

Article

Biofiltration as a Method for Reducing Odour Emissions Generated During Chicken Manure Composting

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Abstract

Composting chicken manure is a source of significant ammonia (NH_3) emissions, which, because of propagation, contributes to the eutrophication of the environment and decreases in air quality. Therefore, it is reasonable to use methods to limit its emission into the atmosphere. Biofiltration, using the metabolic activity of nitrifying and heterotrophic microorganisms capable of oxidizing ammonia, is an effective method to reduce ammonia emissions. In addition, the performance of the biofiltration process depends on operational parameters such as the humidity of the medium, the temperature, the contact time of the gas with the biofiltering medium, and the chemical composition and structure of the filter material. The aim of the study was to evaluate the effectiveness of biofilter fillings in reducing ammonia emissions from composting chicken manure along with the identification of factors allowing us to determine the proposed design solution as the most advantageous in terms of efficiency. Experiments on reducing odour emissions with biofiltration were carried out in two compact composting reactors, in which a compost mixture with a C:N ratio of 10:1 was used. The mixture was prepared in a ratio of 5:1 of chicken manure to the structuring material, with wheat straw used as the structuring material. Based on the results of the research on the course of the composting process, high values of ammonia concentration were recorded. Ammonia concentrations of 886 ppm (composter 1) and 811 ppm (composter 2) were recorded, which confirms the intensive nature of this gas emissions during the process of stabilizing the chicken manure. As part of the conducted research, the effectiveness of biofiltration in reducing ammonia emissions was evaluated by analysing the influence of the aeration intensity of the biofilter (20 dm^3/h and 50 dm^3/h), directly determining the time of contact of the gas with the bed (EBCT—Empty Bed Contact Time). Coconut-activated carbon was used as a filter bed, which was an effective carrier for the development of microorganisms responsible for the biological removal of ammonia from waste gases generated during composting. In addition, this material showed the ability to physically adsorb ammonia, thus supporting the process of its elimination. Each of the test stations has been equipped with a biofiltration installation. To determine the effectiveness of biological removal of ammonia and to assess the legitimacy of the use of selected strains of microorganisms in the process of biological removal of ammonia, the bed of one of the biofilters (biofilter 2) was inoculated with a strain of nitrifying bacteria. During the study, the high efficiency of ammonia removal because of biofiltration was noted in each of the configurations. In the case of an aeration intensity of 20 dm^3/h , a reduction in emissions of 99% was achieved; with a higher aeration value, i.e., 50 dm^3/h , the efficiency was 89%. These results indicate that the intensity of aeration has a significant impact on the efficiency of the biofiltration process. The analysis of a biofilter enriched with a strain of nitrifying bacteria requires long-term testing. This is important to reliably determine the effect of inoculation on the efficiency of

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the biological removal of ammonia in biofilters. It has been shown that optimizing these factors allows us to achieve a reduction in ammonia emissions of up to 90%, while minimizing the formation of unpleasant odours. The use of biofiltration in composting systems for organic waste of animal origin is an effective, sustainable solution that fits into the idea of sustainable development, combining the efficiency of air purification technology with environmental protection and the responsible management of resources. This study demonstrates that biofiltration using coconut-shell-activated carbon is an effective and economical method for reducing ammonia and odour emissions from composting chicken manure. The results provide valuable theoretical and practical information on emissions management in organic waste composting processes. Data from this study could be useful in developing strategies to minimize odour emissions, including from the agricultural sector.

Keywords: composting; ammonia; reduction methods; biofiltration

1. Introduction Manure Ammonia Emissions

Composting, an ecological and effective method of stabilizing organic waste, is an important method for processing animal manure. During this process, some organic substances are mineralized into inorganic compounds, while the rest are transformed into humus, which can serve as a valuable soil additive, contributing to the change of soil structure, improving water retention and aeration, and being a source of nutrients. However, during the transformation of nitrogen (N) in the composting process, it is partially lost, which can reduce the fertilizer value of the compost and lead to the formation of secondary pollution. Nitrogen losses in this process occur mainly by three pathways: ammonia volatilization (NH_3), leaching of soluble nitrogen compounds with leachate, and emission of nitrogen oxides because of denitrification processes [1].

