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Agnieszka GRZELKA[1*], Urszula MILLER[1]
and Izabela SÓWKA[1]

THE ROLE OF BIOLOGICAL METHODS IN THE MUNICIPAL MANAGEMENT ODOR NUISANCE REDUCTION STRATEGY

ROLA METOD BIOLOGICZNYCH W STRATEGII REDUKCJI UCIĄŻLIWOŚCI ZAPACHOWEJ OBIEKTÓW GOSPODARKI KOMUNALNEJ

Abstract: An important potential source of odor emissions is municipal management objects. These include sewage systems, waste water treatment plants, waste landfills and waste processing plants. Both, waste management facilities and waste management facilities are designed to reduce the negative impact of human activities on the environment. The common feature of these objects is the similarity of the chemical composition of emitted gases and their hedonic quality, eventually, the nature of odor emissions dependent on the type of object and technological solutions. Sources differ in the amount of emissions and intensity of odors that can affect the amount of odor nuisance. Problems in reducing odor impact of municipal management objects can be mainly due to the multiplicity and variety of sources of odor emissions located in their area, as well as from the fact that they are often area sources and they might be difficult to encapsulate. The biological methods are increasingly used for the purification of waste gases in relation to other odor reduction methods both, for ecological reasons and for economic competitiveness. Biological purification of gases is carried out using biofilters, bioscrubbers, biotrickling filters or membrane bioreactors. The differences between these methods are a consequence of used solutions and result in the division of operating costs. The efficiency of the removal of hydrogen sulphide by biofiltration obtained by various authors is at least 99 % with a wide range of inlet pollution concentration, while for ammonia it is slightly lower (from 96 to 98 %). The efficiency of the biofiltration of VOCs depends substantially on their nature and properties (water solubility, vapor pressure), and varies from 40 to 100 %. The obtained deodorization efficiency by biofiltration is above 90 %, and can even reach values over 99 %. In the paper examples of the application of biological methods in municipal management objects together with the assessment of their efficiency in reducing the emission of odor and selected odorant pollutants will be presented and discussed.

Keywords: deodorization, odor nuisance, biofilters, bioscrubbers, municipal management

[1] Unit of Engineering and Protection of Atmosphere, Faculty of Environmental Engineering, Wroclaw University of Science and Technology, pl. Grunwaldzki 9, 50-377 Wrocław, Poland, phone: +48 71 320 25 60

* Corresponding author: agnieszka.grzelka@pwr.edu.pl

Introduction

Municipal management, including wastewater treatment plants (WWTPs), composting plants and waste management objects emit odorous gases which are considered to be a nuisance by people in their vicinity [1–5]. The odor impact of this type of objects is varied and the amount of odorant emissions depends on many factors [6]. In sediment, sewage, waste and waste gases mixtures of volatile organic compounds which cause unpleasant fragrances are produced [7]. The problem is aggravated by the urbanization of suburban areas where such facilities are most often built.

Various methods are used to eliminate the problem of odor nuisance, these are among others: absorption, adsorption, combusting, condensation, encapsulation, masking and biological methods [2, 3, 5, 8–14]. The factors determining the choice of suitable gas purification techniques are the physical and chemical properties of the treated gases, the concentration of emitted pollutants, the type of emission source, and the designed purification efficiency. The variety of these parameters makes it difficult to find one universal deodorization method. Due to the fact that biotechnological processes are usually less energy-intensive and more environmentally friendly than traditional technologies, in the municipal economy, where the problem of odor nuisance is widespread, biological deodorizing methods are often used [9, 13–18]. Figure 1 shows the contribution of the individual operating costs including cost of water, energy, filter media and laboratory costs) of the two most popular biological methods – biofiltration and bioscrubbing [8]. The data show that in these methods the largest part of the cost is spent on filter media: 47 % and 44 % for biofilters and bioscrubbers, respectively. In the case of biofilters, the share of total costs also includes unit costs associated with laboratory costs (29 %) and energy costs (18 %). In turn, in the case of bioscrubbers, there are energy costs (22 %) and water costs (21 %).

