

신평장림 공단 폐수처리장 발생의 악취 조사연구

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Survey on Public Responses to Odor Produced at Jangrim-Sinpyoeng Municipal and Industrial Wastewater Treatment Plant in Busan

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ABSTRACT

Objective: Emissions of volatile organic compounds (VOCs) from municipal wastewater treatment plants and industrial wastewater are often overlooked as sources of exposure to toxic chemicals. VOCs from such sources evaporate readily into the air and may have significantly adverse impacts on public health. The present study aimed to establish the concentration of VOCs released from Jangrim-sinpyoeng Municipal and Industrial Wastewater Treatment plant (JWTP) in Busan, South Korea and assess the causes of the odor/stench in the surrounding residential facilities. Stench intensity, frequency and release time, and wind direction were also monitored.

Methods: Onsite data were collected on a daily basis from a laboratory located on the JWTP premises through a period spanning 2006 to 2010. A second set of data was obtained in 2006 by conducting a questionnaire survey with 210 respondents living near JWTP. The experimental and survey data were analysed statistically using the SPSS package.

Results: The survey results showed that people residing around JWTP strongly perceive a stench from the plant. The intensity of the stench was influenced significantly by wind direction and the location of the apartments facing the JWTP. Public participation formed a significant step in determining the quality of the study environment.

Conclusion: Onsite data and survey data obtained in 2006 indicate that the nature of the odor experienced by residents is due to the intensity of total VOCs released by JWTP. However, additional research is needed to determine the effects of the VOC pollution on public health and quality of life.

Key words: Volatile organic compounds, Wastewater, Odor, Stench, VOCs

I. Introduction

Various domestic and industrial activities result in the production of industrial and municipal wastes which then act as emission sources of hazardous substances.¹⁾ Decomposition of these municipal

and industrial wastes results in the release of odor into the surrounding air thus impacting residents.²⁻⁶⁾ Odor nuisances are becoming more frequent because of urbanization and the consequent location of treatment sites near residential places.⁷⁾ Efforts to reduce emissions are very limited since protests

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from people perceiving the odor is also very limited.⁸⁾

Odor is a sensation caused by odorant molecules in the air. Odor perception is the result of reaction between volatile molecules inhaled through the air by the human nose and olfactory sensory neurons situated in the upper parts of the nasal cavity in man.⁸⁾ Pilpel *et al.*⁹⁾ described the transduction mechanisms involved in the stimulus generation at a molecular level in humans. The degree of odor perception by humans is determined by several factors such as individual physiology, individual perception of smell and interaction with factors such as physiology, weather phenomena, and various other odors¹⁰⁻¹²⁾ Estimation of odor intensity using instrumental techniques have been reported.^{13,14)} Similar studies were carried out in swine farms in upper mid West USA.¹⁵⁾ According to analysis of ambient odors from air samples collected from feeding yards, pen yards, and a wastewater storage site in USA, such odors were dominated by hydrogen sulphides and ammonia, in excess of EPA guideline levels. Lim *et al.*¹⁵⁾ found that the intensity of stench/odor in the study area was significantly influenced by the direction of the wind.

Volatile organic compounds (VOCs) are known to produce the widest range of odors in the air¹⁶⁾ with their inorganic counterparts like hydrogen sulfide and ammonia. Generally, odor is perceived physically by the nose receptors and psychologically processed in the brain, thus rendering it difficult for quantitative measurements. Odor perception is personal and is confounded by a number of factors such as gender, age, state of health and individual effects which is why people may not be bothered by odors from their own bodies.

