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Comparison of the efficiency of biofiltration on a compost filter and a scrubber with hydrogen peroxide in removing odors from a composting plant

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ABSTRACT

Composting plants and organic waste treatment plants are significant sources of hydrogen sulfide (H_2S) and ammonia (NH_3) emissions – generated during the decomposition of biomass under anaerobic and aerobic conditions. Although concentrations of these gases are often below toxic thresholds, very low levels (often in the ppb/ppm range) cause odor nuisance and negatively impact residents' quality of life and relationships with the local community. Given current environmental standards, such as the Environmental Protection Law, implementing technologies that effectively reduce odor emissions is becoming essential. This study presents a comparative analysis of two deodorization technologies: compost bed biofiltration – a process in which gaseous odorants are first adsorbed onto a moist, porous medium and then biologically degraded by microorganisms present in the biofilm; hydrogen peroxide (H_2O_2) chemical scrubber – a mechanism based on the instantaneous oxidation of H_2S and NH_3 in an aqueous solution with the addition of H_2O_2 (and optional catalysts) during a short gas-liquid contact time. The study analyzed: H_2S and NH_3 input concentration levels consistent with typical composting plant values (~4 mg/m³ H_2S, ~ 50 mg/m³ NH_3), odor elimination efficiency in both systems, process parameters: retention time (EBRT), moisture, pH, medium structure, operational aspects such as H_2O_2 dosing, and practical criteria: operational stability and resistance to concentration spikes. The main research question concerned information on which technology – biofiltration or H_2O_2 scrubber – offers better efficiency and cost-effectiveness in conditions typical of composting plants.

Keywords: biofilter, biofiltration, deodorization, chemical oxidation

INTRODUCTION

Emissions of hydrogen sulfide (H_2S) and ammonia (NH_3) during the composting of organic waste pose a significant threat to public health and air quality. H_2S is primarily produced by the anaerobic decomposition of sulfates in windrow layers, where oxygen access is limited, while NH_3 is released during the mineralization of nitrogen compounds, especially under conditions of elevated pH, humidity, or unregulated C/N ratios (Minh, 2023). Both gaseous compounds are responsible for over 90% of odorant emissions during composting (Huu Tua, 2024), and their low detectability (H_2S concentrations as low as several dozen ppb) causes significant odor nuisance. Health effects include eye and respiratory irritation, headaches, and psychological distress, especially with chronic exposure to concentrations below 10 ppm (Batterman et al., 2023). Additionally, NH_3 contributes to eutrophication and the formation of $PM_{2,5}$ particles, which increases the risk of respiratory and cardiovascular diseases. Emission intensity depends on composting conditions – low aeration, high humidity exceeding 60%, structural disturbances in the pile, and unstable pH favor the creation of anaerobic zones and increased odor emissions. Composting facilities located near residential areas often become a source of public complaints and administrative restrictions.

In light of the above, effective management of H_2S and NH_3 emissions through optimizing the composting process and implementing deodorization technologies becomes crucial. The following section of the article analyzes the comparative effectiveness of biofiltration (using a compost filter medium) and a bioscrubber with hydrogen peroxide in the context of actual odor elimination in organic waste composting plants.

Reducing odor emissions – especially hydrogen sulfide (H_2S) and ammonia (NH_3) – is crucial for protecting residents' health and the environment. Although atmospheric concentrations of these gases rarely reach toxic levels, their intense odors lead to chronic discomfort, as confirmed by epidemiological studies. People exposed to unpleasant odors for long periods often complain of headaches, coughs, nausea, and decreased sleep quality and mental well-being (Martínez-Galán, 2021). The biofiltration process is based on the flow of contaminated gas through a solid filter medium – usually compost – on whose surface active microbiota grows. Gaseous odorant compounds, such as H_2S and NH_3, are physically adsorbed onto the moist material and then biologically decomposed by the enzymatic mechanisms of the microorganisms. In a well-designed system, hydrogen sulfide removal efficiency reaches up to 95–99%, and ammonia removal efficiency reaches up to 80–96%, provided that appropriate humidity (~50%), a pH of approximately 7, and sufficient gas residence time (~20–60 seconds) are applied. The biofilter operates ecologically and economically – it requires no chemicals or special equipment, and the filter media can be partially regenerated biologically, minimizing post-operational waste. The only limitations of this technology are the relatively large installation space and the need for stable operating parameters, as fluctuations in flow rate can temporarily reduce odor removal efficiency (Barbusiński, 2021).

