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Original Research Article

Treatment of Ammonia from Animal Barns by Using Biofilter

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ABSTRACT

As a result of intensive animal production, decomposition of manure due to various microorganism activities, and metabolic activities of the animal, many gases, especially ammonia, are released. These gases are thrown into the atmosphere cause many environmental problems. This study, it was aimed to treat ammonia originating from animal barns by biofilter. In the study, tree bark, compost, and sawdust were used as biofilter materials. These biological materials were mixed in specific proportions, brought to 80% moisture content, and placed into the biofilter. Ammonia was introduced into the biofilter filled with biological material. Ammonia concentrations in the air leaving the biofilter were measured at nine points by placing multiple gas meters on the front of the biofilter. Moisture content, dry matter content, pH, salinity, and temperature values were determined by taking samples from the biofilter material before and after treatment. According to the study results, the highest treatment efficiency was 98.4% at the first measurement point and the lowest treatment efficiency with 89.4% at the sixth point. An average of 94% treatment efficiency was achieved at all measurement points. As a result of the analyzes, it was observed that the pH and temperature values of the biofilter material did not change significantly before and after the treatment. However, the salinity values changed significantly. In the light of ammonia treatment rates, it can be said that the biofilter developed in this study is useful for animal barns. But biofilter is open to improvement using new biofilter materials.

Keywords: Air quality, emission, mitigation, gas pollutants

INTRODUCTION

Today, emissions that occur due to the production activities of many sectors create an odor problem in the production facilities and on the people residing in the areas close to the facilities. Major odor-causing activities include vegetable oil production, rendering, livestock, paint production, oil processing, wastewater treatment, beer, yeast, alcohol, frozen food production. In order to prevent the adverse effects on the environment and human health and protect the health of workers, it is necessary to control the emissions that cause odor at the source (Sahin and Bayram, 2017).

The first step in combating the odor problem is to identify the odor source. When determining the odor source, it is recommended to examine the processes in which odor-forming compounds are released (Sahin and Bayram, 2017). Some purification techniques are used to purify odorous gases and liquids from odor-forming compounds. These techniques include adsorption, absorption, widely and effectively used biofilters, aqueous filtration, incineration, thermal (thermal) oxidation, and various pH regulation systems. When the efficiencies of treatment techniques in odor removal are compared, 60-90% in condensation, 80-95% in adsorption, 75-95% in biofiltration, 70-80% in bio washing, 70-90% in dropping filter, 80-95% in the thermal oxidation process and 80% in the catalytic oxidation process. It was determined that odor removal efficiency of 95% was achieved (Topal and Topal, 2013).

In odor treatment, biofilters in waste gas streams with high waste gas flow and low pollutant concentration draw attention as it is the cheapest and most effective treatment method. This method is widely used in the compost industry. Biofilters are classified according to their configuration (open or closed) and airflow direction (up-down). While both the inlet and outlet gas flows can be controlled in the biofilter in the closed system, the purified gas in the open system is released directly to the atmosphere from the biofilter surface (Uyar, 2007). Biological reduction of odorous compounds occurs by using wet organic substances in biofilters (Öztürk, 2017). In biofiltration, the biofilm layer can be composed of solid materials such as peat, compost, soil, leaves, or wood. Materials such as granular activated carbon, diatomaceous earth, perlite, or vermiculite strengthen the layers (Dalkılıç and Dursun, 2018).

