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Review of Some Methods of CO_2 Utilization

Abstract

Protecting the environment from harmful substances (carbon oxides, nitrogen oxides, soot products, etc.) is one of the pressing issues of our time. This article discusses specific topics related to the need to reduce carbon dioxide emissions into the atmosphere, which are generated during biomass gasification, Fischer-Tropsch synthesis, and other processes. The article also identifies alternative methods for producing valuable petrochemical products, which significantly reduce gas emissions into the atmosphere.

Keywords: *oil, gas, coal, peat, carbon dioxide*

Introduction

One of the important directions of scientific and technological development is the creation and implementation of new technologies, substances, and materials that ensure resource conservation and meet environmental requirements. In the general concept of "sustainable development of civilization" adopted by the UN, the primary focus is on developing environmentally safe technologies that prevent the release of harmful substances into the atmosphere, utilize existing industrial waste, use non-renewable natural resources rationally, and recycle materials after their service life ends (Gasimova, 2023, p. 153; Kakhramanov, 2022; Gasimova, 2023; Ismayilova, 2024, pp. 25-26).

Research

The extensive use of oil, gas, coal, peat, and other fossil fuels in energy production and manufacturing has led to a deterioration in environmental indicators, particularly the accumulation of greenhouse gases in the atmosphere. It has been calculated that over the last 250 years, carbon dioxide concentration has increased by one-third, and methane by one and a half times (Kreinin, 2010, p. 396; Kalekin, 2012; Kadzhiyev, 2011). The increased use of diesel vehicles has contributed to a rise in the share of nitrogen oxides and soot in exhaust gases.

In 1997, the Kyoto Protocol on reducing greenhouse gas emissions was signed in Kyoto, Japan, to curb global warming. Greenhouse gases (CO_2, methane) absorb infrared rays, potentially leading to an increase in air temperature, glacier melting, and a rise in sea levels (Ilinsky, 2003, pp. 25-26). Forests partially absorb CO_2; however, the amount of carbon dioxide released into the atmosphere has become so large that the "green lungs of the planet" can no longer process it entirely. The main source of CO_2 emissions into the atmosphere is flue gases from various types of energy installations. A single large thermal power plant (TPP) operating on natural gas consumes between 0.5 to 2 million cubic meters of gas per day, leading to CO_2 emissions of 1,000 to 4,000 tons per day. If carbon dioxide in such quantities were used as a raw material for the production of

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hydrocarbons or other petrochemical synthesis products, it would result in a large petrochemical complex producing at least 2 million tons of products per year.

The Kyoto Protocol, which regulates greenhouse gas emission limits, has been extended until 2020. About 200 countries, including 38 industrially developed ones, supported the extension. However, the United States, China, India, Japan, Russia, and Canada (which officially withdrew from the agreement) do not intend to participate in the new commitment period. Therefore, entirely new approaches are needed for environmental protection, as no agreement can stop the accumulation of harmful substances in nature unless specific measures are taken to improve existing technologies and implement more progressive ones (Juang, 2010, pp. 3346-3364; Zasa, 2011).

Let's consider recent developments on carbon dioxide utilization and the development of new methods for integrating it into technological processes for synthesizing important petrochemical products (Patent, No. 2349371, 9304247, 2458005, 2385836, 2036900, 2455048; White, 2004, pp. 4-10).

One method proposed (Patent No. 2478074, 2001) involves the complete utilization of CO_2 produced during underground coal gasification (UCG). In this method, coal gasification is carried out in situ using a series of blast and gas extraction wells in an underground gas generator, and CO_2 is captured from the burning gas mixture in a surface chemical complex. The CO_2 captured in the surface chemical complex is divided into two streams. The first stream is injected into the blast wells of the operating underground gas generator, initiating the endothermic reaction according to the scheme: $CO_2 + C \rightarrow 2CO - 173$ kJ/mol.

This enriches the UCG with carbon monoxide. The second stream of CO_2 is injected into the exhausted gas generator for storage. Injection of CO_2 is stopped when its concentration (in periodically taken samples) reaches 90 %. The UCG gas undergoes sequential preparation for use in the surface complex: cooling, purification, conversion of CO to CO_2 ($CO + H_2O \rightarrow CO_2 + H_2$), H_2S removal, and finally, CO_2 utilization.

The remaining combustible components ($CO_2 + H_2 + CH_4$) are directed to the consumer. This CO_2 utilization method is planned for implementation at an experimental underground gas generator (in Kuzbass).

Known UCG technologies also involve drilling a series of blast and gas extraction wells on a coal seam intended for coal gasification in situ, capturing the gas mixture in a surface chemical complex (Patent No. 2293845, 2007).

A patent (Patent No. 2513947, 2011) describes a method of partial CO_2 utilization based on injecting CO_2 and water into the underground gas generator, allowing for the regulation of UCG gas composition. However, this technology does not fully solve the problem.

In the chemical industry, the so-called "monoethanolamine method" of CO_2 utilization is widely used, based on absorbing CO_2 from gas mixtures according to the reaction: $HO(CH_2)NH_2 + CO_2 \rightarrow HO(CH_2)NHCO(OH)$.

The monoethanolcarbamate obtained by this method is thermally unstable and easily decomposes by the reverse reaction. Therefore, it cannot be used in underground coal gasification.

Technologies have been developed to use carbon dioxide for injection into oil reservoirs to enhance oil recovery. The CO_2 injection method to increase oil recovery is applied in practice.

It should be noted that the requirements for CO_2 injection into hydrocarbon reservoirs to increase oil recovery differ from those for underground storage. In recent years, researchers have focused on not only CO_2 utilization but also its storage. The fact is that the amount of CO_2 needed for reservoir oil recovery constitutes a much smaller part than that injected into underground storage.

A method has been developed for underground CO_2 storage in a porous and permeable hydrocarbon reservoir, which has at least one injection well and at least one production well, and includes the following stages:

1. Extraction of a production fluid stream from the production well, consisting of produced hydrocarbons, water, and CO_2.

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2. Directing the production fluid stream to a processing facility, where a vapor-phase stream containing CO_2 and volatile hydrocarbons is separated.
3. Compressing the vapor-phase stream to a pressure above the maximum at which gas and liquid phases can coexist.
4. Cooling the compressed stream (resulting in a cooled stream in the vapor phase).
5. Directing the incoming CO_2 stream from the feed to the injection equipment (it can be either in liquid phase or supercritical state).
6. Mixing the cooled stream from stage 4 with the incoming CO_2 stream from the feed (forming a single stream).
7. Injecting the combined stream into the hydrocarbon reservoir through the injection well.
   The hydrocarbon reservoir represents a hydrocarbon-bearing geological horizon with an underlying aquifer communicating with the hydrocarbon-bearing geological horizon, and the aforementioned combined stream is injected into the aquifer.

The storage of carbon dioxide, which is formed in large quantities in many chemical processes as a by-product, is also an urgent problem, such as in ammonia production, hydrogen production by hydrocarbon feedstock reforming, and others.

Hydrogen and syngas production has become one of the priorities in modern energy and basic organic synthesis in recent years. Therefore, finding rational ways to produce additional hydrogen is important. Among the alternative methods of hydrogen production, steam catalytic conversion (SCC) of hydrocarbons is currently the most widely used industrial process in the world for oil refining and petrochemistry.

SCC primarily uses natural and plant gases, as well as straight-run gasoline. The process occurs in two stages:

H_2 + 42,4 kJ/ C_nH_m + nH_2O □ □CO + (n+0,5) (1)

m/H_2 - Q1.... (1) CO +H_2O □ □CO_2 + mol (2)

where n and m are the number of carbon and hydrogen atoms, respectively, in the hydrocarbon molecule. The higher the hydrogen content in the raw material, the higher the hydrogen yield. In this regard, methane is the most favorable raw material (hydrogen content in it is 23 %). The source of methane is, as is known, natural gases (CH_4 concentration is 94-95 %). Cheap dry gases from oil refining can also be used for hydrogen production. SCC is a fairly energy-intensive process; the first stage of the process is highly endothermic. The second stage occurs with heat release (in methane conversion, Q=206.7 kJ/mol), and the process can be carried out without a catalyst at temperatures above 1000°C or in the presence of catalysts at 800-900°C.

In modern processes, special attention is given to the processing of natural, associated, and waste gases, as well as biogas. Fedotov and others consider processes conducted on catalytic membranes prepared from Ni(Al) and Co_3O_4 powders in a 1:1 ratio to be promising (Fedotov, 2014, pp. 309-311). They discovered a non-additive increase in the catalytic activity of these systems during the dry reforming of methane compared to the sum of the activities of Ni- and Co-containing membranes. It was established that the specific productivity of synthesis gas from the bimetallic sample reaches 85,000 L/h·dm³, exceeding similar performance for membranes with other nickel-cobalt component ratios. The dry reforming process is carried out on a membrane-catalytic setup in a flow reactor at temperatures ranging from 400 to 800°C with a CH_4 $_2$ ratio of 1:1. The feed rate varies from 20 to 750 L/h (Fedotov, 2014, pp. 339-340). The pressure at the membrane inlet is 1.1 atm, and 1 atm at the outlet. The high selectivity of the developed catalytic system is attributed by the authors to the nano-sized Ni-Co alloy particles found in the membrane structure, formed on the surface of γ-Al_2O_3 .

Nickel-cobalt-containing catalysts were also used in high-selectivity gasification processes of carbon dioxide from biomass fermentation products under the guidance of Academician I.I.Moiseyev (Moiseyev, 2001, pp. 5-10).

Biomass gasification is seen as an important method for linking biomass carbon with products of basic organic synthesis. The hydrocarbon components of biomass are thermally unstable and degrade under relatively mild conditions.

