Microbiological methods of air purification

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Under conditions of increasing technological activity the tasks of removing industrial pollutants from the environment are growing into a challenging problem. The basic contribution to air pollution is made by chemical, pulp and paper, paint and varnish, food industries, agricultural processing enterprises, complexes of livestock breeding, waste water settlers, plants for detoxication wastes which are sources of emission into the atmosphere of toxic and odorous materials that even at small concentrations cause a feeling of discomfort and endanger people's health.

In organic matter with a sharp smell, that can often be found in used air, one can distinguish aromatic, unsaturated substances, nitrogen-, oxygen-, sulfur- and halogen-containing hydrocarbons. Inorganic substances, which are most frequently responsible for odor of foul air, include hydrogen sulfide, sulfur dioxide, carbon disulfide, ammonia, hydrazine, hydrogen chloride, halogens (1,2).

As a rule, flue gases of industrial and agricultural enterprises contain a large number of substances. Therefore, it is possible to analyse quantitatively the composition of impurities and determine their concentration in the air only in particular cases, when the number of impurities is limited. The most common method is gas chromatography using selective detectors. It is promising to use new, selective, highly sensitive detecting systems — modifications of ozone, chemiluminescent detectors. However, the most reliable data on the composition of the impurities under consideration can be obtained by chromato-mass-spectrometry. The odor intensity of flue gases is determined by olfactometry.

At present physical, chemical and biological methods are employed to purify the air. Physical methods include adsorption on active coal, and absorption by liquids. Calcianation, catalytic combustion, ozonization, chlorination appear to be the most common chemical methods. Biological methods are associated with the use of biofilters, bioscrubbers and bioreactors with a washed bed (2 – 5).

The most important advantage of biological air purification methods over chemical ones is the possibility of running the process at ambient temperature (10 – 14°C) and atmospheric pressure. Apart from this, there is no need to regenerate the working medium of the plant, which is a characteristic feature of physical purification methods. Plants for biological air purification are inexpensive, accessible and simple in operation as well as ecologically clean. Since microorganisms are generally in the aquatic environment, water insoluble substances, as a rule, are more resistant to a microbial attack than water soluble ones. Hence the use of all methods of biological air purification are most efficient for the removal of water soluble substances.

The application range of biological methods is largely determined by the ability of microorganisms to destroy organic matter under aerobic conditions to form harmless products, for instance CO_2, H_2O and biomass. By now, a large body of information has been accumulated on the microbial metabolism of aliphatic, aromatic, heterocyclic and C_1 — compounds. These compounds can be used by microorganisms for their growth as the only source of carbon, nitrogen, sulfur and phosphorus. Soil bacteria, primarily those of the genus *Pseudomonas*, are noted for the broadest spectrum of catabolic ways (6 – 15).

Data on the possibility of biodegradation of one or another organic compound, which are adduced in various publications, are sometimes conflicting, but not always exhaustive; this arises from high adaptability of microorganisms. There have been cases of successful adaptation of microorganisms to the growth on 2,2-dichloropropyonate, naphthyl-2-sulfonate, 2,4,5-triphenoxy-acetate, some azo dyes, which, as previously believed, could not support the growth of microorganisms.

By now, theories and methods of selecting microorganisms utilizing toxic substrates have been developed. Investigations are also aimed at creating highly active microorganisms destructors with a wider spectrum of action by gene engineering methods.

Biological methods can also be used for air purification from inorganic substances. Ammonia, for example, is utilized by many microorganisms as a source of nitrogen. Oxidation of hydrogen sulfide and sulfur dioxide leads to the formation of sulfate, which can be utilized as a source of sulfur by almost all bacteria. There are also data on the microbiological destruction of hydrazine.

Although the majority of substances endangering people's health can be destroyed by pure cultures of microorganisms, in a number of cases this can be more efficiently achieved by mixed cultures. Destruction of complex mixtures of toxic compounds is possible only by using mixed cultures. In a practical process a population of microorganisms destroying undesirable components of used air is formed in the working medium of the air purification plant through selection of adapted microorganisms from flue gases or specially added active sludge from waste water settlers. Such method of forming a population of microorganisms destroyers is sufficiently effective when it is necessary to remove substances readily utilized by bacteria. To destroy compounds which are difficult to assimilate it is expedient, and in a number of cases necessary, to introduce into the working volume of the plant, monocultures or mixed culture of microorganisms adapted beforehand to their growth on these compounds. Thus, it is possible to ensure a higher efficiency of air purification and reduce the time of introducing the plant into operation.