Furthermore, there is a risk of gas contamination with toxic compounds that affect the viability of microorganisms inhabiting biofilms (Pagans, 2005, Hartikainen et al., 2001). Chemical scrubbers using H_2O_2 rely on the rapid oxidation of H_2S and NH_3 in a liquid. In this type of device, the gas is passed through a water or ceramic layer with the addition of H_2O_2 and optional catalysts such as sodium carbonate or transition ions. Oxidation of hydrogen sulfide leads to the formation of elemental sulfur or sulfates, while ammonia is bound as an ammonium salt. The system typically achieves 97–99% efficiency for H_2S and nearly 100% efficiency for NH_3, while maintaining a pH of 10–11 and adequate liquid flow, even with a very short contact time of just 1–3 s (Aroca et al., 2002). This method is characterized by high resistance to sudden changes in odor concentration, compact design, and high efficiency, but requires chemical dosing systems, neutralization of the resulting solutions, and compliance with safety requirements.

Although both technologies achieve high deodorization efficiency, they differ in operational and logistical terms. A biofilter requires a larger surface area and constant conditions, but is less expensive to operate and environmentally friendly (Kim et al., 2003). A scrubber, on the other hand, operates immediately and in a limited space, but generates post-process waste and is associated with chemical costs. A preliminary comparison of these solutions will determine which solution – or combination thereof – is most suitable for organic waste composting plants (Yi et al., 2022)

The aim of this study is a practical and comprehensive comparison of the effectiveness of two deodorization systems used in composting plants: biofiltration on a solid composting medium and a chemical scrubber using H_2O_2. The studies were conducted in laboratory conditions. This allows for the assessment of their effectiveness and applicability, but requires testing in industrial settings.

The main research objectives include:

- estimating the H_2S and NH_3 reduction efficiency, determined by comparing the concentrations of these odorants before and after treatment in both systems;
- analyzing operational parameters such as retention time (EBRT), temperature, pH, compost moisture content, and H_2O_2 dose, which are important for process stability and repeatability;
- comparing the operating and logistical costs of both technologies, taking into account material consumption (compost, H_2O_2), energy, maintenance, and waste or wastewater generation;
- developing practical recommendations that will indicate the optimal solution for each composting plant – from both an economic and environmental perspective.

The achievement of these goals will make it possible to indicate which solution works best in the specific conditions of Polish composting plants, and whether it is justified to implement sequential or hybrid deodorization systems adapted to the changing composition and amount of organic waste (Charron et al., 2020)

RESEARCH EQUIPMENT AND MATERIALS

Biofiter with a solid compost deposit

In laboratory tests, a biofilter was constructed in the form of a modular unit with dimensions of 70 × 70 × 70 cm, operating in up-flow mode, which allows for an even flow of polluted air through the compost layer. Figure 1 shows a schematic laboratory layout of the process. The medium consisted of screened compost with grain sizes < 1.3 cm, combined with sawdust, which provided a porous structure capable of retaining moisture and effectively supporting biofilm development. This system was then inoculated with "mature" compost enriched with nitrifying and sulfur-fixing bacteria (SBS), which significantly accelerated the development of active biological flora.

The biofiltration mechanism is based on the combination of two complementary processes: adsorption and biodegradation, which occur in compost infested with microorganisms.

Physical structure: Compost with grains > 3 mm, mixed with sawdust, which prevents compaction and gas channeling; the known porosity is provided by both organic matter and the addition of wood chips or supporting structures.

Microorganism colonization: Naturally present sulfur bacteria (e.g., *Thiobacillus* spp.) and nitrogen bacteria (e.g., *Nitrosomonas* spp.) in compost are often supplemented with enrichment and colonization cultures to increase resistance to fluctuations in gas concentration.

This biofilter, using compost as the biological filter, demonstrates excellent efficiency (> 95%) under real-world composting conditions, minimal waste production, and low maintenance. However, it requires regular monitoring of moisture content, bed structure, and EBRT values to maintain stable and efficient operation (Jayanta, 2021).