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The main thermolysis routes include carbon-releasing reactions:

$C_6H_{12}O_6 \rightarrow 3CO_2 + 6H_2 + 3C$ (1)

Stoichiometrically, thermolysis with the formation of synthesis gas according to the following scheme is also possible:

$C_6H_{12}O_6 \rightarrow 6CO + 6H_2$ (2)

In a study, a two-stage gasification scheme was first proposed, allowing for the production of synthesis gas from any fermentable carbohydrate biomass. In the first stage, the raw material undergoes fermentation: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (3)

In the second stage, the alcohol and the resulting carbon dioxide undergo catalytic reforming to produce synthesis gas: $C_2H_5OH + CO_2 \rightarrow 3CO + 3H_2$ (4)

During fermentation processes, by-products (such as fusel alcohols, i.e., higher molecular weight alcohols) are also formed. It has been established that these products can be used to obtain energy carriers through carbon dioxide reforming using ceramic nickel-cobalt porous membrane catalysts. Samples of porous ceramic membranes were prepared by the method of self-propagating synthesis. Precursors included Ni metal powders, 5 % Al metal, and mixtures of Ni metal containing aluminum and cobalt oxide (Co_3O_4). Materials with various Ni and Co contents (with ratios of 19, 4, and 1) were obtained. It was found that complete ethanol conversion (according to reaction 4) on all membranes was achieved at 400°C, while on a granular catalyst of identical composition, methane formation from ethanol was observed at 700°C. Further temperature increases led to a decrease in methane content, likely due to the enhancement of endothermic reactions of its transformations according to the following schemes:

$CH_4 \leftrightarrow 2H_2 + C$ $CO_2 + C \leftrightarrow 2CO$

$CH_4 + H_2O \rightarrow CO + 3H_2$

In the temperature range of 300-400°C, the formation of hydrogen, acetaldehyde, and methane was observed:

$C_2H_5OH \rightarrow CH_3CHO + H_2O$

$CH_3CHO \rightarrow CH_4 + CO$

With an increase in temperature to 420-430°C, the acetaldehyde concentration decreases, with the intensive formation of CO and CH_4 .

Thus, these studies have demonstrated the importance of using effective catalytic systems in biomass thermolysis processes to increase technically important raw material resources. At the same time, it is necessary to consider potential reactions that could lead to CO_2 formation outside of a closed cycle.

To maintain ecological balance, the limiting stage of the global CO_2 cycle should be its formation rather than its consumption. Due to extensive industrialization and human activities, especially in recent years, the dynamics of CO_2 utilization have lagged behind its usage (as building blocks in the synthesis of various organic compounds). Various methods for chemical utilization of CO_2 have been proposed (Rozovsky, 1980). For instance, a process for obtaining CH_4 and O_2 by reacting CO_2 with water vapor in the presence of Ni, Co, or Rh-based catalysts has been developed:

$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$

This process takes place at high temperatures in the presence of rare catalysts. Carbon dioxide and ammonia can also be used to synthesize urea. The process is carried out at high pressure (approximately 200 kg/cm³) at a temperature 40°C lower than in the main reactor. This technology is complex and requires special equipment.

A method for utilizing carbon dioxide in closed systems and industry has also been described. The method involves passing a gas or gas mixture through a substance with the empirical formula $(a \cdot CaO) \cdot (b \cdot V_2O_5) \cdot (c \cdot M_2O) \cdot (d \cdot MO) \cdot (e \cdot M_2O_3) \cdot (f \cdot MO_2) \cdot (g \cdot M_2O_5)$ (where M is a metal, and a, b, c, d, e, f, g are molar fractions, with a as (2-4):1) activated by radiation with a wavelength of 370 nm at 250-800°C. The reaction completeness is 98-100 %. However, this method is not sufficiently effective due to the complex CO_2 utilization system, which includes radiation use and high temperature conditions.

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A new method for CO_2 utilization has been proposed, which could find applications in the chemical industry. This method uses trifluoroacetic acid (TFA) saturated with oxygen (TFA-O_2). CO_2 is passed through a container filled with TFA-O_2 at a temperature of 10-25°C and atmospheric pressure, forming a resin-like product – a mixture of products with the formula (C_4 H_7 O_9)n, where n ranges from 2 to 9. The breakthrough point of CO_2 through the first container is recorded, after which it is fed into a second container filled with a fresh portion of TFA-O_2 . The spent TFA is sent for regeneration, which involves its saturation with a new portion of oxygen, after which TFA-O_2 is reused in the process.

The authors of this development, Vishnevskaya M. V., Ivanova M. S., and others, propose using the resulting hydrocarbon mixture as an octane-enhancing additive to motor fuel. The use of 1-2 % by mass (of the base gasoline) allows for an increase in octane number by 10-12 points (according to the research method). It is noted that this additive improves fuel stability, reduces losses during storage and transportation, improves fuel cleaning properties, removes deposits in the engine's intake system, and reduces the amount of toxic substances in the exhaust gases. The CO_2 utilization rate is approximately 100 %.

The developed process is simple, carried out at low temperatures and atmospheric pressure. However, TFA used in the oxidation process is a toxic substance. Trifluoroacetic acid was also used by E. G. Chepaikin, A. P. Bezruchenko (2010), and others in the catalytic oxidation reaction of natural gas and associated oil gas to develop single-stage methods for obtaining basic oxygenated products. In oxidative functionalization of C1-C4 alkanes under the influence of O_2 and CO, catalytic systems consisting of Rh, Pd, and Pt halides and copper compounds were used (Chepaikin, 2002). The reaction was carried out in aqueous trifluoroacetic acid according to the following schemes:

$CH_4 + CO + O_2 \rightarrow CH_3OH + CO_2$

$CH_4 + CO + O_2 \rightarrow CH_3COOH + CO_2$

$CH_4 + 2CO + 52O_2 \rightarrow HCOOH + 2CO_2 + H_2O$

It was found that the oxidation of alkanes proceeds not only through C-H bonds but also through C-C bond cleavage. The problem of direct oxidation of alkanes in the presence of metal complex catalysts is associated with the activation of C-H bonds and molecular oxygen (Chepaikin, 2006). E.P. Chepaikin and others studied the mechanism of action of the Rh- and Pd-containing catalysts they developed in the oxidation reactions of lower alkanes. The authors found that catalytic systems effectively operate in aqueous trifluoroacetic acid. To convert oxygen into an active state, a reductant (carbon monoxide) is introduced, and co-catalysts (iodine, iron, copper compounds) are used. In catalysis with rhodium or palladium complexes, co-catalysts are reduced by carbon monoxide to a low-valent state, in which they can interact with oxygen. Attempts were made to replace the corrosive and toxic trifluoroacetic acid with less toxic solvents (tetrahydrofuran, acetonitrile, or ionic liquids), but replacement was unsuccessful; the activity of the catalysts decreased (Chepaikin, 2014).

The method for utilizing carbon dioxide in an aquifer was developed by A. A. Barenbaum, S.N.Zakirov, and others (Patent No. 2514076, 2014). For this purpose, a subsurface aquifer is selected, preferably one that has an outlet to the Earth's surface and a recharge area in the form of a river, sea, lake, and a generally active filtration regime. At least one local trap is identified, and the selected aquifer and local trap are prepared for industrial use by determining the chemical composition of the water in the aquifer, as well as the composition of the rocks through core samples. The rocks are selected to contain compounds of iron group metals (Fe, Ni, Co, Mo, SiO_2, Al_2O_3), as well as clays and zeolites. These act as catalysts in the polycondensation synthesis of hydrocarbons, as well as hydrogen and oxygen from CO_2 and water. This method can be applied to depleted oil and gas fields to form new deposits (Patent No. 2036900, 2011).

In, processes for the formation of CO_2 and water during the purification of gases from harmful impurities are considered, which involve the decomposition of gases into corresponding products and their subsequent oxidation by oxygen in the high-frequency discharge zone. The decomposition scheme, for example, of polyurethane foam and the subsequent oxidation of the resulting products in the discharge zone can be represented as follows:

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$CH_3C_6H_3(NH_2)_2 \rightarrow 7C+10H+2N \rightarrow C+H+N_2$ (1)

$2O_2 \rightarrow O+O_3$ (2)

$C+H+N_2+O+O_3 \rightarrow N_2+CO_2+H_2O$ (3)

Thermodynamic calculations of these processes have been made, but no information is provided on what to do with the CO_2 (even the authors note the "harmless" formation of carbon dioxide and water).

The method of separating exhaust gas or smoke formed during fuel oxidation, as well as isolating carbon dioxide from it, is described in patent (Patent No. 2458005, 2012). The flow of exhaust gases is passed through a gas-permeable material, which consists of molecular sieves or activated carbon, then the gas flow containing high-concentration carbon dioxide is separated. The gas with lower carbon dioxide content is released into the atmosphere, while the high-concentration carbon dioxide is used in installations for the production of ammonia, urea, or methanol.

Patent describes a method for extracting CO_2 from flue gases and an installation for this purpose (Patent No. 2513947, 2011). The installation includes a CO_2 adsorbent into which flue gases containing CO_2 are introduced. The CO_2 is contacted with the adsorbent, where it is separated from the flue gases. The installation for extracting CO_2 includes a combustion catalyst (based on metallic Pd or metallic Pt). CO_2 in the enriched solution (absorbed CO_2) is removed in the regenerator, and the depleted solution is reused separately in the CO_2 absorber.

