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MUTUAL NEUTRALIZATION OF ALKALINE WASTE WATER BY EMISSION GASES OF HEAT AND POWER ENGINEERING

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Kherson city CHP at work pollutes the atmosphere with harmful substances. An analysis of emissions revealed that the maximum surface concentration of sulfur dioxide in it is 1.37 mg/m^3, which is 2.74 times the maximum permissible concentration for populated areas. The presence of sulfur dioxide in the exhaust gases causes their acidic environment. Such gases can neutralize alkaline wastewater available at any textile plant. To study the process of neutralization, a laboratory setup was created. The studies were carried out on the basis of natural wastewater of a textile mill and an air mixture containing sulfur dioxide. The task of laboratory research was to study the influence of various physico-chemical factors on the process of neutralizing wastewater. Exhaust gas purification was investigated in parallel. In the present work, the method of a full four-factor experiment was applied. It makes it possible to obtain a mathematical description of the process under study. An apparatus for neutralizing alkaline wastewater with acidic flue gases is also proposed. As a result of the absorption of sulfur dioxide and carbon dioxide, acid is formed, which is necessary to neutralize the alkali. Decolorization of wastewater is carried out by ash formed during the combustion of solid or liquid fuels and acting as an adsorbent for colored organic wastewater compounds. To verify the data obtained in laboratory conditions, studies were conducted on a pilot plant developed by us using natural gases and wastewater. The pilot plant is a torus absorber with a capacity of 5 thousand cubic meters of gas per hour. The device has a diameter of 3 meters and a height of 1.5 meters. The scheme adopted a closed cycle of irrigation. Gas supply was made directly from the gas duct. The contact between the liquid and gas in the absorber was carried out by spraying the liquid with five centrifugal nebulizers with intersecting irrigation fields. On the basis of experimental data, the influence of various factors on the degree of neutralization of wastewater was established. *Key words:* neutralize alkaline wastewater, torus absorber, exhaust gas purification

Взаємна нейтралізація лужних стічних вод відхідними газами теплоенергетичних підприємств Кузнєцов С.І., Венгер О.О., Міщенко О.В., Охременко І.В.

Херсонська міська ТЕЦ при роботі забруднює атмосферу шкідливими речовинами. Аналіз викидів виявив, що максимальна приземна концентрація сірчистого ангідриду в ній становить 1,37 мг/м^3, що в 2,74 рази більше гранично допустимої концентрації для населених місць. Наявність сірчистого ангідриду в газах обумовлює їх кисле середовище. Такими газами можна нейтралізувати лужні стічні води, які наявні на будь-якому текстильному підприємстві. Для вивчення процесу нейтралізації, була створена лабораторна установка. Дослідження проводилися на основі натуральних стічних вод текстильного комбінату і повітряної суміші, що містить сірчистий ангідрид. У завдання лабораторних досліджень входило вивчення впливу різних фізико-хімічних факторів на процес нейтралізації стічних вод. Паралельно досліджувалися параметри очищення газів, що відходять. У даній роботі був застосований метод повного чотирьохфакторного експерименту. Він дає можливість отримати математичний опис досліджуваного процесу. Також запропонований апарат для нейтралізації лужних стічних вод кислими димовими газами. В результаті абсорбції двооксиду сульфуру і карбону, утворюється кислота, необхідна для нейтралізації лугу. Знебарвлення стічних вод здійснюється золою, що утворюється при згоранні твердого або рідкого палива і виступає в ролі адсорбенту для забарвлених органічних сполук стічних вод. З метою перевірки даних, отриманих в лабораторних умовах були проведені дослідження на дослідно-промисловій установці розробленої нами з використанням натуральних газів і стічних вод. Вона являє собою торовий абсорбер продуктивністю 5 тисяч кубометрів газу на годину. Апарат має діаметр 3 метри і висоту 1,5 метра. У схемі прийнятий замкнутий цикл зрошення. Подача газів проводилася безпосередньо з газоходу. Контакт між рідиною і газом в абсорбері здійснювався за рахунок розбризкування рідини п'ятьма відцентровими розпилювачами з пересічними полями зрошення. На підставі досліджень встановлено вплив деяких фізико-хімічних чинників на ступінь нейтралізації стічних вод. *Ключові слова:* нейтралізація лужних стоків, торовий абсорбер, очищення газів.