As a moist gaseous stream containing pollutants (H_2S, NH_3, VOCs) flows through a compost bed, volatile compounds initially physically adhere to the particle surfaces – this is adsorption, supported by the porous structure of the medium with a specific surface area of hundreds of m^2/m^3, high water capacity, and pH buffering capacity.

Then, in the surface biological layer (biofilm), the polluted compounds biodegrade. Microorganisms, such as sulfur-producing or nitrifying bacteria (e.g., *Thiobacillus* spp., *Nitrosomonas* spp.), enzymatically degrade H_2S and NH_3 into safe products: CO_2, H_2O, sulfur, and inorganic salts. Biodegradation occurs in two stages: first, the uptake of pollutants by cells (biosorption), and then enzymatic decomposition within the microorganisms, resulting in mineralization.

This combination of processes allows for high efficiency: H_2S at 89–99%, NH_3 at 80–96%. Key factors include retention time (≥ 20 seconds), moisture (40–70%), and near-neutral pH. When conditions are right, microflora regenerates naturally, and the compost remains functional for a long time without the need for replacement. In short, biofiltration in compost is a two-stage process – adsorption on the bed helps initially retain odorants, while the living biofilm biologically converts them into safe compounds, ensuring effective and environmentally friendly waste gas treatment. Table 1 presents the optimal parameters for conducting biofiltration on a compost or compost-sawdust bed. These data were used to establish the experimental conditions.

Hydrogen peroxide scrubbers

A laboratory column, approximately one meter high and 15 cm in diameter, was filled with a highly porous mineral sorbent (packed bed).

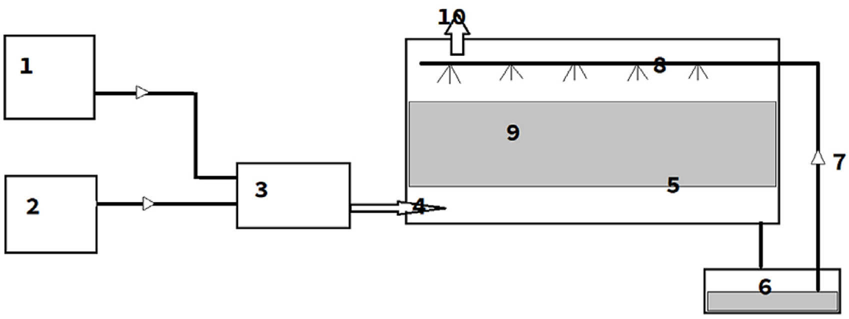

Figure 1. Schematic diagram of the biofiltration process of odor–generating gases: 1 – process gas tank, 2 – humid air tank, 3 – mixing chamber, 4 – biogas supply, 5 – perforated partition, 6 – process effluent tank, 7 – effluent supply to the sprinkler system, 8 – sprinkler system, 9 – compost bed, 10 – air discharge after treatment

Table 1. Summary of optimal conditions for conducting the biofiltration process on a solid medium (Hou et al., 2016)

Parameter	Recommended values	Impact on efficiency
Gas residence time in the total volume of the deposit	20–60 s	EBRT ≥ 20 s guarantees effective H_2S removal (95–99%), below 25 s the effect decreases at high concentrations
Gas flow speed	Matched to the volume of the biofilter	Too high lowers EBRT, which reduces effectiveness
Medium humidity	40–60% (optimal ~50 %)	Too little – slowing down of enzymatic activity and gas channeling; too much – risk of anaerobic digestion
Operating temperature	20–50 °C (optimal 25–40 °C)	Optimal bacterial activity in the range of 25–40 °C; below 20 °C the process slows down, above 50 °C there is a risk of inactivation
pH deposit	About neutral (6.5–7.5)	Microbial enzymes function optimally in this range; a pH below 6 reduces H_2S degradation
The structure of the medium	Grains > 4 mm, porosity ≥ 40%	Ensures smooth flow and good diffusion; a compost-sawdust bed with a porosity of 50–60% achieves high efficiency
Additives (e.g. sawdust)	Compost with 20–30% sawdust	They improve the structure, prevent bed settling and reduce pressure drop

These media are durable and do not require biological regeneration, enabling clean chemical analysis. The gas containing H_2S and NH_3 passes through the bed, where it is sprayed with a H_2O_2 solution, enabling rapid oxidation of these compounds. Laboratory results confirm that at a flow rate of 10 L/h, ≥ 95% H_2S and NH_3 reduction is achieved, provided appropriate contact time and pH are maintained. This configuration allows for precise analysis of reaction parameters and preparation of data for scale-up to pilot plants. Figure 2 shows the laboratory setup of the chemical scrubber used in the experiment.

