UDC 623.459.7

A.V. Galak[1], Candidate of technical science
N.D. Sakhnenko[2], Doctor of technical sciences, Full Professor
O.I. Kravchuk[3], Candidate of technical science, senior researcher
S.N. Menshov[1],
O.P. Klimov[1],
O.V. Linyvtsev[1]
[1] *Military institute of Tank Troops of National Technical University «Kharkiv Polytechnic Institute», Ukraine*
[2] *National Technical University «Kharkiv Polytechnic Institute», Ukraine*
[3] *Odesa Military academy, Ukraine*

IMPROVEMENT OF OPERATION OF FILTERING SYSTEMS BY METHODS FOR CLEANING GAS EMISSIONS

Pollution with hazardous chemical substances is now considered one of the major environmental problems. The methods of purifying gas emissions depending on the physical-chemical properties of pollutants, including hazardous chemical ones, their aggregate state, concentration in the gaseous medium are considered. The influence of the content of aerosols such as dust and soot, the efficiency of cleaning methods in various temperature ranges, and the methods for cleaning multicomponent mixtures are analyzed. The comparative characteristics of thermo-chemical, reagent, sorption and catalytic methods are given and the prospects of their application in the filter systems of stationary and mobile objects are estimated. It is shown that almost any organic compounds can be oxidized (mineralized) on the TiO_2 *surface. In practice, any photocatalytic air purıfier includes a porous carrier with a* TiO_2 *deposite that is irradiated with ultraviolet rays and through which the air is blown. Photocatalysis is suitable for household use, as it can occur at room temperature. For example, the thermocatalytic way of destroying harmful substances requires preheating of air to temperatures above 200 °C. Photocatalysis destroys substances that penetrate even through activated charcoal-based filters. Peculiarities of formation of oxide coatings by plasma-electrolytic oxidation of titanium alloys are considered. Therefore, it is proposed to retrofit the construction of collective protection systems on armored vehicles and stationary objects with the additional installation in a filter-absorbent of a mesh with a deposited layer of catalytic material that will neutralize various types of hazardous chemical substances by photocatalytic purıfication of air by titanium oxides.*

Keywords: *filter-ventilator unit, collective protection system, hazardous chemical substances, purıfication methods, titanium alloys, mesh, photocatalyst.*

Problem statement

There are more than 1,5 thousands chemically dangerous objects on the territory of Ukraine, whose activity is related to the production, use, storage and transportation of hazardous chemicals, and more than 22 million people live in the areas of their location. The danger of functioning of these objects of economic activity (chemically dangerous objects) is related to the probability of accidental emissions (spillages) of a large number of hazardous chemical substances (hereinafter – HCHS) outside the objects, because many of them retain 3-15 daily supplies of chemicals [1].

In modern conditions of combat operations, namely, hybrid challenges, terrorism, the use of chemical weapons in Syria, an urgent problem is the issue of collective protection of fortification structures and mobile machinery from hazardous chemical substances. So, during the destruction of chemically dangerous objects, filter-ventilator installations (units), stationary and on armored objects that were created in Soviet times, do not fully protect personnel from hazardous chemicals [2, 3], thus creating preconditions for significant losses of personnel and reducing the combat readiness of military units and subunits.

Therefore, the existing systems of collective protection on armored vehicles and stationary objects from hazardous chemical substances need to be improved.

Taking into account the above, we will consider different methods of air purification from pollutants and determine the most optimal and most effective method.

In order to neutralize emissions by the principle of removing toxic impurities, chemical processes can also be used along with physical processes, by which the physical properties of impurities can be varied widely (for example, to convert the initial gaseous pollutants into compounds with a high boiling point) in order to facilitate their further capture.

Means of chemical technology are generally used for gases purification. Therefore, the classification of the means of neutralization of emissions is almost identical to the classification of processes and apparatuses of the chemical industry, which form harmful emissions as a waste of the main production [4].

For the purpose of trapping gaseous impurities, condensation, sorption (both absorption and adsorption), and chemisorption processes are used and convert pollutants into innocuous compounds via thermo-chemical (thermal destruction, thermo-catalytic and catalytic oxidation) and chemical processes.