Problem statement. Wastewater of textile enterprises is a complex physicochemical multicomponent system containing insoluble impurities, suspensions, molecularly dissolved substances of mineral and organic origin. They have a specific color, an active reaction of pH 6–12.5. The concentration of synthetic surfactants and individual drugs is in the range of 10–140 mg/l.

The relevance of research. Today, pollution of water and air basins with gaseous and solid substances has become one of the most pressing contemporary problems. The bulk of industrial pollution is formed during the burning of fossil fuels. The most common contaminants are sulfur dioxide, carbon monoxide, and nitrogen oxides.

The effective treatment of industrial wastewater and flue gases from sulfur dioxide, carbon monoxide, nitrogen oxides is an urgent environmental safety problem, the solution of which is of great practical importance [1; 2].

Analysis of recent research and publications. Existing wastewater treatment methods are chemical, physicochemical, mechanical and biological [3; 4].

In chemical methods, coagulants and excipients – flocculants and adsorbents – are used [5]. Coagulants translate colloidal contaminants into an aggregate-unstable state and create the conditions under which the suspension of suspended particles and separation of the solid phase from the liquid occurs. Adsorbents extract dissolved impurities, flocculants promote the formation of large, strong flakes from contaminant particles, hydrolysis products of coagulants and adsorbents. As coagulants, salts of trivalent metals of aluminum and iron (sulfates, chlorides, chlorohydrates), as well as magnesium chloride, sodium aluminate, etc. are used. Cations of these salts reduce the aggregate stability of colloidal particles, and the substances formed during their hydrolysis have adsorption and flocculating properties.

Chemical wastewater treatment usually consists of the following operations: regulation of pH, coagulation and sedimentation to isolate reaction products. Before chemical treatment, wastewater is averaged and settled if necessary. Reagents and their doses should provide an active reaction favorable for the release of coagulated suspension and colloids into the sediment. The type of coagulants and their doses, the sequence of input into the treated water, the amount of sludge, its properties and the method of dehydration are determined experimentally in the design process and specified during the commissioning of structures.

Studies and operating experience of existing facilities have shown that chemical methods for wastewater treatment in textile enterprises have limited effectiveness.

Physico-chemical methods of wastewater treatment are very diverse. The most widely used in purification practice are adsorption, ion exchange, and flotation. Adsorption purification is based on the extraction of dissolved organic substances from water by the surface of solids – adsorbents. A characteristic property of adsorbents is their porous structure with a large specific surface. Adsorption is widely used for wastewater treatment containing a large amount of aromatic compounds.

Also, in the treatment of industrial wastewater, ion-exchange resins, which are insoluble high-molecular substances, are used. Ion exchange resins are used in industry for demineralization of water, extraction of non-ferrous and rare metal ions. At textile enterprises, this method is widely used in the treatment of wastewater containing copper ions.

The flotation purification method can be used to reduce the concentration of synthetic surface-active substances (surfactants) in the wastewater of finishing plants. The essence of the flotation process is the molecular interaction of the impurity with air bubbles that float to the surface and form a foam. Thus, in large quantities of compounds of manganese, phosphorus, and iron are contained. The content of these elements is hundreds of times greater than in water. Thus, foaming promotes the concentration of substances. It should be noted that at present the productivity of flotation machines is small [6], and this method has not been widely used.

Mechanical treatment is used to average wastewater by quantity and composition. In the pre-treatment system, averagers are provided, which are tanks equipped with a system of perforated pipes that supply compressed air to mix the liquid and prevent sediment from entering.

Using the biological method using activated sludge, it is possible to purify wastewater within the active reaction pH 6.5–9.2 at a temperature of 20 °C. An increase in the alkalinity of wastewater above pH 9.2 causes a progressive decrease in oxygen consumption and the death of microorganisms [7].

Currently, in the textile industry, only 20 % of fabrics are produced by dyed with durable and especially durable dyes, and 70 % of fabrics are dyed with sulfur dyes. A significant predominance of alkaline reagents over acidic and neutral (75-80 %), as well as discharges of unused mercerizing liquors into the sewer, leads to an increase in the alkalinity of wastewater with an increase in the activity of the pH to 11–12.5 [1]. The high alkalinity of the wastewater of textile enterprises creates certain difficulties in the treatment of these waters in the system of city-wide treatment facilities, where the main method is biological treatment. The pH value of wastewater significantly affects the life of microorganisms.

The novelty of the work lies in the development of a method and apparatus for wastewater treatment of textile enterprises with flue gas from a CHP plant. From an economic point of view, the proposed method is most preferred. It does not require the use of sulfuric acid to neutralize alkaline effluents.