Wind speed and direction can exert a direct effect on the dispersion of odorous compounds.¹⁷⁾ High speed winds will spread the odor rapidly, thereby diluting its intensity over a wider area under the low wind speed conditions; the odor is close to the ground, thereby strengthening its intensity. The specific weight/density of the odorant molecule will also influence its dispersion by wind. As heavy odors stay close to the ground they can be detected more easily by humans. During decomposition of organic waste (such as sewage), 80 to 200 different gases are produced.¹⁸⁾ A combination of several gases together can

produce odors either higher intensity or lower intensity than the individual gases.^{18,19)}

Studies on Creeks that acted as open sewers carrying wastewater from industry and residential areas in Izmir city in Turkey revealed that volatile sulphur compounds caused most of the odor.²⁰⁾ A similar study, on the effects of exposure to biosolids used on farms in Wood County in Ohio, USA, reported that health hazards were significantly elevated among the residents.²¹⁾ The symptoms reported included increased secretion of tears, abdominal bloating, jaundice, skin ulcers, dehydration, weight loss and general body weakness. The report also showed increased cases of bronchitis, upper respiratory infection and giardiasis.²²⁾ Little information is available on the relationship between odor and human, as most studies emphasize the effect of individual gases like ammonia rather than the odor as a whole.¹⁸⁾

The aim of this research was 1) to establish if the Jangrim-Sinpyoeng Municipal and Industrial Wastewater Treatment Plant (JWTP) in Busan City release any bad odor and 2) if they are released, how serious it will be on the local residents. It was also intended to assess the possible management practices to mitigate the effects.

II. Materials and Methods

1. Data from onsite laboratory

The 5 years data (2006 to 2010) in this study was collected from two major sources. The first form of the data with different chemical parameters were obtained from the onsite laboratory at the Jangrim-Sinpyoeng area in Busan city (035° 04' 51"N and 128° 58' 18"E), which was maintained by the Korea Institute of Public Health and Environment. The detailed information about the data collection of chemical and physical parameters is given in Table 1. The sampling was done every hours by the instrument installed at the onsite laboratory was online gas chromatography – flame ionization detector (GC-FID) for the analysis of VOC substances. All data were calculated to average ppm per day. All the VOC compounds were computed as prescribed by Son and Striebig⁷⁾ (2003) (Table 1). Also, the release of odor substances was correlated with wind direction and speed.

The stench/odor intensity (Y) data for all VOC

Table 1. Sampling period and parameters of interest on onsite data

Year	Sampling period		Total operating time (hrs)	VOC type	Physical parameters
	Start Month/day	End Month/day			
2006	01/01	12/31	8760	Class 1: toluene, m/p-xylene, styrene, o-xylene, Class 2-3: ethane, ethylene, propane, propylene, acetylene, Class 4: iso-Butane, n-butane, trans-2-butene, 1-butene, cis-2-butene, Class 5: cyclopentane, iso-pentane, n-pentane, trans-2-pentene, 1-pentene, cis-2-pentene, iso-prene, Class 6: 2,2-dimethylbutane, 2,3-dimethylbutane, 2-methylpentane, 3-methylpentane, n-hexane, 1-hexene, methylcyclopentane, benzene, cyclohexane,	Wind direction, wind speed, temperature and humidity
2007	01/01	12/31		Class 7: 2,4-dimethylpentane, 2-methylhexane, 2,3-dimethylpentane, 3-methylhexane, n-heptane, methylcyclohexane,	
2008	01/01	12/31		Class 8: 2,2,4-trimethylpentane, 2,3,4-trimethylpentane, 2-methylheptane, 3-methylheptane, n-octane, ethylbenzene,	
2009	01/01	12/31		Class 9: n-nonane, isopropylbenzene, n-propylbenzene, m-ethyltoluene, p-ethyltoluene 1,3,5-trimethylbenzene, o-ethyl; toluene, 1,2,4-trimethylbenzene, 1,2,3-trimethylbenzene	
2010	01/01	12/31		Class 10-12: n-decane, m-diethylbenzene, p-diethylbenzene, n-undecane, n-dodecane	