Ammonia (NH_3) is a compound responsible for odour and environmental pollution, while nitrous oxide (N_2O) is a greenhouse gas that contributes to global warming [2]. The global increase in the concentration of ammonia in the gas phase (NH_3) has significant environmental consequences. Ammonia is an important element of the nitrogen cycle, and its excessive deposition promotes algal blooms and deteriorates the quality of water, air, and soil, with toxic effects on ecosystems [3,4]. In the air, ammonia acts as one of the main alkaline components, affecting the pH of clouds, fogs and fine particulate matter (PM 2.5) [5]. The main anthropogenic source of ammonia is agricultural practices, including the use of synthetic fertilizers and animal manure [6–8]. Smaller, but still significant, emissions come from the combustion of biomass and fossil fuels and from automotive activities. Higher temperatures associated with global warming may further increase NH_3 emissions [9]. Since nitrogen fertilizers support food production for about half of the world's population, ammonia emissions are linked to population size and are projected to increase further in the 21st century [9,10].

Gaseous compounds generated in the animal husbandry environment are formed because of microbiological degradation of organic matter, which most often takes place in anaerobic conditions. These products are the result of the fermentative breakdown of carbohydrates [11]. One of the recognized methods of reducing emissions of odorous or toxic substances is biofiltration. The process of purifying the air from volatile fragrance compounds with the use of microorganisms is carried out in biofilters or bio-scrubbers. The mechanism of action of biofilters is based on the biodegradation of odour compounds by microorganisms into products with a neutral odour. The effectiveness of biofiltration is conditioned by the selection of appropriate materials filling the biofilter bed, which provide an optimal environment for the development and activity of microflora [12]. Biofiltration is one

of the methods characterized by high efficiency of removing contaminants with low operating costs. This technology is widely used, including in municipal management, animal husbandry, agriculture and the waste management sector [13]. The range of applications of biofiltration is very wide and includes, among others, oilseed processing, sewage treatment plants, feed plants, livestock farms, slaughterhouses and paint shops [14]. The key element of the biofilter is the filter bed, which is most responsible for the process of removing odour compounds. The basic parameter considered when selecting a filter material is its porosity, which determines the efficiency of gas exchange and the intensity of biodegradation processes. The most used deposit materials are tree bark or sawdust. The organic nature of these materials provides the microorganisms inhabiting the biofilter with appropriate living conditions, including access to nutrient nutrients, which promotes the efficient course of purification processes [15]. One of the significant limitations resulting from the use of organic materials in biofilters is their lower structural stability compared to inorganic materials. The relatively short lifespan of biological materials, such as compost or peat, generates additional costs related to their disposal, maintenance and the need for regular replacement. For example, when using compost as a storage material, a decrease in filtration efficiency and sorption capacity of about 72% was observed after only seven months of operation [16]. Proper functioning of the biofilter and maintaining the activity of microorganisms requires maintaining appropriate operating parameters, such as temperature, humidity, porosity and pH. The optimal moisture content of the deposit should be in the range of 40–60%, as this parameter directly affects the intensity of metabolic processes of microorganisms. Too low humidity leads to inhibition of their biological activity, while excessive humidity results in a deterioration of the sorption properties of the deposit and a decrease in the ability of microorganisms to decompose odorous compounds [15]. Biofilters are highly effective in reducing the emission of various odorous substances [12]. It was found that the use of biofiltration reduces ammonia emissions by about 51%, hydrogen sulphide emissions by 80%, and overall odour intensity by about 67% [17].

The main advantages of biofiltration include the very high efficiency of purification processes: soil biofilters achieve an efficiency of about 99% and non-soil biofilters achieve an efficiency of about 95%. An important advantage of this technology is also its economic benefits [18].

The aim of the study was to determine the effectiveness of different biofilter fillings in reducing ammonia emissions from composting chicken manure, along with the identification of factors that allow us to determine the proposed design solution as the most advantageous in terms of performance.

2. Methodology

2.1. Test Substrate

The research focused on the process of biofiltration of odours resulting from composting chicken manure, which is one of the important sources of emissions of volatile sulphur compounds, ammonia and other substances responsible for unpleasant odour. The basic substrate used in the compost mixture was chicken manure, enriched with a structuring material in the form of wheat straw. These substrates were combined in a volume ratio of 5:1 (chicken manure: wheat straw), which ensured the appropriate structure of the mixture, enabling proper aeration and maintaining the humidity necessary for the intensive development of the compost microflora. Table 1 shows the composition of the compost mix before the composting process. The filter medium used in the biofilters included coconut-activated carbon, which is characterized by a large specific surface area and high adsorption capacity for volatile organic compounds and ammonia. To increase the efficiency of nitrogen compound degradation, part of the activated carbon was inoculated with a culture of nitrifying bacteria. These microorganisms are capable of biological

conversion of ammonia into nitrites and nitrates, which enabled the more effective removal of odours associated with ammonia emissions. This combination of the physical properties of the filter medium (adsorption) with the biological activity of microorganisms (biodegradation) affected the possibility of effective purification of the gas stream.

Table 1. Properties of the compost mix before the composting process.