There are 3 basic types of plants of biological air purification: biofilters, bioscrubbers and bioreactors with a washed bed. Their distinctive features are summarized in Table 1.

TABLE 1
CLASSIFICATION OF BIOLOGICAL AIR PURIFICATION PLANTS

Plant type	Working medium of plant	Water regime	Basic stage of removal of impurities from polluted air	Source of mineral salts
Biofilter	Filter bed-microorganisms immobilized on natural carriers	Without water circulation	1. Absorption by filter bed material 2. Destruction by immobilized cells of microorganisms	Filter bed material
Bioscrubber	Water, active sludge	With water circulation	1. Absorption by water in absorber 2. Destruction in aeration tank by microorganisms of active sludge	Mineral salts are added to water
Bioreactor with washed bed	Biocatalyst-cells of microorganisms immobilized on artificial materials (synthetic polymers, inorganic materials)	With water circulation	1. Diffusion through water film covering layer of microorganisms 2. Destruction in biological layer	Mineral salts are added into water

Biofilters

The basic component of a biofilter is a filter bed on which toxic substances are sorbed from the air to be purified and subsequently destroyed by microorganisms. The air to be purified is generally fed into the plant by means of a fan and can be passed through a filter bed upwards or downwards.

Compost, peat or some other materials of natural origin can be used as a filter bed. The advantage of these materials is due to the fact that they already contain minerals necessary for nutrition of bacteria. To ensure proper conditions for the operation of a biofilter, along with a uniform flow-around of the filter bed by air it is necessary to have a uniform structure of material with a constant pore volume in the bed and sufficient humidity of the filter bed. The water content in the filter bed of 40 – 60% of the weight of carrier material, provides optimum conditions for the function of a biofilter.

In the plants under consideration the carrier is moistened by spraying water over the upper surface of the filter bed. However, the given approach makes it impossible to achieve uniform moistening. Insufficient moistening results in drying up of filter bed material, thus leading to the formation of cracks, disturbances of a uniform passage of gas through the filter bed and losses of the enzymatic activity of microorganisms. Excessive moistening gives rise to anaerobic zones with high aerodynamic resistance. As a result, the time of contact of gas with the filter bed decreases and the efficiency of its cleaning falls. Apart from this, anaerobic zones form volatile metabolites which impart unpleasant odor to the air leaving the biofilter.

Some types of compost, which is often used as a material for a filter bed, tend to form lumps, thus leading to a decrease of the specific area of the filter bed surface. This phenomenon is associated with local drying of carrier material, which springs from a relatively low humidity of air and/or emergence of temperature gradients in the carrier material. The temperature gradients result from the fact that the temperature in those sections of the filter bed where organic matter is subjected to the most intensive microbiological oxidation is slightly higher than in other sections. As a result, biologically active zones tend to drying and the least active ones — to excess moistening. Microbiological oxidation of certain organic substances present in polluted air may entail a decrease in the pH of filter bed material, resulting from the formation of acids (for example, acetic acid). As a result the enzymatic activity of microorganisms may drop or disappear altogether.

Variation of the concentration of toxic substances in purified air may also affect the activity of the filter bed. Although some species of microorganisms may survive the lack of a carbon source for a long time, nevertheless the periodic influx of organic matter with the air to be purified makes it impossible to use the enzymatic activity of microorganisms.

To overcome the listed shortcomings of traditionally used biofilters, the following means have been suggested (16):

1. Polluted air prior to entering the filter bed is moistened in the scrubber. High humidity of air should provide optimum activity of microorganisms. The weight ratio of water sprayed in the scrubber to the passed air may vary over the range from 1:10 to 10:1 and the relative humidity of air should amount to 96 – 100%.

2. The temperature of a filter bed optimal for microbiological destruction of toxic substances is to be maintained by thermostatic control of the working medium of the plant and an ingoing air.