Table 2. Variables included in the questionnaire

Sl. No.	Variables	Value
1. Sex		Male (1), Female (2)
2. Age		>20 (1), 21-30 (2), 31-40 (3), 41-50 (4), 51-60 and above (5)
3. Living area		Dongwon royal (1), Jangrim-dong (2), Business area (3), working area (4), others (5)
4. Frequency		Every day (1), 4-5 times per day (2), 2-3 times per day (3), weekly once (4), 1 or 2 days (5), does not occur (6)
5. Responses about smell		Every day (1), 4-5 times per day (2), 2-3 times per day (3), weekly once (4), 1 or 2 days (5), does not occur (6)
6. Happening time		6-12 am (1), 12-18 pm (2), 12-24 pm (3), 0-6 am (4), irregular (5)
7. Duration of happening		One or more days per week (1), less then one day bur more than 1 hr (2), less than 1 hr but more than 15 min (3), less than 15 minutes (4), not feel any odor (5), does not occur
8. Wind direction		East (1), west (2), south (3), north (4), northwest (5), southwest (6), northeast (7), southeast (8)
9. Displeasure level		Not at all unpleasant (1), Almost does not offend (2), yes I just (3), somewhat Offensive (4), very offensive (5)
10. Seriousness		Not at all serious (1), almost no serious (2), serious (3), less seriousness (4), very seriousness (5)
11. Living environment		Very satisfied (1), somewhat satisfied (2), usual (3), somewhat dissatisfied (4), very dissatisfied (5)
12. Air environment		Very satisfied (1), somewhat satisfied (2), usual (3), somewhat dissatisfied (4), very dissatisfied (5)
13. Who's responsibility to protect the environment		Municipal corporation (1), NGOs (2), Media (3), Residents (4), factories (5), Others (6)
14. Regulation status		Very weak (1), slightly weak (2), keep current (3), slightly enhanced (4), much enhanced (6)
15. Way of handling by the environmental protection authority		Very satisfied (1), satisfied (2), usual (3), some dissatisfied (4), very dissatisfied (5)
16. Involvement of local residents to protect the environment		Do not participate (1), depends on the situation (2), active participation (3)

substances were calculated from the following formulae,

$$Y = [a \times \text{Log}(X) + b]_1 + [a \times \text{Log}(X) + b]_2 + \dots [a \times \text{Log}(X) + b]_n$$

X: headspace in ppm, a and b: threshold level in ppm, Y: higher than fixed ppm level based on smell)

2. Data from questionnaire

The second source of data was surveyed in the year 2006 from individuals living around JWTP area. Two types of respondents were selected, one category was native residents (experimental group) and other was floating population (control group), working in that area for a long time. Totally 210 residents were interviewed^{23,24)} (Table 2). The questionnaire data were correlated using the statistical package for social sciences (SPSS 12.1).

III. Results

1. Onsite laboratory analysis

The summary of the concentration data for the VOC substances in air is shown in Table 3. VOC concentrations in the air varied widely in the measuring site with an overall range from less than 1 ppm to >9 ppm (Table 3) with a mean of 3.0 to 3.1 ppm (Table 4). Data clearly show that the maximum intensity of total VOCs released every year (2006 to 2010) into the air was >9 ppm (Table 3). At >9 ppm, the highest duration of VOC release (400 and 360 hrs) was observed in

Table 4. Annual mean values of VOC's released from Jangrim-Sinpyoeng Municipal and Industrial Wastewater Treatment Plant, Busan

Year	Mean (ppm)
2006	3.0
2007	3.0
2008	3.0
2009	3.1
2010	3.1

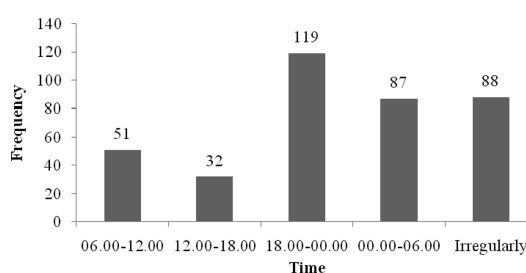


Fig. 1. Frequency of odor in different time period.

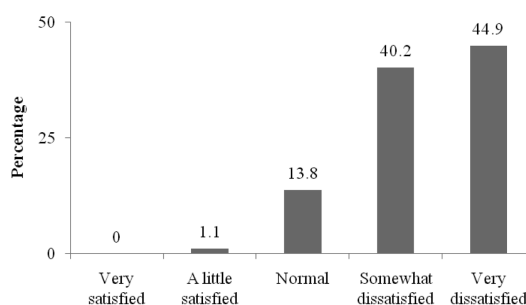


Fig. 2. Resident responses about the industrial stench.