Work related to the possibility of converting CO_2 into valuable chemical products was conducted as early as the 1970s (Yan Yu, 1976, p. 264; Brednikov, 1975, p. 2588). PdCl2-Ni-graphite, Co-Zr, Zn-Cr, Cu-Zn-containing catalysts were used. To obtain the target products, harsh conditions were required: high temperatures and pressures. The authors of aimed to soften the conditions for syntheses based on CO_2. Using a raw material mixture consisting of (mass %): hydrogen – 35, nitrogen – 46, methane – 6, and impurities CO and CO_2 ~13, and industrial catalysts (alumina-cobalt-molybdenum, zinc-chromium, nickel on kieselguhr), they conducted the reaction of CO_2 with H_2 on a flow laboratory unit. The temperature was varied from 200-230°C, the H_2 ratio was (1-3):1 mole, and the pressure was atmospheric. It was found that at a temperature of 200-230°C and a gas flow rate of 120 h^-1, it is possible to achieve almost complete conversion of carbon oxides to methane (at a molar ratio of hydrogen to carbon oxides of: 1). According to the authors, by excluding the separation and purification unit for the products from the technical scheme, as well as recycling the unreacted hydrogen, the entire resulting mixture can be used as a secondary fuel (methane-hydrogen mixture). The use of an industrial nickel on kieselguhr catalyst allows the conversion of CO_2 to methane under relatively mild conditions: temperature 200-250°C and atmospheric pressure. Non-adsorbed gases from hydrocarbon dehydrogenation processes can be used as a source of hydrogen.

As is known, the basis of a number of alternative methods for producing various hydrocarbons from natural and associated gases, coal, peat, oil shale, and biomass is the Fischer-Tropsch synthesis. Interest in this process remains relevant, as it can solve numerous environmental problems associated with reducing gas emissions into the atmosphere while synthesizing valuable products. The Fischer-Tropsch synthesis of hydrocarbons from carbon monoxide and hydrogen is the second stage of most processes for converting alternative raw materials into synthetic oil and motor fuels. For all processing complexes, it is the most important. In recent years, systematic research has been conducted on Fischer-Tropsch synthesis under the leadership of Academician S. N. Khadzhiev at the Institute of Petrochemical Synthesis of the Russian Academy of Sciences. Various catalytic systems based on transition metals of group VIII have been studied. It was found that in the presence of these catalysts, synthesis gas at atmospheric pressure is mainly converted to methane (Khadzhiev, 2011, pp. 25-32).

Fischer-Tropsch syntheses were carried out on nanoscale particles of an iron-containing catalyst (Patent No. 2485048, 2013). It was shown that the main byproduct in Fischer-Tropsch synthesis (with the use of an iron-containing catalyst) is carbon dioxide, which leads to a significant reduction in the yield of synthetic oil (based on the starting product in alternative raw materials (Khadzhiev, 2011, pp. 84-96). Carbon dioxide can be either a primary or a secondary product in these syntheses.

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It is noted that in the first case, the formation of CO_2 occurs as a result of the interaction of CO with surface oxygen formed during the dissociative adsorption of carbon monoxide on the catalyst surface. The carbon from dissociative adsorbed CO participates in the growth of the hydrocarbon chain. The formation of CO_2 as a secondary product occurs during the interaction of CO and water, the primary product of the synthesis. Thus, it is evident from the presented material that by conducting targeted syntheses, the desired result can be achieved and environmental performance improved.

Conclusion

Climate change and environmental protection issues are among the most urgent issues in modern times. In this regard, the disposal of CO_2 for the purpose of air purification is important. From the point of view of the development of science and technology, it is important to carry out research and studies in these directions.

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Physysichemical Properties of Quaternary Ammonium Salts Formed by Undecanoic and Tetradecanoic Acids with Trietanolamine

Abstract

The article presents the results of the study of the oil collecting and oil dispersing properties of the quaternary ammonium salts formed by undecanoic and tetradecanoic acids, which are monobasic carboxylic acids, with triethanolamine (TEA) in distilled, drinking, and sea waters contaminated with Balakhani Oil. The surface activity property of the products of different concentrations of these complexes was calculated using a tensiometer, and the elemental composition was calculated using the calculation method. A comparative study of the element composition of the salts of both acids formed with TEA shows that the mass fraction of carbon in the complex formed by tetradecanoic acid with TEA is higher than in the other complex.

Comparison of the surface activity property of the complexes formed by undecane and tetradecanoic acid with TEA shows that the complex compound formed by tetradecanoic acid with TEA shows more surface activity property.

Therefore, as the mass fraction of carbon element increases in the complexes formed by undecane and tetradecanoic acid with TEA, the complex compound shows more surface activity properties.

Keywords: *carbonic acid, oil accumulation, oil dispersion, surface tension, surfactant*

Introduction

Currently, removal of oil and oil products from the water surface remains an actual problem. Oil spills spilled into water can be removed by mechanical, thermal, physico-chemical and biological methods. The most ecologically safe way to remove small thicknesses of spilled oil is to use oil collecting and oil dispersing reagents based on various surfactants (Asadov et al., 2017a; Asadov et al., 2011a; Asadov et al., 2017b). The study of surfactants has been the focus of attention in the beginning.

Surfactants are also used as demulsifier (Abdelrahman et al., 2023, p. 3162). The demulsifier's emulsion breaking mechanism is very complex (Al-Yaari et al., 2015, pp. 54-61).

Methodology of the Experiment

Undecanoic acid is a monobasic saturated carbonic acid with the formula $C_{10}H_{21}COOH$, well soluble in methanol, ethanol, acetone, chloroform, molar mass 186.3 g/mol, melting point 28-30.5°C, boiling point 284°C in the form of a white powder at room temperature.

Tetradecanoic acid is a monobasic saturated carbonic acid with formula $C_{13}H_{27}COOH$, molar mass 228.4 g/mol, melting point 58.8°C, boiling point 326.2°C in the form of a white powder at room temperature. Triethanolamine (TEA) is a colorless, transparent, ammonia-smelling liquid with a molar mass of 149.19 /mol-1, a density of 1.124 g/ml-1, a solidification point of 22°C, a boiling point of 335°C, and a refractive index of 1.4850 (20°C).

IR-spectra of salts of undecanoic and tetradecanoic acids formed with TEA were recorded on FT-IR, Spectrum BX and ALPHA (Bruker) spectrometers using a KBr disk.

The surface activity of substances was determined at the air-water interface using a KSV Sigma 702 (Finland) tensiometer using a Du Nui ring.

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Conduct of Research

The reaction between undecanoic acid and TEA was carried out in laboratory conditions in a 1:1 mol ratio at 34 °C for 3-4 hours with intensive stirring.

The general scheme of reactions can be shown as follows:

$C_{10}H_{21}COOH + N(C_2H_4OH)_3 \rightarrow [C_{10}H_{21}COO^- N^+ H(C_2H_4OH)_3]$

The reaction between tetradecanoic acid and TEA was carried out in laboratory conditions in a 1:1 mol ratio at 60 °C for 3-4 hours with intensive stirring.

The general scheme of reactions can be shown as follows:

$C_{13}H_{27}COOH + N(C_2H_4OH)_3 \rightarrow [C_{13}H_{27}COO^- N^+ H(C_2H_4OH)_3]$

The relative molecular mass of salts of undecanoic and tetradecanoic acids based on TEA is 335.5 and 377.6 g/mol, respectively. The salts formed by both acids with TEA are well soluble in ethyl and isopropyl alcohol. Based on the calculation, the element composition of the salts formed by octane and nonanoic acid with TEA was calculated. In the salts formed by undecanoic and tetradecanoic acids with TEA, the mass fraction of carbon is 60.9 % and 63.6 %, the mass fraction of hydrogen is 11.2 % and 11.5 %, the mass fraction of oxygen is 23.4 % and 21.1 %, and the mass fraction of nitrogen is 4.5 % and 3.8 %, respectively.

A comparative study of the element composition of the salts of undecanoic and tetradecanoic acids formed with TEA shows that the mass fraction of carbon in the complex formed by tetradecanoic acid with TEA is higher than in the other complex.

Results and their Discussion

The study of oil-collecting and oil-dispersing properties of surfactants has been the focus of various scientists (Asadov et al., 2011b, pp. 1012–1017; Asadov et al., 2010, pp. 327–331; Asadov et al., 2017c, pp. 3297–3305; Asadov et al., 2018, pp. 247–254; Asadov et al., 2017d, p. 244, pp. 533–539).

Taking this into account, the oil collecting and oil dispersing properties of the synthesized new complexes were studied in laboratory conditions.

The surface activity property of the complex formed by undecane and tetradecane acid with TEA was determined using a tensiometer at the water-air interface at a temperature of 21°C (Table 1).

Table 1.
Surface Activity Properties of the Complex Formed by Undecane and Tetradecane Acid with TEA at the Water-Air Interface (21°C)

Item name	Density of SAM (% by mass)											
	0.00025	0.0005	0.00075	0.001	0.0025	0.005	0.0075	0.01	0.025	0.05	0.075	0.1
	Values of surface tension at the air-water boundary, $mN \cdot m^{-1}$											
Undecanoic Acid + TEA	48.4	39.5	35.8	33.1	28.6	26.8	25.8	25.2	23.6	23.1	23.2	23.0
Tetradecanoic Acid + TEA	45.9	43.3	40.1	37.5	33.6	31.9	30.6	29.9	28.2	28.8	28.4	28.7

The complex formed by undecanoic acid with TEA shows high surface activity by reducing the surface tension from 71.98 mN/m to 23 mN/m at that boundary.

The complex formed by tetradecanoic acid with TEA shows high surface activity by reducing the surface tension from 71.98 mN/m to 28.7 mN/m at that boundary.

A comparison of the surface activity property of the salts formed by undecane and tetradecanoic acid with TEA shows that the complex compound formed by tetradecanoic acid with TEA shows more surface activity property.