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Manure formed in animal production facilities becomes an essential source of odor when not adequately managed. Establishing a good waste management system, especially manure management, and extending the use of biofilters are essential in combating odor by arranging the standards for the odor problem in the facilities and maintaining and maintaining sufficient distance between the enterprises and the settlements (Özkan et al., 2015). Among the harmful gases arising from manure in animals, production is ammonia, carbon dioxide, hydrogen sulfide, and nitrogen (Özocak, 2019). Ammonia, which is included in these gases, is a colorless and odorous gas and can cause serious health problems in the environment where it is spread (Dalkılıç and Dursun, 2018). While the typical ammonia concentration level in the ambient air for animal production is determined as 5-70 ppm, it is stated that the ammonia concentration in the environment can rise to 200 ppm levels in poultry farming (Avşar et al., 2018). It is stated that biofilters have high removal efficiency in ammonia treatment, and the ammonia removal efficiency can be increased by choosing the right biofilm thickness in biofilters (Dalkılıç and Dursun, 2018).

Desired properties in biofilters;

- Polluted shelter air remains in the biofilter environment for at least 5 seconds

-The depth of the biofilter must be at least 25.4 cm

-Proper humidity control for the biofilter environment

-It is stated as the inhibition of weed growth on the surface of the biofilter (Nicolai and Schmidt 2005; Kılıç, 2011).

In the literature, it is seen that many studies have been carried out on odor treatment using biofilters in animal production.

Shah et al. (2003) investigated ammonia removal from chicken farms by increasing the carbon dioxide capture efficiency by adding calcium oxide to biofilters with compost material. In the first 37-day period of the 54-day study, direct indoor air was purified; In the second period of 17 days, ammonia emissions (average 26 ppm) were purified using urea as a representative of the cleaned house environment. In the study, in which 97% ammonia removal efficiency was achieved with the biofilter system, it was determined that a 30 m^3 filter would be sufficient for a farm with 27000 chickens.

Uyar (2007) investigated the treatment of ammonia, an odorous gas formed in the indoor environment of animal production facilities, with biofilters, which is one of the biological control methods, and the air/ammonia gas mixture to be produced at the ammonia concentrations encountered in indoor ventilation in livestock facilities were tested in a biofilter experiment setup with compost + sawdust mixture material. It is aimed to be treated under variable loading conditions. It was determined that 97-98% treatment efficiency was achieved within ten days.

Dumont et al. (2014) used a pilot-scale biofilter filled with wood chips to remove ammonia emissions from pig farms. With the biofilter operated for 74 days, removal efficiencies in the range of 90%-100% were achieved at 15 mg/m^3 NH_3 inlet concentration and 6-15 minutes Empty Bed Contact Time values.

Avşar et al. (2018) investigated the purification of odorous waste gases originating from animal farms containing ammonia with biofilters. A mixture of compost and wood shavings produced from domestic solid waste was used as filter filler. Despite different loading rates, aerobic-biological oxidation efficiency of ammonia in biofilters and the factors affecting this efficiency were investigated. During the 130 days, including the acclimation process, eight different values were loaded between 1.32-27 g NH_3/m^3 .hour, and the average ammonia removal efficiency was calculated as 97.2±1.8%.

The main purpose of this study is to determine treatment level of ammonia using biofilter in animal barns. A biofilter was created by mixing different biological materials at different rates.

MATERIALS AND METHODS

Biofilter Design

The biofilter system to be used to treat NH_3 gas in the study is based on the microbial degradation of the waste gases in the contaminated shelter air in a filling material that acts as a filter. In order to purify NH_3 with this method, a 1 m high, 1 m deep, and 1 m wide biofilter case was designed.

The designed biofilter casing is given in Figure 1. Since the biofilter in which the biofilter filling material will be placed is a natural material, it is made of unique wood so that it will not be affected by moisture. It is designed with wheels from the bottom to be easy to carry and easy to operate. A hole with a diameter of about 10 cm was drilled to allow gas to enter the back of the biofilter. The front side is covered with poultry wire with a two – two and a half cm mesh to provide the outlet for the purified air. For the biofilter filling material to be quickly filled and discharged into the biofilter, the front part is hinged, and the wired part is designed as a retractable door. In addition, a 50x50 cm top cover is left on the top of the biofilter to ensure that the filled material is well compacted (Figure 1).

