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A Study on the Odor Removal Control System of Sewage Sludge

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Abstract

Purpose: The purpose of this study is to reduce odor complaints by identifying problems with odor management at the site of the water regeneration center and researching odor management methods. Due to the high population density of Korea, sewage treatment facilities are adjacent to residential and industrial areas. According to previous studies, the main malodor-emitting facilities of sewage treatment facilities were preliminary treatment facilities (2,220 times), sedimentation basins (4,628 times), and sludge treatment facilities (9,616 times). **Research design, data and methodology:** Compound malodors and designated malodor-producing substances were collected from five site boundaries of the water regeneration center and analyzed according to the official methods to test malodor, and a total of two times (August and September 2020) were conducted. **Results:** As a result of the measurement, in the green area in front of the center office, compound malodors were detected at a maximum of 8 times and at least 3 times during the dawn time. As for the designated malodor-producing substances, 0.1ppm of ammonia was detected in the green area in front of the center office and the park golf course. This is within 15 times the maximum allowable emission level of compound malodors and within 1ppm of the maximum allowable emission level of ammonia. **Conclusions:** Even if the dilution rate of the compound malodors did not exceed the maximum allowable emission level, the odor could be recognized, and more research is needed in the future to establish effective reduction measures according to the subjective and individual and seasonal odor characteristics.

Keywords : Sewage treatment facility, Water regeneration center, Odor removal, Odor complaint, Reduction measurement

JEL Classification Codes : I30, I31, Q25, L52, L97

1. Introduction

Due to the nature of Korea, where the population is concentrated in the metropolitan area, sewage treatment facilities in urban areas are adjacent to residential and industrial areas. As the living standards of citizens improve, interest in environmental issues is increasing. Accordingly, complaints related to odor are also on the rise. The number of complaints about odor was 2,760 in 2001 and tripled to 7,247 in 2010. In 2013, there were 13,103 cases, exceeding 10,000 cases. And the number is increasing rapidly to 15,573 cases in 2015, 24,748 cases in 2016, and 32,452 cases in 2018 (Ministry of Environment, 2018). From 2008 to 2011, the number of complaints related to sewage was 34, 42, 55, and 42 in the order of year (Seo, 2013).

The final purpose of this study is to reduce odor complaints by proposing an odor management plan for a water regeneration center from major sources of odor. For this, the papers related to sewage odor were referred to, and compound malodors and designated malodor-producing substances were collected and analyzed according to the maximum allowable emission level. In addition, odor modeling was carried out to predict the effect of odor on the buildings around the water regeneration center. Through this, an improvement plan was derived to resolve complaints about odor.

2. Literature Review

2.1. Characteristics of Odor

Odor is that causes discomfort and disgust by stimulating the sense of smell of hydrogen sulfide, mercaptans, amines, and other irritating gaseous substances. Odors stimulate human sense of smell and cause psychological damage.
Odors are diverse and complex, and even at very low concentrations, they can cause discomfort and headaches (Ko et al., 2012). In fact, residents who complained about odors sometimes reported health problems such as bronchial irritation, nausea, coughing, heart palpitations, stress, discomfort, and loss of appetite (Kim & Kim, 2007).

Public environmental facilities include livestock excreta treatment facilities, wastewater terminal treatment facilities, malodor-emitting facilities, food waste treatment facilities, etc. are indispensable facilities in our lives. The odor generation characteristics of public environmental facilities are as follows. First, public environmental facilities are generally located around residential areas. Second, since the work is done in an open space in the waste treatment process, it is easy to spread to the outside. Third, the cleanliness of the facility is not good, so the odor is complex and continuous. Fourth, there is a possibility that the frequency and spread of odors may increase depending on seasonal and climatic factors (Cho & Jin, 2016).

2.2. Source of Odor Emission from Water Regeneration Center

The main malodor-emitting facilities of the water regeneration center are preliminary treatment facilities, sedimentation basins, and sludge treatment facilities.

2.2.1. Pre-treatment Facility

In the grit chamber, if the flow rate is slow, organic matter and sediment contained in the influent are precipitated, increasing the amount of sedimentation. And organic matter contained in the sedimentary sediment is decomposed, and odor is generated. Contaminants inside the screen are not collected, so the accumulated contaminants are decomposed and an odor is generated. The conveyor belt from which the sediment is lifted is operated in an open state to facilitate inspection, and odors are mainly generated from contaminants and sediment deposited under the conveyor belt (Seo et al., 2013).

