Analysis of the Temporal and Spatial Characteristics of Odor Occurrence in South Korea - focused on Chungcheongnam-do Area

Abstract: This study was performed to analyze the temporal and spatial characteristics of odor occurrence, how to set priorities of institutional support for customized odor management measures suitable for each region's situation, and manage effective odor reduction focusing on the complex odor test for 1,476 odor samples that filed a complaint in 15 cities and counties of Chungcheongnam-do area in South Korea, for 5 years from 2016 to 2020. In particular, the cause of odor focusing on the odor complaints by livestock farms and large businesses place was identified, and spatiotemporal characteristics were investigated. civil complaints caused by odor occurrence are increasing year by year, and over the past five years, 424 cases at the outlet of facilities and 1,052 cases at the borderline were much more frequent. Also, the nonconformity rate exceeding the emission acceptance criteria increased by 3.7 % at the outlet and 13.2 % at the borderline. In addition, the occurrence of odors has been steadily increasing every year since 2016, and the nonconformity rate exceeding the criteria at the borderline is high. The monthly odor occurrence is 184 cases in July, the highest in summer and 56 cases in January, which is relatively low in winter. The number of odor occurrences showed a correlation with temperature (R^2=0.7104) and humidity (R^2=0.7879). In addition, the highest number of complaints occurred when the average humidity 70 ~ 80 %, the average temperature 20 ~ 25 □, and the average wind speed were 1 ~ 1.5 m/s. Looking at the characteristics of odor occurrence by facility, of 1,476 cases that have been filed in Chungcheongnam-do area, odor complaints by livestock farms accounted for 48.4 %, 715 of 1,476. Also, out of 715 cases, 502 cases were pig breeding facilities and 125 cases were poultry places. The nonconformity rate exceeding the emission acceptance criteria was showed as 32.8 % for poultry place and 19.9 % for pig breeding facility. A relationship between the number of breeding livestock and the occurrence of odor complaints was found R^2=0.714. Accordingly, it is considered that it is necessary to study on the separation distance of odor component and the appropriateness of the number of breeding livestock by identifying the odor component of type of livestock and the number of breeding livestock for the administrative and institutional measures. With using geocoding program to visualize the source of odors and use a

system that shows the density of the facility by city and county, it is judged that it will be able to monitor odors, respond quickly to odors, predict their spread, and manage the sources efficiently. The discomfort caused by odor are mostly occurring in surrounding of livestock facility are concentrated. In order to solve the fundamental odor problem, it is urgent to improve technology and related systems for reducing odors generated in livestock facilities, and provide administrative and financial support. Applying big data analysis technology using visualization programs such as geocoding is considered to be useful for systematic odor management policies by scientifically investigating and managing occurrence.

Key words: Odor; Odor complaints, Livestock facility, Geocoding, Odor improvement management

1. Introduction

Odor is a form of sensory pollution that causes psychological and mental damage and health damage to humans. Recent changes in times and lifestyles have increased the demand for a pleasant residential environment, increasing interest in odor. As a result, complaints related to odor are on the rise, and interest in not only regulations on simple odor, but also identifying the cause of odor and the influence of its odor substances is increasing.[1)]

Odor has a unique smell of protein decomposition by natural microorganisms or substances themselves, and artificial sources such as livestock facility, feed manufacturing, fertilizer manufacturing, food manufacturing, chemicals, slaughterhouses, waste treatment facilities, nightsoil treatment facilities, and wastewater treatment plants.[2)]

As the odor problem gradually became a social problem, odor-related regulations, which were part of the 『Air Environment Conservation Act』[3)], were enacted (2004) as a single law called the 『Odor Prevention Act』[4)], laying the legal and institutional basis for overall odor.[5)] According to the 『Odor Prevention Act』[4)], areas requiring odor regulation are designated as odor management areas and odor management is implemented centering on odor discharge facilities in the regulated areas. Chungcheongnam-do area designated Daesan Industrial Complex and Daejuk Regional Industrial Complex in Seosan-si in 2006 and Asan National Industrial Complex and Songsan General Industrial Complex in Dangjin-si in 2010 as odor management areas, respectively, and is applying strict emission acceptance standards[6)] However, the Odor Prevention Act is currently implemented mainly

on regulations on odor emission facilities at workplaces such as industrial facilities, and most cities and counties in Chungcheongnam –doarea are not industrial areas, so it is insufficient to solve the odor problem in this area. As odor complaints in livestock facilities as well as large industrial complexes in Seosan and Dangjin continue to increase, effective and appropriate management measures are urgently needed to resolve odor complaints.

Chungcheongnam-do province is responsible for odor prevention and management by the relevant, city and county. In particular, the designated a odor management area is requiring special odor management because of the large number of industrial facilities located in the these area. Chungcheongnam-do province region, to investicate the cause of odor use in odor provide the systematic political data, and proper odor prevention and management by pollutant source.

This study was performed to analyze the temporal and spatial characteristics of odor occurrence in 15 cities and counties in Chungcheongnam-do area for five years from 2016 to 2020, set priorities for institutional support, and effective odor reduction management.

2. Materials and Methods

2.1. Samples

1,476 odor samples were collected from the outlet or at the borderline of facilities where odor complaints in 15 cities and counties of Chungcheongnam-do area in South Korea, for 5 years from 2016 to 2020.