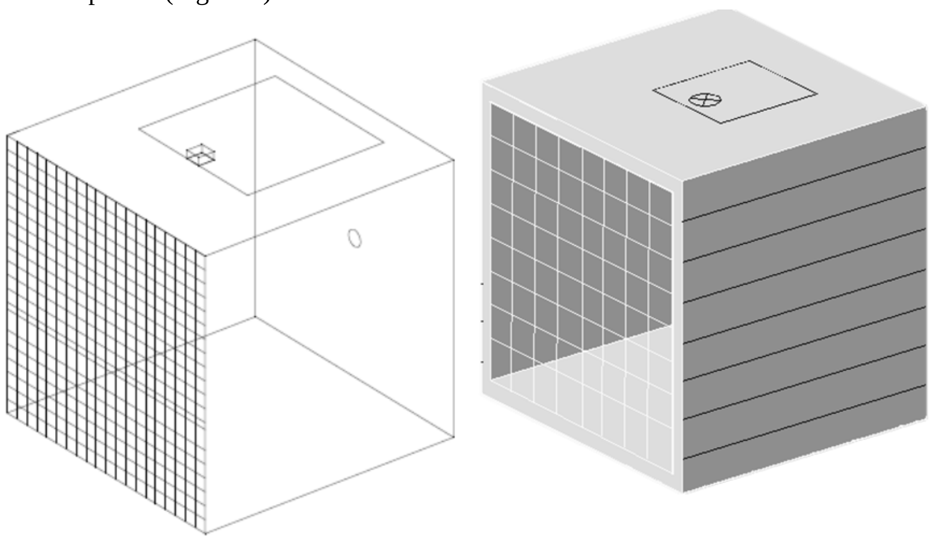


Figure 1. The biofilter designed in the study.

Biofilter Materials

The material used in a biofilter is essential for the biofilter to be effective and efficient. A solid, dry material is used to provide an effective filter system. Because the solid material supports the microorganism and prepares the necessary environment for the microorganisms to sufficiently reach the pollutants in the air stream, in order to provide suitable treatment values, when choosing materials as biofilter material, attention should be paid to the moisture-holding capacity, porosity rate, sorption rate, pH, and cost of the materials.

In the study, cellulose-based materials were used in the biofilter, as it increases porosity and reduces pressure losses due to compression. In addition, cellulose-based materials balance the sudden rise and fall of humidity. In addition to all these features, it is readily available, and therefore its costs are low. In the study, locally readily available bark, compost and sawdust, dry matter ratio, porosity, and the material that provides optimum conditions by being economically analyzed were used as biofilter material.

In order for the biofilter filling material to purify, the surface areas must be expanded by increasing their moisture content. The optimum percentage of moisture in the biofilter; The filling material used may vary depending on factors such as the surface area of the filter media, porosity. Drippers are placed on the biofilter to keep the moisture content of the biofilter material between 60-70%. The amount of water to be given will vary according to the dry matter content of the biofilter material to be used. Before determining the amount of water to be given, the dry matter content, pH, and temperature of the biofilter material were measured in the study.

In the study, the biofilter material's dry matter and moisture content was measured with a moisture analyzer (Shimadzu Moc63U), pH was measured with a pH meter (WTW), and the temperature was measured with a thermometer.

Adding Ammonia to Biofilter

In the study, NH_3 gas was given directly to the biofilter to simulate the polluted shelter air. The literature shows that 1-1,5% ammonia gas mixtures are used in nitrogen gas in similar biofilter studies. For this purpose, NH_3 gas with a purity of 99.95% and a weight of 26 kg was purchased in a pressurized tube from a private company that sells industrial and medical gas with similar content in the gas market. The gas taken from the tube through the regulator was supplied to the biofilter with a pressure of 1 bar with a specially made flexible pipe. The pressure tube, regulator, and flex pipe for the NH_3 gas injected into the biofilter are given in Figure 2.