DM (%)	MC (%)	OM (%DM)	N_Kj (g/kg DM)	C_org (% DM)	C:N	pH
29.62	70.38	55.28	50.82	48.04	~10:1	7

2.2. Test Stand

The biofiltration test bench consisted of two independent biofilters, designed to enable precise control and monitoring of gas purification processes. Each biofilter was equipped with air inlet and outlet systems, allowing gas sampling both before and after biofiltration. This solution enabled a detailed analysis of the chemical composition and concentration of contaminants, which is crucial when assessing the efficiency of the process and the dynamics of degradation of volatile substances and organic compounds in laboratory conditions. The biofilters were filled with a properly selected filter medium, conducive to the development of microorganisms capable of biodegradation of gaseous pollutants. The drainage system enabled controlled drainage of the resulting leachate, which ensured safe management of the waste liquid. In addition, the design of the station enabled the adjustment of operational parameters, which is important when studying the impact of environmental conditions on the performance of biofilters. The monitoring system also made it possible to assess changes in the physicochemical parameters of gases in real time, which allows for the optimization of biofiltration conditions.

Figure 1 shows the reactors for composting organic waste used in the study, i.e., chicken manure and wheat straw. The reactors were equipped with air inlet and outlet systems, which enabled monitoring of gas composition during the process. These design conditions enabled the control of selected operating parameters, such as air flow, and enabled the analysis of gas emissions, including ammonia.



Figure 1. Composting reactors.

Figure 2 shows a biofiltration station, considering the use of selected filter materials and the arrangement of air inlet and outlet systems, which made it possible to monitor the composition of gases both before and after biofiltration. Such design conditions enabled the control of selected operational parameters, e.g., air flow, as well as made it possible to conduct analyses of the biofiltration process and assess the effectiveness of individual combinations of filter materials in terms of the evaluated odour reduction.



Figure 2. Biofiltration station.

3. Selected Analyses

To evaluate the effectiveness of biofilters in reducing ammonia from compost waste gases, the key parameter is the gas contact time with the filter bed (EBCT). This parameter determines how long the air stream remains in contact with the filter medium, which has a direct impact on the degree of adsorption of ammonia and its biodegradation by nitrifying microorganisms.

$$EBCT = \frac{V_{bed}}{Q} \quad (1)$$

where:

V_{bed} —volume of the filter bed (biofilter medium) [m^3 or dm^3];

Q —volume of gas flowing per unit time (air flow) [m^3/s , m^3/h , dm^3/h].

In both cases, 9 L of coconut-activated carbon was used to fill the biofilters. Table 2 shows the conditions for field aeration considering the EBCT indicator.

Table 2. Contact time with the filter bed.

Air Flow (dm^3/h)	Bed Volume (L)	EBCT (min)
50	9	10.8
20	9	27.0

The selected filter material was characterized by the following properties:

- Granulation: 0.6–2.36 mm.
- Adsorption: $1050 m^2/g$.
- Bulk density: $475 kg/m^3 \pm 5$.

The filter bed was enriched with a culture of nitrifying bacteria. The obtained strain of nitrifying bacteria Azoo Nitripro enables the effective nitrification of high concentrations of ammonia and nitrites into nitrates. The preparation consists of a concentration of

5 billion active forms of bacteria per 1 g of the preparation. In biofilter 2, about 1.5 g of strain per 9 L of activated coconut carbon was used.

4. Results

During the study, ammonia emissions were monitored at time intervals of 10 min, from both the composters (composter 1 and composter 2) and the biofilters (biofilter 1 and biofilter 2, inoculated with nitrifying bacteria culture). In addition, the experiment introduced a variable concerning the aeration intensity of biofilters, using two levels of air flow: 50 dm³/h and 20 dm³/h. This made it possible to assess the impact of aeration intensity on the efficiency of ammonia removal. Ammonia emissions in composters 1 and 2 were comparable. In composter 1, they amounted to 866 ppm (Figure 3) for 60 min of analysis. In biofilter 1 (Figure 4), aerated with an air stream of 50 dm³/h, a reduction in ammonia concentration from 886 ppm to ppm to 95 ppm was found. In the case of a lower aeration intensity in the biofilter (Figure 5) of 20 dm³/h, the adsorption of ammonia from 886 ppm was 1 ppm after 60 min, indicating a rapid and effective reduction in ammonia with reduced airflow.