3. To reduce the aerodynamic resistance of the filter bed it is necessary to add into it granules of polyethylene, polystyrene, active coal, etc. These materials are added in the ratio of 30 – 70% to the volume of filter bed

material and thoroughly mixed with it. The optimum size of particles ranges from 3 to 10 mm. For example a mixture of polyethylene granules (4 mm in diameter) with compost in the ratio of 1:1 is comparable to aerodynamic resistance of 8 mm water column with a height of the filter bed per hour.

4. To prevent a decrease of the pH of filter bed material it is mixed with limestone or calcium carbonate in the amount of 20 – 40% of the carrier weight.

5. To ensure steady work of a biofilter with periodic emissions of toxic matter, as well as to enhance the operating efficiency of the biofilter at a high concentration of toxic substances in the air, active coal is added to the filter bed material in the amount up to 250 kg/m^3.

There are methods for calculation of the efficiency of a biofilter as a function of its height, velocity of air flow in the filter bed and microbiological activity. However, in practice the size of biofilters is determined, as a rule, in an empirical way.

After introduction of a biofilter into operation the extent of air purification from toxic substance gradually increases until it reaches a certain value. This is due to the fact that the adaptation of microorganisms to growth on new substrates requires a certain time of contact with these substances. The adaptation period depends on the nature of these substances and the population of microorganisms in filter bed material, and lasts from several hours to several weeks.

With the passage of time the filter material is covered with a considerable layer of biomass, thus affecting a uniform passage of the air to be purified. Therefore, it should be replaced or renewed at certain intervals of time to provide the required efficiency of purification at the predetermined throughput of the biofilter. The service life of a biofilter without replacement of the filter bed may amount to several years.

A theoretical model describing the removal of organic compounds from the air to be purified by a biologically active filter bed is based on the hypothesis that a particle of the filter material is covered with a thin layer of biomass — bipolar, and within the biolayer the substances are transferred as a result of diffusion.

The removal rate of toxic substances from the air can be limited by diffusion or enzymatic reaction. If the substrate is completely destroyed in the biological layer, purification proceeds in a diffusion regime (process rate is limited by diffusion). If the substrate permeates across the entire thickness of the biological layer and it is not completely destroyed, the rate of the purification process is limited by the enzymatic activity of microorganisms rather than by diffusion. The stage limiting the process rate may be replaced with a change in substrate concentration in the air, in air flow rate, thickness and activity of the biological layer (17).

At a high content of organic compounds in the air to be purified they are not destroyed simultaneously. With passage through the filter bed at first the substances resistant to a microbial attack are destroyed and then the more resistant ones. For example the presence of butanol, ethyl acetate and butyl acetate in the air suppressed the utilization of toluene by the microflora of the filter bed. The relative efficient destruction of the latter occurred only after oxidation of the accompanying compounds. Apparently this is associated with catabolic suppression.

Bioscrubbers

The operating principle of bioscrubbers is that the absorption of toxic compounds with water and their destruction by microorganisms are carried out successively in different apparatures.

The most important component of a bioscrubber is an absorber (Fig. 1.) in which mass exchange between used air and absorbent takes place. Packed, bubbling, injection, spray and rotary scrubbers can be used as absorbers. When developing any type of scrubbers the basic consideration is given to the interfacial area which is responsible for the absorption efficiency.

In the absorber, toxic compounds and oxygen pass into water. The air leaves the absorber in a purified state, whereas the water in a contaminated one. The water is usually regenerated in an aeration tank. This requires, as a rule, an additional inflow of oxygen. Carbon dioxide formed during microbiological oxidation of organic matter in the aeration tank is removed from the water into air.