2.2. Method

The odor data was classified by year, month, region, facility, and visualization to identify emission characteristics. In addition, the odor generation point was referred to the sample collection record prepared during sample collection, and it was performed by geocoding to obtain coordinate values of latitude and longitude with a unique name, address, mountain, lake, and so on. All samples were collected according to the odor process test standards, and were transported to the laboratory by avoiding direct sunlight and maintaining room temperature. The transported sample was diluted with odorless air within 48 hours of sampling and examined for complex odor. In the selection of odor determination agents, air dilution sensuality test was performed by recognizing all three types of odor determination solutions for those who recognized 1 degree of odor intensity recognition test solution and selecting 5 judges who felt that odor level was 3 and 4.[7)] Criteria for odor judgement in Korea are shown in Table 1.

Odor is caused by a combination of several substances rather than one odorous substance in nature. And substances that cause odor have a molecular weight less than 300 and have different

characteristics depending on the molecular structure or attached functional group. In addition, the severity of odors and the degree of pollution tend to vary according to people's inclinations, living environments, and their health conditions. In the case of the minimum detection concentration, depending on the odorant, the degree of smelling may vary from person to person to the extent that there may be a difference of 10 times or more depending on the odorant.[16] Due to the individual differences in recognizing these odors and the diversity of odor-causing substances, the air dilution sensory method is measured using the human sense of smell, so it can be directly used to determine the level of complaints about odors that have been continuously raised up to now. As quantitative results are presented, it is a method that compensates for the shortcomings of the instrumental analysis method or the direct sensory method.[2]

Table 1. Criteria for odor judgment in Korea

Odor level	Odor intensity	Content	n-butanol concentration(ppm)
0	None	Relatively odorless, everyone can't detect anything with your normal sense of smell.	0
1	Threshold	Do not know what smell it is, but everyone can feel the smell.	100
2	Moderate	Everyone can tell what it smells like.	400
3	Strong	It refers to a strong smell that can be easily detected, and for example, a smell that smells like cresol in a hospital.	1,500
4	Very strong	It smells very strong. For example, in the summer, it's severe in a conventional bathroom.	7,000
5	Over strong	It's a strong smell that's hard to bear and it feels like breathing is going to stop.	30,000

*Source : The standards for odor process test by the Ministry of Environment in Korea.[8)]

3. Results and Discussion

3.1. Current status of Odor occurrence

The total number of odor complaints in Chungcheongnam-do area from 2016 to 2020 was 1,476, with 207 cases in 2016, 245 cases in 2017, 280 cases in 2018, and 289 cases in 2020, an increasing trend every year. A total of 424 odor complaints occurred at the outlet over the past five years and 1,052 odor complaints occurred at the borderline, 2.4 times higher than those at the outlet, which is odor complaints at the borderline (Fig. 1).

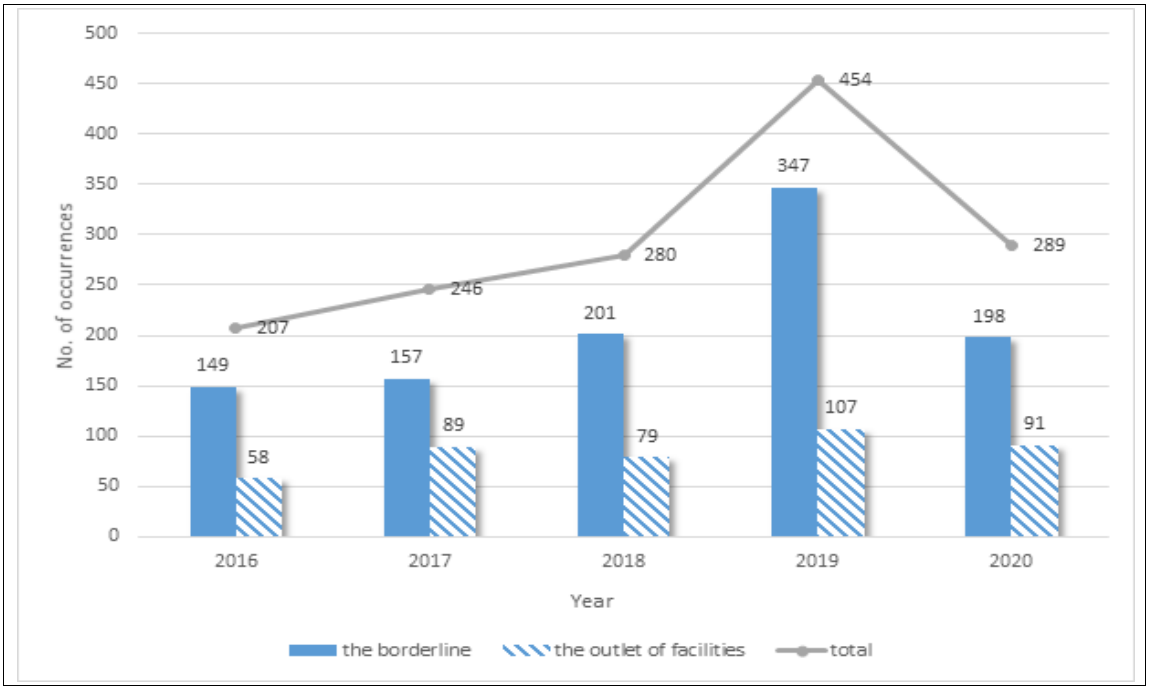

Fig. 1. The number of odor occurrences by year at the outlet and site boundary.

The correlation coefficient (r) between the number of odor complaints and the nonconformity rate at the outlet was 0.02, and odor at the outlet did not significantly affect the complaint. As shown in Fig. 1, the number of odor occurrences at the outlet is constant, but the frequency of odor occurrence at the borderline shows a steadily increasing trend every year. This means that the odor generated at the outlet varies depending on the company's own management, but the odor generation at the borderline is sensitive to the odor around the outlet. Therefore, it is necessary to further strengthen odor reduction and management measures caused by the borderline around the workplace along with odor management measures at the outlet of the workplace.

