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Assessment of Odor Issues and Technologies in Wonju Traditional Market

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Abstract

Purpose: This study investigates the sources and characteristics of odor pollutants, focusing on total volatile organic compounds (TVOCs), hydrogen sulfide, and ammonia in traditional markets. The objective is to assess the impact of these odors on market environments and evaluate the effectiveness of new odor-reducing techniques. **Research design, data, and methodology:** Conducted in Wonju Traditional Market, the research employed a longitudinal design to analyze odor concentrations over time through continuous monitoring at five strategically established points. Measurements were taken continuously for five minutes at one-minute intervals using the AOMS-1000 odor-measuring equipment. The study also applied a sewage odor-reducing substance spraying device designed to minimize unpleasant odors. Data was collected in the summer of 2022 and again in the summer of 2023, allowing for a comparative analysis of odor levels before and after implementing the odor-reducing technique. **Results:** Findings revealed significant concentrations of TVOCs, hydrogen sulfide, and ammonia, with a notable reduction in pollutants following the introduction of the odor-reducing device. **Conclusions:** This study highlights the importance of effective odor management in traditional markets. It recommends the adoption of advanced technologies such as biofilters, electrostatic precipitators, and photocatalytic purification systems to better control odor emissions. Implementing these solutions can significantly enhance the shopping experience for consumers.

Keywords : Traditional Markets, TVOC, Sewage Systems

JEL Classification Code : I15, Q53, Q55, Q56, R11, R58

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1. Introduction

Wonju Traditional Market, situated in the heart of Wonju-city on Wonil-ro, is a vibrant hub known for its diverse offerings of local foods such as charcoal-grilled Korean beef, buckwheat pancakes, and jeonbyeong, as well as various goods including hanbok (traditional Korean clothing). Vendors at the market provide an extensive range of products, from fresh produce and vegetables to household items, textiles, and dried fish. The numerous restaurants and food stalls offer visitors an authentic taste of Korean cuisine, making the market a key cultural and economic center for the community. Its central location in Wonju's downtown commercial district enhances its accessibility, placing it adjacent to popular areas like Jayu Market, Jungang-ro Cultural Street, and Doraemi Market (Wonju City, n.d.).

Despite its vibrancy and significant contribution to local tourism and the economy, Wonju Traditional Market faces pressing environmental and management challenges, particularly concerning odor pollution. Odor, often linked to unpleasant smells, has emerged as a critical environmental issue that is receiving increased attention due to rising industrialization and growing public awareness of the need for a clean environment. This modernization, coupled with the public's heightened interest in environmental quality, has led to greater concern about the impact of odors on overall quality of life. Consequently, many now recognize unpleasant smells as harmful atmospheric pollutants. Such odors can elicit a range of negative emotional responses in individuals, from irritation to measurable health impacts, ultimately diminishing their overall quality of life (B. Vidal, 2015; Palmiotto et al., 2014).Odors arise from the interaction of various volatile chemical compounds, including both volatile inorganic compounds (VICs) such as ammonia and hydrogen sulfide, and volatile organic compounds (VOCs) like sulfur compounds, alcohols, esters, acids, aldehydes, ketones, and terpenes. These compounds, whether organic or inorganic, significantly contribute to overall odor levels (Barth et al., 1984; Zhu et al., 2016; Fang et al., 2015; He et al., 2012). VOCs encompass a wide range of molecules characterized by their volatility, including volatile fatty acids, alcohols, carbonyls, aromatics, and alkenes. The complex composition of these compounds is responsible for the odors typically found in environments like traditional markets.

Odor pollution has become a prominent public concern, exacerbated by the enactment of legislation in 2005 intended to tackle the issue. From 2005 to 2016, complaints related to malodors surged by 21 times, with over 25,000 complaints filed in 2016 alone. The primary sources of these complaints include odors from food waste, smoke from restaurants, and sewage. Experts, such as Kim Myung-ja, president of the Korean Federation of Science and Technology Societies, caution that failure to address these odor issues actively could severely impact the quality of life for residents (Kwon, 2018). Within this context, the traditional market plays a crucial role in the daily lives of citizens, serving as a space where community, economy, and culture intertwine. Additionally, Odor complaints in South Korea have risen sharply, from 7,247 in 2010 to 32,452 in 2018 (MOE, 2022). While industrial complexes are designated as odor management areas under the Odor Prevention Act, traditional markets are not included. Odors in traditional markets are categorized as living odors, but managing these low-concentration odors over large areas remains challenging. Addressing odor problems is essential for preserving environmental quality, as they can detract from the overall experience of the market. Understanding the sources and dispersion of odors, along with effective methods for their detection and control, is crucial for managing odor pollution effectively (Yuwono & Schulze Lammers, 2004).