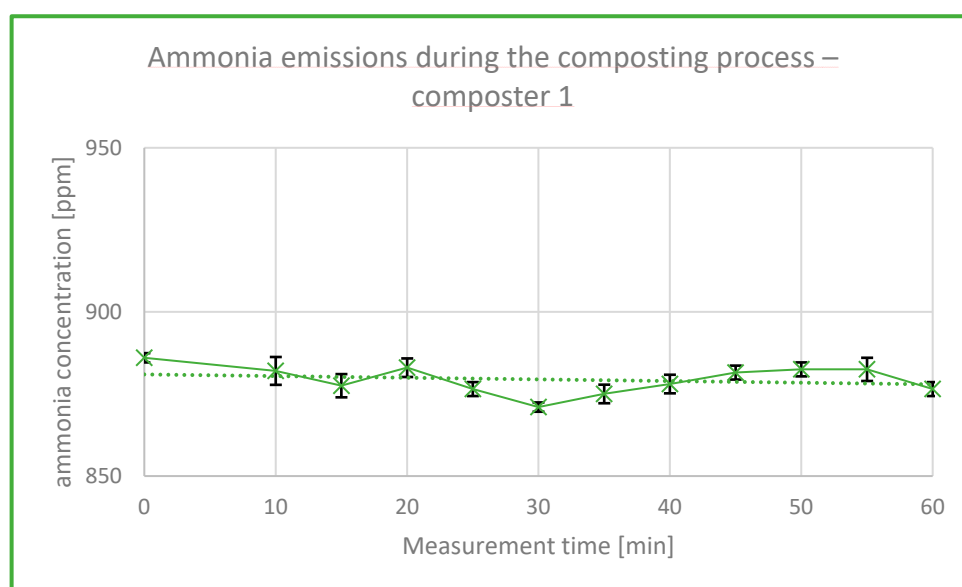


Figure 3. Ammonia emission during the composting process—composter 1. Solid line: measured data; dashed line: trend line

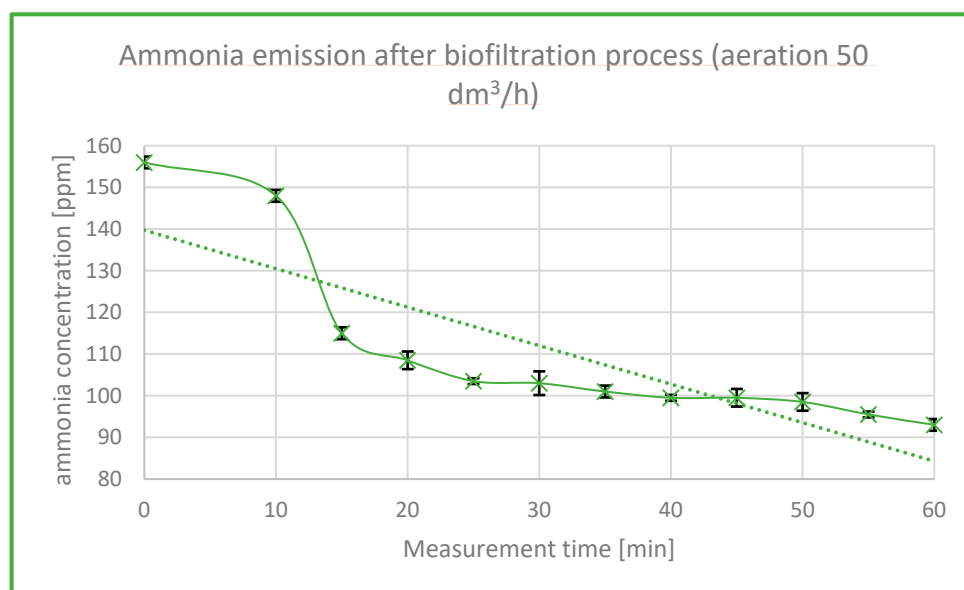


Figure 4. Ammonia emission after the biofiltration process (aeration 50 dm³/h)—biofilter 1. Solid line: measured data; dashed line: trend line