3.2. Characteristics of monthly odor occurrence

The monthly odor incidence was highest in July 225 cases, September 215, August 200, and June 181 for five years. It can be seen that the frequency of odor occurrence is higher in summer when the temperature is higher than in winter that the temperature is low. High temperatures and humidity cause people's discomfort index, which recognizes odors, feels unpleasant, and acts as a behavioral factor in filing complaints. Table 2 shows the average monthly temperature and average humidity from 2016 to 2020, and the total number of monthly complaints and nonconformities for five years.

Table 2. The monthly number of odor occurrences and weather factors from 2016 to 2020

Month	Avg. Humidity(%)	Avg. Temp.(℃)	Number of occurrences	No. of criteria excess	Percentage (%)
1	69.5	-0.9	56	14	25.0
2	65.4	0.8	85	9	10.6
3	65.4	6.5	99	20	20.2
4	65.7	11.8	66	18	27.3
5	69.9	17.6	117	24	20.5
6	76.9	21.7	152	41	27.0
7	85.2	25.1	184	52	28.3
8	82.1	26.2	170	40	23.5
9	79.2	20.7	178	43	24.2
10	75.7	14.1	149	34	22.8
11	71.8	7.3	141	25	17.7
12	69.4	0.9	79	16	20.3
Total			1,476	336	22.8

The frequency of odor occurrence in Chungcheongnam-do area was high from June to September,

the hottest summer, and low from December to February, while the rate of nonconformity exceeding the odor emission acceptance standard showed a constant pattern on a monthly basis regardless of the season. Fig. 2 shows the monthly number of odor occurrences and the nonconformity rate of the emission allowance standard from 2016 to 2020.

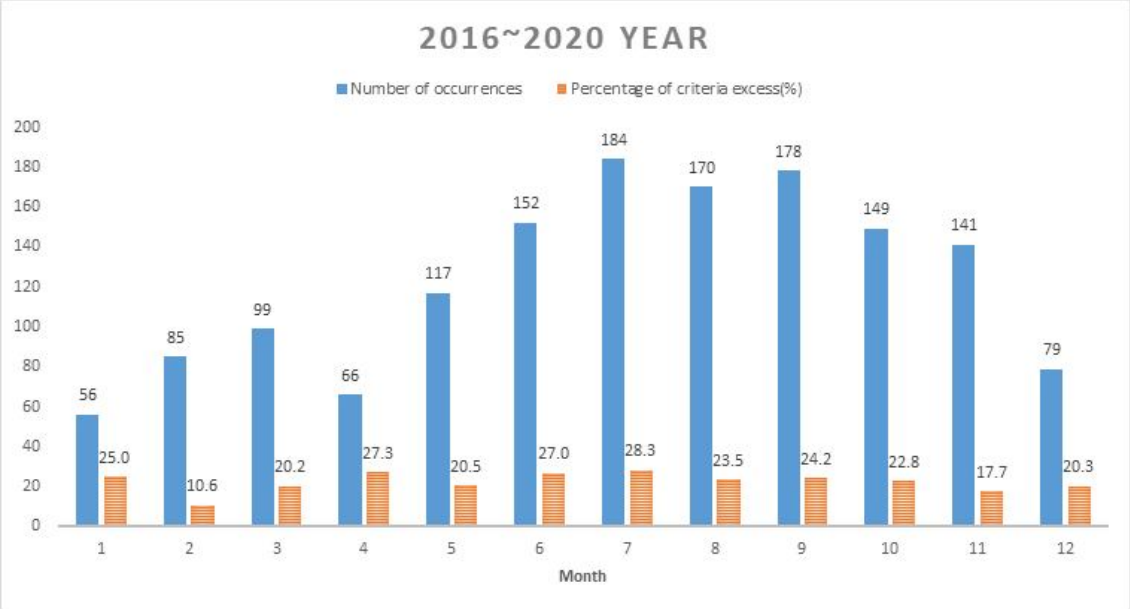

Fig. 2. The monthly number of odor occurrences and the nonconformity rate of the emission acceptance criteria from 2016 to 2020.

As shown in Fig. 2, the complaints caused by odor occur intensively in the summer when temperature and humidity are high, but as a result of odor test, the nonconformity rate exceeding the emission allowance standard did not differ significantly from other times. It can be confirmed that the actual odor and the degree to which a person feels unpleasant are closely related to the atmospheric environment of temperature and humidity. Looking at the occurrence of seasonal odors, odors that occur in winter are low in frequency, but are caused by weather changes such as temporary temperature and humidity increase, and the low occurrence of odors in April is considered to be caused to weakening of odor intensity due to smooth atmospheric circulation.

Most of the areas with the most odor complaints in Chungchoengnam-do area were livestock odors such as Hongseong, Boryeong, and Cheonan regions. Comparing the current status of odor occurrence according to weather conditions such as temperature, humidity, and wind speed in these three regions, 180 cases when the average humidity is 70 ~ 80 %, 205 cases when the average temperature is 20 ~ 25 °C, and 224 cases when the average wind speed is 1 ~ 1.5 m/s. Therefore, it is needed that continuous precise odor monitoring is necessary to analyze monthly odor occurrence trends

considering seasonal weather variables such as temperature and humidity for odor management based on scientific data.

3.3. Regional characteristics of odor occurrence

On classifying the number of complex odor tests analyzed over five years from 2016 to 2020 by 15 regions in Chungcheongnam-do area, the results are 300 cases in Cheonan, 227 in Hongseong, 167 in Asan, 159 in Dangjin, and 149 in Boryeong (Fig. 3).