The chemical mechanism of a hydrogen peroxide scrubber is based on the rapid and efficient oxidation of odor-causing gases by the liquid phase. Gases such as H_2S and NH_3 are introduced into a chamber where they come into contact with a pH-controlled hydrogen peroxide solution, often with the addition of catalysts (e.g., sodium carbonate, iron, copper). In the case of H_2S, the reaction occurs in two pH-dependent variants: under slightly acidic or neutral conditions, H_2O_2 allows oxidation to elemental sulfur (S^0), according to the equation:

$$H_2S + H_2O_2 \rightarrow S^0 + 2\,H_2O \quad (1)$$

In an alkaline environment (pH > 9.2), the dominant reaction leads to sulfates, according to the formula:

$$S^{2-} + 4\,H_2O_2 \rightarrow SO_4^{2-} + 4\,H_2O \quad (2)$$

This second pathway requires larger doses of H_2O_2, but effectively removes H_2S without forming a sulfur precipitate. The reaction mechanism

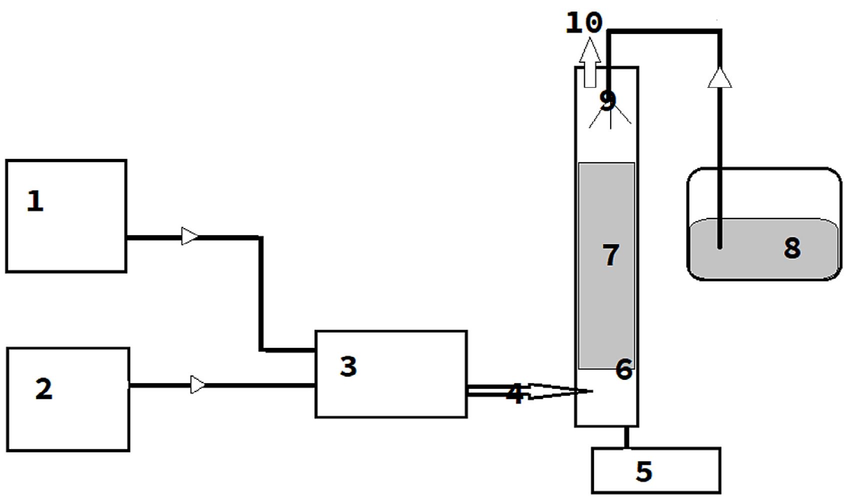

Figure 2. Schematic diagram of the odor-generating gas filtration process using a chemical scrubber: 1 – process gas tank, 2 – humid air tank, 3 – mixing chamber, 4 – biogas supply, 5 – process effluent tank, 6– perforated partition, 7 – ceramic column filling, 8 – oxidizing liquid tank (H_2O_2), 9 – oxidant spray system, 10 – air discharge after treatment

is also supported by transition metal catalysts (Fe^{2+}/Fe^{3+}, Cu^{2+}), which accelerate the formation of active hydroxyl-type oxidants (•OH), particularly through the Fenton reaction, which increases the process efficiency.

In the case of NH_3, the gas, upon contact with water and H_2O_2, converts to ammonium ion (NH_4^+), which, under the influence of free radicals – primarily •OH – and a strong oxidant, is gradually oxidized and chemically bound to form ammonium salts. Although the kinetics of these reactions may be slower than those of H_2S, they achieve almost 100% efficiency, especially in an environment with a pH ≈ 10–11.

The entire process takes place with a short retention time (4–15 seconds), making the bio-scrubber a highly efficient and compact solution. The main reactions occur in the liquid phase, and the effectively purified gas is discharged, while the products: sulfur/elemental, sulfates, and ammonium salts remain in solution, ready for further management or neutralization.

Table 2 presents the optimal process conditions based on literature data, which formed the basis for the experimental design.

Comparative analysis

The main research question of the proposed experiment involved analyzing which technology – biofiltration on a solid composting medium or a chemical scrubber using hydrogen peroxide – is more effective and cost-effective in the real-world operation of an organic waste composting plant.