Therefore, this study investigates the sources of odor pollutants, specifically total volatile organic compounds (TVOCs), hydrogen sulfide(H_2S), and ammonia (NH_3), in traditional markets through continuous monitoring. By establishing strategic monitoring points and comparing data from two consecutive years—before and after implementing a new odor-neutralizing technique—the research evaluates the effectiveness of these methods. Ultimately, the findings aim to develop strategies for mitigating odor pollution and suggest some advanced technologies to enhance the overall shopping experience for consumers.

1.1. Sources of Odor Pollutants

The decomposition of food waste generates malodorous volatile organic compounds (VOCs), which can negatively impact human health and cause significant discomfort. Research has highlighted key VOCs released during the breakdown of various food types. For example, fruit waste predominantly emits oxygenated VOCs like 2-butanone and ethyl acetate, while meat and vegetable waste release sulfur compounds such as dimethyl sulfide and dimethyl disulfide (Zhang et al., 2020; Liang et al., 2024). The release of these VOCs is closely tied to microbial activity, with specific bacterial communities linked to distinct VOCs profiles (Zhang et al., 2020; Liang et al., 2024). Technologies like electronic noses, equipped with metal oxide semiconductor sensors, have been developed to detect spoilage in meat and fish products (Hasan et al., 2012). Additionally, the odors from decomposing bio-organic waste, including food waste and animal by-

products, can negatively affect the health and emotional well-being of workers in waste management facilities and agricultural environments (Kharlamova et al., 2023). Understanding these processes is essential for creating effective strategies to minimize VOCs emissions during food waste decomposition. According to Jung (2021), the main sources of odors in traditional markets stem from cooking smells in restaurants, sewage odors, and food waste, further highlighting the urgent need for effective odor management strategies. Different studies indicate that malodors, total volatile organic compounds (TVOCs), hydrogen sulfide, and ammonia frequently exceed emission standards at various locations (Kim et al., 2021; Kim et al., 2022). High concentrations of these odors are often detected near intersections, restaurants, and clothing stores (Kim et al., 2022). The origins of these odors are varied and typically present in low concentrations, requiring effective technologies for their reduction (Kim et al., 2021). Implementing design strategies, such as ensuring proper ventilation and sunlight exposure, along with strategic layout planning, can significantly reduce odor problems (Houward, 2023). Although air quality in some markets may meet safety standards for pollutants like SO_2 and NO_2, traders still report respiratory discomfort, highlighting the need for further investigation into additional air quality parameters (Gusti, 2019). Effectively addressing odor pollution is essential to preserving the economic relevance of traditional markets and attracting more visitors (Houward, 2023).

Building on the insights gained from a thorough review of existing literature, this study aims to mitigate odor issues in traditional markets. By addressing the challenges faced by vendors and merchants, it seeks to propose effective techniques for neutralizing unpleasant odors, ultimately enhancing the overall market environment. Through empirical investigation, this research will provide practical solutions that contribute to a more pleasant shopping experience, benefiting both consumers and market operators alike.

2. Literature Review

The traditional market plays a crucial role in establishing a system that fosters interconnection and collaboration within the community. As a vital commercial space, it not only represents the region but also serves as a multifunctional hub where visitors can experience local culture, customs, and a sense of community through the dynamic interaction of people, spaces, and various activities (Korea Research Institute of Local Administration, 2013). However, the unpleasant odors produced in traditional markets have become a significant reason for modern consumers to avoid these spaces. The majority of odor complaints in traditional markets are attributed to cooking processes in restaurants, sewer odors, and smells from food waste, collectively contributing to the decline in market appeal (The Seoul Institute, 2013). Achieving a comfortable and fresh market environment can be addressed through the implementation of effective air circulation and lighting systems. These improvements play a crucial role in tackling one of the major issues in the traditional market “odor”. Additionally, problems such as heat, poor ventilation, and insufficient lighting can be resolved. Therefore, incorporating principles of Green Architecture in market design is highly suitable for addressing these concerns (Houward & Eddy, 2023). To address the odor problem in traditional markets, various methods have been employed, including the installation of ventilation systems, the application of Effective Microorganisms (EM), and routine cleaning practices. Given that odors in traditional markets are typically dispersed over a wide area at low concentrations rather than concentrated in a single location, it is evident that a comprehensive and multifaceted approach is required to effectively reduce odor pollution (Kim et al., 2021).

