Міністерство освіти і науки України
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III ВСЕУКРАЇНСЬКА НАУКОВО-ПРАКТИЧНА КОНФЕРЕНЦІЯ

«ФІЗИЧНЕ ВИХОВАННЯ, БЕЗПЕКА ЖИТТЄДІЯЛЬНОСТІ І СУЧАСНІ ТЕХНОЛОГІЇ ВИРОБНИЦТВА»

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Фізичне виховання, безпека життєдіяльності і сучасні технології виробництва : збірник тез доповідей III Всеукраїнської науково-практичної конференції (електронне видання), 12 березня 2026 року / за заг. ред. А. А. Івашури. Харків : ХНЕУ ім. С. Кузнеця, 2026. 284 с.

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Збірник містить матеріали III Всеукраїнської науково-практичної конференції «Фізичне виховання, безпека життєдіяльності і сучасні технології виробництва». У наукових працях висвітлено актуальні проблеми та розвиток фізичного виховання молоді, представлена методологія, конструктивні міждисциплінарні підходи, сучасні технології й можливі моделі підвищення ефективності концепції здорового способу життя, спортивних заходів, безпеки людини і довкілля в сучасних умовах, розглянуті актуальні питання сучасних технологій виробництва та надання послуг.

Матеріали конференції можуть бути використані в науково-дослідній роботі та освітньому процесі закладів вищої освіти.

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CHEMICAL-TECHNOLOGICAL METHODS FOR REDUCING ANTHROPOGENIC EMISSIONS OF CARBON DIOXIDE

Global climate change is one of the most pressing problems of our time. The primary driver of its acceleration is considered to be anthropogenic emissions of greenhouse gases, particularly carbon dioxide (CO_2). Modern industrial activities are among the key sources of these emissions, making the development of effective technological solutions to address this problem essential. Chemical-technological methods for capturing and neutralising CO_2 in industrial processes not only reduce emissions but also optimise the treatment of industrial gases. In this context, the study of prospective approaches to industrial carbon dioxide mitigation becomes important.

For the neutralization of carbon dioxide in industrial emissions, absorption, adsorption, and catalytic methods are employed (Table 1) [1].

The most widely used are absorption purification methods. They are based either on the chemical binding of CO_2 – chemisorption, or on its solubility – physical absorption, as well as their combination. In modern technologies for purifying gas emissions from carbon dioxide, the absorption of CO_2 by amino alcohols (chemical absorption) takes first place. Aqueous solutions of ethanolic amino acid are used as chemisorbents in production:

Table 1

Industrial methods for purification process gases from carbon dioxide

Method	Product after purification	CO2 concentration in process gas before purification, vol. %
Absorption methods		
Absorption by amino alcohol solutions	CO2	≤ 30
Absorption by carbonate solutions (Na2CO3, K2CO3)	CO2	≤ 30
Absorption by organic solvents (CH3OH, (CH3)2CO)	CO2	≤ 30
Absorption by water	CO2	any
Absorption by alkali solutions (NH4OH, KOH, NaOH)	Na2CO3, NaHCO3, NH4HCO3	≤ 0,3
Adsorption methods		
Adsorption by physical sorbents	CO2	≤ 40
Adsorption by chemical sorbents	CO2	≤ 20
Catalytic methods		
Hydrogen reduction (methanation)	CH4, H2O	≤ 0,6

– MEA – monoethanolamine ($(C_2H_5O)NH_2$) – thick oily liquid with a boiling point of 170 °C, miscible with water in all proportions, weak base, toxic (MPC = 30 mg/m^3);

– DEA – diethanolamine ($(C_2H_5O)_2NH$) – thick oily liquid with a boiling point of 280 °C, miscible with water, strong base;

– TEA – triethanolamine ($(C_2H_5O)_3N$) – colorless liquid with a boiling point of 335 °C, miscible with water in all proportions, weak base.

The presence of hydroxyl groups determines the alkaline properties of ethanolamines, and therefore their ability to interact with carbon dioxide. MEA has the highest absorption capacity. However, these substances are highly volatile (the vapour pressure is $0.2 \cdot 10^{-9}$ MPa at a temperature of 38 °C), so contamination of the gas being purified with MEA vapours is possible. Therefore, mixtures of ethanolamines and other substances are used in practice.

