in the vicinity of industrial complex, and measured the concentration emitted from the odor control facility of the Namdong Industrial Complex and the odor emission control to analyze the current situation.

The concentration of odor emitted by the odor prevention facility was analyzed using the air dilution olfactometry method.

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III. Incheon Namdong Industrial Complex Status

Incheon city has located large industrial complexes such as export industrial complex, Namdong industrial complex, Incheon mechanical industrial complex, Incheon district industrial complex, Incheon casting industrial complex. These industrial complexes are mainly composed of large-scale manufacturing industries and chemical industries such as machinery, equipment, assembly metal, automobile, and primary metal. However, these industrial complexes are mixed with residential areas in the city center, and it is also a source of odor generation that can cause complaints by odor inducing substances and VOCs. [4]

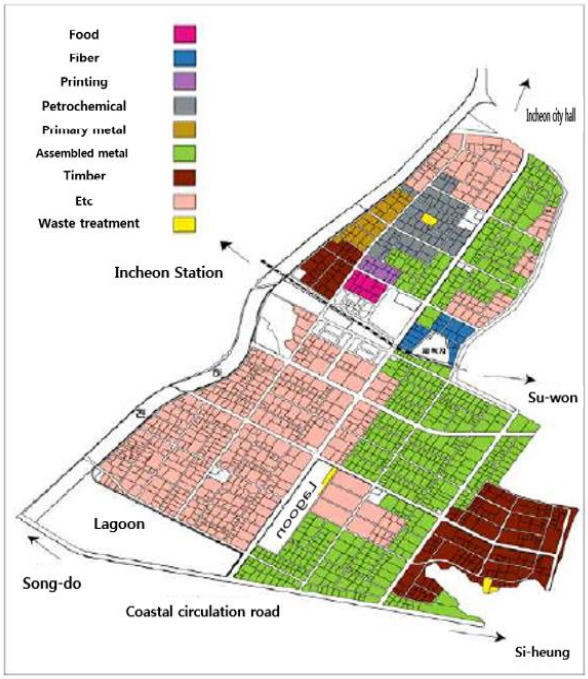

Fig. 1. Nandong industrial complex layout.

In the case of Incheon Namdong Industrial Complex (Fig. 1), there are 7,209 companies and factories are occupied, the machinery sector accounted for the largest proportion of 53.22% in each industry type, followed by electronics, petrochemical, and others.

Incheon Namdong Industrial complex is located in the southwestern part of Incheon, 40 km away from Seoul. It is one of the largest industrial complex in the western part of Korea. It is an industrial complex centered on metal industry, which was established in 1985. The total area is 9,574,000 m^2, which is built in the industrial facility area 5,933,000 m^2, the support facility area 257,000 m^2, the public facility area 2,991,00 m^2, the green area 393,000 m^2. [5]

IV. Odor Emissions by Industry

Organic compounds with heteroatoms, such as fatty acids, sulfur compounds, aldehydes, and amines, tend to have a low odor detection value, and odor related complaints may occur in a workplace where such substances are released.

Especially, in the case of facilities where low odor detection value is low, such as fatty acid, mercaptan, trimethylamine and the like are generated, awareness is necessary as a small amount even if discharged into the atmosphere causes serious offensive odor complaints is there.

Major sources of odor emissions are listed in the following Table I.

TABLE I: Classification of Odor Emission Sources by Mainly Contained Odor [6]

Compound	Main Odor	Name of business (Emission sources)
Sulfur-containing Compounds	Hydrogen Sulfide	Pulp paper Factory, Night-Soil treatment plant, Sewage disposal plant, Drain pit of high-rise building, Rubber factory, Rayon factory, Landfill
Nitrogen-containing Compounds	Ammonia, Trimethyl Amine	Poultry farm, Composting facility, Fish-meal plant, Night-soil treatment plant
Organic Solvent	Toluene, Xylene, Ethyl Acetate	Coating factory, Photogravure factory, Laundry, Adhesive manufacturing factory, Plywood factory, Car repair shop, Furniture manufacturing factory
Aldehyde Compounds	Acetaldehyde	Metal coating factory, Casting factory, Off-set printing factory, Car coating factory, Coffee baking factory
Lower fatty acid	n- Butyric Acid	Poultry farm, Pet shop, Starch manufacturing factory