Research by Ahn and Kim (2016) examined design plans for modernizing traditional markets, particularly emphasizing the importance of addressing odors through proper ventilation as a key psychological factor in the market environment. Although their study did not include actual odor measurements or identify specific causes, it highlighted that managing odors is a critical aspect of modernizing traditional markets.

Despite the acknowledgment of odor issues in traditional markets, existing studies primarily focus on design and theoretical frameworks without empirical data to quantify odor levels or their impacts on consumer behavior. This creates a significant research gap, as there is limited understanding of the specific odor sources and their concentrations within these markets. Furthermore, while some research has highlighted the importance of odor management, there is a lack of comprehensive studies that explore the effectiveness of odor reduction technologies in real-world settings. This study aims to fill this gap by investigating the sources and concentrations of odorous compounds in the Wanju Jayu Traditional Market using continuous monitoring and experimental data collection. By employing an innovative sewage odor-reducing substance spraying device, the research seeks to analyze the effectiveness of this technology in mitigating unpleasant odors. Ultimately, this study aims to provide actionable insights that can enhance the competitiveness of traditional markets, improve customer satisfaction, and promote a cleaner, more inviting shopping environment.

3. Research Methods and Materials

In this study, The Odor Measuring Equipment AOMS-1000 to measure odorous compounds, focusing primarily on volatile organic compounds (VOCs), H_2S and NH_3 in the Wonju Jayu Traditional Market. The AOMS-1000 is a direct-reading odor measurement device that allows for continuous monitoring. Measurements were conducted for 5-minute intervals at each point, with data collected every minute. The results were averaged for accuracy. Additionally, the AOMS-1000 features a portable and automatic odor sample collection system, which can be controlled remotely via the CDMA wireless communication system. This allowed for the collection of standby samples in areas where direct user operation was challenging. Through SMS commands, the device could be activated remotely, making it highly efficient for long-term monitoring.

Figure 1: Odor Measurement Equipment

Table 1: Equipment Specification

Model	AOMS-1000
Fluid	Air (Odor)
Sampling method	Forced suction method
Sensor array module	Basic 4 types, up to 8 types
Field data display	Built-in LCD
Screen size	8" touch-operated (Tablet PC)
Display contents	Quantitative measure value for each substance, dilution factor, complex malodors
Save field data	Possible (built-in)
Suitable operating temperature	-20℃ ~ 65℃
Appearance (WxHxD)	365(W) x 151(H) x 296(D) mm, ABS
weight	About 5 kg
Power	12V SMPS 3.5A Adapter (Optional: 12V 33A Rechargeable Battery)

The area under study was divided into five distinct measurement points where the AOMS-1000 was installed. The devices were strategically placed in locations most affected by odor issues, including areas near restaurants, sewage systems, and waste disposal zones. Each device remained installed at these points throughout the duration of the study to ensure continuous data collection.

The **Sewage Odor-Reducing Substance Spraying Device** was developed to address the challenges associated with sewage odors, particularly focusing on hydrogen sulfide removal. This innovative system integrates a specially formulated odor-reduction material, consisting of hydrogen sulfide removers, microbial agents, and microbial enhancers, with an injection device manufactured by Dongyeon Environmental Technology. In a shift from conventional designs, which typically attach the injection device beneath manhole covers, this new configuration allows for installation on the side of the manhole. This design alteration enhances accessibility and management while effectively targeting the identified primary odor source—the square rainwater pipe. The incorporation of AIoT technology (Clio) facilitates real-time monitoring and control, ensuring optimal operation. By deploying this device in the summer of 2023, the study aims to compare data on volatile organic compounds (VOCs), H_2S, and NH_3 before and after its application, assessing the effectiveness of the odor neutralization approach in reducing malodors in the environment.

Figure 2: Sewage Odor Reduction Material Spray Device

3.1. Study Period

The research was conducted over two years, focusing on data collection during the summer months of 2022 and 2023. The first set of data was collected during the summer of 2022, serving as a baseline to assess the level of VOCs emissions before any intervention. Following this, a Sewage Odor-Reducing Substance Spraying Device was introduced to mitigate odor levels in the market, targeting the main sources of odor, including sewage, food waste, and restaurant areas.