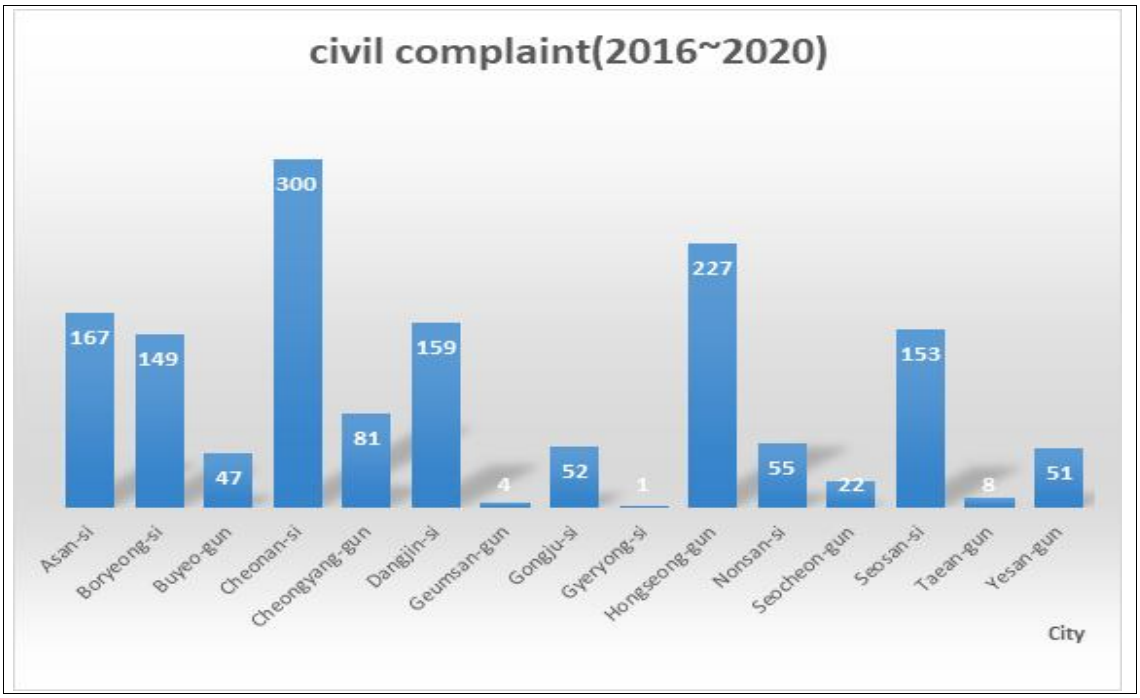

Fig. 3. The number of odor occurrences by city and county in Chungcheongnam-do area.

According to the 2020 Chungcheongnam-do Statistical Yearbook, the population of Chungchoengnam-do area is about 2.1 million, which is concentrated and biased in major cities Cheonan and Asan, and the total population of these two cities is about 1 million, accounting for 47.6% of the total population of Chungnam.[9)] The number of complex odors that occurred in Cheonan and Asan for five years was 467, accounting for 31.6% of the total 1,476 cases. In most regions except Hongseong, the number of requests for complex odors was found to be proportional to the size of the resident population. In addition, when comparing the number of odor complaints between cities and counties, odor complaints increase every year in cities with a larger population than in counties with a smaller population. This phenomenon is presumed to be due to the higher sensitivity of city residents to odors and higher degree of discomfort in living than those in rural areas. However, unlike other

regions, the Hongseong region is believed to have affected more odor complaints by the concentration of public institutions, the influx of younger generations on the rise, and new facilities and residential environment conditions.

3.4. Characteristics of odor occurrence by facility.

As a result of analyzing the odor occurrence characteristics of each facility in Chungchoengnam-do area for five years from 2016 to 2020, livestock facilities accounted for the largest number of 715 cases, fertilizer compost production facilities with 156, waste recycling facilities and chemical product manufacturing facilities. In addition, the areas where the odor incidence rate of livestock facilities exceeded 50 % were Boryeong, Buyeo, Cheonan, Geumsan, Gyeryong, Hongseong, Seocheon, and Taean region, most of which were rural areas. In particular, the number of odors in the Hongseong region was overwhelmingly high, even though the population was relatively small compared to other regions. This is due to 2,522 livestock facilities and 4,229,473 livestock farms, the nation's largest livestock complex as well as Chungchoengnam-do area.[10] Meanwhile, Cheonan region has a higher incidence of livestock odor than livestock facilities. The number of odor complaints was livestock facilities, fertilizer compost production facilities, waste recycling facilities, and chemical product manufacturing facilities in order. The facility groups with high non-conformity rates based on odor emission were analyzed in the order of ascon manufacturing (55.6%), food processing (36.4%), printing (33.3%), and fertilizer compost production (30.8%).

It can be seen that there is a big difference between filing a odor complaint because people feel uncomfortable and a facility that exceeds the actual odor emission allowance standard. Accordingly, it is judged that the institutional improvement management of odor-occurring facilities that people easily feel unpleasant should be strengthened. Guidance and support are required so that workplaces can comply with the emission allowance standards through appropriate guidance and frequent crackdowns on facilities that actually occurs a lot of odors. It is unclear to specify the odor emission point because various components generally function in combination to occur odor. The current odor prevention law restricts the application of odor emission allowance standards to outlets and borderlines, and limits target substances to complex odors and 22 designated odor materials.[11]