V. VOCs Management Direction

A. United States

In the United States, VOCs regulations were started in 1960's when California SCAQMD (South Coast Air Quality Management District) regulated the VOC content of organic solvents through California Rule 66. Along with the revision of the Clean Air Act in 1977, it began to regulate the emission of large emission sources emitting more than 100 tons of VOCs per year. In CAAA1990 (Clean Air Act Amendment), the ozone standards were classified into five levels and strengthened regulations on mobile pollution sources. [7]

Through the Clean Air Conservation Act, the federal government submitted a State Implementation Plan (SIP) incorporating VOCs reduction measures. The SIP, developed by a state agency and approved by EPA, which consists of narrative, rules, technical documentation, and agreements that an individual state will use to clean up the polluted areas. [8]

Also, in order to manage NOx, VOCs and ozone due to atmospheric pollutants, the US federal government has already operated regulation on total quantity for NOx and VOC for a long time.

B. Europe

In 1992, the European Economic Community (EEC) established a unified standard for air pollutants based on German regulatory law and pursues to achieve low cost goal by using Best Available Technique Not Entailing Excessive Cost (BATNEEC).

Main goal is to reduce organic solvent emissions from processes and industrial facilities. There are restrictions on emission of organic solvents and emission standards that classify target industries according to their industries.

Europe regulates according the two kinds of methods. There are being regulated with Solvent Emission Directive (SED, 1999) and Products Directive (PD, 2004) [9]

C. Japan

Japan comprehensively regulates various substances as VOCs without limiting the names of regulated substances. It is estimated that about 200 kinds of substances corresponding to VOCs are widely used in the industry. In order to facilitate the understanding of the stakeholders, the name of the main substance corresponding to VOCs are indicated in a document notified to the head of each local governments by the director of the Environmental Management Agency of Japan. [9]

D. Republic of Korea

The primary pollutants such as sulfur dioxide and carbon monoxide tend to be gradually improved due to promotion of fuel policy etc. However, secondary pollutants such as ozone and fine dust are getting worse. Hence, it is necessary to strengthen regulations on VOCs.

Therefore, regulations were enacted with VOCs regulatory rationale provisions in 1995. “Special Act on Seoul Metropolitan Air Quality Improvement” was established for the metropolitan area, and it was enforced from 2005. [10]

In order to prevent the generation of VOCs in the workplace, the pilot project for the installation of the oil vapor recovery system was implemented all gas stations in the metropolitan area in stages since 2007. Other projects that have been implemented include: limitation on the content of organic solvents in paints for building and automobiles, expansion plan of water-based paint, improvement of packaging inhibition and packaging method etc. [11]

Recently, management measures are being implemented such as strengthen management of VOCs emission sources in urban areas and preparation VOCs contain standards for living consumer goods. [12]

VI. Result

A. Status of Incheon Offensive Odor Complaints Occurrence

In this study, we investigated the ingredients of odor complaints in the Incheon area and divided it into 6 regions of the area for more effective analysis (Fig. 2). A-region where landfill sites and industrial sites is located, B-region where factories with high pollutant emissions is located and adjacent to harbors, C-region where a odorous source such as a lagoon is located in the center of a city, D-region where large-scale industrial complex and residential area is mixed, E-region where a lot of motorways with various highways, and F-region where many green areas is located, as compared to other areas. [13]

Fig. 2. Incheon area classification by region.

The A-region is the largest incineration area for odor civil complaints due to the location of landfills and industrial complexes. Recently, odor civil complaints have increased rapidly in moving into a new apartment, but it has been gradually improved due to efficient management of odor in landfills.