After implementing the odor-reducing technology, data collection was repeated in the summer of 2023, with the same five measuring points and methods used. This allowed for a comparative analysis to evaluate the effectiveness of the spraying device in reducing VOCs concentrations in the market. The comparison between 2022 and 2023 data helped assess the overall reduction in odorous compounds after employing the sewage odor-reducing intervention.

Table 2: Measurement results of odor compounds

Measurement	TVOCs (ppb) 2022	TVOCs (ppb)2023	H_2S (ppb)2022	H_2S (ppb)2023	NH_3 (ppb)2022	NH_3 (ppb)2023
Point 1	1144.55	512.28	30.42	26	0	0
Point 2	1058.96	511.39	29.92	28.75	0	0
Point 3	1446.59	511.04	28.92	28.58	0	0
Point 4	797.52	511.53	29.33	4.94	0	0
Point 5	691.48	514.87	27.92	28.25	0	0

4. Results and Discussion

The data collected from the Wonju Jayu Traditional Market 2022 and 2023 indicate a significant reduction in odor levels following the implementation of the Sewage Odor-Reducing Substance Spraying Device. The results of the odor measurements conducted in the traditional market are presented in Table 2. The measurements, presented in parts per billion (ppb), reflect changes in total volatile organic compounds (TVOCs), hydrogen sulfide (H_2S), and ammonia (NH_3) across five designated monitoring points.

The measurement results for odor compounds across the five monitoring points in Free Market reveal significant changes between 2022 and 2023. At Point 1, the TVOCs concentration decreased from 1144.55 ppb in 2022 to 512.28 ppb in 2023, while hydrogen sulfide (H_2S) dropped from 30.42 ppb to 26 ppb, and ammonia (NH_3) was not detected in either year. Point 2 showed a similar pattern, with TVOCs falling from 1058.96 ppb in 2022 to 511.39 ppb in 2023, while H_2S slightly reduced from 29.92 ppb to 28.75 ppb. Ammonia was also absent at this point. At Point 3, the initial TVOCs level of 1446.59 ppb in 2022 significantly declined to 511.04 ppb in 2023, with a minor reduction in H_2S from 28.92 ppb to 28.58 ppb. Again, ammonia was not detected here. Point 4 exhibited a noteworthy drop in TVOCs, from 797.52 ppb in 2022 to 511.53 ppb in 2023, and H_2S dropped considerably from 29.33 ppb to 4.94 ppb. Ammonia remained undetected. Finally, point 5 saw TVOCs reduce from 691.48 ppb in 2022 to 514.87 ppb in 2023, with a slight decrease in H_2S levels from 27.92 ppb to 28.25 ppb, and no detectable ammonia (Table 2). Overall, the results show a consistent reduction in odor pollutants across all points.

4.1. Total Volatile Organic Compounds (TVOCs)

The measurements of TVOCs show a marked decrease from 2022 to 2023. For instance, In (Table 2 and Figure 3) Point 1 exhibited a decline from 1144.55 ppb to 512.28 ppb, representing a reduction of approximately 55.3%. Similar trends were observed at all points, with reductions ranging from 50.4% to 64.7%. This significant decrease in TVOCs levels suggests that the Sewage Odor-Reducing Substance Spraying Device effectively mitigated the emission of odorous compounds in the market environment.

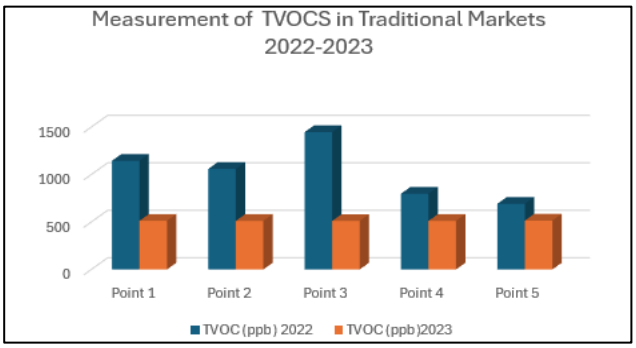

Figure 3: Measurement result of TVOCs

4.2. Hydrogen Sulfide (H_2S) & Ammonia (NH_3)

Hydrogen sulfide levels also showed a notable decline. For example, the H_2S concentration at Point 1 decreased from 30.42 ppb in 2022 to 26.00 ppb in 2023. Although the decrease was less dramatic than that of TVOCs, it indicates a successful reduction in this specific malodorous compound. Other points exhibited similar patterns, with H_2S concentrations remaining relatively low, suggesting that the device contributed to improved air quality. Interestingly, as we can see from (Table 2 and Figure 4) Ammonia (NH_3) levels were negligible at all measuring points in both years, suggesting that the market may not have been a significant source of NH_3 or that the odor-reduction measures successfully addressed potential sources.