Statement of the main material. Recently, in many countries, the question of using as a neutralizing agent for alkaline wastewater, boiler exhaust gas, which is available at each textile mill, has been investigated.

Our proposed method of neutralizing alkaline wastewater with flue gases is carried out in scrubbers [8; 9]. As a result of the absorption of sulfur dioxide and carbon dioxide, which are contained in flue gases, acid is formed, which is necessary to neutralize the alkali. Discoloration of wastewater with ash formed during the combustion of coal occurs as a result of adsorption of colored organic compounds in wastewater by carbon. Fly ash, due to its large surface area and high carbon content (over 40 %), is a good adsorbent.

It should be noted that the appropriateness of using this method of wastewater neutralization is not in doubt.

To study the process of neutralizing wastewater with the waste gases of a CHP, studies were conducted in a laboratory setting. Research was conducted on the basis of natural wastewater and an air mixture containing sulfur dioxide. The task of laboratory research was to study the influence of various physicochemical factors on the process of neutralizing wastewater, identifying the optimal parameters of the neutralization process, and obtaining a mathematical model of the process.

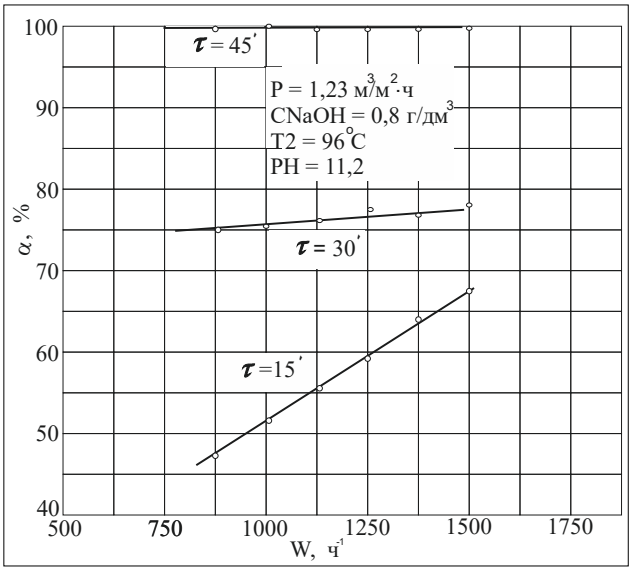


Fig. 1. The effect of the gas volumetric velocity on the degree of neutralization of wastewater.

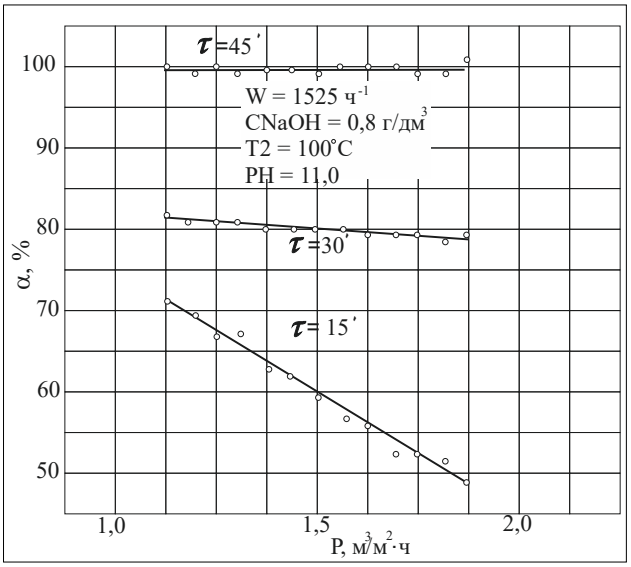
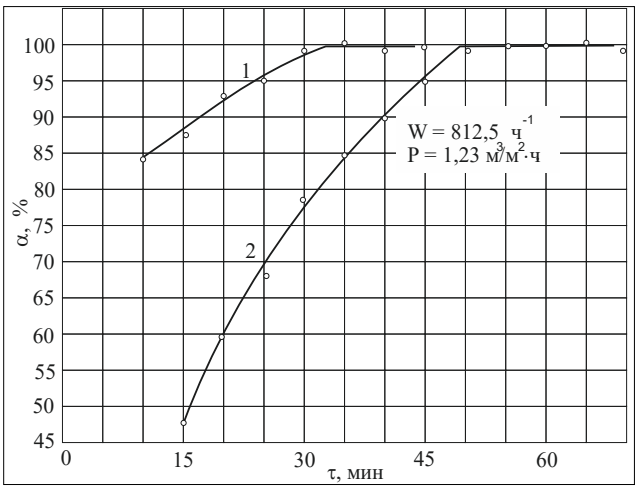
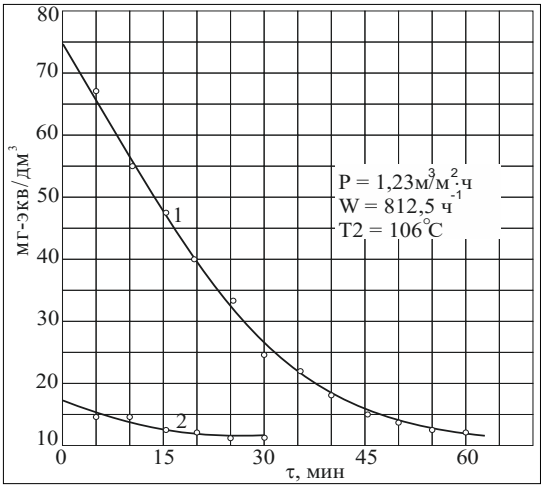