Figure 2. NH_3, regulator and pipe.

Calculation of Biofilter Efficiency

Biofilter efficiency was calculated by dividing the difference between the NH_3 concentration entering the biofilter and the NH_3 concentration in the air leaving the measurement result to the inlet concentration. Multiple gas meters (MultiRAE IR Lite RAE Systems, San Jose, CA, USA) were used to determine the NH_3 concentration in the exhaust air.

Treatment Efficiency (%) = $\frac{C_{inlet} - C_{exhaust}}{C_{inlet}}$

C inlet = Gas concentration at the system inlet
C outlet = Gas concentration at the system exhaust

RESULTS and DISCUSSION

Properties of Biofilter Material

The filling material that will carry out NH_3 treatment into the biofilter designed in the study consists of a high dry matter ratio and absorption capacity. Accordingly, the measurement results of the pH, dry matter content, moisture content, salinity value, and temperature of the materials used in the study are given in Table 1.

Table 1. Some properties of biofilter material.

Material	Humidity (%)	Content of dry matter (%)	pH	EC (µms)	Temperature (°C)
Bark	14,95	85,05	4,9	330	26
Compost	16,44	83,56	8,6	399	26
Shavings	16,37	83,63	5,2	313	26,7

A total of 235 kg of biofilter material was formed by mixing 125 kg of compost, 45 kg of sawdust, and 65 kg of bark, in line with the ratios determined in the light of the studies carried out in the literature.

Nicolai and Janni (2001) reported in their study that the biofilter material reached the highest treatment level at 80% moisture content. For this reason, the biofilter material used in the study was wetted with water to increase the moisture content of the mixture to 80%. The samples taken from the mixture at intervals were analyzed instantly in the moisture analyzer, and the moisture content of the mixture was checked. The wetting process was completed when the moisture content of the mixture reached 80%.

In the study, the biofilter material, which was created using different materials, was taken wet after wetting, and samples were taken in dry form from the pile that was not placed in the biofilter, which was set aside, and analyzed for various properties in the laboratory. Analysis results are given in Table 2.

Table 2. Some properties of wet biofilter material.

Material	Humidity (%)	Content of dry matter (%)	pH	EC (µms)	Temperature (°C)
Dry Biofilter Material	16,26	83,74	8,04	3999	26,1
Wet Biofilter Material	80,58	19,42	7,5	3160	27,7

In order to prevent possible gas entrapment in the biofilter, the biofilter was not fully filled with material and 15% of the total volume was left as air margin at the top (Figure 7).

Figure 7. Biofilter with biofilter material**.**

After filling, the temperature of the filling material in the biofilter was measured again with a stud thermometer (50 cm long). The material temperature is essential for the microorganism activities in the biofilter filling material. The measurement results are given in Figure 8. The average temperature of the biofilter filling material was measured to be 23°C. As it can be seen from Figure 8, it is seen that the temperature is uniform throughout the biofilter material in the biofilter.

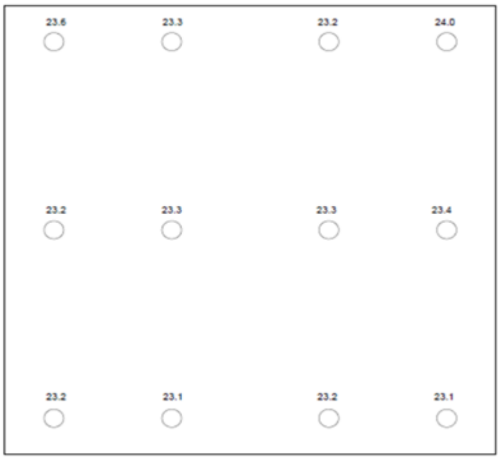


Figure 8. Temperature of biofilter material in the biofilter.