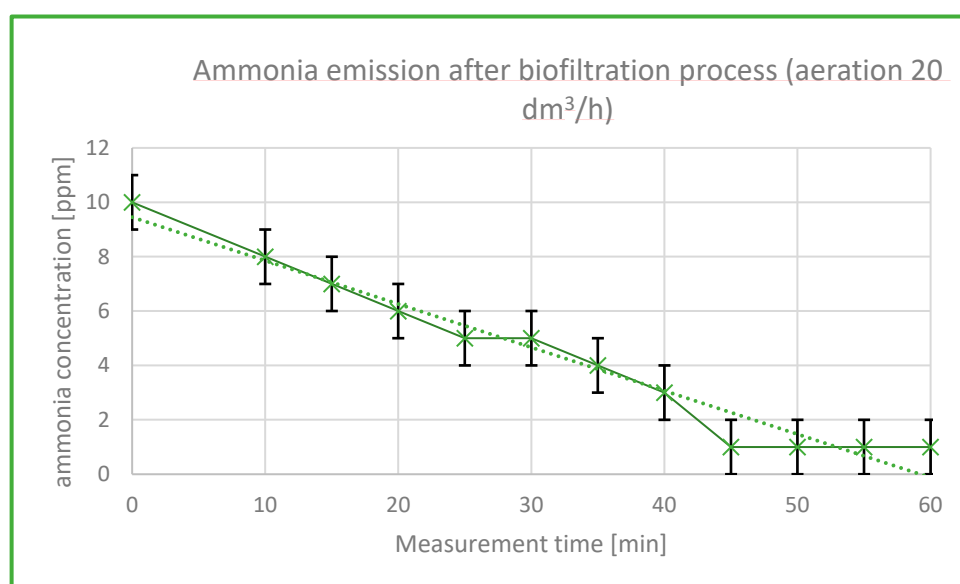


Figure 5. Ammonia emission after biofiltration process (aeration 20 dm³/h)—biofilter 1. Solid line: measured data; dashed line: trend line.

Ammonia emissions for composter 2 were 811 ppm (Figure 6) for 60 min of analysis. For composter 2, in which a biofilter inoculated with nitrifying bacteria culture was used, at an aeration of 50 dm³/h (Figure 7), the concentration of ammonia decreased from 811 ppm to 94 ppm within an hour. On the other hand, at 20 dm³/h aeration (Figure 8), the initial concentration of ammonia was also 811 ppm and dropped to 1 ppm after 60 min, which indicates a very high biofiltration efficiency in low airflow conditions. These results indicate a synergistic effect of a combination of physical absorption by activated carbon and biological biodegradation by nitrifying microorganisms, especially at low airflow, where the contact time of gas with the filter medium is extended. Higher concentrations of ammonia in the biofilter with higher airflow can be explained by the mechanism of gas transport through the filter bed. The higher ammonia value at higher airflow was because the gas was not completely absorbed in the pores of the filter material, while at low flow the ammonia concentration was limited by the possibility of gas retention in the pores of

the medium, which enabled almost complete absorption. The obtained results indicate that both the use of biofilters and the support of the process with the presence of a strain of nitrifying bacteria significantly increase the absorption capacity of ammonia in the waste gas stream from composters. In addition, the intensity of the aeration of the biofilters has a significant impact on the process kinetics: higher air flows lead to gradual absorption, while lower flows allow for an almost immediate reduction in ammonia to very low concentrations.

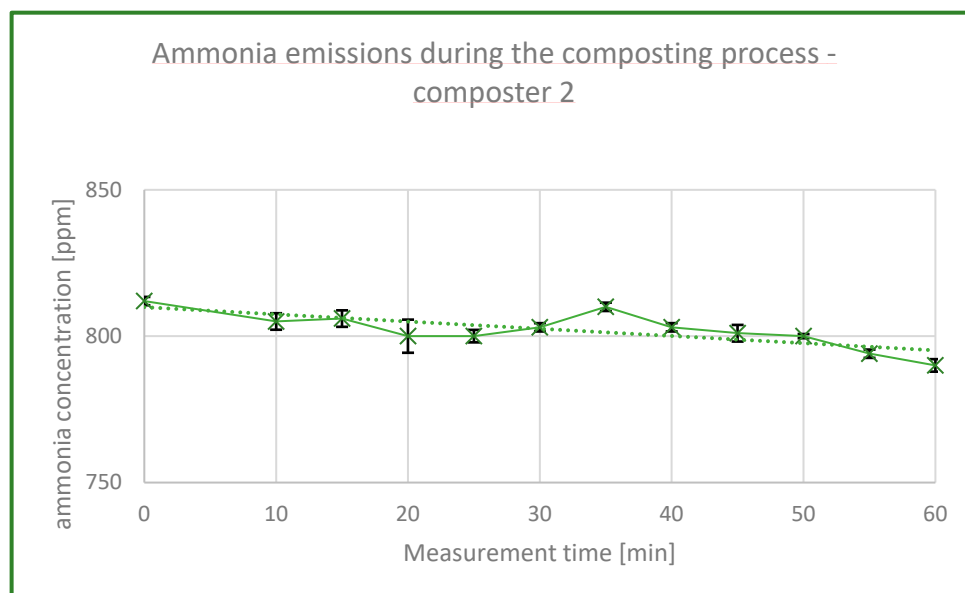


Figure 6. Ammonia emission during the composting process—composter 2. Solid line: measured data; dashed line: trend line.