Fig. 2. The effect of irrigation density on the degree of neutralization of wastewater



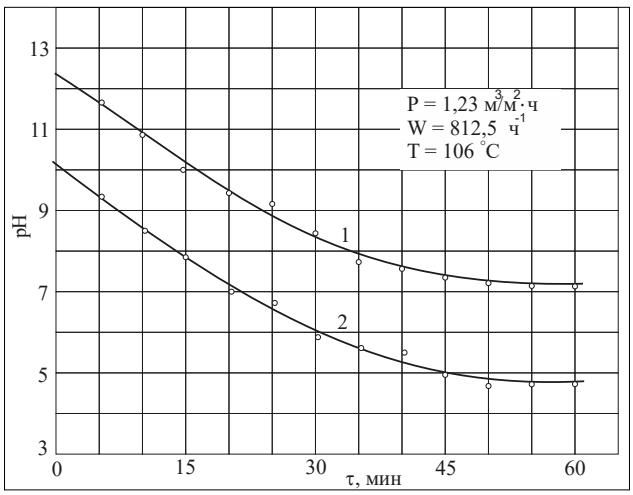
1 – pH = 10,1; 2 – pH = 11,0.

Fig. 3. The influence of the circulation time of the solution on the degree of neutralization



1 – pHinitial = 75 mg·ékv/dm³; 2 – pHinitial = 12,3 mg·ékv/dm³

Fig. 4. The effect of circulation time on the alkalinity of the solution



1 – pHinitial = 12,3; 2 – pHinitial = 10,4

Fig. 5. The effect of circulation time on the pH of the solution

Research in a laboratory setup was carried out by the method of mathematical design of the experiment. The choice of such an experimental technique can significantly reduce the time and material costs of research work. In addition, using mathematical methods for optimal design of an experiment, one can obtain a mathematical model of the process. This makes it possible to judge the degree of influence of various factors on the process under study, quantitatively determine the degree of the process, find the optimal parameters for the process.

In the present work, the method of the full factorial experiment was applied, which makes it possible to obtain a mathematical description of the process under study in a certain local region of the studied parameters.

When the exhaust gases pass through the wastewater, they are neutralized by sulfur dioxide. The neutralization process can be expressed by the following equations:

$$2NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$$
$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4$$

Total alkalinity (or acidity after the neutralization process) was determined by direct testing of the effluent sample (100 ml) with a mixed indicator. The application of this method makes it possible to determine the active pH reaction in a wide range with fairly high accuracy in colored and turbid waters.

Determination of the concentration of sulfur dioxide in the gas mixture before and after the neutralization process was carried out by the iodometric method according to the reaction:

$$SO_2 + 2H_2O + I_2 \rightarrow H_2SO_4 + 2HI$$

On the basis of experimental data, the influence of various factors on the degree of neutralization of wastewater was established.

The main findings. The basic laws of the processes and the conditions of industrial application are determined, the effectiveness of the developed equipment is shown. The research results showed that the proposed method of neutralization fully meets the requirements for the quality of discharged effluents. In addition, a large economic effect is achieved due to the saving of sulfuric acid required to neutralize wastewater with existing methods.

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