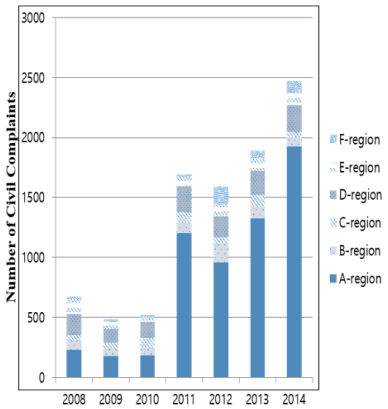

Fig. 3. Current status of odor civil complaints by Incheon area [14].

The B-region is located in port facilities, so it’s easy to transport of raw materials. Therefore, This region located in grain-related industries and petroleum-related facilities, and then these industries causing odor civil complaints. In addition, the J-zone of B-region is a combined sewage treatment system in which domestic sewage and rainwater are treated at once. Living sewage is continuously flowing into rivers, this water flow to be blocked at the tide, so that odor is generated.

The C-region is located in lagoons and industrial complexes, this region is the central area of Incheon.

The N-zone of D-region is located in largest industrial complex which is the main cause of odorous civil complaints. Also, it affects the adjacent Y-zone, and this area is complaining about the odor of adjacent industrial complex

rather than the complaint caused by its own odor source.

In the P-zone of the E-region, It uncompleted sewer system had neglected by state of uncovered, and then causing damage to sewage odors and pests for local residents. However, civil complaints has been decreasing due to the implementation of environment improvement project. G-zone of the E-region also complained due to sewer problem. Thus, the main cause of this region is the living odor unlike in the other regions.

Finally, the F-region is thought to have caused complaints due to odor of household garbage, livestock farms and beaches that are not suitable for standards

Fig. 3 showed the status of Incheon offensive odor complaints between 2008 and 2014.

B. Status of Incheon Offensive Odor Complaints Occurrence

A total of 7, 209 companies are located in the Incheon Namdong Industrial complex in 2016. There are companies in various industries such as metal machinery manufacturing, electrical and electronics manufacturing, and petrochemical industries. [15] Fig. 4 shows type of industries in NIndustrial Complex

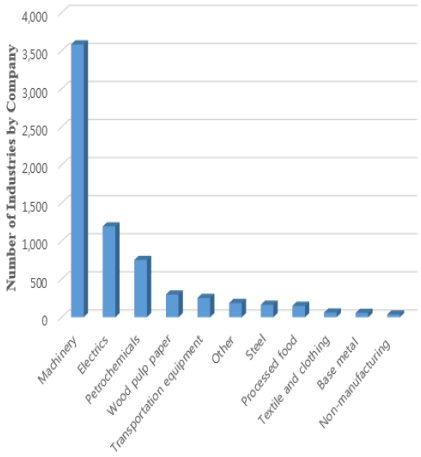

Fig. 4. Types of industries in Namdong industrial complex in Incheon area.

TABLE II: MONTHLY INCHEON NAMDONG INDUSTRIAL COMPLEX OPERATION RATE

Month	Operating Rate(%)
1	74.6
2	69
3	73.6
4	79.2
5	78.9
6	76
7	75.6
8	69.7
9	71.6
10	78.1
11	78.1
12	77.3

The monthly operating rates of companies that Namdong Industrial Complex are shown in the Table II. The monthly operating rates of companies that Namdong Industrial Complex are as shown in the table below. The operating rates fell to 69% in February and August of the year, but another monthly operating rates were more than 75%.

C. Status of VOC Measurement at the Namdong Industrial Complex

Among the VOCs, 56 items that greatly contribute to the ozone generation were analyzed. [16] The most emitted items were Ethane, Propane, Toluene, n-Butane, etc. As a result of the monthly measurement, the majority of VOCs showed low measured concentrations in August and September, it seems that the result was influenced by the operation rate of the nearby industrial complex. The related content is shown in Fig. 5-7.