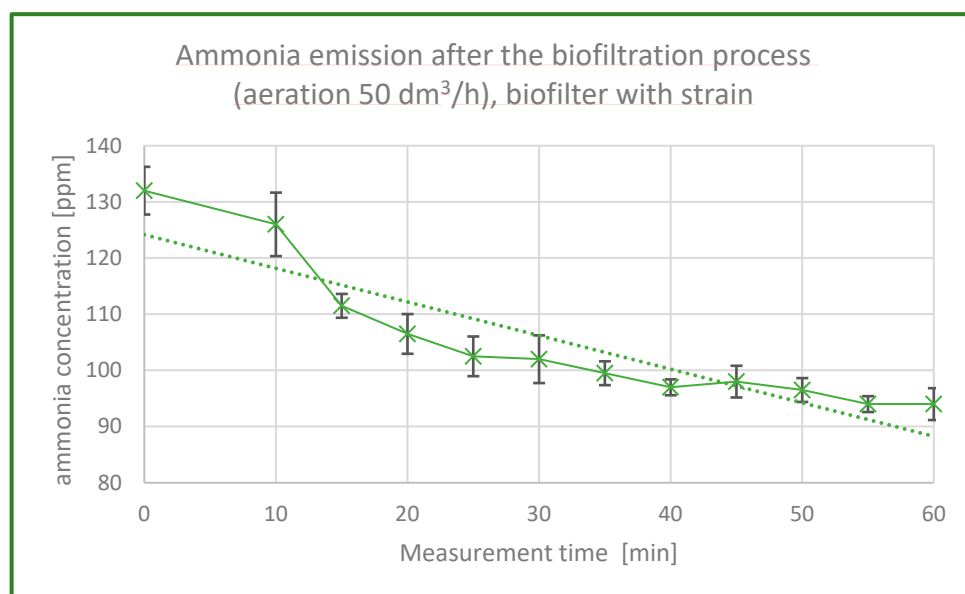


Figure 7. Ammonia emission after biofiltration process (aeration 50 dm³/h), biofilter 2 with strain. Solid line: measured data; dashed line: trend line.

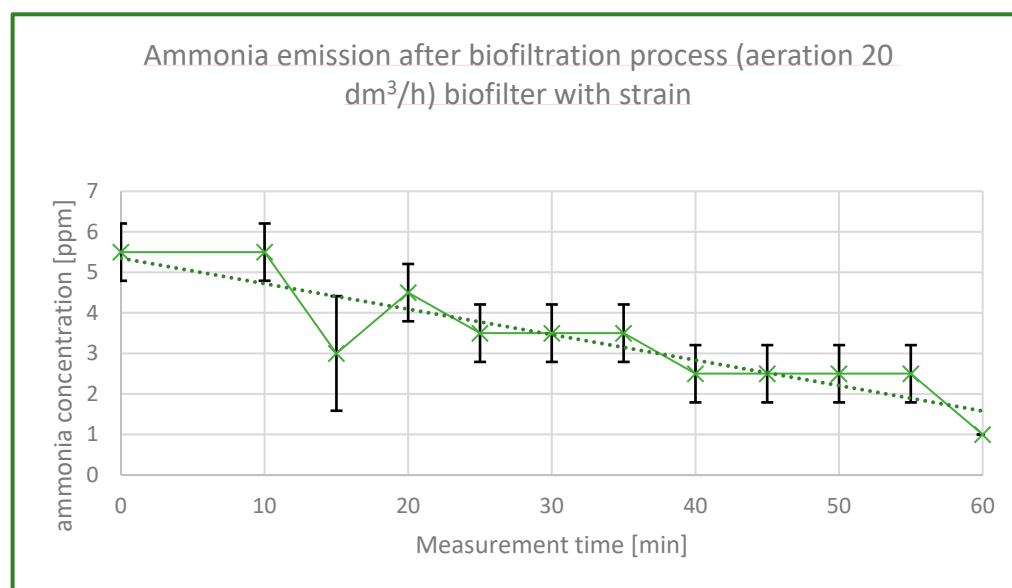


Figure 8. Ammonia emission after the biofiltration process (aeration 20 dm³/h) biofilter 2 with strain. Solid line: measured data; dashed line: trend line.

Figures 3–8 show the ammonia emission during the composting process of chicken manure and the application of biofiltration at different factors, respectively, which allows us to assess the efficiency and effectiveness of the proposed test solution.