Table 3. Annual VOC intensity level

Intensity level (ppm)	2006		2007		2008		2009		2010	
	Time (hours)	%*	Time (hours)	%*	Time (hours)	%*	Time (hours)	%*	Time (hours)	%*
> 1	8595	98.1	8592	98.1	6792	77.3	7056	80.5	7015	80.1
> 2	4677	53.9	4680	53.4	5016	57.1	5184	59.2	5281	60.3
> 3	3301	37.7	3312	37.8	3696	42.1	3384	38.6	3655	41.7
> 4	2326	26.5	2376	27.1	2616	29.8	2352	26.8	2214	26.5
> 5	1739	19.8	1728	19.7	1608	18.3	1704	19.5	1672	19.1
> 6	1255	14.3	1248	14.2	1008	11.5	1152	13.2	1456	16.6
> 7	857	9.8	864	9.9	528	6.0	648	7.4	1264	14.4
> 8	560	6.4	600	6.8	264	3.0	384	4.4	386	4.4
> 9	400	4.6	360	4.1	168	1.9	216	2.5	272	3.1

* % = (total hours released / hours per year) × 100

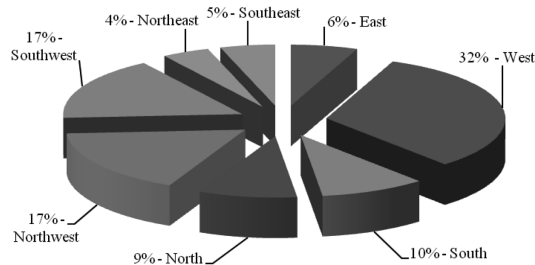


Fig. 3. Relationship between wind direction and stench perception.

the year 2006 and 2007 (Table 3). At above 1 ppm level, the highest duration occurred in the year 2006 (8595 hrs) and 2007 (8592 hrs).

2. Responses to questionnaire

The result from the questionnaires were analyzed and represented in graphs (Figs. 1 to 9). The results of the study showed that most of the residents (119) living in Jamgrim-Sinpyoeng area felt the stench between 6 to 12 pm (18.00 to 00.00). Eighty eight (88) residents felt heavy and irregular stench between 0.00 to 6.00 o'clock. Less than 51 residents felt the stench between 6.00 to 18.00 o'clock. Fig. 2 illustrates how the residents coped with the industrial stench. This section had five options (very satisfied, a little satisfied, normal, some what dissatisfied and very dissatisfied) and the respondents were required to choose only one. The results clearly show that more than 40 per cent of the residents were moderately dissatisfied or very dissatisfied in their daily life because of the stench. The next section of the questionnaire dealt with the relationship between the wind direction and stench perception (Fig. 3). The respondents were required to choose the direction in which they felt the stench came from. The feedback from the questionnaire indicated that most of the residents (24%) felt the wind come from west. However, less than 13% of the residents felt different directions like northwest (12.7), southwest (12.4), south (7.1), north (6.6), east (4.5%), southeast (3.7%) and northeast (3.2%).

The questionnaire also asked the respondents to find the intensity of the stench at 6 scale levels based on the resident responses (Fig. 4). Responses were given a 6 point scale ranging from not at all offended, almost not at all offended, 50-50, somewhat

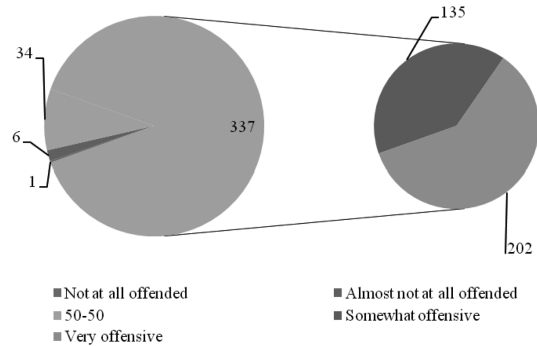


Fig. 4. Residents responses about the degree of nuisance.