For the purification of emissions from gaseous pollutants, methods of absorption, adsorption, catalytic purification, thermal neutralization and condensation of gas impurities are most often used.

The analysis of recent researches and publications

There are such methods of air purification from pollutants as:

electric cleaning;

тhermo-chemical neutralization of gas emissions;

catalytic purification of gas emissions;

high-temperature neutralization of gas emissions;

absorption purification of emissions;

biochemical gas purification.

photocatalytic method of gas purification, etc.

One of the perfect methods for cleaning gases from suspended particles dust and fog are electric cleaning which allows you to catch up to 99% particles [5]. Electrofiltrations are available for placing charge zones and deposition single-band and dual-zone. Electrostatic precipitators (ESPs) on the placement of charging and precipitation zone are divided into single-band and dual-band. In single-band electrostatic precipitators, charging and precipitating zones are combined. In dual-band apparatuses, charging occurs in the ionizer, and precipitation – in the precipitator.

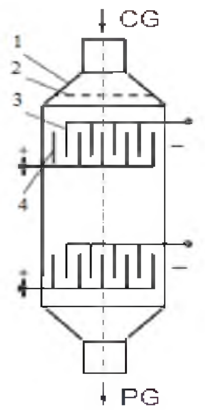


Fig. 1. Diagram of a single-band double-layer electrostatic precipitator:
1 – housing; 2 – gas distribution grid; 3 – discharge electrodes; 4 – collecting electrodes

Depending on the number of consecutive collecting electrodes, single-, double-, triple-, and quadruple-layer electrostatic precipitators are distinguished. The diagram of a single-band double-layer ESP is shown in Fig. 1., and the dual-band - in the Fig. 2.

According to the method of regeneration of the collecting and discharge electrodes, the electrostatic precipitators can be dry and wet. In dry ESPs, vibratory, magnetic-pulse, shock-hammer and shock-spring shaking systems are used to remove the precipitated dust. In wet ESPs, washing the electrodes with a necessary amount of liquid is used to remove dust.

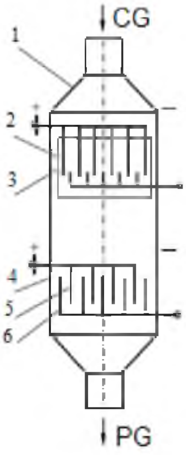


Fig. 2. Diagram of a dual-band electrostatic precipitator:
1 – housing; 2 – ionizer; 3 – ionizer electrodes
4 – precipitator; 5 – collecting electrodes; 6 – discharge electrodes

The method of thermo-chemical neutralization of gas emissions consists in combustion and post-combustion of harmful impurities that can be oxidized; this method is increasingly used for cleaning of drainage and ventilation emissions. It compares favorably with others (for example, wet scrubbing) with a high degree of purification.

According to the type of reaction, the methods of thermal neutralization can be divided into thermo-reductive and thermo-oxidative.

In turn, thermo-reductive methods are specific and are developed individually for each specific pollutant. Of these, methods of thermo-chemical (using ammonia) and thermo-catalytic reduction of NOx to N_2, thermo-catalytic reduction of SO_2 to S_2, some others have been used until now in the gas purification technique. Of all thermo-oxidative processes for thermal neutralization, only reactions with oxygen are suitable, since it is not possible in principle to produce harmless oxidation products with the participation of other oxidizing agents. Thermo-oxidative methods are less specific than thermo-reductive, but they are also not universal.

The possibilities of the thermo-oxidative methods of neutralization are also limited by the amount of gases and the content of combustible components in them. If the concentration of combustible emission components does not reach the lower limit of ignition (“poor” fuel emissions), their fire treatment requires additional fuel consumption for heating emissions to a self-ignition temperature, which for hydrocarbons vapors is about 500-700°C. The temperature level of the thermo-catalytic oxidation process is slightly lower (usually 350-500°C), which also requires appropriate fuel consumption [5].