5. Discussion

In the study by Zhao et al., the authors showed that the process of composting chicken manure in industrial conditions is associated with very high concentrations of ammonia in the air discharged from the facility. The authors recorded average NH₃ concentrations of 123 ppm in the spring and as high as 167 ppm in the summer, with the momentary values being even higher [19]. Such high concentrations of ammonia confirm that composting chicken manure is an important source of this gas emissions, especially in the phase of intensive mineralization of organic nitrogen. In Soto-Herranz's [20] study on closed-loop composting of chicken manure using gas-permeable membranes, the concentration of ammonia in the process gas increased rapidly in the initial composting stage, reaching maximum values of 200–300 ppm, which was presented in the form of time waveforms of NH₃ concentration. These results confirm that even under controlled conditions, ammonia emissions can reach high levels.

In this study, when analysing the concentration of ammonia from the composting process of chicken manure, concentrations of this gas reaching more than 800 ppm were recorded, before biofiltration was applied. The results confirm that composting chicken manure can lead to extremely high concentrations of ammonia, posing a significant risk both in terms of exposure to public health and environmental impact. In this context, the use of biofiltration in this study should be considered particularly justified. The fact that the biofiltration system has been tested at input concentrations of 800 ppm NH₃ proves its suitability under real-world conditions characterized by high variability and high pollutant load.

The study by Vela Aparicio et al. [21] identifies a significant effect of biofilter inoculation on the efficiency of ammonia removal from waste gases: the biofilter enriched with a culture of nitrifying and sulphur-oxidizing bacteria showed high efficiency of NH₃ removal in the range of ~85–100%, even under variable conditions and very high gas loads. In the non-inoculated biofilter, the ammonia removal efficiency was noticeably lower (approx. 75–100%) under similar operating conditions, indicating a beneficial effect of

inoculation in contexts with variable gas concentrations. The efficiency of NH_3 removal was expressed in % ammonia reduction, which is a solid comparative basis for the efficiency of biofiltration in industrial conditions and allows us to refer to the results of our own studies; here, reductions in ammonia concentrations from over 811 ppm to 1 ppm at 20 dm³/h aeration (approx. 99% reduction) and from 811 ppm to 94 ppm at 50 dm³/h aeration (approx. 89% reduction) were observed.

In this study, coconut-activated carbon was used as the biofilter filling medium. The use of biofilters filled with coconut-activated carbon enabled a very effective reduction in ammonia emissions. At a flow rate of 50 dm³/h, the concentration decreased from 886 ppm to 92 ppm, which corresponds to a reduction of ~89.6%; meanwhile, at a flow rate of 20 dm³/h, the concentration decreased from 886 ppm to 1 ppm, achieving a reduction of ~99.9% resulting from the extended contact time of ammonia with the bed (biofilter 1). In the biofilter enriched with a strain of nitrifying bacteria (biofilter 2), similar results were obtained: at a flow rate of 50 dm³/h, the concentration dropped from 811 ppm to 94 ppm, which is a reduction of ~88.4%; meanwhile, at 20 dm³/h, the almost complete removal of ammonia was also achieved, from 811 ppm to 1 ppm ~99.9%. The results confirm that both bed type and airflow intensity play a key role in biofiltration efficiency, and longer contact time promotes maximum ammonia reduction. In the research conducted by la Pagans et al. [22], the use of mature compost as a biofilter medium for the removal of ammonia from waste gases generated during the composting process was evaluated. The authors found that biofiltration achieved an overall ammonia removal efficiency of 95.9% over a wide range of loads from 846 to 67,100 mg NH_3 m⁻³ biofilter, which corresponds to a high efficiency in the elimination of NH_3 from waste gases. In the literature on ammonia biofiltration, it is clearly emphasized that the selection and properties of the filling are crucial for the effective elimination of NH_3 from waste gases. In long-term studies in which the biofilter was filled with compost with the addition of activated carbon, ammonia removal of >95% was achieved at inlet concentrations of 20–500 ppm, which confirms the high efficiency of a biological filtration system based on a properly selected biofiltration medium [23]. Research by Kim et al. [24] on the use of activated carbon and zeolite showed that such a filling can achieve ammonia removal efficiency of more than 90% at NH_3 input concentrations below 150 ppm and gas contact time above 23 s.

Studies on gas biofilter media have shown that physical properties of the media, such as porosity, particle size, moisture content, and airflow resistance, significantly impact biofilter performance and the removal efficiency of odorous gases, including ammonia. Maia et al. provided a detailed description of methods for characterizing these properties in compost biofilters, demonstrating the correlation between the physical properties of the media and key operational parameters of gas biofiltration. Materials with higher porosity and specific surface area provide more sites for microorganisms to adhere, which supports biofilm development and increases its metabolic activity. Adequate media moisture and optimal airflow resistance also help maintain stable conditions for microorganisms, enabling more effective ammonia degradation. These results confirm that the physical properties of the media are a key factor determining the synergy between adsorption and biodegradation in gas biofilters [25].