The salts formed by undecanoic and tetradecanoic acids with TEA were studied as an oil collecting and oil dispersing agent in cleaning the water surface clouded with an oil layer with a

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thickness of 0.17 nm. The effectiveness of this reagent was studied in the laboratory on waters with different degrees of mineralization using the Balakhani light oil sample. The reagent was used both in its pure form and in the form of a 5 % aqueous solution. The reduction of the area of the initial oil layer due to the penetration of the reagent into oil-contaminated waters determines its effectiveness. The oil accumulation coefficient is a quantity that characterizes this effect. K is calculated as the ratio of the initial area of the oil layer to the area of the oil spot formed by the effect of the reagent.

Table 2.
Research results of the oil collection and oil dispersing ability of the TEA complex of undecanoic acid (Balakhani Oil; thickness 0.17 mm)

The case of giving the reagent to the surface of the oil	Distilled water		Drinkable water		Sea water	
	τ, hour	K (K_D, %)	τ, hour	K (K_D, %)	τ, hour	K (K_D, %)
Undiluted Product	0-24 48-72 72-96	15.1 8.7 12.2	0-24 48-72 72-96	10.3 8.7 7.6	0-24 48-72 72-96	Dispersed
5 % Aqueous Dispersion	0-24 48-72 72-96	15.2 2.6 2.5	0-24 48-72 72-96	12.2 3.5 Dispersed	0-24 48-72 72-96	17.3 15.2 11.1

Table 3.
Research results of the oil collection and oil dispersing ability of the TEA complex of tetradecanoic acid (Balakhani oil; thickness 0.17 mm)

The case of giving the reagent to the surface of the oil	Distilled water		Drinkable water		Sea water	
	τ, hour	K (K_D, %)	τ, hour	K (K_D, %)	τ, hour	K (K_D, %)
Undiluted product	0-24 48-72 72-96	Dispersed	0-24 48-72 72-96	3.9 7.5 7.5	0-24 48-72 72-96	7.5 8.6 6.1
5 % aqueous dispersion	0-24 48-72 72-96	12.2 7.6 6.7	0-24 48-72 72-96	Dispersed	0-24 48-72 72-96	8.7 7.5 6.7

As can be seen from Table 3, the complex of Undecanoic acid and TEA exhibits the ability to accumulate oil in seawater for the 5 % application forms of the reagent.

Conclusion

Based on the results of the study, quaternary ammonium salts formed by undecanoic and tetradecanoic acids with TEA show high surface-activity properties, similar to quaternary ammonium salts formed by TEA of other higher carboxylic acids (Shahverdiyeva, 2024, pp. 21-25; Shahverdiyeva & Salamova, 2024, pp. 34-38).

Solutions of new complexes of undecanoic and tetradecanoic acids synthesized on the basis of TEA in different concentrations have oil-dispersing and oil-collecting properties.

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Investigation of the Properties of Unsaturated Allyl Alcohol and its Oxidation Reaction Products

Abstract

Organic substances in which the -OH group is directly attached to the carbon atom are called alcohols. Unsaturated alcohols are obtained by replacing the hydrogen of ethylene or acetylene-type compounds with a hydroxyl group. Allyl alcohol, the first representative of the class of unsaturated alcohols, contains oxygen. Allyl alcohol is used in optical resins, protective glasses, paints and coatings and polymer cross-linking agents, as well as in the production of pharmaceuticals, organic chemicals, plastics, herbicides, and pesticides. In organic chemistry, alcohols can be oxidized to aldehydes, ketones, carboxylic acids, and esters that carry a higher oxidation state of carbon. Therefore, the selective oxidation of alcohols is an important issue. The properties and selective oxidation reaction of allyl alcohol were investigated in the presented work.

Keywords: *unsaturated alcohols, allyl, properties, selective oxidation, acrylic acid*

Introduction

Alcohols are organic substances in which the -OH group is directly attached to a carbon atom. According to the nature of the hydrocarbon radical, they are classified into saturated, unsaturated and aromatic alcohols.

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Research

Organic compounds consisting of one or more hydroxyl groups combined with a radical of saturated hydrocarbons in the molecule are called saturated alcohols (Dashdamirov, 2017). Unsaturated alcohols are obtained by replacing the hydrogen of ethylene or acetylene-type compounds with a hydroxyl group. Esters of vinyl alcohols are very valuable raw materials in polymer chemistr (Selda, 2003). For example; Allyl alcohol (CH_2=CH-CH_2OH), a foul-smelling liquid contained in garlic, is used in the production of ether synthetic resin with phthalic acid. In nature, unsaturated alcohols with higher carbon numbers are found in vegetable oils. These are called isoprene-type compounds. Because they exist as dimers, trimers and tetramers of isoprene (Selda, 2003).

According to the number of hydroxyl group (OH), saturated alcohols are monoatomic ($C_nH_{2n+1}OH$), diatomic ($C_nH_{2n}(OH)_2$), triatomic ($C_nH_{2n-1}(OH)_3$) and so on. The polarity of the hydroxyl group and its hydrogen bond formation is an important physical property of alcohols. As a result, they dissolve well in water by boiling at high temperatures (Dashdamirov, 2017).

Unsaturated Alcohol Allyl, its Preparation and Properties

Allyl alcohol, the first representative of the class of unsaturated alcohols, contains oxygen. Allyl alcohol can also be called Vinylcarbinol, 2-Propenyl alcohol, 3-Hydroxypropene, 2-Propenol, allylic alcohol, 1-Propen-3-ol, Propenyl alcohol. It is a colorless liquid with a pungent, mustard-like odor. It is soluble in water as well as in many organic solvents. It is miscible with water in all proportions and forms an azeotropic mixture (28.3 % H_2O) and its chemical structure is CH_2CHCH_2OH. It is very toxic and dangerous for the environment. It is a transparent liquid with a molecular mass of 58.1, a melting point of-129°C and a boiling point of 97°C. Allyl alcohol can be obtained by the following methods.

1. From the hydrolysis of allyl chloride.
2. From the isomerization of propylene oxide.
3. From the dehydrogenation of propanol-1.
4. From the reaction of glycerin with formic acid.
5. From the oxoacylation of propylene to allylacetate.

Despite environmental concerns, allyl alcohol is an important organic intermediate in the synthesis of polymeric compounds produced industrially from petroleum-derived propylene. It is an industrially important olefinic alcohol, it can be used as a raw material or precursor for many chemicals. It is raw material for the synthesis of various allylic derivatives like allyl diglycol carbonate, allyl glycidyl ether, 1,4-butanediol, polystyrene-allyl alcohol, etc. When allyl alcohol is treated with concentrated HCl at 100^0C in the presence of $ZnCl_2$ or at 200^0C in the presence of $CuCl_2$, it turns into allyl chloride, and when passed over Al_2O_3 at 200-300^0C, diallyl ether is obtained. Simple and complex esters are easily obtained from allyl alcohol. The conversion of allyl alcohol to acrolein occurs by alcohol dehydrogenase. Allyl alcohol is used in optical resins, protective glasses, paints and coatings, silane coupling agents, and polymer cross-linking agents. It is also used in the production of pharmaceuticals, organic chemicals, plastics, herbicides and pesticides. Before handling allyl alcohol, workers should be trained in proper safe handling and storage procedures (Shashkova, Mezhuev, & Tsatsakis, 2024; Aliahmadi, Kharat, & Janczak, 2024; Sawant & Mehendale, 2005).

Oxidation of Allyl Alcohol

In recent decades, a number of reagents and methods have been developed for the oxidation of alcohols to carbonyl compounds. In organic chemistry, alcohols can be oxidized to aldehydes, ketones, carboxylic acids, and esters that carry a higher oxidation state of carbon.

Oxidation of Allyl Alcohol to Acrolein: $C_3H_5OH+[O]\rightarrow C_3H_4O+H_2O$

The subsequent oxidation of acrolein (C_3H_4O) leads to the formation of acrylic acid ($C_3H_4O_2$).

Oxidation of Acrolein to Acrylic Acid: $C_3H_4O+[O]\rightarrow C_3H_4O_2$

Overall Reaction Sequence: $C_3H_5OH+2[O]\rightarrow C_3H_4O_2+H_2O$

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Recent experimental and theoretical studies have been presented on the mechanisms of formation of oxygen-containing active sites on the silver surface and their participation in the oxidation of alcohols to carbonyl compounds, as well as in the conversion to new Ag-containing catalytic composites (Vodyankina, 2022).

The move towards the production of more sustainable and greener chemicals requires the development of new synthetic materials and processes that offer enhanced atom economy and energy efficiency. In this regard, the oxidation of the corresponding alcohol derivatives, which offers a low temperature, cost-effective and clean approach, has wide applications in the agrochemical, fragrance/flavor and pharmaceutical sectors, as the green synthesis of allyl aldehydes, an important class of multifunctional chemical intermediates, has been the focus of intensive academic and commercial research due to its selectivity. Using highly organized mesoporous alumina produced by Evaporation-induced self-assembly (EISA) synthesis as a support for Pd nanoparticles Atom-efficient, aerobic oxidation of allyl alcohols to aldehydes/ketones under mild reaction conditions gives active and highly selective catalysts (Parlett et al., 2013).

Allyl alcohol molecularly adsorbs and desorbs from the pure Au(111) surface without undergoing any chemical transformation. Oxidation of allyl alcohol to acrolein occurs on oxygen-covered Au(111) surfaces via a mechanism similar to that proposed for other alcohol species over gold catalysts: dehydrogenation of the hydroxyl hydrogen to form alkoxide on the surface, followed by α-dehydrogenation of the alkoxide to selectively form the aldehyde product. The oxidation of allyl alcohol to acrolein occurs via three distinct reaction pathways on the Au(111) surface, dictated by the relative populations of atomic oxygen and hydroxyl species on the surface. Similar results were not observed in the TPD (Utilizing temperature-programmed desorption) spectra for the oxidation of simple alcohols on the Au(111) surface, which may indicate that allyl alcohols and simple alcohols react differently with the presence of different pores on the surface or that aldehydes are formed on the surface during oxidation (Mullen et al., 2014). It was studied that E- and Z-allylic alcohols (E- and Z-allylic) become stereoconvergent to E-a,b − unsaturated aldehydes (Könning et al., 2014).