The disadvantage of this method is the impossibility of its use for the neutralization of gases, which during combustion form products that are many times more toxic than the original gas emissions (e.g., by combusting gases that contain phosphorus, halogens, sulfur).

Catalytic methods of gas purification are based on reactions in the presence of solid catalysts, i.e. on the laws of heterogeneous catalysis. AS a result of catalytic reactions impurities that are in a gas are converted into other compounds, in contrast to the considered methods, impurities are not extracted from the gas, but transformed into harmless compounds.

Catalytic converters are used for the removal of carbon monoxide, volatile hydrocarbons, solvents, exhaust gases in chemical plants.

Catalytic purification is mainly used with a small concentration of the component, which is removed in the purified gas. In this case, the process takes place at a temperature of 200-300°C, which is significantly less than the temperature required for complete neutralization during direct combustion in furnaces and is equal to 950-1100°C. Due to the use of catalysts, a high degree of gas purification can be achieved, which in some cases reaches 99.9%.

There are two types of catalysis: homogeneous and heterogeneous.

In homogeneous catalysis, the substances and the catalyst form a single-phase system (liquid or solid).

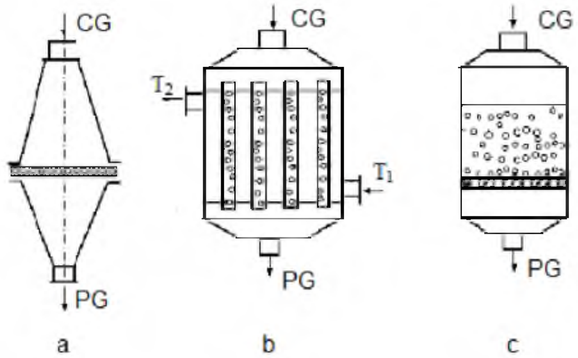
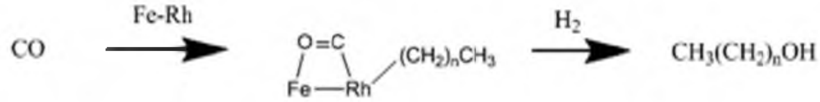


Fig. 3. Contact apparatus scheme:
a – with a metal mesh; b – with a tubular catalyst; c – with a bulk layer

In heterogeneous catalysis, the catalyst is a separate phase (usually solid). A significant part of the products that are produced by the chemical and related industries are obtained using heterogeneous catalysis. Less common is heterogeneous catalysis in the liquid phase.



Catalytic reactions are subject to the general laws of chemistry and thermodynamics, but have their own peculiarities as they are always involved with one additional component - a catalyst. In the role of effective catalysts, it is necessary to use expensive substances - platinum, palladium, ruthenium, the cheaper ones - nickel, chromium, copper - are also used, but they are less effective. In the processes of sanitary catalytic purification of waste gases, catalysts based on noble metals (platinum, palladium, silver, etc.), manganese, copper, cobalt oxides, and oxide contact masses activated by noble metals (1.0–1.5%) have a high activity.

The disadvantage of this method is that during operation the catalysts to some extent amenable to gradual deactivation or destruction, which are caused by chemical or catalytic poisons, mechanical erasure, sintering, aggregation, which leads to the necessity of periodic regeneration (activation) or replacement of catalysts [5].

The method of high-temperature gas purification consists in oxidizing the components that are to be neutralized, with oxygen. This method can be used practically for neutralization of any vapors and gases, the combustion products of which are less toxic than the original substances. Direct combustion is used in cases where the concentration of combustible substances in the waste gases does not exceed the limits of ignition. By fire treatment, as well as by thermo-catalytic oxidation, it is in principle possible to neutralize only substances whose molecules do not contain any other elements, except hydrogen, carbon and oxygen. With the help of combustion, it is possible to neutralize these substances in the gaseous, liquid and solid states, dispersed or compact, and with the help of thermo-catalytic oxidation - only in the gaseous state. Thermo-catalysis is unacceptable for the treatment of gases (vapors) and high-molecular high-boiling substances, which, poorly evaporating from the catalyst, coke and "poison" it.