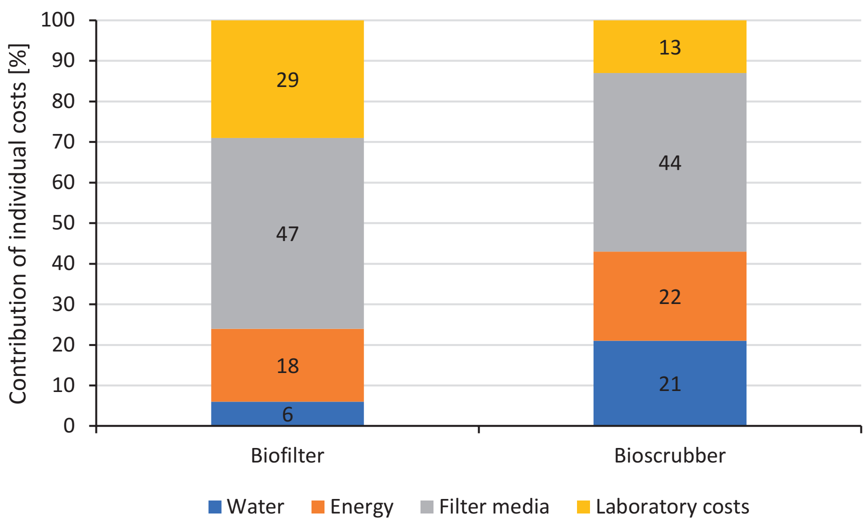

Fig. 1. Contribution of individual costs of biofilters and bioscrubbers [8]

Characterization of biological methods used in deodorization of odorous gases

Biological gas purification is based on naturally occurring biodegradation processes. It uses the ability of some heterotrophic microorganisms to decompose organic matter as well as autotrophs to oxidize inorganic compounds [9, 16, 19]. Therefore, the biodegradability of biodegradable contaminants is a prerequisite for the use of biological treatment methods. The purification mechanism is based on two main processes: sorption and biodegradation. The purification process is carried out using biofilters, bioscrubbers, biotrickling filters or membrane bioreactors [9, 13, 18–23].

Biofilters

The operation of the biofilter is based on the slow gas blowing through the moist porous fixed bed. Contamination is absorbed into the water, which is moistened to the bed and thus into the biofilm, where the biodegradation of the removed substances occurs. Gases are fed into the bed typically from the bottom of the perforated pipe system. The bed is moisturized counter-current, and with nutrients for microorganisms (including biogenic compounds). Biofiltration is a natural process and, thanks to the self-healing of the filter bed and the possibility of recycling the effluents, practically waste-free. In addition, this technology is relatively simple and allows to achieve high efficiency in removing many contaminants. Disadvantages of the method are mainly due to restrictions on its use. This method is less useful for gases characterized by high concentration of pollutants, consist substances that are hardly biodegradable or toxic for microorganisms and gas flows with a variable: volume flow, chemical composition or concentration of contaminants [9, 18, 24]. In practice, different types of biofilters are used, both in terms of construction and bed type used, or additives and treatments to improve the efficiency of gas purification. Popular biofilters are closed containers made of sheet or concrete. A common solution is also open biofilters, but their capabilities are limited their application in regions characterized by heavy rainfalls. The most common, for open biofilters, are terrestrial installations, but it is also possible to find biofilters deposited at a depth of about 1 m from the ground [25].

Bioscrubbers

Bioscrubber is a system consisting of an absorption column and an aerated activated sludge chamber. The flow of gas and sorbent through the filled column is usually counter-current, because of higher absorption efficiency, lower associated energy costs and lower pressure drop. However, both, counter- and co-current flow bioscrubbers are used. There are two types of construction – a packed tower and spray tower absorbers. Both of them are most suitable for bioscrubbing, because the elimination efficiencies for less water-soluble pollutants in other types of absorbers are lower [9, 25]. The sorption liquid, depending on the technology, is water [5] or an aqueous suspension of microorganisms [26]. As a result of the contact of the gas with the liquid, the contaminants are absorbed and, together with the sorbent, enter the aerated reactor. The activated sludge therein leads to the biodegradation of the absorbed compounds and the regeneration of the sorbent, which is recycled to the absorber. Mineral nutrients are fed into the bioreactor to provide optimal conditions for the growth of microorganisms. Excessive biomass is removed from the system. The disadvantage of bioscrubbers, in relation to biofilters, is primarily high on biological methods, investment and operating costs, and the need to remove excessive biomass [27].

Biotrickling filters

The main difference between biotrickling biofilters and conventional biofilter is the spraying of the biofilm-coated filter bed with water that is continuous. The central part of the system is an inert fill made of plastic or ceramic, placed on the grid, in the form of packages or piled up fittings. The filling elements are covered with biofilm, where biodegradation of the impurities takes place. Contamination can occur directly into the biofilm or first be absorbed in the spray liquid and then transferred to the biofilm [21]. The bed is continuously sprayed with water or sewage (in the latter case it is not necessary to inoculate the bed with a microflora). Gas purification can take place here as a separate process, or in combination with wastewater treatment. Filtration in this type of device can be performed using co-current or counter-current flow of gas and liquids [8, 29]. Problems that may occur during the operation of the biotrickling filter include excessive overgrowth of the bed with biomass and uneven flow of treated gases. Also, when off-gases characterized by high pollutant concentrations are treated, too high nutrient doses can lead to filter bed clogging by an overgrowth of biomass [9].