2.2.2. Sedimentation Basin

In the primary sedimentation basin, the degree of decay of the sludge differs according to the properties of the sewage, the residence time, and the height of the sludge interface. In addition, although an odor collecting facility is operated at the upper part of the primary sedimentation basin with a closed structure, a high concentration of odor is generated due to insufficient number of ducts and improper installation location (Seo et al., 2013).

2.2.3. Sludge Treatment Facility

In the raw sludge distribution tank, odor is generated by the drop generated during the process of transferring the raw sludge from the primary sedimentation basin.

In the thickening basin, a high-concentration odor is generated during the process of concentrating raw sludge. The excess sludge storage basin of the sewage treatment facility without the primary sedimentation basin generates a relatively high concentration of odor compared to the sewage treatment facility where the sludge is treated in the primary sedimentation basin. The odor in the dewatering room is mainly generated from the supernatant discharge system and the dewatered sludge transfer conveyor. And the concentration of odor generation is different depending on the properties of the sludge and the performance of the dewatering machine (Seo et al., 2013).

3. Research Methods and Materials

3.1. Collection Location and Time of the Sample

Samples were collected from five selected locations: inside the park site boundary of the water regeneration center, outside the park site boundary, tennis courts, green area in front of the center office, and park golf course. The sample was measured twice during the daytime, nighttime, and dawn time.

3.2. Research Methods

3.2.1. Sample Collection Method

Compound malodors and designated malodor-producing substances were collected. As for the designated malodor-producing substances, sulfur compounds (methyl mercaptan, hydrogen sulfide, dimethyl sulfide, and dimethyl disulfide) that are mainly generated in basic environmental facilities were collected. Ammonia was collected for 5min by sucking sample air at a flow rate of 10 L/min to a sampling device by performing a 0.5% boric acid solution absorption method.

Samples except ammonia were bag-collected using a suction box, for 5 (L/min) 2 min. Before sampling, the sample bag was washed with odorless air at least once, and the odorless state of the sample bag was checked.

In addition, before using the collection pipe and pump, foreign substances were removed and used after washing with odorless air for at least 10 minutes (Ministry of Environment, 2019a).

3.2.1. Sample Analysis Method

The compound malodor was diluted 10 times and 300 times according to the site boundary and outlet standards and compound malodor was determined up to the stage before the odorless diluted sample by sensory evaluation of 5 judges. For judgment, the geometric mean was calculated after excluding the maximum and minimum values, and the results are displayed by integer , and judges according to the maximum allowable emission level (Ministry of Environment, 2019a). For designated malodor-producing substances, device analysis was performed according to the official methods to test malodor.

Table 1: Measuring Device Information

Odor contents		Ammonia	Sulfur compounds
Sampling methods	Media and flow	Absorption method of impinger solution (Absorption liquid: 0.5% Boric acid) Flow: 50L(10L/min x 5min)	Tedlar bag sampling Total flow: 10L
Analytical equipments		UV-vis: Shimadzu - 1201	GC/FPD: Shimadzu 2010/plus

For ammonia, add phenol-nitroprusside sodium solution and sodium hypochlorite solution to the sample solution and the absorbance of indophenols produced by reacting with ammonium ions was measured using a UV-Vis (Ministry of Environment, 2019b).

For sulfur compounds (hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide) are analyzed by low temperature concentration - capillary column - gas chromatography. The sample collected in the sample bag is used immediately without pretreatment. The sulfur compound sample collected in the sample bag was concentrated to -183°C or lower using a refrigerant in a low-temperature concentrator, and then desorbed and analyzed by gas chromatography. The detector is capable of detecting trace sulfur compounds, has good linearity, and uses a flame photometric detector (FPD) that can selectively detect sulfur compounds (Ministry of Environment, 2019c).

4. Results and Discussions

4.1. Experiment Results

At the first measurement, the concentration of compound malodors in the green area in front of the center office at dawn time was measured at a maximum of 8 times and at least 3 times. This is within the maximum allowable emission level (15 times) and the strict maximum allowable emission level (10 times). For the designated malodor-producing substances, the concentration of ammonia in the green area in front of the center office was measured to be 0.1ppm during the nighttime. This is within the maximum allowable emission level of ammonia (1ppm). At the second measurement, compound malodors in the green area in front of the center office at daytime was measured at a maximum of 5 times and a minimum of 3 times. All designated malodor-producing substances were not detected.