The research aimed to:

- directly compare the removal efficiency of key odorants (H_2S and NH_3) in laboratory conditions,
- assess waste generation and the need for its neutralization (wastewater production, compost consumption).

This makes it possible to develop specific technological recommendations – indicating which method works better in specific composting plant scenarios in Poland, where differences in odor concentrations, available space or economic conditions can significantly affect the effectiveness and profitability of implementation.

Analysis methods

Biogas analysis was performed using the GA-5000 analyzer. This portable device is ATEX Zone1 ExibIIA T1 Gb certified and designed to measure H_2S (range up to 10.000 ppm) and NH_3 (up to 1.000 ppm).

- measurement ranges: H_2S up to 10.000 ppm, NH_3 up to 1.000 ppm, CH_4, CO_2, O_2, CO, and H_2,
- response time: $T_{90} \leq 30$ s for H_2S, ≤ 90 s for NH_3,
- equipped with a sampling pump: ~550 ml/min, allowing for measurements in low-flow conditions. Powered by a Ni-MH battery. Operating conditions: -10 °C to +50 °C. Built-in temperature, pressure, and humidity sensors,
- calibration and certifications: IECEx, CSA, MCERTS, UKAS/ISO17025 compliant.

The analyzer enables direct measurement of H_2S and NH_3 concentrations before and after the biofilter with an accuracy of ± 1.5–2% FS (higher H_2S ranges).

RESULTS AND DISCUSSION

H_2S gas at a fixed concentration was obtained from a calibration bottle, then dosed and mixed with humidified air to simulate composting plant conditions. Ammonia was obtained from a calibration bottle – 98% NH_3 in nitrogen, and was fed using precision equipment. The gas was fed to the

Table 2. Summary of optimal conditions for the filtration process on a solid ceramic medium using an oxidizer (Deshusses, 2008)

Parameter	Recommended values	Impact on process efficiency
Liquid-gas contact time	A few seconds to 5 minutes	The complete oxidation of H_2S and NH_3 requires a time of several seconds, in some systems even 5 minutes are used for a stable reaction
H_2O_2 concentration relative to H_2S	5:1 mol/mol	Excess H_2O_2 ensures almost 100% elimination of H_2S, even at concentrations up to 500 ppm
pH of the solution	Range 10–11	At pH 10–11, the oxidation reactions of H_2S and NH_3 are most effective; at pH < 8, the effectiveness decreases (< 99%)
Stabilizers	Na_2SiO_3, transition metal salts	The addition of stabilizers protects H_2O_2 from excessive decomposition and improves the efficiency of the process

Table 3. Summary of results obtained under natural conditions at the biogas outlet in a commercial composting plant (own study)

Parameter	Typical concentration
H_2S	0.2–3.7 mg/m³ (normal to 0.6 mg/m³)
NH_3	10–60 mg/m³ (~6–35 ppm)

biofilter and column, where it was mixed with air to achieve the final concentration. Table 3 presents the concentration ranges of the tested gases produced in commercial composting plants under natural conditions (analyses were conducted under technical conditions). Table 4 presents a summary of the results obtained during laboratory analyses. The presented values are averages of three cyclical measurements taken daily. This sampling minimizes the effect of random deviations and enhances the stability of the results. The following test parameters were used to evaluate the effectiveness of odor removal under near-realistic conditions:

- H_2S and NH_3 concentrations were selected based on measurements near composting facilities and literature data typical of biomass biodegradation processes.

In one of the experiments conducted with a biofilter, $H_2S \approx 4.2$ mg/m³ and $NH_3 \approx 0.9$ mg/m³ were used – values consistent with average concentrations in composting effluents (Pagans et al., 2005, own study).

Experimental conditions

H_2S – typical H_2S concentrations in composting flue gases range from 0.2 to 3.7 mg/m³, with standards allowing levels up to approximately 0.6 mg/m³ (Shang et al., 2022). In this study, an average concentration of 4.13 mg/m³ (range 4.0–4.2 mg/m³) was used, deliberately choosing a slightly higher value to test the technologies under increased load conditions (Moosavi et al., 2005).

NH_3 – natural ammonia concentrations in composting plants are estimated at 10–60 mg/m³, although values up to 150 mg/m³ have been reported (Charon et al., 2020). In the experiment, the concentration of 50 mg/m³ (~± 1 mg/m³) was selected – a value on the verge of the upper limit – which allowed for verification of the operation of the devices with increased availability of the nitrogen substrate.