Membrane bioreactors

The mechanism of operation of the membrane bioreactors is based on the difference in the concentrations of pollutants between the gas phase and the biofilm and the values of the air-to-water coefficient which influence the penetration of impurities through the membrane [9, 19]. The advantage of this method is the ability to selectively remove impurities from the treated gas. Furthermore, in the bioreactor, water is a constant moisturizing agent of the biofilm and allows easy removal of the absorbed impurities from the system. At the same time, the water present on the opposite side of the biofilm rather than the gas phase does not constitute a barrier to penetration of the poorly soluble pollutant mass. The element that is responsible for transporting the removed compounds is the membrane and the biofilm that covers it. The main disadvantage of this type of installation is much higher costs than traditional purification systems [9, 19]. There are two main types of membrane materials, that are in use – hydrophobic microporous membranes and dense membranes [9, 30]. The microporous membrane Is made with hydrophobic material characterized by a porous structure, what provides higher gas permeability and as a result can be used in gas transfer application. The dense membrane does not have pores and pollutants get dissolved and diffuse through the polymeric material [9].

Examples of application of biological methods in reducing odor emissions from municipal economy management

Municipal facilities related to wastewater treatment and waste management, i.e. sewage treatment plants, composting plants, landfill sites and associated facilities (sewage basins, pumping stations, sediment lagoons) are often characterized by odor nuisance [6, 13–16, 31, 32]. This is due to the accumulation of organic matter, which is subject to numerous biochemical changes, mainly with the involvement of microorganisms whose products are often odorous substances. Microorganisms are not only responsible for the formation of odors but are also often used to combat them in biological processes. The first step used to reduce odor nuisance is the encapsulation of sources and the deodorization of waste gases. Biological methods are the most often used for this purpose (in about 80 % of cases) [31]. In Poland, according to market biological methods are the most often offered by companies dedicated to deodorization (Fig. 2). About 25 % of examined companies offer biological methods. Absorption (16 %), encapsulation of odor sources (14 %) and adsorption methods are also often offered [33].

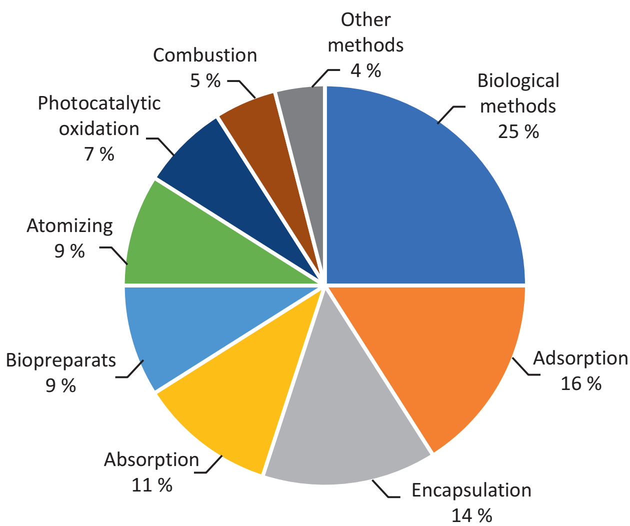

Fig. 2. Participation of biological methods in deodorization methods offered on the Polish market for municipal economy, based on market research [33]

In the case of waste management facilities, fragile primary compounds (found in the raw material supplied) and secondary pollutants (arising from biological and chemical processes) are above all methylamine and ethylamine, hydrogen sulphide, methane, ethane- and butanethiol, carboxylic acids (formic, acetic and propionic) and alcohols (methanol, ethanol, n-butanol) [38]. Hydrogen sulphide and alkyl thiols are the most troublesome. The processes that emit odor to the atmosphere include waste sorting and disposals, mechanical and biological processing of waste and biological treatment of waste, including composting. According to literature data, biofiltration as a method of deodorization of gases emitted from waste composting plants allows for good purification efficiency (over 99 %), even with loads exceeding 8 million ou_E/m^3. However, studies have shown that even a biofiltration efficiency of > 98 % may be insufficient to fully reduce the emitted odor [32]. In such cases, it is necessary to modify the composting parameters to limit the formation of anaerobic conditions. Research has shown that emissions of volatile organic compounds and ammonia are largely dependent on the type of composted waste, which decides about biofiltration effects [30]. Table 1 presents a compilation of literature data on the efficiency of biological methods for the removal of odors and chosen odorants in waste management processes. Data analysis shows that in the case of ammonia removal, purification efficiencies range from 86 to 98.3 % for biofiltration and from 67.2 to 98.3 % for biotrickling filters. The efficiency of the removal of hydrogen sulphide in the biofiltration process ranges from 95 to 99.9 %. In turn, the purification efficiency for VOCs is 20–95 % and 26.1–81.5 % for biofilters and bitrickling filters, respectively.