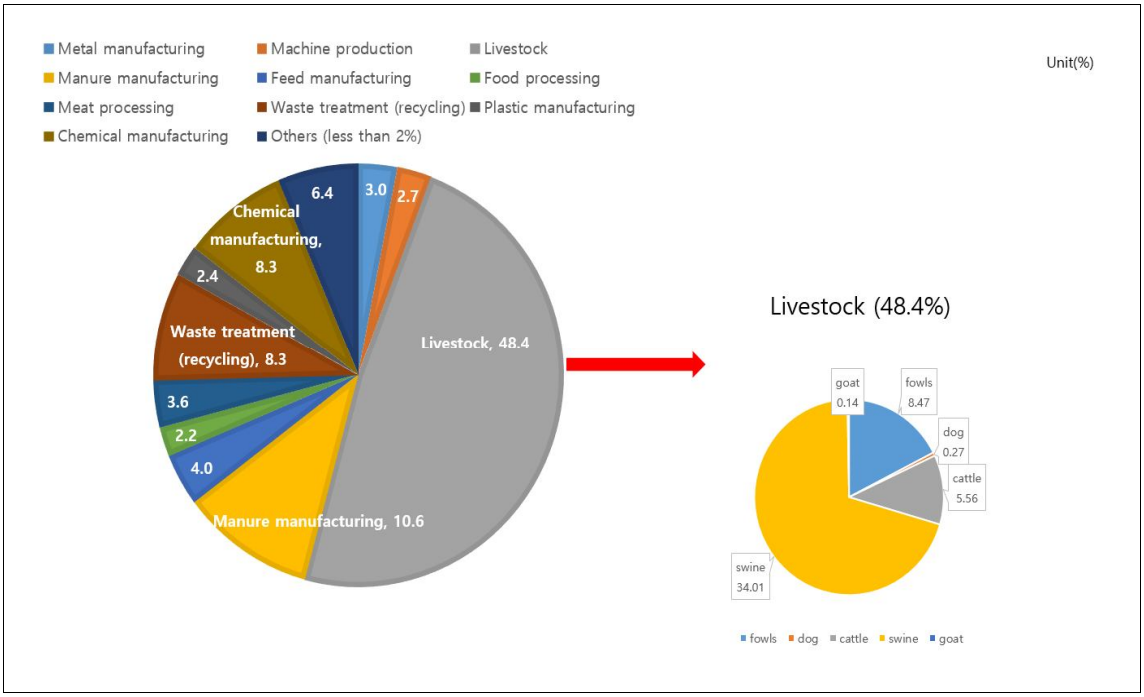

Fig. 4. Odor occurrence portion according to facility.

As shown in Fig. 4, 715 of the 1,476 odor complaints in Chungnam, or 48.4%, were livestock facilities, Pig farming of which 34.7% (512 cases), Chicken breeding facilities 8.5% (125 cases), and Cow breeding and other facilities 5.2% (78 cases). The number of tests for complex odor at livestock facilities was 502 cases for pighouses and 125 cases for poultry, 4 times higher than that of poultry facilities, but the rate of nonconformity was 41 cases out of 125 cases poultry facilities (32.8%) and 100 cases (19.9%) for pighouses. The odor substances occurrence in livestock facilities are very diverse and extensive. The main odor-occurring substances for each facility are hydrogen sulfide at pig farming facilities and methyl mercaptan at poultry facilities.[1)] Therefore, in order to prevent odors in livestock facilities, a scientific approach is needed to manage facilities by livestock species such as pig farming facilities as well as chicken and cow.[12)] Continuous research is needed to reflect the accumulated scientific data by scrutinizing odor-occurring components considering odor-occurring variables such as distance between breeding facilities and residential areas for each livestock species.[13)]

In general, representative facilities where odor complaints occur are known as livestock facilities, fertilizer compost production facilities, waste recycling facilities, and chemical product manufacturing facilities. In the results of this study, livestock facilities were also the largest number of odor complaints in Chungchoengnam-do area. Looking at the current status of odor-occurring facilities by region, in the Asan region, where urban development such as the creation of large-scale apartment

complexes is rapidly taking place, the highest odor complaints in livestock facilities and comprehensive recycling facilities was 27.5% and 22.2% respectively. Besides, most of the odor complaints caused by livestock farms account for Boryeong region 60.4%, Buyeo 93.6%, Geumsan 50%, Hongseong 81.5%, Seocheon 90.9%, and Taean 75%. Accordingly, , it is necessary to establish a odor reduction system through the operation of a pilot farm and the Environmental Improvement and Odor Deodorant Support Project [11)] in each region to prepare a livestock facility odor management plan that can have a practical odor reduction effect.

3.5. Visualization of odor occurrence characteristics

In odor management, preventive management takes precedence over follow-up management after occurrence. Therefore, urbanizing the temporal and spatial distribution of odor occurrence can be very useful in odor management because the overall odor occurrence status can be comprehensively grasped. [5)] The work of urbanizing time and space is to change the address of the place where the odor-occurring sample was collected to latitude and longitude using geocoding, and visualize it as a dot on the map.