The kinetics of oxidation of allyl alcohol with quinaldinium chlorochromate is studied in 40 % acetic acid – water (v/v) medium. According to the concentration of oxidizing and hydrogen ions, the order is one. It is fractional according to the substrate. Increasing the ionic strength has little effect on the rate of the reaction. The reaction does not lead to the polymerization of acrylonitrile (Sekar & Palanivel, 2012).

In the presence of copper (I) chloride, tert-butyl 1-hydroxy-2-methyl-6-trifluoromethyl-1H-indole-3-carboxylate acted as a catalyst for the chemoselective aerobic oxidation of allyl and benzyl alcohols. Various primary and secondary allyl and benzyl alcohols were oxidized to the corresponding a,b − unsaturated carbonyl compounds in good yield without affecting non-allylic alcohols (Shen et al., 2012).

Selective oxidation is very important in synthesis. Here, we reported a Pd-catalyzed method to selectively oxidize allylic alcohols to enones and enals at room temperature. 27 compounds, including enones and enals, were obtained in moderate to excellent yields (Zhang, Li, & Gao, 2022).

Acrylic acid, an important chemical with various downstream applications, is currently produced from petroleum. A new way of producing acrylic acid using a more sustainable and environmentally friendly method, especially starting from biomass-derived glycerol, is being actively pursued. In this study, the selective oxidation of allyl alcohol to acrylic acid, which can be obtained from glycerol with >99 % efficiency without a catalyst, using only water, allyl alcohol, and a catalyst under pressurized oxygen conditions was investigated. Among various metal catalysts, Pd showed the highest activity for acrylic acid production. Oxidation, hydration and hydrogenation pathways were observed simultaneously. When Pd nanoparticle catalysts were used, the starch-coated catalyst produced less hydrogenated propanal and propionic acid species with high yields for acrylic acid. The effect of reaction temperature, oxygen pressure, amount of reactant and catalyst was evaluated (Kim & Lee, 2017).

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Conclusion

Despite environmental concerns, allyl alcohol is an important organic intermediate in the synthesis of polymeric compounds produced industrially from petroleum-derived propylene. At the same time, acrylic acid, which is a product of selective oxidation, is one of the most important monomers in the industry. Acrylic acid and its complex esters are used in the production of acrylic fibers, lacquer coatings, glues, paints, textile auxiliary materials, paper and leather industry. It is used in the production of plastic masses, coating materials, varnishes, copolymers with various monomers, typographic colors, acrylic rubbers, fibers, water-soluble polymers, glues, as well as in the preparation of coatings for the preservation of soil structure in agriculture and preparation of coatings for the storage of medicinal preparations in medicine. Thus, the process of selective oxidation of allyl alcohol for the production of acrylic acid is one of the most important issues.

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Ecological State and Characteristics of *Charadriiformes*, *Ciconiiformes*, and *Gruiformes* on the Southern Coast of the Caspian Sea

Abstract

The paper contains information about the current state of habitats of species of the orders *Charadriiformes, Ciconiiformes,* and *Gruiformes* found in the southern coastal part of the Caspian Sea, the influence of anthropogenic factors on their habitability, and the status of species included in international conventions. It was revealed that, 24 species found in the southern coastal part of the Caspian Sea have the status of global protection. Of the 154 species with European conservation status, only 48 are eligible for higher global conservation statuses. That is, 3 species are in crisis, 13 species are endangered and 29 species are vulnerable. The number of 2 species is unknown, and there is no sufficient information about 1 species.

Keywords: *Charadriiformes, Ciconiiformes, Gruiformes, Caspian Sea, habitability, anthropogenic factors*

Introduction

The studies were carried out on the Southern coast of the Azerbaijan sector of the Caspian Sea (Shahdili-Astara) in the spring, autumn and winter periods of 2018-2019. The current state of habitats of species of the orders *Charadriiformes, Ciconiiformes, Gruiformes,* the influence of anthropogenic factors on their habitability and the status of species included in international conventions were studied.

The main purpose of the work was to identify species that have international status, to study anthropogenic factors affecting their abundance, distribution and habitats, and to develop a scientifically based system of measures for their protection.

Research

Due to the change (rise and fall) of the level of the Caspian Sea over the past 50 years and the increased influence of anthropogenic factors on the coastline (more over the past 20 years), species from the orders *Charadriiformes, Ciconiiformes, Gruiformes* inhabiting and arriving for wintering on the southern coast of the Caspian Sea (Shahdili-Astara: indicated on the map) face the threat of

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loss of their habitats. This, in turn, has a serious impact on the population dynamics and status of a number of species (Babayev, 2002).

It was established that the status of the Eurasian Spoonbill (*Platalea leucorodia* Linn, 1758), Corn Crake (*Crex crex* Linn, 1758), Collared Pratincole (*Glareola pratincola* Linn, 1766), Common Snipe (*Gallinago gallinago* Linn, 1758) inhabiting the Southern coast of the Azerbaijan sector of the Caspian Sea are near threated (NT), the Sociable Plover (*Chettusia gregaria* (Pallas, 1771) and Slender-billed Curlew (*Numenius tenuirostris* Vieillot, 1817) are critically endangered (CR).

The main negative anthropogenic factors affecting the habitats and distribution patterns of these species are intensive construction work by private companies and individuals in biotopes inhabited by species (Gasimov, 2004).

As a result of hunting and using the habitats of species of the orders *Charadriiformes, Ciconiiformes, Gruiformes* for human economic activity throughout the world, including in Azerbaijan, the number of species included in these groups has significantly decreased. In addition to hunting and aesthetic value, the species belonging to these groups play an important role in the circulation of substances and the transformation of energy in nature. In addition to the above, species belonging to the orders *Charadriiformes, Ciconiiformes, Gruiformes* are also important as biological indicators of wetland biotopes. Therefore, the preservation of the integrity of biological diversity requires the study of each species of birds.

Material and Methods

The studies were carried out during the period between 2017-2020 on the coast of the Southern part of the Azerbaijan sector of the Caspian Sea. It took 178 days to collect material in the field. The material was collected in the Absheron, Gobustan, South-Eastern Shirvan, Salyan, Lankaran coastal waters of the Caspian Sea, in the Gizilaghaj State Nature Reserve, in the Lesser Gizilaghaj State Nature Reserve, in the Shirvan National Park (Greater and Lesser Gizilgaz lakes) and in the Yenikand floodland.

In the open waters of the Caspian Sea, the Bays of Greater and Lesser Gizilaghaj, birds were counted by point count method. Hills of 5-10 m high in the studied area served as points. A complete count of birds was carried out at a distance of 2-3 km. Birds were counted after dividing the area into squares. The area of the squares was 0.2 km^2 in reservoirs rich in reeds and 18–20 km^2 in water areas. The total number of birds in the port of Pirman, Khazar and Aghgush subasars was determined by extrapolation. The information of scientists and guards of the Absheron and Shirvan National Parks, Gizilaghaj State Nature Reserve was also used.

The categories of animals according to population density are based on A. P. Kuzyakin (Kuzyakin, 1962) and G. T. Mustafayev (Mustafayev, 1985): the population of 0.1-0.9 individuals per 1 km^2 is considered rare; A population of 1-10 individuals is considered normal, and a population of more than 10 individuals per the same area is considered numerous.

During the research, a telescope, binoculars, a car, motor and non-motor boats were used.

Brief ecological and geographical characteristics of the Southern coast of the Azerbaijan sector of the Caspian Sea. The coastline of the Southern part of the Azerbaijani sector of the Caspian Sea consists of the Absheron-Gobustan, Southern-Eastern Shirvan, Lankaran coastal waters and adjacent territories.

Absheron-Gobustan coast. The islands, reefs and rivers that make up the Southern and Southern-Eastern extension of the Absheron Peninsula bear the common name of the Absheron Archipelago. The Absheron archipelago occupies an important place in offshore oil production.

It is extended towards the coastline in the Southern part of the Absheron Peninsula. To the West of the Shah Spit (cape), the coast stretches for 25 km towards Cape Hovsan. Baku Bay is surrounded by the islands of Bayil Spit, Nargin (Greater Zira), Wulf (Sone tire) and Plate (Tava) in the South, Sand Zira Islands in the East. Cape Sangachal consists of sand dunes up to 16 m high, extending along the coast to the north for a distance of 4 m, and the Northern-Eastern coast smoothly flows into the sea. Starting from Sangachal, the coast stretches to the South and South-

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Eastern and borders on Cape Alat. Cape Alat is located 13.5 km south of Sangachal (Geography of the Azerbaijan Republic, 2014).

Intensive oil and gas production, various construction works by private companies and individuals have been and are being carried out in the region.

South-Eastern coast of Shirvan. It starts from Cape Pirsaat, and 22 km South of it is Cape Bandovan, then the coast stretches to the South-Western for 21 km, and from there it passes to the delta of the Kura River at 16 km to the South-Eastern. In this part, the coast is mostly covered with sandy plains that have recently been freed from sea waters. The delta of the Kura River is located 37 km South of Cape Bandovan. Garabatdagh, Gutan, Babur, Sangi-Mughan, Greater and Lesser Gizilgaz lakes are located in the Northern-Western part of this region, and Yenikand Subasari is located in the Southern part. Oil wells are drilled in coastal waters. In general, this coastline was exposed to strong anthropogenic influence.