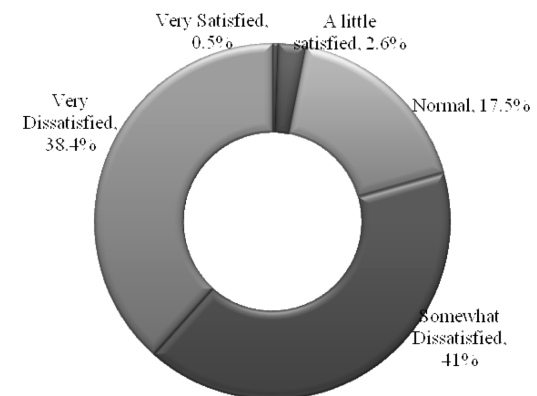


Fig. 5. Resident satisfaction about their living environment.

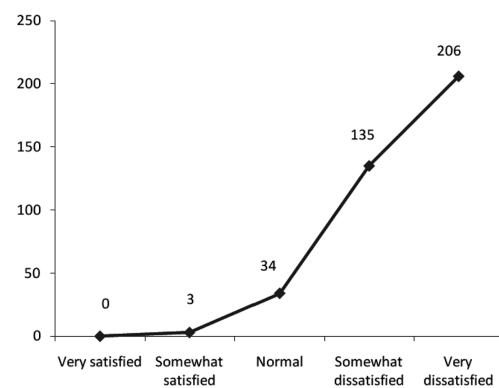


Fig. 6. Resident satisfaction about the air environment.

offensive, and very offensive. The results are shown in Fig. 4. The results indicate that most respondents (337) felt that it was very offensive (202) and somewhat offensive (135). Thirty five (35) respondents felt 50-50, 6 respondents felt

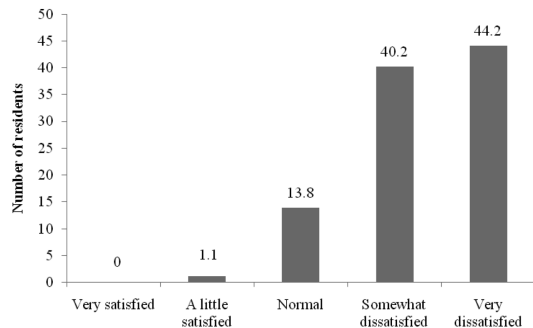


Fig. 7. Residents satisfaction about the agencies involved in the regulation of air quality.

almost not at all offended and 1 respondent felt not at all offended. The next section of the questionnaire indicates the residents satisfaction with the environment in relation to the presence of the stench (Fig. 5). The order of satisfaction based on their living environment was: some what dissatisfied (41%) > very dissatisfied (38.4%) > normal (17.5%) > a little satisfied (2.6%) > very satisfied (0.5%). The next part of the questionnaire was sorted to find out the resident satisfaction of air quality with respect to presence of stench (Fig. 6). Many residents who participated in this programme felt that their air quality is somewhat dissatisfied (135) and very dissatisfied (206). The resident's satisfaction in the questionnaire about the agencies involved with the regulation of their living environment air quality is shown in Fig. 7. Most respondents (>84 percent) felt that they were somewhat dissatisfied and very dissatisfied with the agencies involved in this issue to minimize risk.

This section of the questionnaire was sorted to assess the resident's view of which organization should be responsible for clearing the stench off the area. Forty percent of residents who participated in the questionnaire survey felt that the Busan city agency would have the major response to maintain the healthy air environment, and 29 and 19% felt responsibility of Sahagucheong Agency and local Environment Agency (Fig. 8). However, some residents (<10%) felt responsibility of other agencies like Corporate agency, Dongsamuso agency and Local residents. This part of the questionnaire was concerned with the residents' view in identifying the most effective way of dealing with the stench

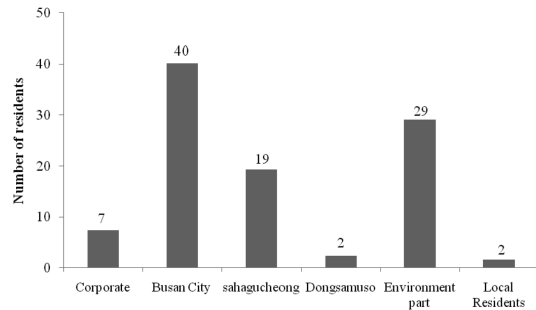


Fig. 8. Residents view of responsible organization to maintain the air quality.