During combustion, the following basic reactions take place:

$$CO + O_2 \rightarrow CO_2 + Q;$$

$$2C + O_2 \rightarrow 2CO + Q;$$

$$2CO + O_2 \rightarrow 2CO_2 + Q;$$

$$2H_2 + O_2 \rightarrow 2H_2O + Q;$$

$$S + O_2 \rightarrow SO_2 + Q.$$

There are three schemes of thermal purification:

- direct combustion (t = 600 – 800°C);
- thermal oxidation (t = 600 – 800°C);
- catalytic combustion (t = 250 – 480°C).

Direct combustion is used when the waste gases provide a significant portion of the energy that is needed to carry out the process. For economic reasons, this contribution should exceed 50% of the total calorific value [6].

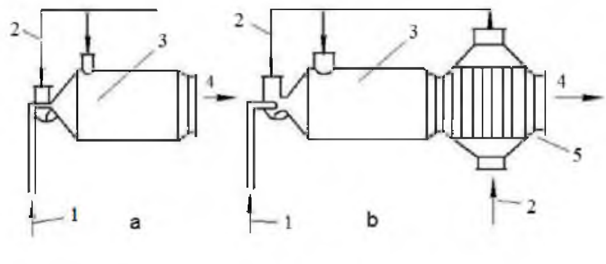


Fig. 4. The scheme of thermal converters.
a) without heat exchanger; b)with a heat exchanger:
1 – fuel supply; 2 – polluted gas supply; 3 – combustion chambers; 4 – neutralized gases; 5 – heat exchanger

Thermal oxidation is used, firstly, when the source gases have a high temperature, but they do not have enough oxygen, secondly, when the concentration of combustible impurities is extremely low (does not provide heat to maintain the flame, i.e., direct combustion is economically disadvantageous).

The essence of the method of the absorption purification method is the extraction of sulfur dioxide, hydrogen sulfide and other sulfur compounds, oxides, acid vapors (HCl, HF), carbon dioxide and monoxide, various organic compounds (phenol, formaldehyde, volatile compounds) from gases.

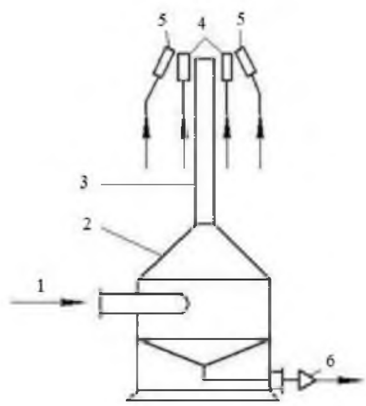


Fig. 5. Scheme of flare unit
1 – polluted air; 2 – separator; 3 – flare pipe
4 – multiple burners; 5 – pilot burner;
6 – water seal

The absorption method implements the processes that occur between the molecules of gases and liquids. If there is no interaction between the sprayed liquid and the irrigated gas, then the efficiency of absorption of components from the vapor-air mixture is determined only by the vapor-liquid equilibrium.

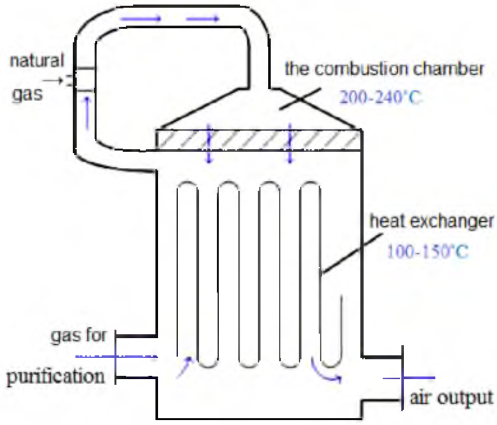


Fig. 6. The basic scheme of the thermo-catalytic converter

Absorption purification is used both for removing valuable components from the gas stream and returning them to the technological process for re-use and for the absorption from the exhaust gases of harmful substances for the purpose of sanitary purification of gases.