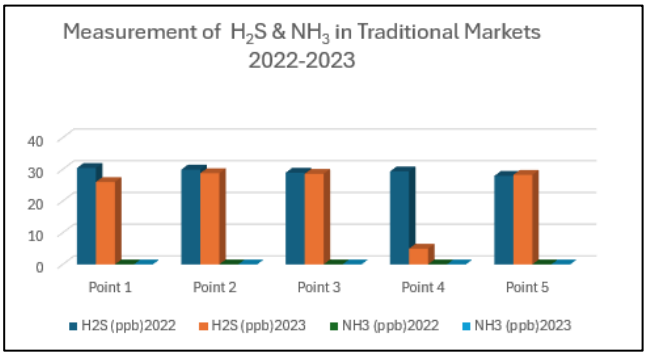

Figure 4: Measurement result of H_2S and NH_3

The results of this study support the argument that **comprehensive odor management strategies**—involving the use of advanced odor-reducing devices and careful monitoring—can significantly reduce pollutant levels in traditional market environments. The consistent reduction of TVOCs and H_2S across various points highlights the potential for such interventions to improve air quality, enhance the market experience for visitors and workers, and address public concerns about odors.

However, some challenges remain. For instance, the variation in H_2S reduction across different points suggests that localized factors may affect the distribution and persistence of odor compounds. Future research should focus on identifying these factors, as well as testing the long-term effectiveness of odor reduction technologies. Additionally, exploring the influence of seasonal variations and other environmental conditions on odor emissions could provide a more nuanced understanding of how best to implement and optimize these solutions.

5. Conclusions

This study investigated the sources and characteristics of odor pollutants in the Wonju Jayu Traditional Market, focusing on the measurement of volatile organic compounds (VOCs), hydrogen sulfide (H_2S), and ammonia (NH_3) before and after the implementation of a sewage odor-reducing substance spraying device. The findings demonstrated a significant reduction in odor levels across all measuring points following the use of odor control technology.

The results from the summer of 2023 revealed substantial decreases in total volatile organic compounds, with values dropping from an average of 1,067.82 ppb in 2022 to 511.61 ppb in 2023. Similarly, H_2S concentrations also saw a decline, reinforcing the effectiveness of the odor-reducing measures. This indicates that targeted interventions can successfully mitigate unpleasant odors and improve air quality in traditional markets, enhancing both the shopping experience for consumers and the working conditions for vendors.

The study highlights the necessity for continuous monitoring and improvement in managing odor pollution within traditional markets. Given the complex nature of odor sources, including food waste, sewer emissions, and cooking processes, it is crucial to adopt a multifaceted approach that incorporates advanced odor management technologies. By addressing these odor-related challenges, traditional markets can maintain their cultural and economic significance while providing a healthier environment for all stakeholders involved. Future research should focus on the long-term effects of such interventions

and explore additional strategies to further reduce odor pollution.

6. Recommendations

- Implement biofilters to reduce up to 95% of hydrogen sulfide (H_2S) and 80% of ammonia (NH_3) in traditional markets, especially near waste collection areas and sewage systems.
- Use electrostatic precipitators in food stall areas to capture fine particles, smoke, and cooking odors, improving overall air quality.
- Apply dielectric barrier discharge (DBD) technology to remove H_2S and NH_3 from market air streams, optimizing for specific gas compositions for maximum efficiency.
- Introduce photocatalytic purification systems in ventilation areas to break down VOCs and reduce malodorous compounds using light-activated catalysts.
- Utilize sealed containers and vacuum packaging for food waste management to prevent the release of VOCs, supported by AIoT systems for automatic control and remote monitoring.
- Adopt plasma purification and catalytic combustion methods to target VOCs emissions, reducing odors from kitchens, food waste, and sewage systems in an energy-efficient manner.
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- Remove sewage odors by using chemical deodorants and microorganism carriers to target hydrogen sulfide in sewage pipes, which is a hazardous substance that can cause suffocation and requires careful management.

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