The bacteria suspended in the water are separated in a settling tank. The water which passed the stage of biological purification and was freed from biomass is fed into the absorber. The biomass separated in the settling tank is fed back into the bioreactor. The formation of excessive biomass from water in the settling tank leads to the formation of a biological bed in the

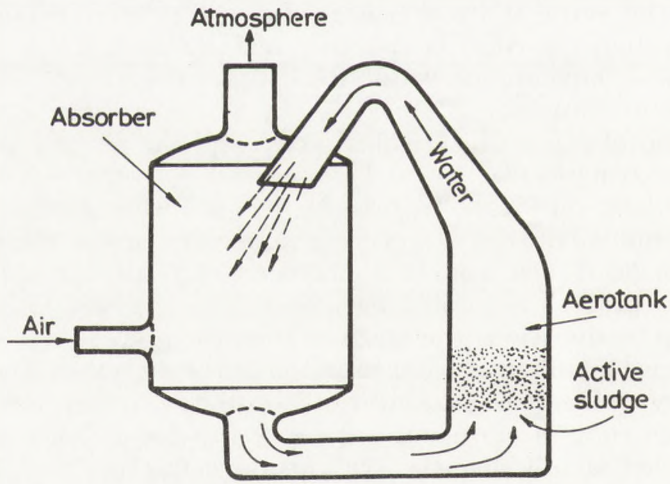

Fig. 1. Bioscrubber.

absorber. If the latter is not designed for it, this may lead to plugs which will inevitably affect mass exchange characteristics.

Prior to the development of a bioscrubber it is necessary to carry out semicommercial trials and study the effect of the following changing parameters on the efficiency of biological purification: concentration of biomass of active sludge and its form, dimensions of the aeration tank. pH of rinsing water, gas/liquid volume ratio, interfacial area, temperature of polluted air (2).

Bioreactors with a washed bed

The operating principle of a bioreactor with a washed bed is that gas is purified during its passage through a layer of biocatalyst, which is a carrier covered with a layer of microorganisms — biological layers (Fig. 2). Artificial materials, for example synthetic polymers or active coal, are used as carriers for immobilized microorganisms. The biocatalyst layer is washed with water containing mineral salts needed for the nutrition of the bacteria. The compounds to be destroyed when polluted air passes through the biocatalyst layer are distributed between gas phase and water film covering biocatalyst particles, diffused through it and destroyed in the biological layer.

The air purification rate may be limited either by the diffusion of substrates from the gas phase through the water film covering biocatalyst particles, or by the rate of their destruction by microorganisms. The diffusion rate depends upon the nature of compounds and their concentrations on the external and internal boundaries of the water film. The destruction rate is determined by the enzymatic activity of microorganisms that bring about the process. If enzymatic reaction results in a complete destruction of the compound diffused through the water film, this means that the process takes

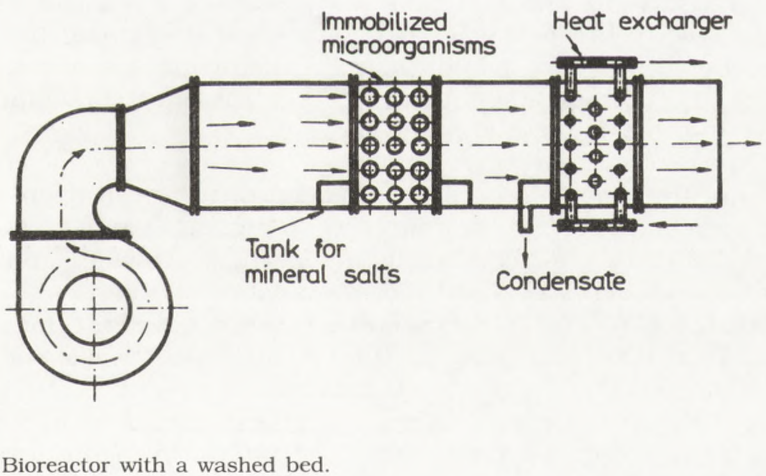

Fig. 2. Bioreactor with a washed bed.

place in a diffusion regime. The fact that the purification process is in a diffusion regime can be attested by the absence of the effect of carrier and biomass concentration on the eliminating ability of the biocatalist layer. The conversion degree of substrates, reflecting the efficiency of the purification process, diminishes with increase in air flow rate.

Introduction of a bioreactor with a washed bed into operation usually lasts 5 – 10 days, if 5% of active sludge from waste water settler is added to water used for spraying biocatalyst. However, when microorganisms adapted to the growth on toxic substances present in the air to be purified are used, this period can be reduced in some cases to several hours. With time the aerodynamic resistance of the biocatalyst layer increases due to a rise of biomass content. Cleaning of the bioreactor from excessive biomass should be carried out once for several months.