Table 1

Efficiency of biological deodorization methods in waste management processes on the basis of selected odorants

Method	Source of odor controlled	Pollutant	Efficiency [%]	References
Biofilter	composting	VOCs	20–95	[34]
Biofilter	composting	H_2S	99–99.9	[32]
Biofilter	composting	NH_3	96.4–98.3	[32]
Biofilter	composting	VOCs	40–70	[32]
Biofilter	composting	H_2S	99, 95	[35]
Biofilter	composting	NH_3	94, 86	[35]
Biotrickling filter	composting	VOCs	26.1–81.5	[36]
Biotrickling filter	composting	NH_3	97.4–98.3	[36]
Biotrickling filter	composting	NH_3	67.2–94.3	[37]

In turn, wastewater treatment plants odors are mainly formed in anaerobic processes. The most common odorants include hydrogen sulphide, ammonia, methane thiol ethanes, indole, skatole, carboxylic acids, aldehydes and ketones. Potential sources of odors can be: raw sewage pumping stations, drainage basins of effluent discharge, collector inlet for treatment plants and grate chambers, sand and grease separators, preconditions, biological beds, activated sludge tanks, secondary sludge, sewage flow points, sludge treatment. In addition, the storage locations of process by-products such as sand, fats, screenings can also be a source of odor nuisance compounds. [6]. Table 2 presents a compilation of literature data on the efficiency of biological methods for the removal of odors and chosen odorants in wastewater treatment processes Data analysis shows that in the case of ammonia removal, purification efficiencies range of 100 % for biofiltration and of 82 % for biotrickling filters. The efficiency of the removal of hydrogen sulphide in the biofiltration process ranges from 91 to 99 % and for bioscrubbers and biotrickling filters in every cases efficiency was over 99 %. In turn, the purification efficiency for VOCs in biotricking filters reached 46 % and overall deodorization efficiency on the example of odors was from 97 to 98.8 % and from 99 to 99.4 % for biotrickling filters and biofilters, respectively.

Table 2

Efficiency of biological deodorization methods in wastewater treatment processes on the basis of odors and selected odorants

Method	Source of odor controlled	Pollutant	Efficiency [%]	References
Biofilter	sludge holding tanks	H_2S	96–99	[38]
Biotrickling filter	sewage sludge composting	NH_3	82	[39]
Biotrickling filter	sewage sludge composting	VOCs	46	[39]
Biotrickling filter	biological wastewater treatment	odor	97–98.8	[20]
Biofilter	biological wastewater treatment	odor	99–99.4	[20]
Biofilter	—	H_2S	91, 96	[40]
Biofilter	—	NH_3	100	[40]
Bioscrubber	screen building	H_2S	> 99	[21]
Bioscrubber	anaerobic treatment	H_2S	> 99	[41]
Biofilter	pumping station	H_2S	> 99, 99.5	[22]
Biotrickling filter	inlet channel, grit chamber, creening room, grit classifier, pumping station	H_2S	> 99	[22]
Biotrickling filter	inlet channel, grit chamber, creening room, grit classifier, pumping station	odor	> 95	[22]
Biotrickling filter	anaerobic treatment	H_2S	> 99	[23]
Biotrickling filter	anaerobic treatment	odor	97	[23]

Table 3

Application of biofilters in municipal economy according to VDI 3447 guidelines [42]

Process	Removed pollutants
Composting	odors, aliphatic hydrocarbons, oxygenated organic compounds, sulfur compounds, nitrogen compounds, halogenated hydrocarbons, hydrogen sulphide, ammonia
Storage and processing of waste	odors, aliphatic hydrocarbons, sulfur compounds, nitrogen compounds, halogenated hydrocarbons, hydrogen sulphide, ammonia
The purification of landfill gas	odors, aerobic organic compounds, sulfur compounds, hydrogen sulphide
Industrial wastewater treatment	odors, aliphatic hydrocarbons, aromatic hydrocarbons, oxygen organic compounds, sulfur compounds, nitrogen compounds, halogenated hydrocarbons, hydrogen sulphide, ammonia, essential oils
Municipal wastewater treatment	odors, aliphatic hydrocarbons, aromatic hydrocarbons, oxygen organic compounds, sulfur compounds, nitrogen compounds, halogenated hydrocarbons, hydrogen sulphide, ammonia
Drying of sewage sludge	odors, aliphatic hydrocarbons, aromatic hydrocarbons, oxygen organic compounds, sulfur compounds, nitrogen compounds, halogenated hydrocarbons, hydrogen sulphide, ammonia