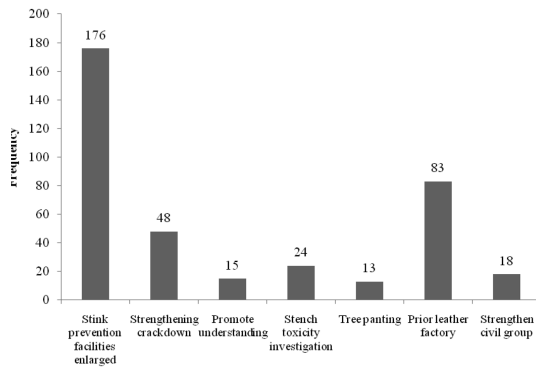


Fig. 9. Residents view about the stench problem.

problem (Fig. 9). Most respondents (176) recommended "stink prevention facilities enlarged" and prior leather factory (83) or strengthening crackdown (48) to control the stench problem. However, less than 25 respondents felt "stench toxicity investigation", "strengthen civil group", "promote understanding" and "tree planting" is most effective way of dealing the stench problem.

Responses to the questionnaire indicates that the people living close to the plant receive odor/stench of varying intensities at different times of the day depending on where their apartments are located in relation to the plant. People living in apartments situated at the West seemed to be affected the most. Physicochemical factors like wind speed, specific weight/density of the odorising molecules, temperature and humidity were found to affect the intensity of stench.

The results show that people living close to the plant receive higher concentration of the stench. Residents who felt the stench between 18.00 to 0.0 hours may be daily worker, and they felt the

stench after returning to home at evening, even though the stench was frequently released on that day. In addition, house wives and others those who stay at home felt stench at different time periods.

IV. Discussion

The data on the chemical composition of the ambient odorant molecules in terms of VOCs present here (Table 1) were in agreement with analytical data obtained in similar studies such as those by Kim *et al.* and Aysen.^{20,25)} The present study results indicate that the JWTP release VOCs into the air at a wide range of concentrations (Table 3). Generally, the VOC's released in lower concentration (>1 ppm) level is high (8595 hrs) and it decreased with increasing concentration in all years (Table 3). As per data, it can be concluded that VOC's released at different concentration levels, even though the duration of release of higher concentration was low, may be very harmful to the people living in that area. As shown in Table 4, the annual mean value of total VOC is above 3.0 ppm in all durations (2006 to 2010). This finding indicates that VOC emission is static in origin.

Surveys by questionnaire are probably the most common design in environmental research. In the present study, questionnaire survey was conducted in the year 2006 with residents at five different apartments in and around Jamgrim-Sinpyoeng area (Table 2). The questionnaire indicates the nature of the odor felt by the residents. The final result was then represented as odor frequency versus time (Fig. 1). The majority of residents reported unpleasant living environment. None of the residents took up the very satisfied option about the agencies.

The questionnaire data collected from the year 2006 concluded that the majority (very dissatisfied 38.4% and somewhat dissatisfied 41%) of respondents felt dissatisfied about their living environment. An onsite data and survey data obtained the same year 2006 indicates that the nature of the odor felt by the residents was due to the intensity of total VOCs released by JWTP.

V. Conclusion

Our study results from onsite monitoring as well

as questionnaire suggests that the air quality in Jangrim-sinpyoeng industrial area should be immediately responded. The need for public involvement in decision making process is emphasized. The annual mean value of total VOC is above 3.0 ppm in all years indicates that VOC emission is static in origin. Therefore, further research need to be done to assess the effect of the volatile organic compound on people's health and quality of life. There is need to ensure that the plant releases of volatile organic compound should be negligible if not zero in the near future and this means more advanced filtering of air from the area.

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