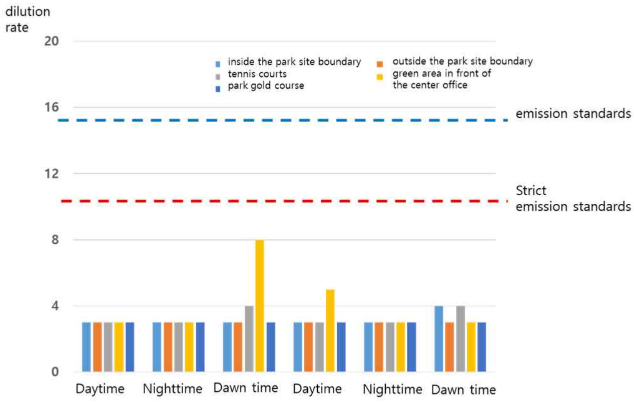

Figure 1: Compound malodor Dilution Rate by Hour

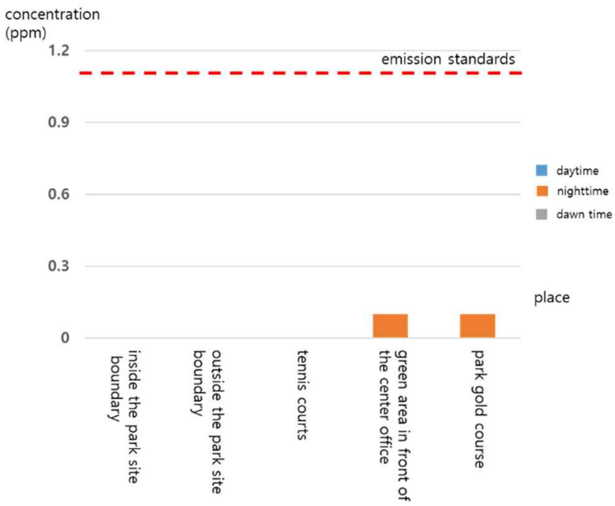

Figure 2: Ammonia Concentration by Hour

However, unlike all the results that satisfied maximum allowable emission level, odor complaints are occurring continuously. This result is not considering the seasonal characteristics of the odor.

4.2. Problems in the Field

We directly visited the site to study the odor management method of the water regeneration center. There, the following problems were found:

Figure 3: Screen contaminants

Figure 4: Rubber packing of aeration tank

Contaminants caught in the screen of the silt were left unattended and rotted, resulting in an odor. The rubber packing of the aeration tank was torn or separated by the pipe connected to the tank.

Figure 5: Open storage yard

Figure 6: Hood odor trap

A lot of odor was generated due to the sludge left in the open storage yard. The odor collection port of the hood was not cleaned for a long time, so the efficiency of odor collection was low, making it impossible to properly inhale.

Figure 7: Dewatered sludge cake removal room

Figure 8: Branch duct of pipe

The dewatered sludge cake removal room was opened, the air curtain was not operated, and the floor of the removal room was not cleaned. In many cases, the angle of the branch duct of pipe connection was 90 degrees. In this case, the captured odor cannot flow along the pipe and is clogged, making proper odor collection impossible.

Figure 9: Opening of a window in a building

Figure 10: Opening the inspection door in the facility

The odor spread outside because the windows of the building or the facility inspection door were not sealed.

Table 2: Major Sources of Odor from Water Regeneration Centers and Their Current Status

Major Sources of Emissions	Odor Occurrence Status
Influent building and grit chamber	Strong odor generated inside and outside
Primary sedimentation basin	A large amount of odorous substances generated
Dewatering room	Odor generated during sludge dewatering
Deodorization facility	Efficiency treatment cannot be done due to aging

In Table 2, most of the facilities of the water regeneration center had a malodor.

Even now, the same problem continues to occur over time. Therefore, it can be seen that the sealing of the facility and the management of the aging facility are important.

4.3. Odor Modeling

From July 1, 2020 to October 16, 2020, odor diffusion modeling was carried out every hour. The average temperature was 22.9°C, the average wind speed was 1.6 m/s, and the main wind direction was the south. The CALPUFF model was used as the odor diffusion model. The puff model is a model that assumes that the smoke is emitted from the chimney in the form of finely divided smoke chunks.

This is a model in which the emitted puffs move and spread the three-dimensional wind field and the size of the puff grows. As a model that can implement an abnormal state, changes in wind direction and speed over time can be more accurately reflected in diffusion than a Gaussian model. It is also useful for representing rapid wind field changes in complex terrain (Korea Environment Institute, 2005). The instantaneous odor was evaluated (3-minute average concentration) using the peak conversion factor.

In order to evaluate the odor according to the height of the building, the building downwash phenomenon was considered. A downwash phenomenon is a phenomenon in which a high concentration occurs due to a vortex phenomenon caused by a building when there is a building near a point source. Since the outlet is located on the roof of the building, the building information for the outlet was inputted into the modeling and applied.