Ethanolamines are highly soluble in water (maximum concentration is 50 mas. %). But they cause metal corrosion; therefore, to limit this phenomenon, solutions with an ethanolamine content of 10–20 mas. % are used during purification. Modern installations operate under pressure up to 2.76 MPa at a temperature of 35–47 °C.

Spent solutions of amino alcohols are regenerated by raising the temperature of the solution to the boiling point. The greatest effect is achieved at a pressure of 0.138–0.246 MPa, when the heat of gas desorption is higher than the heat of solvent evaporation. In this case, a more complete regeneration of the solution occurs with lower heat consumption.

The process of carbon dioxide disposal using solutions of amino alcohols is characterized by increased selectivity and a high degree of cleaning. However, the maximum permissible absorption capacity of the adsorbent is limited by the permissible corrosion of the equipment and the maximum permissible heat of chemisorption. The disadvantages of the process also include high energy costs (approximately 70%) for the regeneration of the adsorbent and heat generation [2].

The authors of [3] proved that it is possible to reduce energy and capital costs for regeneration by using an electrochemical removal cycle, which will facilitate CO_2 desorption and amine regeneration.

It is also possible to predicate industrial gases from carbon dioxide by absorbing CO_2 with carbonate solutions, usually sodium or potassium. In industry, there are various modifications of this process. These methods differ in temperature, concentration of working solutions, and the use of different activators. The most widely used method is the purification with hot potash solutions under a pressure of 2.56–2.95 MPa with K_2CO_3 concentration of 20–30 mas. %. Approximately 2% DEA is added as an activator, and 0.5% V_2O_5 is added as a corrosion inhibitor. The temperature during the absorption process is increased from 87 to 107 °C, and the regeneration temperature is maintained at no lower than 117 °C [1].

After process gas cleaning with ethanolamine and potash solutions, it contains 0.03–0.05 vol. % CO_2. Such concentration requires further fine purification. In addition, in this case, carbon oxide is not removed. The content of CO in the process gas can be 0.3–0.4 vol. %.

It should be noted that before the process of chemical absorption of carbon dioxide carrying out from process gases, it is necessary to remove SO_2 and NO_x, which are also present in it. For this, certain purification methods are used.

The process of purifying gases from carbon dioxide by physical absorption at low temperatures has been widely developed. The method is based on the high solubility of CO_2 in organic polar solvents at low temperatures and elevated pressures, and is easily removed from them when the pressure is reduced. The most practical application has been found in purification processes where methanol (the «Rectisol» process) and acetone are used as solvents. CO_2 removal is carried out under a pressure of 0.5–1.5 MPa at a temperature from – 40 to – 80 °C [2].

The main advantages of low-temperature absorption are:

– low specific solvent consumption due to its high absorption capacity at elevated pressure and low temperatures;

– significant reduction in specific energy consumption, as the saturated solvent is cooled due to the pressure reduction in the regeneration stage;

– low equipment corrosion;

– availability and low cost of the solvents used.

At the same time, such schemes also have disadvantages. The main disadvantages are careful installation, high maintenance culture, and high-quality thermal insulation of equipment.

Washing of gas containing CO_2 with water is used in practice as a preliminary purification. The process is carried out in the temperature range of 5–15 °C at an elevated pressure of 1.0–3.0 MPa. The water consumption for irrigation is 0.1 m^3 per 1 m^3 of gas being purified. In the case of using elevated pressure, CO_2 regeneration is advisable to be carried out by reducing the pressure of the solution after absorption in special devices - regenerators. The advantage of this method is simplicity and relatively low cost. The main disadvantage is the low degree of purification, approximately 70–80%. This is due to the maximum absorption capacity of water (8 kg of CO_2 per 100 kg of water) and low selectivity.

Carbon dioxide absorption in gas emissions using aqueous alkali solutions is a rational option for the final purification of small volumes of gas with a low CO_2 concentration. In other cases, the choice of method will be determined by the technical and economic feasibility of the process. The authors of [4] propose to use a NaOH solution as an absorber, which will provide an opportunity to obtain a marketable product – soda ash (Na_2CO_3). The sale of this product compensates for the cost of the purification process. Studies [5] have proven the effectiveness of carbon dioxide disposal using an aqueous ammonia solution (NH_4OH). Such an integrated approach will allow not only to remove CO_2 from gas emissions, but also to reduce the NH_3 concentration in the solution, which minimizes energy consumption for ammonia extraction in a certain technology.