Let us consider immobilized cells in terms of microbiology. It is obvious that the function of immobilized cells in a bioreactor is based on the principle of chemostat. It is of no importance whether an utilized compound is supplied as solution or as vapour in the gaseous phase which subsequently dissolves or diffuses into the aqueous of the system. In contrast to classical problems that can be easily solved using the theory of chemostat, we are concerned here with low concentrations of substrates with variable limiting factors and with low growth rates. The non-linear form of the Mono equation for the rate of substrate utilization can also be used here for calculations and scaling. For more complete characterization of the process the following parameters are required: the proportion of substrate oxidized to end products, the proportion of substrate involved in constructive metabolism, i.e. formation of biomass, the proportion of substrate eliminated with salt solution used for reflux. In experimental conditions, it is necessary to calculate the limiting amount of living cells which will be able to perform catalysis at given concentrations of substrate. One should remember that the catalytic process is effected here by living microbial cells, i.e. those appearing predominantly while the system is in use. The biomass growth, however, causes an additional resistance of the packing. Therefore, when developing the operation modes we should strive for minimization of the biomass amount. In fact, it is necessary to determine an optimum relation between the minimum growth of biomass and maximum energy metabolism.

Practice has shown that the enzymatic degradation of organic compounds, which are not traditional sources for nutrition of the given microorganisms, requires a special mode of cultivation prior to immobilization. It is necessary to add into the culture medium an inductor which allows microbial cells to have a high-efficient enzyme system for degradation of a particular substrate. Some difficulties may arise if the substrate is water-insoluble. For some compounds, close structural analogs of the so-called nonspecific inductors, or intermediate metabolites formed upon enzymatic degradation and possessing the inductive effect can be used. When biomass is pretreated in a given way, the bioreactor is put into operation for 5 – 10 days. In "acute" experiments, when substrates and a microbial cell suspension are components of the system, it is necessary to obtain kinetic parameters of the process. The main purpurose of such experiments is to show the presence or absence of inhibition metabolites derived from destruction of a given substrate or to find the minimum substrate concentration at which the function of the system is disturbed. Triacetate fibers are the most widely used support for immobilization of microbial cells that can be immobilized either in the course of polymerization or on completely finished fibers. In the former case it is necessary to have information about the number of dead cells and of those which lost the ability to multiply. It is desirable to show in independent experiments the effect of organic compounds involved in polymerization on the viability of microbial cells. If the system is prepared for future use and for this is subjected to lyophilization, it is necessary to have a reliable information about the time required to put the system into operation mode.

Comparative characteristics and prospects for development of biological air purification methods

The basic requirements for plants of biological air purification include simplicity of their operation, high purification extent and specific throughput (the ratio of air volume passed through the plant per 1 hour to the working volume of the plant), low aerodynamic resistance.

The most common plants of biological air purification appear to be biofilters, since their application is related to low production costs (inexpensive and accessible material of filter bed, low consumption of water and energy).

However, the throughput of biofilters is relatively low and ranges from 5 to 400 m^3 of air to be purified per 1 m^2 of cross section area of the filter bed per 1 hour. This is due to the fact that the eliminating ability of a biofilter is limited by a low content of microorganisms per unit of filter bed volume. Since the height of the filter bed is not usually larger than 1 m (due to the requirements for the homogeneity of layer structure, the uniform moistening and valve of aerodynamic resistance), biofilters have a large area of cross section which ranges from 10 to 1600 m^2. At present, developments are underway aimed at reducing industrial space by designing multistage structures (2).

Biofilters with a fixed filter bed used in agriculture make it possible to attain the degree of air purification of 90%. Further increase of purification efficiency is associated with creation of plants which provide more uniform passage of air through the working medium of the plant. An example of such a plant is a biofilter developed by Gebruder Weiss KG (West Germany). Finely ground compost obtained by processing rubbish and sludge passes through it downwards in a countercurrent to the air fed upwards.

Biologically active compost is unloaded on the bottom of the plant and charged in the upper part of the plant again by means of a transporter made of steel. This moving layer ensures a uniform passage of the air to be purified. The extent of air purification from n-alkanes, toluene and hydrogen sulfide amounts to 96,7 – 99,9%. This ensures the absence of odour in the purified air (3).