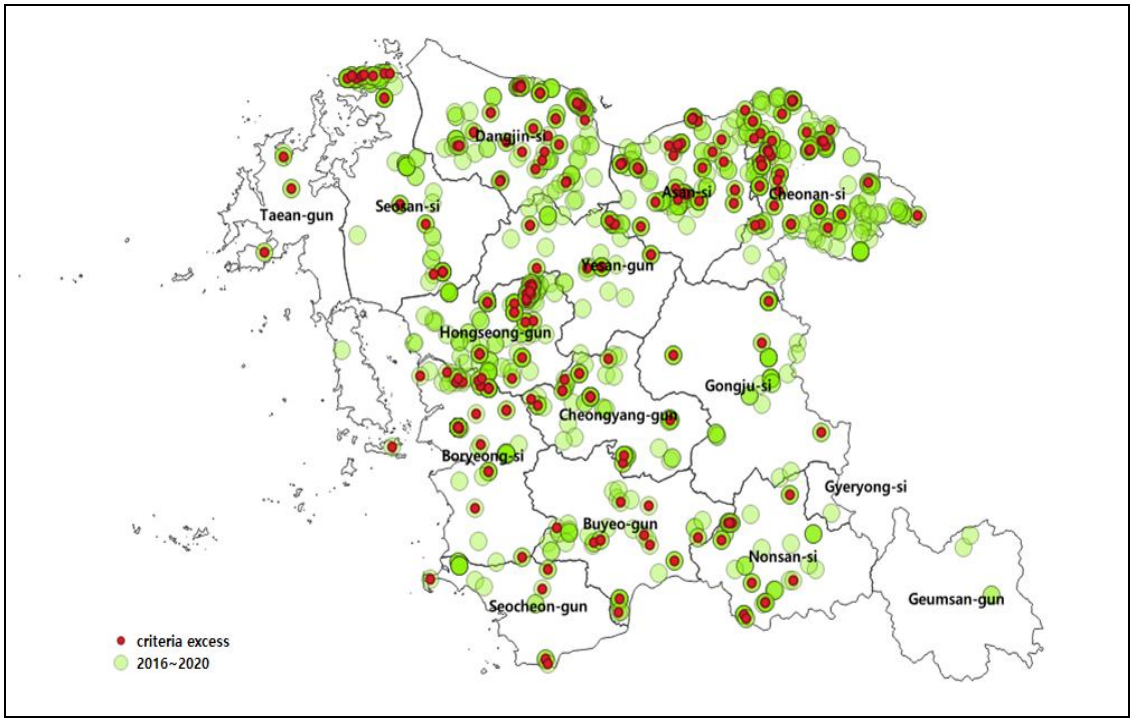

Fig. 5. Distribution for Odor Occurrence in Chungcheongnam-do area and the emission acceptance criteria nonconformity.

The complaints of odor occurrence in Chungcheongnam-do area are mainly caused by odors in industrial complexes in Cheonan and Asan region in the northeast, where 47.6% of the population of the area live in Seosan and Dangjin region in the north, designated as odor management areas. In addition, it can be seen that the number of odor complaints in the Hongseong and Boryeong regions, the nation's largest livestock complexes located in the center of the west, is significantly higher than in the Cheongyang, Taean, and Geumsan regions. As a result, it can be confirmed that the region that exceeds the emission allowance standard and the region where many odor complaints occur are proportional (Fig. 5). Therefore, it is necessary to focus on odor management of industrial complexes in Seosan, Dangjin, Cheonan, and Asan and livestock facilities in Hongseong and Boryeong region in Chungcheongnam-do area.

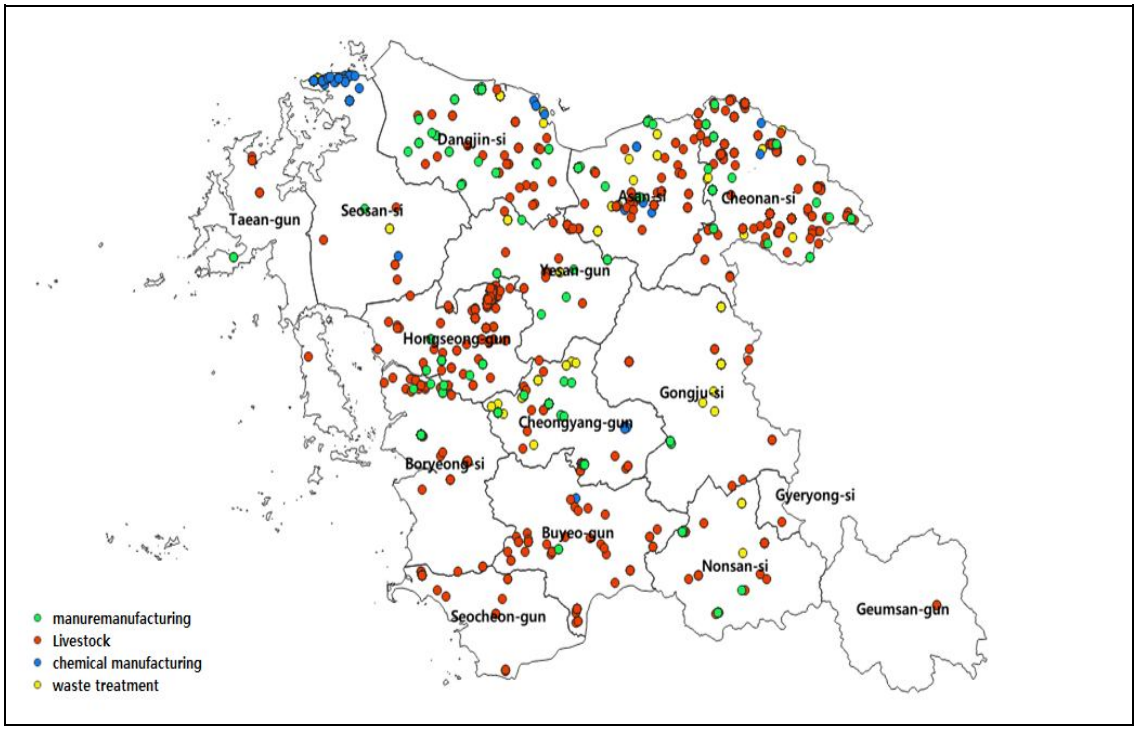

Fig. 6. Distribution of Odor Occurrence by the main facilities in Chungcheongnam -do area.

As shown in Fig. 6, it can be seen that most of Chungcheongnam-do province except for Seosan, Dangjin, Cheonan, and Asan region, mainly odor complaints caused by livestock. By facility, there were the most complaints about odor in pig farming facilities (Fig. 7), and the facilities that exceeded the emission allowance standard the most were pig farming and chicken breeding facilities (Fig. 8).