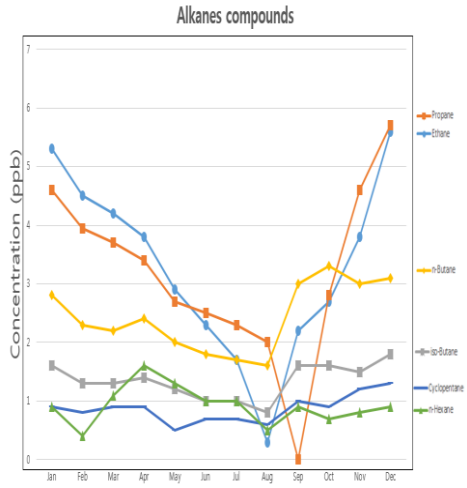

Fig. 5. Tendency of concentration of alkanes components.

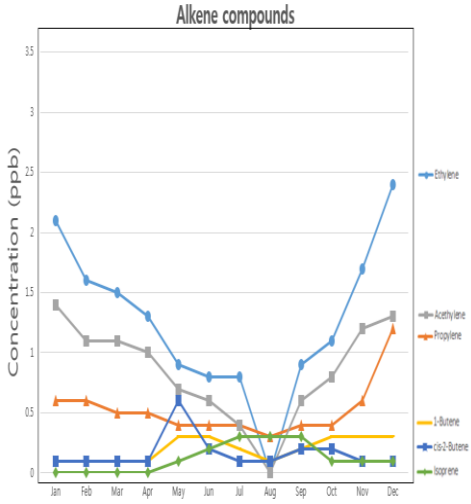

Fig. 6. Tendency of concentration of alkenes components.

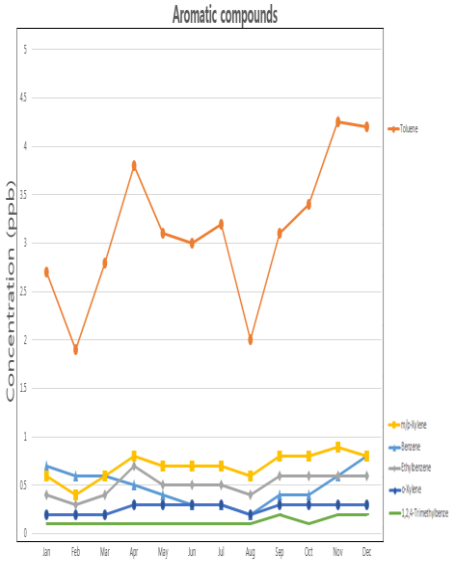

Fig. 7. Tendency of concentration of aromatic components.

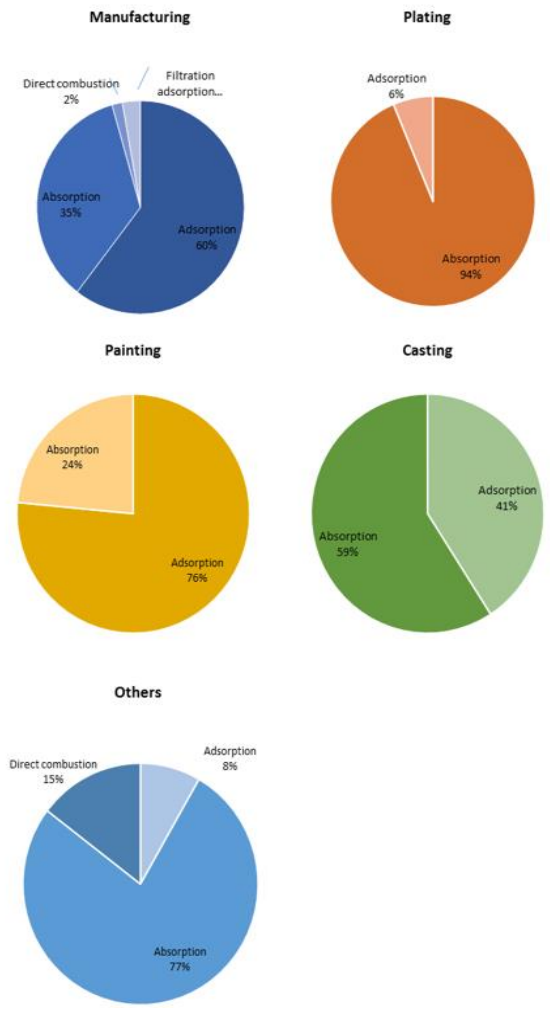

Fig. 8. Odor control facilities by industry.