Treatment Efficiency of Biofilter

In the study, in order to determine the efficiency of the biofilter, the NH_3 gas concentration was measured simultaneously with a multi-gas meter at the height of approximately 50 cm in front of the biofilter, at the top of the biofilter, and at the point of supplying the gas from the pressurized gas tube to the biofilter.

Nine different measurement points where the concentration of the gas leaving the biofilter is measured are given in Figure 9. After filling the biofilter, the regulator of the pressurized gas cylinder was adjusted to 1 bar pressure, and the valve of the cylinder was opened for gas flow to the system.

Figure 9. Measuring NH_3 concentrations at the biofilter exhaust.

While measuring points 1-8 gives the biofilter outlet's concentration values, the 9th measuring point is placed at the biofilter inlet and shows the gas leakage at the inlet point (Figure 10). By measuring the outlet concentrations at different points, more reliable measurement of the biofilter efficiency has been achieved. Because although the biofilter material is mixed well, a complete homogenization cannot be achieved. Measurements were made at different points, and this situation was tried to be eliminated to some extent.

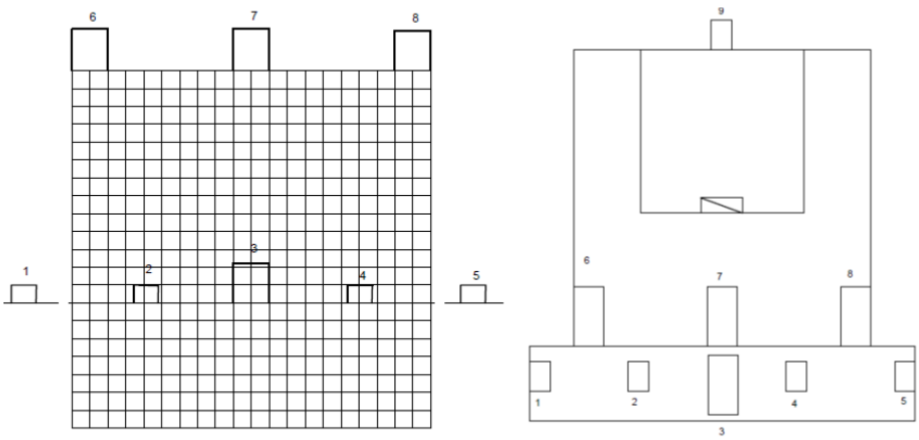