Salyan coast. It consists of the coastal waters of the Caspian Sea and the deserts bordering it. The coastal waters of Salyan are located between the delta of the Kura and the island of Kurdili. The front part of the Gizilaghaj reserve is called the Aghgush subasar. The Aghgush river flows into this part. The delta of the Kura River is located 37 km South of Cape Bandovan. The Kura delta begins near Salyan. The vegetation of the coast is of desert and semi-desert type. The predominant groups of plants in the area are wormwood and wormwood-saline. Soil types: a certain part is made up of medium-humus soils with salinization and humus, solonchaks, ordinary meadow soils and bog soils. In the delta of the Kura river and on the territory of the Gizilaghaj reserve, bulrush and reed thickets are found (Geography of the Azerbaijan Republic, 2014).

Lankaran coast. It covers the Lankaran plain. Until the 50s of the 20th century, most of the lowland territory was rich in swampy biotopes, typical for the habitat of waterfowl and shore birds. However, by the 70s of the 20th century, the swamp biotopes in the Southern, central and Northern-Western parts of the lowland were completely dried up. These biotopes were replaced by areas of gourds that are not important for bird habitat. In modern conditions, wetland biotopes consist of the lesser Gizilaghaj basin and the Pirman harbor, located only in the Northern-Eastern part of the lowland. The shallow coastal waters of the South Caspian bordering the plain are also habitats for waterfowl and shore birds (Babayev, Rajabova, & Samadova, 2015). The maximum depth of the Caspian Sea (1025 m) is located in the South Caspian lowland near Lankaran. The maximum development of organisms that make up the food of birds was recorded at a depth of 110 m, and that of mollusks at a depth of up to 25 m (Babayev, 2003). The oxygen regime in the shallow waters of the South Caspian is favorable for the life of phytoplankton, which is the food of birds, and marine animals. There is very little oxygen in the deep part of the sea. In places with hydrogen sulfide, there is no oxygen at all. In places with great depth, benthic fauna does not develop (Babayev, Askerov, & Akhmedov, 2006).

Results and Discussion

Over the past 20 years, intensive works have been carried out on the extraction of oil and gas on the Southern coast of the Azerbaijan part of the Caspian Sea and border areas. It has has a negative impact on the main places where birds gather. Since the birds are restless in crowded places, they are forced to move to other areas with a smaller food supply, as a result, they weaken and die of starvation.

An analysis of the literature data shows that in the Southern coastal strip of the Azerbaijan part of the Caspian Sea, the habitats of species belonging to the orders *Charadriformes, Ciconiiformes* and *Gruiformes,* and the factors influencing them, often change. Therefore, scientific information given 10-20 years ago is of a historical nature (Babayev, 2002; Babayev, 2003; Babayev, Askerov, & Akhmedov, 2006).

Order *Charadriiformes.* The fauna of Azerbaijan includes 72 species belonging to 8 families and 30 genera (Babayev, 2002). In the course of the studies, 48 out of 72 species included in this order were recorded on the Southern coast of the Caspian Sea. Of these, 5 species are sedentary, 17 are migratory (they occur in our country during migration), 17 arrive for breeding, 8 arrive for wintering, and 1 species is random (Table 1).

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As can be seen from the table, 6 species (*Chettuisa gregaria*, Pall, 1771 (CR), *Numenius arquata* Linn, 1758 (NT), *Numenius tenuirostris* Vieillot, 1817 (CR), *Glareola nordmanni* Nord, 1842 (DD)) from 48 ones included in the order Charadriformes has a global conservation status (Table 1). These species are also included in the "Red Book" of Azerbaijan ("Red Book" of the Azerbaijan Republic, 2013).

Order *Ciconiiformes.* In Azerbaijan, there are 14 species belonging to 3 families and 11 genera (Taxonomic spectrum of the Azerbaijan fauna (vertebrates), 2020). At the time of our research (2017-2019), 12 out of 14 species were distributed on the Southern coast of the Caspian Sea. Of these species, 4 are sedentary (they occur year-round), and 8 species come to breed (Table 1). As can be seen from the table, 8 species (12 species) have a European conservation status, and 4 species are not protected. Among these species, the Eurasian Spoonbill has a global conservation status, being included in all 5 conventions (Table 1). This species is also listed in the Red Book of Azerbaijan ("Red Book" of the Azerbaijan Republic, 2013).

Order *Gruiformes.* There are 14 species belonging to 3 families in Azerbaijan (Taxonomic spectrum of the Azerbaijan fauna (vertebrates), 2020). 6 out of 14 species included in this order are recorded on the Southern coast of the Caspian Sea. 3 of them are sedentary and 3 species are migratory (Table 1).

Of 6 species included in this group, 3 are included in the European conservation status. One species, the Corn Crake is included in the global (*IUCN Red List*) conservation status, and 2 species are not protected (Table 1). Corn Crake is also included in the "Red Book" of Azerbaijan (Taxonomic spectrum of the Azerbaijan fauna (vertebrates), 2020). It is protected worldwide as a near threatened species and as a non-recovery species (H) in Europe (Birds in Europe, 2004; Ward et al., 1997). It has the status of protection in most European countries and included in the Ramsar, Bern, Benn conventions.

Table 1.

The current state of species of the orders *Charadriiformes, Ciconiiformes, Gruiiformes* in the Southern coastal strip of the Azerbaijan sector of the Caspian Sea (Absheron-Gobustan, South-Eastern Shirvan, Salyan, Lankaran) and their relation to international conventions

Orders / Species	International conventions							Status	Habitability (seasonal characteristics)
	Global conservation status	European conservation status	Ramsar	CITES Appendices 1 and 2	Bern Appendices 1 and 3	Bonn Appendices 1 and 2	AEWA		
Ciconiiformes									S
1. Great Bittern		H	+		+	+	+		N
2. Little Bittern		H	+		+	+	+		N
3. Black-crowned Night heron		H	+		+				S
4. Great White Egret		S	+		+				S
5. Little Egret		S	+		+				S
6. Grey Heron		S	+		+				N

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7. Purple Heron		D	+		+	+	+		N
8. Boat-billed Heron		D	+		+				N
9. Cattle Egret		S	+		+				N
10. Glossy Ibis		D	+		+	+	+		N
11. Common Spoonbill		R	+	+	+	+	+	n,a	N
12. White Stork		H	+		+	+	+		
Gruiformes									
1. Spotted Crake		S	+		+	+	+		S
2. Baillon's Crake		R	+		+	+	+		Tr
3. Corn Crake	NT	H	+		+	+			Tr
4. Common Moorhen		S	+		+				S
5. Purples Wamphen		L	+		+			sch	Tr
6. Common Coot		S	+		+	+	+		S
Charadriiformes									
Charadriidae									
1. Eurasian Golden Plover		S	+		+	+	+		Tr
2. Common Ringed Plover		S	+		+	+	+		Tr
3. Little Ringed Plover		S	+		+	+	+		N
4. Caspian Plover		EN	+		+	+	+		Tr
5. Kentish Plover		D	+		+	+	+		N
6. Simply Stone-curlew		VU	+		+	+			N
7. Sociable Plover	CR	CR	+		+	+	+	nk,a, b	Tr
8. White-tailed Plover		S	+		+	+	+	nk,a	N
9. Northern Lapwing		VU	+		+	+	+		S
Recurvirostridae									
10. Black-winged Stilt		S	+		+	+	+		N
11. Pied Avocet		S	+		+	+	+		N,H, Tr
Scolopacidae									
12. Green Sandpiper		S	+		+	+	+		S
13. Common Redshank		D	+		+	+	+		N
14. Spotted Redshank		D	+		+	+	+		Tr
15. Red-necked Phalarope		S	+		+	+	+		Tr
16. Terek Sandpiper		S	+		+	+	+		Tr
17. Little Stint		S	+		+	+	+		Tr
18. Temminck's Stint		S	+		+	+	+		Tr
19. Curlew Sandpiper		NE	+		+	+	+		Tr
20. Dunlin		H	+		+	+	+		H
21. Slender-billed Curlew	CR	NE	+		+	+	+	a,b,x	Tr
22. Great Snipe	NT	D			+	+	+	n,k,b	Tr
23. Eurasian Woodcock		D			+	+	+		H
24. Common Snipe		D			+	+	+		Tr

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25. Eurasian Curlew	NT	D	+		+	+	+	n,b,a	H
26. Whimbrel		S	+		+	+	+		Tr
27. Black-tailed Godwit	NT	VU	+		+	+	+	n,b,a	H
Glareolidae									
28. Cream-colored Courser		EN	+		+		+	n,b,a	Er
29. Collared Pratincole		D	+		+	+	+		N
30. Black-winged Pratincole	DD	EN	+		+	+	+	n,k,a, b	N,Tr
Laridae									
31. Pallas's Gull		S	+		+	+	+		H
32. Little Gull		S	+		+	+	+		Tr
33. Black-headed Gull		S	+		+		+		S
34. Slender-billed Gull		L	+		+	+	+		N
35. Herring Gull		S	+		+				H
36. Caspian Gull		S	+		+				S
37. Grey Gull		H	+		+				H
38. Mediterranean Gull		S	+		+	+	+	a,n	N
39. Little Gull		H	+		+				Tr
40. Black Tern		H	+		+	+	+		N
41. White-winged Tern		S	+		+	+	+		N
42. Whiskered Tern		H	+		+				N
43. Caspian Tern		S	+		+	+	+		Tr
44. Sandwich Tern		H	+		+	+	+		N
45. Common Tern		S	+		+	+	+		N
46. Little Tern		D	+		+	+	+		S
47. Gull-billed Tern		VU	+		+	+	+		N

Note: *CR* – the critically endangered species; *EN* – endangered; *VU* – vulnerable; *NT* – near threatened; *NE* – not evaluated; *DD* – data deficient; *D* – species with decreasing number; *R* – rare species; *L* – species collected in a small area; *S* – unprotected species; *n* – speciesless than 1 individual per 1 km^2; *a* – "Red Book" of Azerbaijan; *nk* – endangered (less than 1 individual per 10 km^2); *b* – Red List of the IUCN; *x* – not found; *k* – occurs during migration; *sch* – the number of elements is too large; *S* – sedentary; *N* – come to breed; *H* – come to hibernate; *Tr* – occurs during the migration period; *Er* – wandering bird.