The uniform passage of air through filter bed material can be accomplished by its mixing using a special, highly efficient device.

It is obvious that the increase in the operating efficiency of biofilters by the described methods is related to higher energy input. Also production costs considerably rise due to the necessity of thermostatic control of the filter bed because of its large volume.

Bioscrubbers occupy smaller production space than biofilters and, as a rule, appear to be towers, several meters high. Production costs of their operation are considerably higher than those of biofilters. This arises from high cost of water regeneration. Since the first stage of air purification is absorption of impurities by water, the use of bioscrubbers is most efficient if these compounds are water soluble. Bioscrubbers are not inferior to biofilters in air purification efficiency, but they are noted for higher throughput (Table 2). Thus, In West Germany in 1978 a plant for purification of flue gases from metallurgical works was put into operation having a throughput of 120 000 m^3/s. The conversion extent of organic compounds amounted almost to 50% and odour intensity fell from 76 to 85% (3).

TABLE 2

SPECIFICATIONS OF STANDARD PLANTS FOR AIR PURIFICATION AT ENTERPRISES OF INTENSIVE LIVESTOCK BREEDING

Plant type	Working volume	Specific throughput. hr^{-1}	Purification degree, %	Pressure losses H/m^2	Water consuption 1/day	Specific water consumption d^{-1}
Biofilter with compost	288,0	88	92	1700 (1)$^+$	510	$1{,}8 \cdot 10^{-3}$
Biofilter with fibrous peat	19,5	564	66 – 90	55 (0,5)$^+$	48	$2{,}5 \cdot 10^{-3}$
Bioscrubber	44,4	900	97,0 – 99,7	1200	9600	0,2
Bioreactor with polymer packing	1,5	5000	60 – 90	170 (1,04)$^+$	48000	32

$^+$ height of layer in meters.

Specific water consumption — ratio of water volume used per 24 hr to the working volume of the plant.

There are other approaches to air purification by using suspensions of microorganisms. For instance, Shimko et al., (18) suggested that air should be purified from sulfur containing compounds by passing it through a suspension of microalgae *Chlorella* in plants used for the cultivation of algae and having a large gas-liquid contact area. This process makes it possible to achieve high air purification from sulfur-containing compounds and form biomass with high feed value. It was also described as an air purification method by passing it through a suspension of active sludge. To reduce the production costs it is recommended to carry this out in aeration tanks used for waste water treatment.

These methods are attractive because they allow to cut costs of air purification due to their conjunction with other technological processes. However, the use of aeration tanks as plants for air purification seems to show little promise because of low process efficiency, which arises from a small area of gas-liquid interface for bubbling and low density of cells in bacterial suspension.

Bioreactors with a washed bed show the greatest promise for air purification, since at comparable purification degree and aerodynamic resistance they are characterized by a far greater specific capacity than the other types of plants (Table 2). At present small bioreactors with a washed bed are used in a number of countries for purification of flue gases from enterprises of intensive livestock breeding. In volume they are several times smaller than biofilters used for the same purposes. Porous polymer materials are used in them as a carrier for microorganisms.

In 1985 Kirkhner et al., (19) published data on laboratory trials of a bioreactor with a washed bed, which in terms of its parameters measures up to the current requirements for air purification systems. As a biocatalyst they used the densely packed granulated active coal on which highly active microorganism-destructor was immobilized. The degree of air purification from acetone, propionic aldehyde, butanol and ethyl acetate amounted to 40 – 90% with a specific throughput of the plant being 10 000 hr^{-1} and aerodynamic resistance of 10 – 30 H/m^2 per 1 cm layer. Small bioreactors are noted for a number of advantages over the traditionally used biofilters and bioscrubbers. The small dimensions of the plant solve the problem of its installation and thermostatic control, ensure uniform filling of the working volume of the plant with biocatalysts and its moistening.