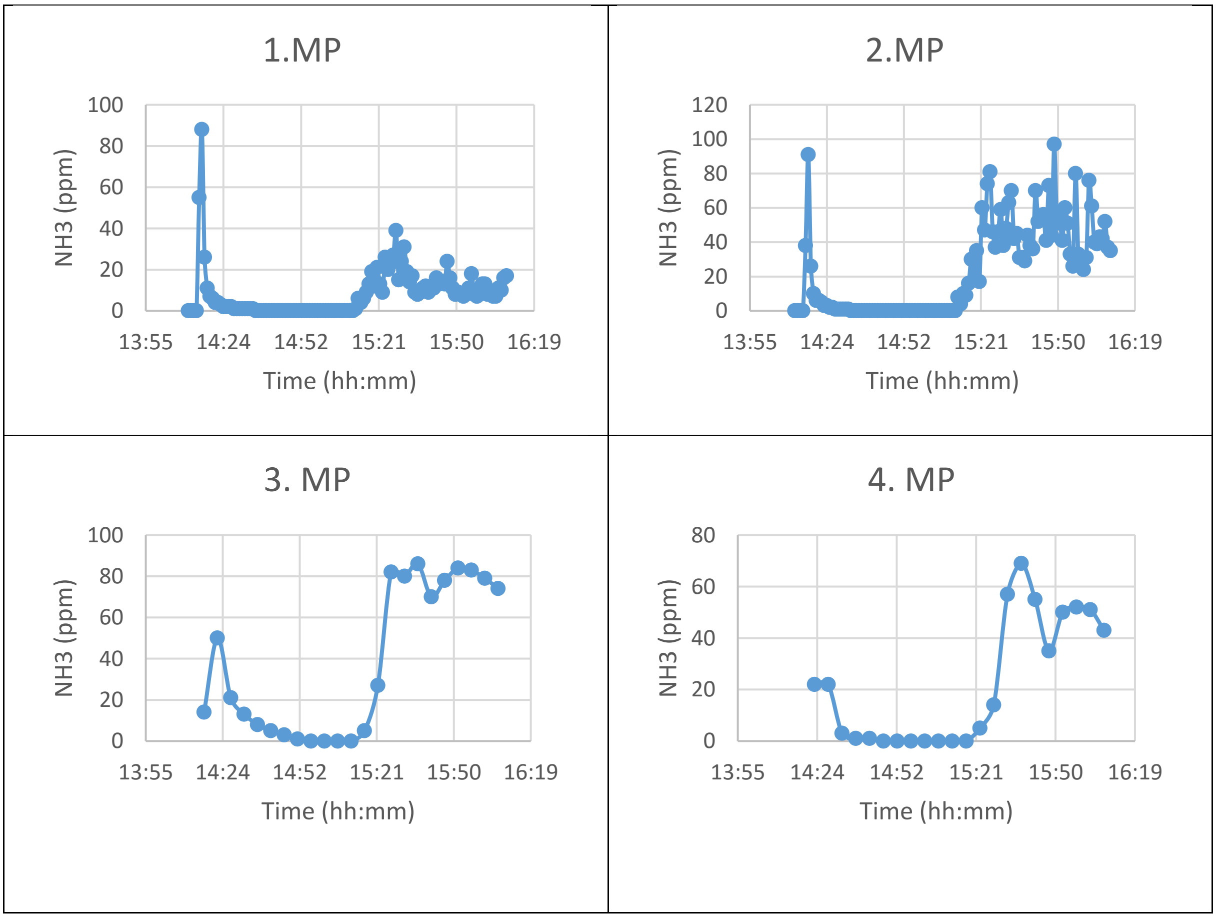
Figure 10. Biofilter exhaust concentration measuring points.

As a result of the study, the NH_3 gas concentrations measured at the biofilter outlet are given in Table 3. Data could not be obtained at the 5th point, which is one of the points where biofilter outlet concentrations are measured. Accordingly, the average gas concentration calculated by averaging the values obtained at all points is 31 ppm. 500 ppm NH_3 gas is given to the biofilter. Accordingly, the average removal efficiency was determined as 94%.

Table 3. NH_3 gas concentrations measured at the biofilter exhaust.

Measurement Point (MP)	NH_3 Concentrations (ppm)				Treatment Efficiency (%)
	Min	**Avg**	**Max**	**SD**	
1	0	8	88	12	98.4
2	0	23	97	26	95.4
3	0	38	86	36	92.4
4	0	23	69	24	95.4
5	0	0	0	0	0
6	0	52	100	47	89.6
7	0	47	100	48	90.6
8	0	48	100	46	90.4
9	0	10	99	3	
Average	**0**	**31**	**100**	**17**	**94**

The variation of NH_3 concentrations measured at the measurement points over time is given in Figure 11. In the study, it was observed that the NH_3 gas was significantly treated in the first hour of the measurement, and the biofilter outlet concentrations increased due to the contamination of the biofilter material with time and thus the decrease in the absorption capacity (Figure 11).