D. Namdong Industrial Complex's Odor Reduction Technology

Over the past three years, the results of analyzing odorous samples in the Namdong Industrial Complex by air dilution olfactory method were classified by industrial process, and the operating characteristics of the odor control facilities are described. The analyzed industries are manufacturing, plumbing, wastewater treatment, aluminum casting, painting and other coating processing, metal heating treatment, and casting etc.

The classification of odor control facilities by industry type are as follows. In the manufacturing industry, various odor control facilities are operating for instance absorption, adsorption, direct combustion, filtration adsorption, microbial catalyst, etc. Among them, adsorption facility is most frequently used at 60%. The industries that occupy the largest number of the manufacturing industry are the printed circuit board manufacturing companies and the cosmetics manufacturing companies.

In general, it was investigated to used by one type of adsorption and absorption facilities as odor control facilities in all industries. 94% of the plumbing companies using absorption facilities, and 76% of the painting companies using adsorption facilities. (Fig. 8)

The odor removal efficiency of the odor control facilities by type of industries are shown in Table III. In the manufacturing industry and the plating industry, the adsorption facilities had the highest removal efficiency for odor, and in the casting industry, the absorption facility had the highest odor removal efficiency.

TABLE III: REMOVAL EFFICIENCY OF ODOR CONTROL FACILITIES BY INDUSTRY

Type	Odor control facilities	Removal efficiency
Manufacturing	Adsorption	66%
	Absorption	85%
	Direct combustion	78%
	Filtration adsorption	61%
	Microbial catalyst	69%
Plating	Adsorption	29%
	Absorption	60%
Painting	Adsorption	64%
	Absorption	65%
Casting	Adsorption	82%
	Absorption	53%
Others	Adsorption	39%
	Absorption	52%
	Direct combustion	35%

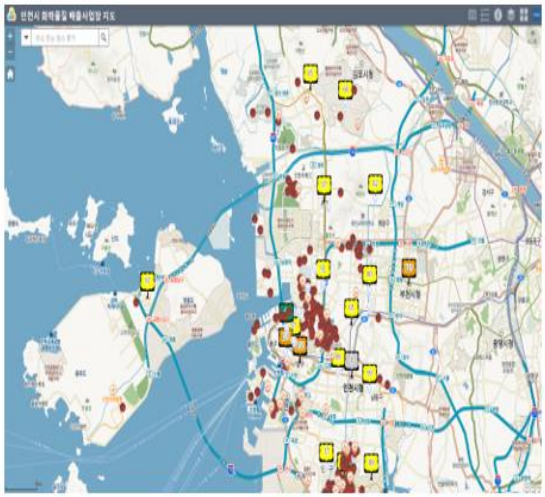

Fig. 9. Illustration of odor emission inventories.

VII. CONCLUSION

In Incheon area, there are various source of odor kinds of industries such as heavy industry, automobile, steelmaking, paint, oil reservoir, contractor, chemical industry, food manufacturing industry, etc.

Especially odors are generated by various VOCs substances rather than being limited to eight main odorous substances, and it seems to be influenced by the state of

operation of the industrial complex in the nearby area.

The concentrations of odorous components appeared low in summer season, and seasonal fluctuations increased in the order of ethane, propane, toluene and n-butane.

These components are measured higher concentration from autumn to spring than in other components, so it is a necessary to continuous monitoring on these components.

Based on the GIS platform (Fig. 9), Incheon City creates a map of the chemical substance discharge site in the Incheon area, conducting of survey on the status of hazardous air pollutants at 15 points in the center of the city, and plan to continuously reduce environmental pollutants.[17] In this regard, it is considered necessary to monitor the odor emission characteristics of the area at the same time as the meteorological condition, to correlate the concentration of measurement data with the wind direction, wind speed to check the relation with the discharge site.

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