It is usually rational to use absorption purification when the concentration of impurities in the gas stream exceeds 1%.

It is inappropriate to use water to clean emissions with insoluble organic impurities. Such pollutants are generally well absorbed by organic liquids, among which high-boiling substances such as ethanolamines and heavy hydrocarbons can be used as absorbents. Absorption with organic solvent is most effective for the removal of gaseous organic pollutants, since sufficient solubility is provided in this case. In the form of liquid organic absorbents mono -, di - and triethanolamine and methyldiethanolamine are used. The use of such absorbents is limited to systems that do not contain solid particles, since solids contaminate organic liquids. Before processing with organic absorbent gases, it is necessary to remove dispersed impurities, otherwise the absorbent becomes quickly contaminated and becomes a waste that is practically impossible to clean [5, 6].

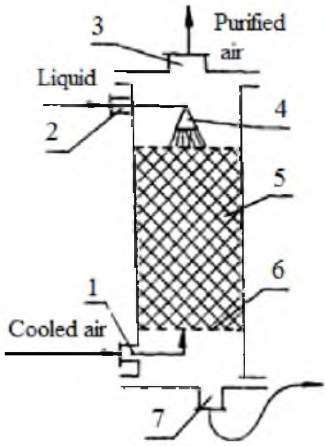


Fig. 7. Scheme of tower absorber:
1 – inlet nozzle for contaminated air; 2 - fluid inlet nozzle; 3 – outlet for removal of purified air; 4 – sprinkler; 5 – layer of liquid with a nozzle; 6 – mesh; 7 – outlet for removal of polluted water

The disadvantages of this method are the possibility of using only with a low content of impurities in the inlet gas, the complexity of the treatment of regeneration gases, mechanical destruction of the absorbent, reduction of its activity during operation, significant pressure loss in the apparatus.

Biochemical gas purification method is based on the ability of microorganisms to degrade and convert different compounds. Absorption and neutralization of harmful impurities that are contained in the air during biological treatment is carried out due to the vital activity of microorganisms. The feature of the method is the use of natural biological processes without the use of alien ecological system materials and reagents.

The essence of the biochemical method is aerobic decomposition, oxidation and assimilation of trapped impurities by microorganisms. Decomposition of sub-stances occurs under the action of enzymes that are produced by microorganisms under the action of individual compounds or groups of substances contained in the gases to be purified. It is used for disposal of a wide range of pollutants of organic origin, as well as some inorganic compounds, e.g. H_2S, SO_2 and NH_3 [7].

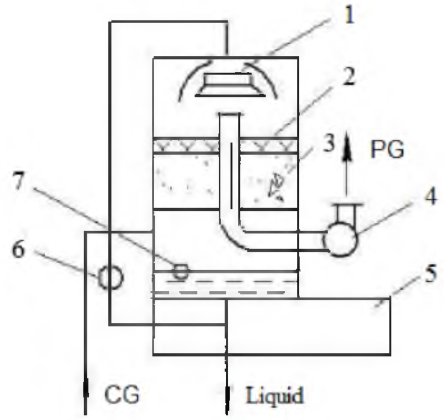


Fig. 8. Bioreactor of fine purification with a nozzle «Polynet»:
1 – overflow plate; 2 – distribution plate; 3 – noz-zle; 4 – fan; 5 – supporting fittings;
6 – pump; 7 – float water line

The disadvantage of this method is that in the bio-logical treatment, it is necessary to create a certain tem-perature and humidity conditions for microorganisms that are living beings and need a certain medium and nutrition. If one of the conditions (temperature, humidity, appropriate nutrient medium) is not created, the number of microorganisms is reduced dramatically and they may die.