Figure 11: Prediction Points for Odor Modeling

For the analysis by altitude, according to Fig. 11., 10 prediction points were set at 1.5m altitude (1st floor) for the low floor, 24m altitude (8th floor) for the middle floor, and 45m altitude (15th floor) for the high floor.

Table 3: Compound malodor Concentration by Altitude

Prediction points	Altitude		
	1.5m	24m	45m
1	9.0	6.5	3.2
2	5.9	7.6	3.5
3	3.9	6.3	3.2
4	3.1	5.7	2.9
5	3.3	5.8	2.9
6	2.5	5.0	3.0
7	2.4	4.5	2.7
8	4.9	5.7	3.0
9	3.8	5.5	2.9
10	3.6	5.6	3.0

As a result of modeling, according to Table 3., the peak of the compound malodor concentration was 9.0 times (prediction point 1) at 1.5m altitude, 7.6 times (prediction point 2) at 24m altitude, and 3.5 times (prediction point 2) at 45m altitude.

Table 4: Frequency of Exceeding 1OU by Altitude

Prediction points	Altitude		
	1.5m	24m	45m
1	20.1	17.2	3.0
2	20.7	22.3	4.9
3	14.2	19.5	4.7
4	11.2	19.3	5.9
5	11.0	18.3	5.7
6	10.4	18.1	4.6
7	9.2	16.8	3.5
8	14.9	19.5	3.1
9	13.7	19.4	4.0
10	12.9	18.3	4.2

The peak of frequency of exceeding 1OU by altitude was 20.1% (prediction point 1) at 1.5m altitude, 22.3% at 24m altitude (prediction point 2), and 5.9% at 45m altitude (prediction point 4). Therefore, it can be seen that the middle floor showed the highest frequency of exceeding 1OU.

4.4. Discussions

The odor measurement at the water regeneration center was conducted in August and September at the end of summer. It seems that the results are somewhat different from the previous results because July, the midsummer, when the odor is severe, is not taken into account. According to the odor modeling results, complaints about odors are expected to increase if there are buildings such as residential facilities near the water regeneration center.

According to previous studies, the following measures were proposed to reduce odors in sewage treatment facilities. The sludge treatment facility, the inlet of excreta septic tank, and the sludge transshipment site, which are the main sources of odor in the water regeneration center, are completely sealed. Periodically clean the malodor-emitting facilities and devices and conduct environmental management. Work at night rather than daytime, and use an odor control checklist. Establish odor management strategies through continuous odor monitoring and communication with local residents.

Expand the odor management budget to support the installation of preferential reduction facilities for areas that exceed the maximum allowable emission level or are close to areas affected by odors (Seo et al., 2013; Cho et al., 2016; Kim et al., 2020).

This study also proposes the same odor reduction measures as in previous studies and ultimately proposes the underground of the water regeneration center. Anyang Saemul Park is an excellent example of underground sewage treatment facility, and Hanam Union Park and Yongin Suji Respia are representative examples of underground sewage treatment facility. By installing a sewage treatment facility in the basement and a park and sports facilities on the ground, the number of users is continuously increasing.

5. Conclusions

As interest in environmental issues increases, complaints about odors are continuously increasing. This study tried to research correlation between odor concentration and odor complaints at the water regeneration center and derive damage by predicting odor impact through odor diffusion modeling. As a result of the experiment, compound malodor was measured at a maximum of 8 times and at least 3 times in the dawn time in the green area in front of the center office during the first measurement, and at a maximum of 5 times and at least 3 times in the green area in front of the center office during the second measurement during the daytime. For designated malodor-producing substances, in the first measurement, ammonia was measured at 0.1ppm in the green area in front of the center office during the nighttime, and in the second measurement, nothing was detected. As a result of odor modeling, the peak of the compound malodor concentration was 9.0 times (prediction point 1) at 1.5m altitude, 7.6 times (prediction point 2) at 24m altitude, and 3.5 times (prediction point 2) at 45m altitude.

The peaks of the frequency of exceeding 1OU by altitude were 20.1% (point of interest 1) at 1.5m altitude, 22.3% (point of interest 2) at 24m altitude, and 5.9% (point of interest 4) at 45m altitude.

There is great individual variation in the degree of malodor perceived by age, lifestyle, and seasonal factors. Therefore, it is often the case that a serious odor to a specific person does not have much effect on other people, and thus complaints about odor continue to occur. In order to prevent any further increase in complaints about odors, the water regeneration center should periodically clean the facilities and seal the windows and inspection doors in the management building where the odors are generated.

It is necessary to improve the angle of the pipe and the direction of the collector, periodically remove contaminants from the screen, and develop odor reduction technologies such as underground water regeneration center and odor monitoring.

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