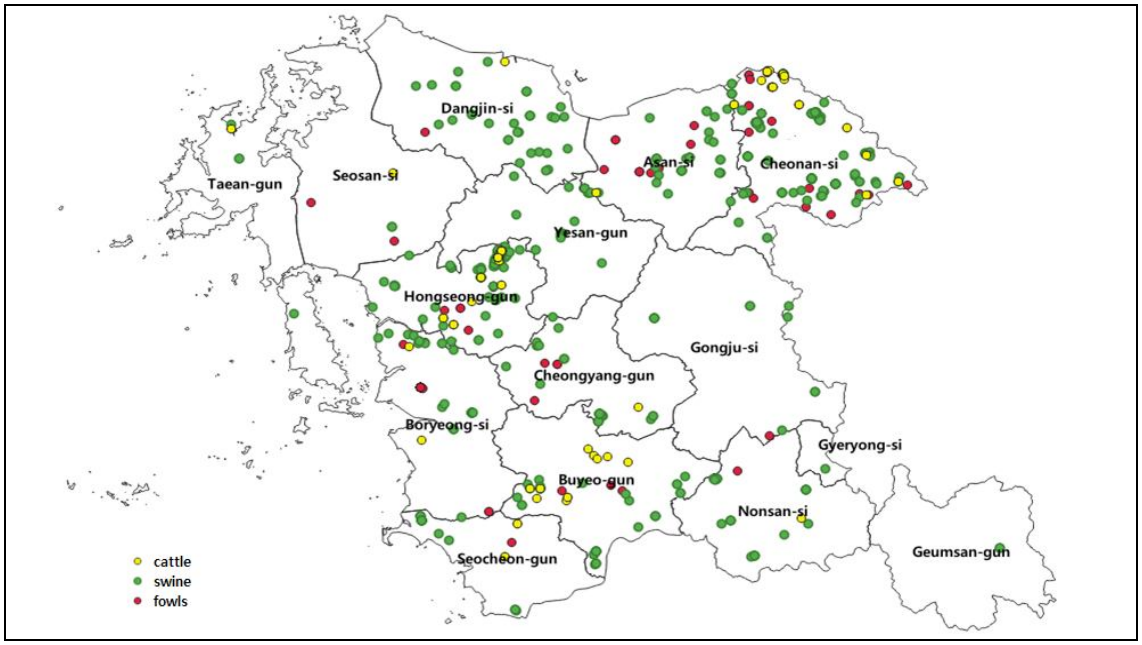

Fig. 7. Distribution of Odor Occurrence by liverstock facility.

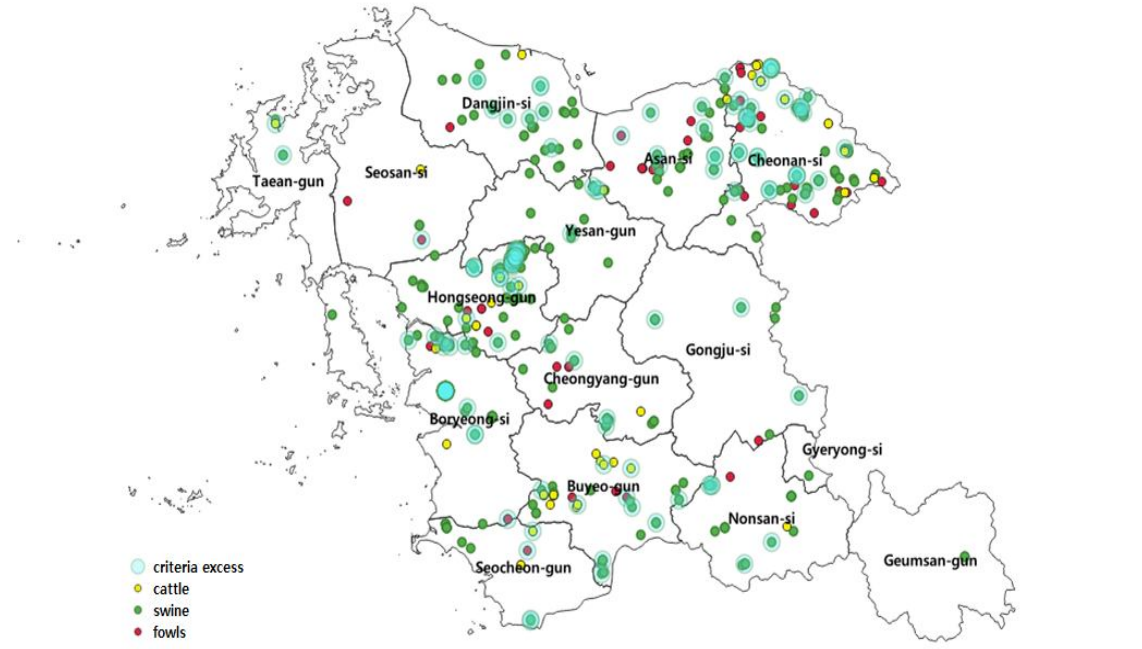

Fig. 8. Distribution for Odor Occurrence by liverstock facility and the emission acceptance criteria nonconformity.