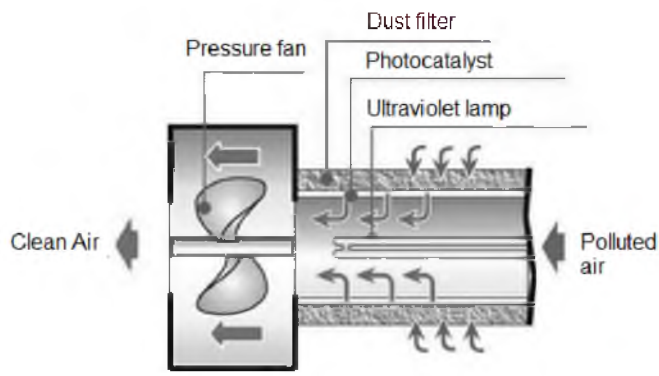


Fig. 9. Air purification by photocatalytic method

The essence of the method of photocatalytic purification of gases is the oxidation of toxic impurities on the surface of the photocatalyst under the action of ultraviolet radiation. Photocatalytic processes that take place, allow solving such problems as the de-composition of toxic organic and inorganic compounds in gas emissions and wastewater, the creation of nanophotonics devices for producing hydrogen and the intensification of organic synthesis processes [8]. Practical use is difficult due to the relatively low activity of the photocatalyst in the visible region of the spectrum. An effective way to increase the spectral sensitivity of a material is the doping of semiconductor nanostructures with transition metal oxides in an amount of 1 to 10 wt% [9, 10].

The only drawback of photo-catalysis is the for-mation of peroxide compounds (such as nitrogen oxides), which are often found among the "fragments", molecules that are not completely decomposed. But they are much safer than ozone, which is not formed during photo-catalysis. Photo-catalysis is suitable for domestic use, as it can occur at room temperature. For example, the thermo-catalytic method of destruction of harmful substances requires pre-heating the air to a temperature above 200°C.

The purpose of research

Having considered the existing air purification methods, it should be noted that photocatalytic gas purification is the best method of air purification, in which titanium alloys are used as a photocatalyst, which are able to effectively neutralize (decompose) toxins of various nature with high perfor-mance in a wide temperature range. Therefore, in the future, it is possible to consider the installation of filter-absorbers of filter-ventilation units on armored vehicles and stationary objects of the mesh with oxide systems of titanium alloy to neutralize the HCHS.

It is established that there are no absorbent filters that can protect against all types of HCHS, and the time of action in insulating gas masks may not be sufficient in places of possible contamination [9]. For this purpose, it is necessary to improve the collective protection systems, stationary and in armored vehicles, using oxide catalysts based on titanium alloys with their subsequent installation in existing absorbent filters for efficient neutralization of HCHS.

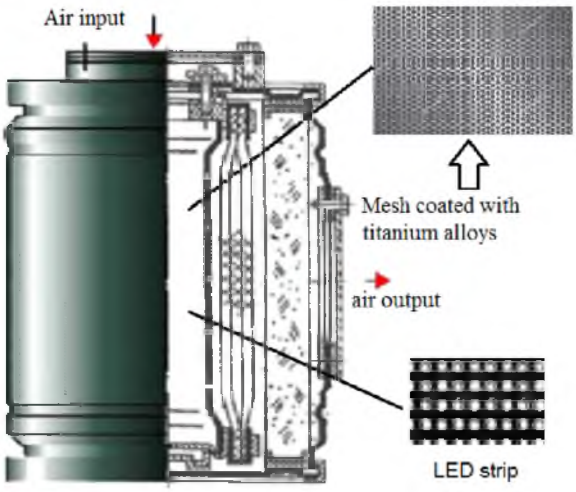


Fig. 10. Installation of mesh coated with titanium dioxide in the collective protection system

The improvement of the filter-absorbent system on the armored equipment is shown (Fig. 10), in which a mesh with a deposited layer of a catalytic material that penetrates UV rays on its part of a surface, is installed [11].

The optimal method of air purification from HCHS is photocatalytic air purification, where titanium dioxide is used as a photocatalyst, which can efficiently neutralize (decompose) different kinds of toxins at high rates of efficiency over a wide range of temperatures [10]. Researches of the catalytic properties of coatings with mixed oxides will be conducted in the reactions of oxidation of sulfur dioxide, ammonia, chlorine and carbon monoxide.

Conclusion

It is established that the existing filter-ventilator units of armored vehicles do not provide full protection against HCHS.