These selected parameters ensured, above all:

- realistic test conditions reflecting the operating environment of a composting plant,
- comparability with reference studies based on biofiltration and chemical scrubbers operating at a pilot scale,
- methodological reliability – the data obtained are both reliable and representative.

In the biofiltration reactor, a final H_2S concentration of 0.15 mg/m³ was achieved, corresponding to an efficiency of 96.2%. The results for the chemical scrubber were slightly worse: a final concentration of 0.17 mg/m³, or a 95.6% reduction, which is consistent with the results of other researchers (Yuan, 2019).

The data obtained in the experiment, despite the smaller scale, are consistent with the literature: compost biofilters typically eliminate H_2S by 96–100% at concentrations ranging from 2 to

Table 4. Summary of experimental results divided by odor-generating gas type

Measurement day	Concentration before filtration	Concentration after biofiltration	Removal efficiency [%]	Concentration before filtration	Concentration after scrubber	Removal efficiency [%]
1	H_2S: 4.0 mg/m³	H_2S: 0.2 mg/m³	95	H_2S: 4.1 mg/m³	H_2S: 0.2 mg/m³	95
2	H_2S: 4.11 mg/m³	H_2S: 0.2 mg/m³	95	H_2S: 4.0 mg/m³	H_2S: 0.2 mg/m³	95
3	H_2S: 4.10 mg/m³	H_2S: 0.12 mg/m³	97	H_2S: 4.0 mg/m³	H_2S: 0.16 mg/m³	96
4	H_2S: 4.2 mg/m³	H_2S: 0.12 mg/m³	97	H_2S: 4.1 mg/m³	H_2S: 0.16 mg/m³	96
5	H_2S: 4.0 mg/m³	H_2S: 0.12 mg/m³	97	H_2S: 4.2 mg/m³	H_2S: 0.16 mg/m³	96
Mean	H_2S: 4.13 mg/m³	H_2S: 0.15 mg/m³	96.2	H_2S: 4.08 mg/m³	H_2S: 0.17 mg/m³	95.6
1	NH_3: 50 mg/m³	NH_3: 6 mg/m³	88	NH_3: 51 mg/m³	NH_3: 1.02 mg/m³	98
2	NH_3: 51 mg/m³	NH_3: 6.12 mg/m³	88	NH_3: 51 mg/m³	NH_3: 0.51 mg/m³	99
3	NH_3: 50 mg/m³	NH_3: 4.5 mg/m³	91	NH_3: 49 mg/m³	NH_3: 0.49 mg/m³	99
4	NH_3: 49 mg/m³	NH_3: 4.41 mg/m³	91	NH_3: 50 mg/m³	NH_3: 0.5 mg/m³	99
5	NH_3: 50 mg/m³	NH_3: 4.0 mg/m³	92	NH_3: 51 mg/m³	NH_3: 0.51 mg/m³	99
Mean	NH_3:50 mg/m³	NH_3: 5.0 mg/m³	90	NH_3: 50 mg/m³	NH_3: 0.5 mg/m³	99

15 mg/m³ (Vela-Aparicio, 2022), while chemical scrubbers with hydrogen peroxide dosing remove it by 97–99% (Vela-Aparicio et al., 2021).

The biofilter reduced the ammonia concentration to 5.0 mg/m³, indicating an efficiency of 90%. The chemical scrubber achieved almost complete removal – 0.5 mg/m³, i.e., 99% efficiency.

Comparative literature data indicate that compost biofilters achieve 90–100% NH_3 reduction at concentrations up to 70 mg/m³, while chemical scrubbers eliminate ammonia almost completely – at levels of ≥ 99% (Chung, 2007, Vela-Aparicio et al., 2023, Charron et al., 2004).

The results confirm the high efficiency of both technologies in H_2S removal – significantly above 95%, which confirms the literature and technical standards. The difference between biofiltration and scrubber is minor and may be due to operating conditions such as EBRT, humidity, or bed configuration.