Therefore, biological methods can be considered as effective in the odor reduction strategy, which is reflected, among others in European legislation. A good example is German guidelines VDI 3447, where biofiltration is the method that can be used in practically all processes connected with the municipal economy (Table 3) [42]. According to the recommendations in the norm, processes for which the biofiltration, as an effective method of deodorization, can be applied successfully are composting, storage and processing of waste, purification of landfill gas, wastewater treatment processes and processes connected with sewage sludge drying. Table 3 summarizes the branches of municipal economy and the pollution generated by the processes involved, which can be successfully removed by biofiltration.

Conclusions

The use of biological processes in municipal facilities, mainly due to the low investment and operating costs, the simplicity of operation of the system, the availability of biological methods on the deodorization market, and practically no-waste is a reasonable alternative to other traditional methods used in odorous gas purification. equipment to consider such aspects as the relatively large dimensions of the planned installations, the problem of clogging the filter media due to overgrowth of biomass, as well as the composition and parameters of the emitted gases to be treated with the use of this kind of methods.

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Zakład Inżynierii i Ochrony Atmosfery, Wydział Inżynierii Środowiska,
Politechnika Wrocławska, Wrocław

Abstrakt: Ważnym potencjalnym źródłem emisji zapachów są obiekty gospodarki komunalnej (OGK). Należą tu systemy kanalizacyjne, oczyszczalnie ścieków, składowiska odpadów, zakłady segregacji przetwarzania odpadów. Zarówno obiekty gospodarki ściekowej, jak i zakłady gospodarowania odpadami mają na celu ograniczenie negatywnego wpływu działalności człowieka na środowisko naturalne. Wspólną cechą tych obiektów jest podobieństwo pod względem składu chemicznego emitowanych gazów oraz ich jakości hedonicznej, jednak ostatecznie charakter emisji zapachów zależy od typu obiektu i zastosowanych rozwiązań technologicznych. Źródła różnią się wielkością emisji oraz intensywnością zapachów, co może wpływać na skalę uciążliwości zapachowej. Problemy w ograniczaniu zapachowego oddziaływania OGK mogą wynikać w głównej mierze z wielości i różnorodności źródeł emisji odorów zlokalizowanych na ich terenie, a także z faktu, że są to często źródła dyfuzyjne i trudne do hermetyzacji. Standardowo, w ograniczaniu emisji odorów, stosuje się metody adsorpcyjne, absorpcyjne, kondensacyjne, spalania termicznego i utleniania katalitycznego oraz metody biologiczne. Te ostatnie są coraz powszechniej stosowana w oczyszczaniu gazów odlotowych, zarówno ze względów ekologicznych, jak i z uwagi na ekonomiczną konkurencyjność w stosunku do innych metod. Oczyszczanie gazów metodami biologicznymi prowadzi się przy pomocy biofiltrów, biopłuczek (bioskruberów), złóż biologicznie zraszanych (biofiltrów zraszanych) lub biomembran. Różnice pomiędzy metodami wynikają ze stosowanych w nich rozwiązań i przekładają się na rozkład kosztów operacyjnych. Skuteczność usuwania siarkowodoru metodą biofiltracji uzyskiwana przez różnych autorów wynosi co najmniej 99 % przy szerokim zakresie wlotowego stężenia zanieczyszczeń, natomiast dla amoniaku jest nieco niższa. Skuteczność biofiltracji lotnych związków organicznych zależy w znacznym stopniu od ich rodzaju i właściwości (rozpuszczalność w wodzie, prężność par), i wynosi od 40 do 100 %. Uzyskiwane skuteczności dezodoryzacji metodą biofiltracji wynoszą natomiast powyżej 90 %, a nawet mogą osiągać wartości powyżej 99 %. W pracy przedstawiono przykłady zastosowania metod biologicznych w obiektach gospodarki komunalnej wraz z oceną ich efektowności w ograniczaniu emisji odorów i wybranych zanieczyszczeń zapachowo czynnych.

Słowa kluczowe: dezodoryzacja, uciążliwość zapachowa, biofiltry, biopłuczki, obiekty gospodarki komunalnej