In order to provide protection against chemical hazards, it is promising to improve existing systems of collective protection of arms and military equipment, which are in active service of the country, using oxide catalysts on titanium alloys with their further installation in available absorbent filters for efficient neutralization of HCHS. In order to improve the existing systems of collective protection, it is necessary to develop an installation where it is anticipated that ultraviolet rays penetrate the part of the mesh surface.

Список використаних джерел

1. Казмірчук Р.В. Джерела та фактори виникнення небезпечної екологічної обстановки в зоні територіальної оборони. Сили та засоби виявлення та оцінки / Р.В. Казмірчук, В.В. Ларіонов, В.В. Ільченко // Техногенно-екологічна безпека та цивільний захист. — 2010. — Вип. 1. — С. 145-153.

2. Галак О. В. Фільтровентиляційні установки (агрегати) стаціонарні та на бронеоб'єктах / О. В. Галак, Г. В. Каракуркчі, Я. В. Грибинюк // Системи озброєння і військової техніки. 2016. – № 4 (48). – С. 5–9.

3. Галак О. В. Фільтровентиляційні установки на бронеоб'єктах іноземних держав світу / О. В. Галак, Г. В. Каракуркчі, М. Д. Сахненко, С. М. Меньшов // Системи озброєння та військова техніка. – Х : ХНУПС. 2017. – № 1 (49). – С. 92–95.

4. Артем'єв С. Р. Екологічна безпека військ / [С. Р. Артем'єв, О. М. Блекот, В. В. Марущенко та ін.]. – Х : НТУ "ХПІ", 2012. – 308 с.

5. Ратушняк Г. С. Засоби очищення газових викидів / Г. С. Ратушняк, О. Г. Лялюк. – Вінниця: УНІВЕРСУМ, 2008. – 208 с.

6. Кузнецов И. Е. Оборудование для санитарной очистки газов / И. Е. Кузнецов, К. И. Шмат, С. И. Кузнецов. – К.: "Техника", 1989. – 304 с.

7. Кричковська Л. В. Процеси та апарати біологічної очистки та дезодорації газоповітряних викидів / Л. В. Кричковська, О. В. Шестопалов, Г. Ю. Бахарєва. – Х.: НТУ "ХПІ", 2013. – 200 с.

8. Быканова В. В. Синтез и фотокаталитические свойства покрытий Ti/Ti_nO ZrO_2/ В. В. Быканова, Н. Д. Сахненко, М. В. Ведь // Вісник НТУ "ХПІ". 2014. – № 27 (1070). – С. 13–20.

9. Сахненко Н. Д. Конверсионные и композиционные покрытия на сплавах титана: монография / Н. Д. Сахненко, М. В. Ведь, М. В. Майба. – Х : НТУ "ХПИ", 2015. – 176 с.

10. Bykanova V. V. Synthesis and photocatalytic activity of coatings based on the $Ti_xZr_yO_z$ system / V. V. Bykanova, N. D. Sakhnenko, M. V. Ved' // Surface Engineering and Applied Electrochemistry. 2015. – vol. 51, No 3. – pp. 276–282. DOI: 10.3103/S1068375515030047.

11. Зайнишев А. В. Применение ультрафиолетовых светодиодов в фотокаталитических воздухоочистителях для очистки воздуха кабин мобильных машин / А. В. Зайнишев, Г. А. Полунин // Интернет-журнал "Технологии техносферной безопасности". – 2012. – Выпуск № 6 (46). – (http://ipb.mos.ru/ttb).