Our laboratory has constructed an air purification plant based on a system of cells of microorganisms immobilized on polymer carrier. We produced a highly active, uniformly distributed biological film containing from 300 to 400 mg of active biomass per 1 g of carrier. The system is characterized by high specific throughput with aerodynamic resistance being low. The strain of microorganism used in these systems shows a broad substrate specificity and is highly destructive to toxic compounds present in emissions of many industrial enterprises (Table 3).

The plant designed in our laboratory in collaboration with industrial enterprises is intended for purification of air passing with a flow rate of 5000 – 20 000 m^3/h and measures 3 – 5 m by 1,2 m overall. The efficiency of purification depends on the concentration of pollutants in the effluent: the higher the concentration, the lower the efficiency of purification. The given method is the most efficient up to a concentration range from 100 to 150 mg/m^3. In some cases, however, the plants can be used for purification of air from pollutants present at a concentration of 1 – 3 g/m^3. Thus, when the air flow is 4300 m^3/h, the purification efficiency of the plant is 70%. The working volume of the plant is 1,5 m^3 and aerodynamic resistance 350 H/m^2.

TABLE 3

EFFICIENCY OF AIR PURIFICATION — FROM HARMFUL IMPURITIES

Substrate	Purification efficiency [%]
Styrene	95 ± 3
M-xylene	90 ± 10
Decane	75 ± 5
Naphthaline	90 ± 10
Acetaldehyde	97 ± 3
Ammonia	90 ± 10
Benzene	80 ± 5
Undecane	95 ± 5
Ethyl benzol	60 ± 10
Ethyl acetate	95 ± 5
Ethanol	100
Acetone	70 ± 10

Concentration of substrates — from 50 to 100 mg/m^3.
Specific throughput — in the order of 10 000 hr^{-1} (20).

The cost of the plant is composed of the cost of the reactor with accessories, the cost of biomass, and adjustment alignment expenses. A plant with a volume of 1,5 m^3 requires about 5 kg of wet biomass and 35 kg of fibers per 1 m^3. To compare economic characteristics of various methods of air purification let us consider the results obtained in 1983. If the absolute values are different today, the relation of the characteristics seems to be the same (Table 4).

In conclusion it should be noted that the considerably higher throughput of bioreactors as compared to other plants of biological air purification can be explained by a high concentration of biomass in the working volume of the reactor due to the immobilization of microorganisms on polymer and inorganic carriers. Apart from concentrated biomass these carriers perform one more very important function — provide a large area of gas-liquid interface. Since the efficiency of air purification by bioreactors at a high volume velocity of air is limited by diffusion rate of compounds to be removed, through water film covering a biological layer (21), further increase in the capacity of bioreactors will obviously be related to the improvement of the bioreactor design and search for new materials for an immobilization of microorganisms which will provide a larger interfacial area.

TABLE 4

COMPARATIVE ECONOMIC CHARACTERISTICS OF VARIOUS METHODS OF AIR PURIFICATION (FLOW RATE IS 10 000 M^3/H) (5)

Type of purification	Capital investments $1 \cdot 10^4$ DM	Maintenance charges for 1000 m^3 DM
Combustion	15	1,4 - 1,7
Catalytic afterburning	17	1,3 - 1,5
Adsorption	9	0,5 - 1,0
Ozonization	9	0,4 - 0,6
Bioscrubbers	8,5	0,3 - 0,5
Biofilters	7	0,3 - 0,5

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Mikrobiologiczne metody oczyszczania powietrza

Streszczenie

Powietrze zanieczyszczone przez przemysł i wielkie fermy hodowlane można pozbawić toksycznych substancji, stosując rozmaite metody — fizyczne, chemiczne i przede wszystkim — biologiczne. W tych ostatnich, najkorzystniejszych ekologicznie i ekonomicznie, degradacji zanieczyszczeń dokonują specjalnie dobrane drobnoustroje, wykorzystujące te związki jako źródła węgla, azotu, fosforu, czy też siarki.

W artykule omówiono rodzaje, zasady działania i sposoby wykorzystania podstawowych urządzeń, stosowanych w mikrobiologicznej detoksyfikacji powietrza, tj. biofiltrów, bioskruberów i bioreaktorów z przemywanym złożem.

Key words:
environmental biotechnology, air pollutant, biodegradation, microbiological filters, bioscrubbers, bioreactors.

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