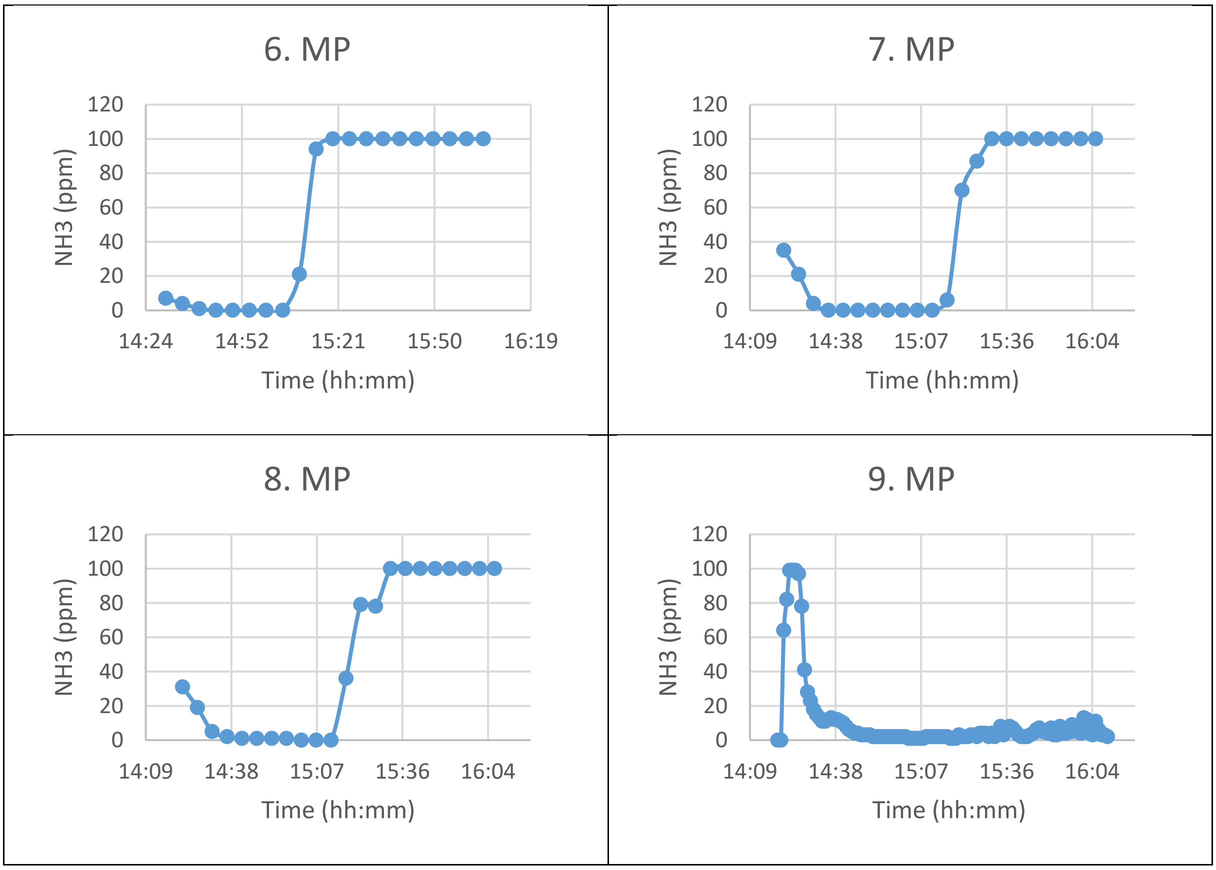


Figure 11. Time variation of the measured NH_3 concentration at the measurement points.

CONCLUSIONS

In this study, biofilter material was created to mix different natural materials at different ratio. The moisture content of biofilter material was kept at 80% to increase the surface area of the material and thus the treatment efficiency. In the light of the measurement values obtained as a result of the study, it can be said that NH_3 was treated significantly (90%) with the designed biofilter.

With this study, a biofilter design that can be used mainly in the treatment of NH_3 has been realized.the ammonia treatment rates are acceptable for animal barns. Therefore, biofilter designed in this study open to improvement. Thus, it has been revealed that studies can be carried out in this field in our country, and a treatment system can be designed using domestic products. Different biofilters can be tested in future studies using other materials at different mixing ratios and moisture contents.

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