Results and Recommendations

1. Over the past 20 years, great changes have taken place in the avifauna of the Azerbaijani shores of the Caspian Sea. In the avifauna of this territory, 66 species of rare and endangered birds have been studied.
2. Coastal waters bordering the Shah Spit, Gobustan, Yenikand flood lands of the Caspian Sea, the Greater and Lesser Gizilaghaj Bays are places where the number of birds gathered here is of international importance.
3. 8 out of 12 species belonging to the order *Ciconiiformes* living on the Southern coast of the Azerbaijan sector of the Caspian Sea have European conservation status. One species (Common spoonbill) has the status of global protection with inclusion in all 5 international conventions.
4. 3 out of 6 species of the order *Gruiformes* living on the Southern coast of the Azerbaijani sector of the Caspian Sea have European conservation status. One species (Corn Crake) has global protection status, being included in 3 international conventions.

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5. 26 out of 48 species belonging to the order *Charadriformes*, found on the Southern coast of the Azerbaijani sector of the Caspian Sea, have European conservation status, 6 species (Sociable Plover, Slender-billed Curlew, Great Snipe, Black-winged Pratincole, Common Curlew, Black-tailed Godwit) have the status of global protection.

6. It is important to take the following conservation measures to protect species belonging to the orders *Charadriiformes, Ciconiiformes* and *Gruiformes,* which have global and European status, and to protect their habitats.

1. Restore the border and the main canal of the Gizilaghaj National Park and restore the pumping of water from the Kura to the port of Pirman, the Khazar and Aghgush floodlands through the main canal.
2. To expand the area of Absheron National Park.
3. In order to prevent the threat of complete extinction of the birds living on the coastline of the Caspian Sea, as well as the threat of complete extinction of the ecosystems, the State should prohibit the construction works of individuals and private companies (legal and illegal) operating in these areas.
4. In order to preserve species that are in critical state (Sociable Plover, Slender-billed Curlew), near to threatened (Corn Crake, Great Snipe), and species that are declining in numbers (Black-winged Pratincole), special areas should be allocated in their habitats, and in these places it is necessary to reduce the negative impact of anthropogenic factors.
5. It is advisable to declare the Kura delta, the Yenikand floodland and the waters of the Caspian Sea adjacent to them as a reserve, given that they are one of the largest concentrations of waterbirds during migration and wintering in Azerbaijan.
6. The nesting, wintering and feeding places of the species (Black-winged Pratincole, Slender-billed Curlew, Sociable Plover, Corn Crake) along the coast of the Caspian Sea, about which there is insufficient information in the territory of Azerbaijan, should be identified, monitored and their numbers should be determined.
7. Species that have the status of protected on a global scale and make up a small part of the total number in the world in Azerbaijan (crake, slender-billed curlew, great snipe) and, conversely, make up the majority of the number in the world, are listed in the Red Book of Azerbaijan and are subject to protection on the territory of the republic.
8. Identify the main dangerous sites for species included in the IUCN Red List and Red Book of Azerbaijan on the coast of the Caspian Sea, and at the same time identify threats to these species.
9. Find out the factors that directly and indirectly affect the deterioration of living conditions, the decline in numbers and the gradual death of species common on the coast of the Caspian Sea in Azerbaijan and included in the IUCN Red List and European conservation status lists.
10. It is expedient to create a reserve in the Kura delta, the Yenikand foodland and the adjacent coastal waters of the Caspian Sea, since these territories are one of the largest concentrations of wetland birds and shorebirds during migration and wintering in Azerbaijan.

Thus, 24 species found in the Southern coastal part of the Caspian Sea have the status of global protection. Of the 154 species with European conservation status, only 48 are eligible for higher global conservation statuses (CR, VU, EN). That is, 3 species (CR) are in crisis, 13 species (EN) are endangered, 29 species (VU) are vulnerable. The number of 2 species is unknown (NE), and thefe is no sufficient information about 1 species (DD).

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The Oriental Fruit Moth (*Grapholitha Molesta* Busck.) and its Natural Enemies in the Absheron Peninsula

Abstract

Garden plants, trees and bushes suffer damages caused by lots of pests by 30-50 % every year, and sometimes by 80-90 % during the period when they grow massively. For this purpose, scientific bases for the use of perspective entomophages in the biological fight against harsh pests by studying the species composition, bioecological features of 6 species of insects, which damage garden and forest plants, and entomophages (parasites and predators), which regulate their number, have been developed in Azerbaijan. The research paper established that the oriental fruit moth infests fruit crops by 50-60 %. It was found that 22 types of parasites play a role in the regulation of abundance. Among them, macrocentrus infests oriental fruit moth larva up to 80 %, scambus up to 60 %, apanteles up to 40-50 %. The scoliidae parasite is of economic importance and can be used for biological control against the oriental fruit moth. Considering the prospects of some parasites, the bioecological features on the Absheron Peninsula have been studied.

Keywords: *pest, biology, ecology, fruit, imago, egg, larva, offspring, butterfly*

Introduction

In the economy of the Republic of Azerbaijan, fruit cultivation holds a significant place. To meet the population's demand for fruit, establishing new orchards and creating farming enterprises in this sector have become key issues based on government directives. In this context, identifying pest insects that damage fruit plants and implementing effective control measures are crucial tasks to ensure high fruit yields.

In Azerbaijan, more than 300 insect species damage fruit trees. Among them, the Oriental fruit moth is one of the most serious pests. This pest affects most stone and pome fruit plants, causing significant harm to peaches, pears, and plums, which results in a considerable decrease in fruit yields. It is widespread in the Nakhchivan Autonomous Republic, the Guba-Khachmaz region, and the Sheki-Zagatala region. Recent studies have also reported severe damage in orchards in the Absheron region, where the pest was introduced from Ordubad, affecting peach, apricot, and particularly quince varieties.

Research

The adult oriental fruit moth, or its butterfly form, has a wingspan of 12-14 mm and is brownish-gray in color. Its forewings have seven pairs of white spots shaped like claws along the leading edge and seven pairs of black spots along the trailing edge. The hindwings are brownish-gray with a bronze sheen and covered with fringed edges. Its antennae are threadlike with thin, noticeable rings. The underside of the abdomen is white, while the top is gray-brown. The eggs are oval, measuring 0.4-0.5 mm in length and 0.15 mm in width. They are initially white and turn pinkish-orange after 2-3 days. The caterpillars are whitish-milk colored in the first instar and pinkish-whitish in the 4th-5th instar, reaching a length of 11 mm. The pupa is oval, brown, and measures 6-8 mm in length.

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The Oriental fruit moth overwinters in the 4th or 5th instar larval stage inside a silk cocoon, located beneath the bark of tree trunks at a height of 30-40 cm above the ground. Additionally, it has been observed overwintering in fallen leaves and inside quince fruits. According to studies, larvae that have overwintered inside the cocoons transition to the pupal stage by the end of March or early April. The pupal development takes 10-12 days. Butterflies begin emerging from the pupae in the second half of April, with the flight period extending until the end of May. Newly emerged butterflies start mating on the same day they emerge. They lay eggs 14-18 hours after mating. The eggs are laid singly on the upper and lower surfaces of leaves, on shoots, and on fruit stalks. A single female butterfly can lay between 50 and 250 eggs. After 8-10 days, small larvae emerge from the eggs. They enter the young shoots of trees, where they feed for 10-25 days, reaching the 4th or 5th instar before pupating. New butterflies emerge from the pupae after 25-30 days. The development of one generation of the Oriental fruit moth takes 30-45 days. Depending on climatic conditions, the pest can produce 6-7 generations per year. According to literature, in Azerbaijan (Beybutov, 1965; Mammadov & Mamedov, 2004), particularly in the Absheron, Guba-Khachmaz, and Sheki-Zagatala regions, the pest produces 4 generations per year.

Based on calculations, the larvae of the Oriental fruit moth cause damage to quince and apricot buds ranging from 45-50 %, to early-ripening peach varieties 28-36 %, to late-ripening peach varieties 50-60 %, and to quince fruit 80-90 %.

Result. Based on multi-year research conducted in Absheron (2015-2017), it has been determined that 22 species of parasitoid wasps from the order Hymenoptera are involved in the biological control of the Oriental fruit moth. These include: Ixneumonidae – *Glypta rufoscutellata* Cress., *Pristomerus eurypthychiae* Grav., *Liotryphon punctulatus* Ratz., *Netelia fuscicornis* Holmgr., *Scambus calobata* Grav.; Braconide – *Macrocentrus ancylivorus* Roh., *Macrocentrus delicatulus* Cress, *Macrocentrus* Instabilis Mucs., *Macrocentrus collaris* Spin., *Bracon hebetor* Say., *Bracon Intercessor* Nees., *Orgilus laevigator* Nees., *Microdus rufipes* Nees., *Ascoqaster quadridentata* Wesm.; Chalcidoidae – *Brachymeria intermedia* Nees.; Tetrastichidae – *Tetrastichus* sp.; Trichoqrammatidae – *Trichoqramma minitum* Ril, *Trichoqramma Palluta* Meger., *Trichoqramma Cacoecia* March.; Larvaevoridae – *Arrhinomiya innoxia* Mg.; *Tachina praeceps* Mg.