In the case of NH_3, the advantage of a chemical scrubber is clear – thanks to its rapid oxidation mechanism, final reduction to trace levels (0.5 mg/m³) makes this technology suitable for situations requiring low nitrogen emissions. Despite its relatively high efficiency (90%), a biofilter can be successfully used in conjunction with other stages, such as a chemical phase or extended contact time. In a practical context, a biofilter proves to be an economical and ecological solution for H_2S reduction.

The greatest advantage of biofiltration using compost as the filter medium is its environmental friendliness: microorganisms embedded in the moist biofilm adsorb and biodegrade odorants such as H_2S and NH_3, without the need for chemicals and with minimal operating costs. Biofiltration is characterized by high stability at moderate pollutant concentrations, and its medium can be partially regenerated, reducing waste. Furthermore, this design can be relatively inexpensive to operate and practical for ecological biomass management.

However, this technology has significant limitations: it requires a large installation area, and its effectiveness is strongly dependent on stable process conditions – fluctuations in humidity, temperature, or pH can reduce efficiency. Furthermore, the biofilter can be susceptible to bioclogging and the formation of gas flow channels, which reduces efficiency and requires regular monitoring and maintenance. Lower temperatures also adversely affect microbial activity, slowing down biodegradation. Environmental and technological trends are favoring the development of biofiltration – particularly through microflora optimization (bioaugmentation), automation of operating parameters, and integration with organic waste management. Such solutions align with the circular economy approach and the growing ecological needs of investors. However, small composting plants may struggle to maintain such operating conditions, especially in winter and during periods of rapid increases in odor load.

A chemical scrubber ensures almost complete NH_3 removal, making it the preferred choice where extreme emission purity is required. Chemical scrubber technology using H_2O_2 offers immediate and high H_2S and NH_3 removal efficiency, often reaching 97–99% even with short contact times (a few seconds) and a compact design. Chemical scrubbers are particularly useful where space is limited and very low emission levels are required, regardless of changes in odor intensity. Significant drawbacks of this approach include high chemical consumption – both H_2O_2 itself and stabilizers. The system also generates post-process waste requiring neutralization and safe disposal. Scrubber efficiency is also sensitive to parameters such as pH, oxidant dosage, and gas-to-liquid ratio, requiring precise process control. Furthermore, H_2O_2 is a weaker oxidizer than NaOCl or permanganate, which can limit efficiency in more complex odor environments. In terms of scrubber technology, there is a growing demand for automatic dosing and maintenance systems that increase precision and reduce operating costs. Integrating scrubbers as the final stage in multi-stage deodorization plants is also possible. However, these systems require skilled operation and specialized technical personnel, which can be a barrier in smaller plants or those with limited technical equipment.

This analysis provides a reliable basis for technological recommendations in the design of deodorization systems for composting and processing plants, combining efficiency with consideration of operating costs and environmental requirements.

CONCLUSIONS

The conducted research clearly demonstrates the high effectiveness of both deodorization technologies – biofiltration using compost and a chemical scrubber with H_2O_2 – in reducing the main odorants H_2S and NH_3 under typical composting conditions. In a 70×70×70 cm biofilter, hydrogen sulfide reduction of 96.2% and ammonia reduction of 90% was achieved, confirming its effectiveness at typical concentrations (H_2S ~ 4 mg/m³, NH_3 ~ 50 mg/m³). This technology is characterized by its environmental friendliness, minimal chemical input, self-regeneration of the medium, and low operating costs. However, it requires stable operating conditions (EBRT ≥ 20 s, neutral pH, humidity ~ 50%).

A chemical scrubber with H_2O_2 achieved H_2S reduction efficiency of 95.6% and NH_3 reduction efficiency of nearly 99%, while maintaining controlled pH and a short contact time (a few seconds). This technology is particularly effective in addressing sudden spikes in odorant concentrations, but requires precise chemical dosing and leachate neutralization.

While the difference in H_2S elimination between the two technologies is minimal, the chemical scrubber clearly outperforms NH_3 reduction. However, a biofilter remains an attractive option where H_2S emissions are prevalent or where budget and environmental constraints are a priority.

The analysis shows that a hybrid strategy, combining biofiltration as a preliminary step with targeted scrubber treatment, can provide the best compromise: high efficiency, chemical savings, and lower operating costs.

In the context of practical application in organic waste composting plants, the proposed solutions enable the selection of technology appropriate to local conditions: type of odorants, available space, emission requirements, and operational capabilities.

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