The Ministry of Environment of Korea enforces orders to suspend and close the use of odor farms

based on the Act on the Management and Use of Livestock Manure. Recently, the odor Prevention Act has been strengthened to plan measures to regulate odors at outlets, and plans to introduce a total nutrient system, strengthen restrictions on livestock breeding distances, and mandate electronic transfer of livestock manure.[11] Currently, a local governments enact ordinances and manage them on their own, but the effect is low due to budget difficulties such as project costs.[14] Therefore, considering the characteristics of Chungcheongnam-do area, where livestock facilities are distributed in large quantities, closing or reducing livestock farms directly related to the local economy has many environmental policy limitations, so various eco-friendly livestock farm management plans at the local government and central government level should be reviewed.[15]

4. Conclusions

The number of odor complaints in the Chungcheongnam-do area is increasing year by year by year. It is considered that odor management measures at the borderline should be further strengthened as the number of odor complaints at the borderline is increasing more than at the facility's outlet. Particularly, looking at the monthly trend of odor occurrence, it was concentrated in July, August, and September when the temperature was high, indicating that there was a significant correlation with the odor complaints depending on weather conditions such as temperature and humidity. If seasonal odor response measures are prepared, it is expected to have a great effect on reducing odor complaints.
In many cities and counties in Chungcheongnam-do area, most of them are odor complaints centered on livestock houses rather than industrial complexes, so a odor system suitable for the region is needed. In Seosan and Dangjin region, odor prevention laws suitable for industrial areas are in effect. On the other hand, in the case of Hongseong, Boryeong, and Cheonan region, intensive countermeasures are required to manage odors occurred in livestock houses.

Especially, there were more odors in swine and poultry facilities than cow breeding facilities and the nonconformity rate exceeded the emission allowance criteria(standard) in those facilities was also higher. In addition, it was analyzed that the number of breeding heads rather than the number of livestock was correlated with the odor complaints. Therefore, it is necessary to prepare management measures focusing on restrictions on the number of breeding heads and management plans for each livestock species. Furthermore, the priority of policy support should be set for cities and counties in consideration of the number of odors per area. Preliminary prevention and management measures on odor problems should be prioritized over follow-up management. Accordingly, if spatial distribution is urbanized using visualization programs such as geocoding for odor monitoring, it is expected to be

very useful for odor management as it can grasp the actual overall odor situation.

This study focuses on areas where complaints are frequent due to the seriousness of odor damge, so there is a limit to the study to determine the actual degree of direct and indirect damage to residents. Further work of studies, it is considered that more effective odor management should be carried out through a proactive odor prevention management and an environmental epidemiological survey of local residents living the serious odor occurrence region.

References

1. Lee, Sang-hee et al., A Study on the Emission Characteristics of Odor occurred from the Liverstock facility, The Report of Gyeongsangnam-do Institute od Health and Environmental Research, Vol.16, pp.227 ~244, 2020
2. Lee, Dong-hyun, Effect analysis of odor occurred from the liverstock facility using ISCST-3 Model., Hanbat national University, Master Degree paper, 2021
3. Air Environment Conservation Act, Ministry of Environment, South Korea, 2004
4. Odor Prevention Act, National Legal Information Center of Korea
5. Kim, Byeong-uk, Analysis of the Spatial Characteristics and Distribution of Odor in Gangwon-do, J. Korean Society of Environmental Health, Vol.46, No.4, pp.376 ~378, 2020
6. Status of designation of odor management area, , Ministry of Environment, South Korea, 2016
7. Odor Test Standards, Ministry of Environment, South Korea, 2019
8. Odor Management Manual, Ministry of Environment, South Korea, 2012
9. Statistical Yearbook of Chungcheongnam-do province, 2020.
10. Choi, Don-jeong et al., Number of breeding heads and breeding area by livestock in Chungcheongna m-do, ChungNam Institute, Chungcheongnam-do Policy Decision Making Support Map, Vol.21, pp.1 ~24, 2018
11. Kim, Sun-tae, Analysis and Policy Direction of Livestock Odor Generation in Chungcheongnam-do province, ChungNam Institute, Vol.244, pp.1 ~17 , 2016

12. Young Kee Jang et al., Assessment of Odor Characterization and Odor Unit from Livestock Facilities by Animals, Journal of Environmental Impact Assessment, Vol.19, No.1, pp. 29 ~38, 2010

13. Lee, Eun-young et al., Current Status and Perspectives of Livestock Environment Improving Agents for the Characteristics and Control of Swine Manure Odor, Kor.J.Microbiol.Biotechnol, Vol.38, No.3, pp.244 ~ 254, 2010

14. Yoo, Yeong-sung et al., A Study on the Effective Odor Reduction in the Area where Strong Civil Complaints Take Place to Odor, Gyeonggi Research Institute, Vol 33, pp.1~93, 2007

15. Kim, Dong-yeong et al., Reducing Odor from Livestock Operations in Gyeonggi-Do, Gyeonggi Research Institute, Vol. 53, pp.1 ~ 147, 2016

16. Shin, Seo Hyeon, The Characteristics analysis on Atmospheric environment at neighbourhood park in Daejeon, Hanbat national University, Master Degree paper, 2020

17. Lee, Myeong-gyu et al., Policy improvement measures to reduce odor and environmental pollution problems in the agricultural and livestock industry, Korea Rural Economic Research Institute, Vol.6, No.7, pp.1~178, 2019

18. Jung, Juyong et al., Analysis of Barrier Factors in the Validity and Reliability of Odor Measurement Methods, Environmental Policy Research Institute, Vol.26, No.1, pp.1~20, 2018

19. Choi, Sung-Deuk, Occurrnece of Odor and Suggestions for a comprehensive Management System in Ulsan, South Korea, Journal of Environmental Analysis, Health and Toxicology, Vol.25, No.1, pp.43~49,2022

20. Cho, Deok-hee, Problems of odor Prevention Law&Odor Analysis Method in South Korea, Korean Journal of Odor Research and Engineering, Vol.6, No.2, pp.124~129, 2007