Currently, the most promising method for purifying process gases from carbon dioxide is considered to be physical and chemical adsorption. The main difference between these two types is due to the energy characteristics of the bonds between CO_2 and the adsorbent. Physical adsorption is caused by Van der Waals forces, so the physical adsorption heat is of small importance and is 10–30 kJ/mol. For this process, adsorbent regeneration is possible. In addition, the process occurs at low temperatures (approximately 20 °C). Physical adsorption can occur on activated carbon, silica gel, and alumina gel. But the low adsorption capacity limits their use. Therefore, synthetic zeolites with high selectivity and sorption capacity are mainly used in industry for the purification from CO_2. The desorption stage is carried out by heating the adsorbent or purging it with an inert gas. This requires significant energy consumption.

Research is also underway to develop more efficient carbon-based absorbent materials (Starbons). These absorbents are made from organic waste. They have up to 65% greater adsorption capacity and also demonstrate three times higher selectivity for CO_2 adsorption compared to activated carbon [6].

Chemical adsorption is based on the chemical bond between the adsorbate and the adsorbent. As a result, surface compounds are formed. The process has an activation nature, since the reaction heat is about 100–400 kJ/mol. Iron and zinc oxides are used as chemical adsorbents. But their use is limited due to low manufacturability, the impossibility of regeneration and the need to dispose of the spent sorbent. The following high-temperature adsorbents operating in sorption-desorption cycles can be used for the selective carbon dioxide absorption: calcined dolomite, hydrotalcites, silicates and alkali metal zirconates, calcium oxide modified with alkali metal cations. Such adsorbents are capable of removing CO_2 from process gases at temperatures of 400–900 °C [2].

In addition to the above methods of gas purification from carbon dioxide, catalytic methods are also used. These methods are based on heterogeneous catalysis by converting impurities into harmless compounds or those that are easily removed from the gas. Catalytic methods are used when the gas contains impurities that are not sufficiently removed using liquid absorbers or solid adsorbents, i.e. as a fine purification.

The catalytic purification process occurs by reducing CO_2 with hydrogen on the catalyst surface to produce CH_4 and H_2O. Systems consisting of an active phase (cobalt, nickel, molybdenum oxides) and a carrier – aluminium oxide are used as catalysts. The most effective in this case are nickel-aluminium catalysts (30–50 mas. % NiO), which have a high active surface area, heat resistance and strength during the reduction process. The technological parameters are: temperature – 250–400 °C, pressure – up to 29.6 MPa, gas volume velocity – 6000–20000 h^{-1} [1].

The main advantage of the catalytic methods is a high degree of purification (up to 98%). The main disadvantages are certain requirements for the catalyst quality, strict requirements for the composition of the gas being purified. The latter requirement is particularly relevant to the sulfur compounds content. The sulfur compounds are catalytic poisons and contribute to the formation of new substances that must be removed from the gas.

Currently, among the methods of carbon dioxide disposal in industrial gas emissions, a significant share is accounted for by purification using ethanolamine solutions – 62%. The share of other technologies is approximately 15%. The rest are emissions of untreated gas. The choice of the most effective purification method for each specific production will depend on the required purification degree, the volume of gas emitted, and the location of the enterprise. As factors that will influence the choice of the optimal method can also be distinguished, the following parameters:

– presence of water vapour and other impurities (SO_2, NO_x, CO, dust) in the composition of the gas being purified;

– absorbent volatility;

– adsorbent strength;

– catalyst activity;

– selectivity and possibility of regeneration;

– cost and service life.

After purification of process gases from carbon dioxide, the main question is the utilization of CO_2 or products formed during this process. Currently, in the world, the main direction of utilization of carbon dioxide removed from gases is its use for commercial purposes:

– for oil extraction by a secondary method;

– in the food industry for the food and beverages production after CO_2 purification to the food purity level;

– as a raw material for the polymers, methanol, and baking soda production.

The products of the purification process can be used as fuel (CH_4), mineral fertilizers (NH_4HCO_3) and mineral salts ($NaHCO_3$).

The implementation of absorption, adsorption, and catalytic methods in industrial processes has proven to be highly effective in neutralizing CO_2 and reducing anthropogenic emissions. These technologies not only decrease the concentration of carbon dioxide in gas streams but also optimize the treatment of industrial emissions, enhancing environmental safety in production. Further development and implementation of such methods are essential for ensuring sustainable industrial development.

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