Рецензент: Стаховський О.В., д.т.н., проф., Військовий інститут танкових військ Національного технічного університету «Харківський політехнічний інститут» (м. Харків)

УЛУЧШЕНИЯ РАБОТЫ ФИЛЬТРУЮЩИХ СИСТЕМ МЕТОДАМИ ОЧИСТКИ ГАЗОВЫХ ВЫБРОСОВ

А.В. Галак, Н.Д. Сахненко, О.И. Кравчук, С.Н. Меньшов, А.П. Климов, А.В. Ленивцев

Загрязнения опасными химическими веществами в настоящее время считается одной из основных проблем экологии. Рассмотрены методы очистки газообразных выбросов в зависимости от физико-химических свойств загрязняющих веществ, в том числе химически опасных, их агрегатного состояния, концентрации в газовой среде. Проанализировано влияние содержания аэрозолей, таких как пыль и сажа; работоспособность методов очистки в различных температурных интервалах, способы очистки многокомпонентных смесей. Приведена сравнительная характеристика термохимических, реагентных, сорбционных и каталитических методов и оценены перспективы их применения в фильтровальных системах *стационарных и мобильных объектов. Доказано, что на поверхности TiO_2 могут быть окислены (минерализованы) практически любые органические соединения. На практике любой фотокаталитический очиститель воздуха включает в себя пористый носитель с нанесенным TiO_2, который облучается ультрафиолетовыми лучами и через который продувается воздух. Фотокатализ пригоден для бытового использования, так как может происходить при комнатной температуре. Например, термокаталитический способ разрушения вредных веществ требует предварительного нагрева воздуха до температуры свыше 200°С. Фотокатализ разрушает вещества, которые проникают даже через фильтры на основе активированного угля. Рассмотрены особенности формирования оксидных покрытий плазменно-электролитическим оксидированием сплавов титана. Предложено дооборудовать конструкцию систем коллективной защиты на бронетехнике и стационарных объектов дополнительным установлением в фильтр-поглотитель сетки с нанесенным слоем каталитического материала, который будет нейтрализовать различные виды опасных химических веществ за счет фотокаталитической очистки воздуха.*

Ключевые слова: *фильтровентиляционная установка, система коллективной защиты, опасные химические вещества, методы очистки, сплавы титана, сетка фотокаталізатор.*

ПОКРАЩЕННЯ РОБОТИ ФІЛЬТРУВАЛЬНИХ СИСТЕМ МЕТОДАМИ ОЧИЩЕННЯ ГАЗОВИХ ВИКИДІВ

О.В. Галак, М.Д. Сахненко, О.І. Кравчук, С.М. Меньшов, О.П. Клімов, О.В. Лінивцев

Забруднення небезпечними хімічними речовинами на даний час вважається однією з основних проблем екології. Розглянуто методи очищення газоподібних викидів залежно від фізико-хімічних властивостей забруднювальних речовин, зокрема небезпечних хімічних, їх агрегатного стану, концентрації в газовому середовищі. Проаналізовано вплив вмісту аерозолів, таких як пил і сажа; працездатність методів очищення в різних температурних інтервалах, способи очищення багатокомпонентних сумішей. Наведено порівняльну характеристику термохімічних, реагентних, сорбційних і каталітичних методів та оцінено перспективи їх застосування в фільтрувальних системах стаціонарних і мобільних об'єктів. Доведено, що на поверхні TiO2 можуть бути окиснені (мінералізовані) практично будь-які органічні сполуки. На практиці будь-який фотокаталітичний очищувач повітря включає в себе пористий носій з нанесеним TiO2, який опромінюється ультрафіолетовими променями і через який продувається повітря. Фотокаталіз придатний для побутового використання, оскільки може відбуватися при кімнатній температурі. Наприклад, термокаталітичний спосіб руйнування шкідливих речовин вимагає попереднього нагрівання повітря до температури понад 200°С. Фотокаталіз руйнує речовини, які проникають навіть через фільтри на основі активованого вугілля. Розглянуті особливості формування оксидних покривів плазмово-електролітичним оксидуванням сплавів титану. Запропоновано дообладнати конструкцію систем колективного захисту на бронетехніці та стаціонарних об'єктів додатковим встановленням у фільтр-поглинач сітки з нанесеним шаром каталітичного матеріалу, що буде нейтралізувати різні види небезпечних хімічних речовин за рахунок фотокаталітичного очищення повітря.

Ключові слова: *фільтровентиляційна установка, система колективного захисту, небезпечні хімічні речовини, методи очищення, сплави титану, мережка, фотокаталізатор.*