The results obtained in this study emphasize that the reduction in ammonia and odorous compounds is not merely a biological process but the result of a complex synergy between the physical properties of the filler material and microbial activity. As suggested by recent findings on lignocellulosic biocarriers [26], the physical architecture of the carrier, particularly the roughness and porosity of its surface, is a key factor determining the system's performance. In the case of composting chicken manure, the organic medium used in the biofilter acted as a functional interface. High porosity facilitated the initial physical adsorption of NH_3 molecules, while the irregular, rough carrier surface ensured

the safe development of a stable biofilm. This interaction constitutes a synergistic effect: the lignocellulosic structure captures odorous gases through adsorption, effectively extending the contact time between contaminants and microorganisms. The immobilized biomass then biologically degrades these captured compounds. This mechanism is consistent with the findings of [26], who observed that material properties directly determine biofilm stability and metabolic efficiency. Therefore, optimizing the physical parameters of the biofilter bed, such as particle size and moisture content, is essential in maximizing the efficiency of both adsorption and the subsequent biodegradation in the process of mitigating odours associated with poultry production [26]. This study not only expands theoretical knowledge on mass transfer in organic media but also offers valuable practical insights. It can aid in the design of gas purification systems by better tailoring filter media parameters, such as coconut-activated carbon, to more effectively control ammonia emissions generated during composting.

Aerobic composting of organic wastes, including chicken manure, is known to release significant amounts of ammonia, contributing to environmental pollution and odour nuisance. In a study by [27], ammonia emissions were analysed during the composting of organic waste, including manure and straw. They found that a significant amount of ammonia was released during the composting process, contributing to environmental pollution and odour nuisance. To reduce emissions, the authors used additives such as biochar and fulvic acid, which effectively reduced ammonia volatilization. These results provide important context for our study, demonstrating that ammonia emissions are a significant problem in composting and highlighting the potential for reduction strategies, like our experiment with chicken manure composting and the use of a biofilter to reduce ammonia emissions [27]. Similarly, [28] reviewed microbial nitrogen conservation technologies and demonstrated that the use of specific microbial consortia can regulate microbial community structure and enzyme activity, increase nitrogen retention and reduce gaseous nitrogen losses. Our study confirms that composting naturally generates significant amounts of ammonia, and that the use of biofiltration with coconut-activated carbon significantly reduced emissions, confirming the potential of this strategy to reduce ammonia emissions and mitigate its negative environmental impacts. Further studies using biofilters enriched with specific strains of nitrifying microorganisms are planned to confirm and extend the effectiveness observed in this preliminary study [28].

6. Conclusions

The use of biofiltration in composting or waste gas treatment processes significantly contributes to the reduction in ammonia emissions, while allowing the control of ammonia (NH_3) concentrations.

1. Ammonia emissions in composters 1 and 2 were 886 ppm and 811 ppm, respectively, constituting the gas output level during the composting process and the benchmark for assessing the effectiveness of the biofilters.
2. The higher airflow ($50 \text{ dm}^3/\text{h}$) resulted in a shorter contact time between the gas and the bed ($\text{EBCT} = 10.8 \text{ min}$), which limited the total absorption of ammonia. The lower flow rate ($20 \text{ dm}^3/\text{h}$) extended the EBCT to 27 min and allowed the ammonia to be almost completely retained in the pores of the filter medium.
3. With a higher airflow, some of the ammonia did not have time to fully adsorb in the pores of the medium, so the concentrations were higher. At a lower flow, the gas was retained in the pores of the material, which enabled almost complete absorption.
4. Process analysis indicates that the full effectiveness of biofilters requires time for microorganisms to break down ammonia after saturating the pores of the filter material.
5. The effectiveness of ammonia absorption depends on both the airflow rate, the time of contact of the gas with the bed (EBCT), and the presence of the bacterial strain.

Adjusting the airflow and properly inoculating the medium increases the efficiency of biofiltration.

6. In the perspective of further research, an assessment of the impact of selected strains of microorganisms inhabiting the biofiltration bed on its efficiency is considered, in terms of reducing odour emissions.

The analysis of absorption kinetics indicates that the biofiltration process largely depends on the degree of saturation of the pores of the filter material—after achieving high absorption saturation, further reduction in ammonia concentration is possible, only thanks to the activity of microorganisms capable of biodegradation. Therefore, a full evaluation of the effectiveness of biofilters requires a longer follow-up time to determine the extent to which microorganisms degrade ammonia after saturation of the pores of the filter material, which highlights the importance of both the physicochemical properties of the medium and the biological activity of the microorganisms participating in the biofiltration process.

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