1. *Macrocentrus ancylivorus* Roh. Parasites play a crucial role in regulating the population of the Oriental fruit moth. According to literature (Moiseyeva & Polyakova, 1970; Mammadov, 2004), this species was introduced from Canada and the USA to Russia between 1965 and 1967 and has been used in biological control against the Oriental fruit moth. In Azerbaijan, it was collected from the larval stage of the Oriental fruit moth, a significant pest of peaches and quinces, in the Ordubad and Guba regions (Mamedov, 2004).

The first generation of the *Macrocentrus* parasite infects 45-50 % of the host's larval stage in spring and 80-90 % of the 2nd and 3rd instar larvae during the summer months. Species belonging to the *Macrocentrus* genus are considered direct parasites of insects, butterflies, and flies (Mammadov, 2004).

The body of the parasite is yellowish-brown and measures 11-12 mm in length. Its antennae are longer than its body. The eggs are spindle-shaped and about 1 mm long. During development, the egg undergoes division, forming several embryos, but only one larva will develop. The larva is segmented, with a distinct head and thorax. It is light brown in color and 4-5 mm long. The parasite develops inside the host larva's body. Before completing its internal feeding, the larva moves to the upper part of the host's body and continues feeding until the host is entirely destroyed, leaving only the head capsule. After feeding is complete, the larva constructs a brown cocoon within which it pupates (Meyer, 1933-1936). The transparent cocoon allows the pupa to be clearly visible. After 5-6 days, holes are made in the front part of the cocoon, and the parasite emerges into the environment. The flight period from the pupae lasts 10-12 days. Parasites begin mating on the day they emerge from the pupae and lay eggs the following day. The eggs are placed inside the host larva's body.

In the larval stage, *Macrocentrus* overwinters inside the body of the Oriental fruit moth larvae. In early March, when the overwintering larvae emerge, the parasite's second instar larvae are

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observed inside the host larvae's body (under a microscope). The overwintering larvae of the parasite develop inside the host's body until mature individuals are formed, which coincides with the development stage of the Oriental fruit moth's first generation larvae.

Considering the high effectiveness of the *Macrocentrus* in controlling the Oriental fruit moth, it has been bred in laboratories in the USA and Canada and released into orchards (Shapiro, 1960). This has resulted in a significant reduction in the Oriental fruit moth population, with fruit infestation decreasing by 60-80 %. In our country, efforts are underway to investigate methods for mass-rearing *Macrocentrus* and its parasitoid under laboratory conditions to expand its use in controlling the pest.

2. *Scambus pomorum* Ratz. The parasite is widely distributed in Azerbaijan and is considered the primary parasitoid of the Oriental fruit moth. It was first recorded by Z. M. Mammadov (2004) in the Nakhchivan Autonomous Republic as a parasite of the apple blossom weevil. Research conducted in the Greater Caucasus region has shown that the parasite lays eggs singly on the third instar larvae of the host, with one egg per larva. After 3-4 days, larvae emerge from these eggs (Rubtsov, 1948). The parasite larvae feed on the host's body for 5-6 days before pupating. The pupal stage lasts 10-12 days, resulting in a total development time of 20-25 days.

In the imago stage, the parasite overwinters beneath the bark of trees. It emerges from hibernation in the first decade of May. In nature, it has been collected from flowering plants in clover fields and orchards. On new plum tree varieties, the pest is parasitized by 50-60 %. In the Sheki, Zagatala, and Ismailly regions, 40-45 parasites were obtained from 120 infested larvae (Aghayev & Zeynalova, 2008). It has become evident that the parasite's activity is particularly high in private gardens, where no chemical control measures are applied. According to A. I. Vorontsov (Beybutov, 1965), and Z.M.Mammadov (2004), the parasite produces two generations per year. The first generation develops on the larvae of the Oriental fruit moth, while the second generation targets caterpillars of moths that damage forest and fruit trees.

Under laboratory conditions at 22-24°C and fed with sugar syrup, the parasites live for 12-16 days, whereas they die within 3-4 days without food. The economic significance of this parasite is considerable.

3. *Apanteles laeviqatus* Ratz. *Apanteles* is a parasitoid from the Hymenoptera order, Braconidae family, and is one of the significant parasites of vegetable and fruit pests. This parasite infects the first and second instar larvae of its host. It lays 50-60 eggs per larva and can lay up to 2000 eggs during its lifetime. The larvae complete their development in the 4th and 5th instar stages (Guliyeva & Guliyev, 2007). Once the larvae have finished developing, they emerge through the host's skin and form a yellow, cotton-like cocoon on the host's surface. Inside this cocoon, each larva transitions to the pupal stage individually. *Apanteles* overwinters both as a pupa and as a final instar larva. The first generation of adults emerges during the second decade of April and the beginning of May. The second generation emerges in early June. Observations indicate that adults of the first generation typically parasitize 60-80 % of hawthorn moth larvae. Subsequent generations of *Apanteles* increase and proliferate by infecting the larvae of fruit pests. During the second decade of April, the parasite is rarely found in the fields due to overwintering, and the infection rate of larvae is also low (10-12 %). The parasitism rate can vary annually depending on climatic conditions and the population of the pest in the agroecosystem.

Observations in fruit farms and personal garden areas have shown that *Apanteles* produces three generations per year, with two of these generations developing on fruit pests. During late May and early June, the larvae appear on fruits and leaves about 10-12 days before the larvae emerge from their eggs. At this time, the host plants have fertilized eggs (Ismayilova, 2024). The first larvae emerging from eggs are parasitized by 40-50 %. The development of parasites completes by early June. The role of nectar-rich plants in the activity of *Apanteles* has been studied. When they feed on nectar-rich plants such as clover and dill, their reproductive capacity is high, significantly contributing to the regulation of the host population. In fruit orchards, when there is a food base for additional feeding, they are more active; without such a food base, the parasitism rate decreases. Additionally, chemical control measures against pests in orchards negatively impact their activity.

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4. ***Scolia quadripunctata* F.** Based on the materials collected from both the Guba-Khachmaz and Sheki-Zagatala regions, this parasite from the Scolidae family of the Hymenoptera order, which was first encountered in Azerbaijan, is considered one of the most important parasites in reducing host populations. Consequently, the bioecological characteristics of this species have been extensively studied. According to A. I. Vorontsov (Beybutov, 1965), species from this family are more widely distributed in tropical countries. In the former USSR, 40 species are known, with most found in Central Asia and the Caucasus. In Azerbaijan, it was first recorded by Z. M. Mammadov (2004). Based on specimens collected from soil around tree roots and from entomological traps, it was found that the parasite's flight period in nature occurs from June to July and lasts 30-35 days. In laboratory conditions, when five larvae of the beetle were placed in a 0.5-liter jar with parasites, the parasites began mating and laying eggs within 5-6 hours (Zeynalova, 2004). Female parasites congregate at the feeding sites of the host larvae, use their antennae to detect the exact location of the larvae in the soil, and then insert their ovipositor to sting and paralyze the host. The paralyzed larva remains immobile. The parasite then deposits the larva into the prepared soil nest and covers it with a secretion. After moving over the surface for a few minutes, the parasite lays one egg on the last segment of the larva's abdomen. The egg is deposited on the larva of the beetle's third instar. The egg stage lasts 3-4 days. Once hatched, the parasite larva begins feeding on the host's body contents. The larval feeding is very rapid, and the larva grows quickly. It passes through three instar stages. When the daily temperature is 26-32°C, the development of the larvae takes 10-12 days. After completing the larval stage, they pupate inside elliptical cocoons. According to V. N. Starkin (Moiseyeva & Polyakova, 1970), cocoons are typically found at a depth of 40 cm in the soil, and sometimes at 10-12 cm. Our observations indicate that cocoons were found at a depth of 5 cm in the jar with a humidity of 60 %. The pupal stage lasts 18-22 days at a temperature of 28-30°C. Initially, the parasites emerge singly, but as the temperature rises and the soil warms, the emergence rate increases. In laboratory conditions, when provided with nectar-rich plants for additional feeding, the parasites lived for 15-20 days on apricot, quince, and peach blossoms, and 10-12 days on dill and clover juice. Without additional food, they lived for only 5-6 days. They produce 3-4 generations per year.

According to V. N. Starkin (Moiseyeva & Polyakova, 1970), in the former USSR Plant Protection Institute, the multiplication of this parasite on May beetles and click beetles in special cages yielded good results.

Conclusion

The study of pest insects, particularly the Oriental fruit moth, and methods of combating them in the fruit-growing sector of Azerbaijan is crucial. Research indicates that the Oriental fruit moth is widespread in Azerbaijan and causes significant damage to orchards, leading to reduced crop yields. This pest has become a serious issue in regions such as the Nakhchivan Autonomous Republic, Guba-Khachmaz, Shaki-Zagatala, and recently in the Absheron area.

As part of biological control measures against the Oriental fruit moth, 22 species of parasitic wasps have been identified as playing a crucial role in combating this pest. Species such as *Macrocentrus ancylivorus* and *Scambus pomorum* have been noted for their high effectiveness. The mass rearing of these parasites under laboratory conditions and their application in orchards have shown positive results in reducing the pest population.

Research indicates that biological control measures against the Oriental fruit moth are not only economically viable but also beneficial for the ecosystem. Therefore, it is advisable to continue scientific research in this direction and expand the use of biological control methods in Azerbaijan.

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The Influence of Spraying and Fertilizer Rate on the Structural Indicators of Soft Wheat Varieties in the Mountainous Areas of Guba Region

Abstract

The article mentions different productivity indicators of sowing, fertilizer and without fertilizer. From the results of the research, it is seen that the influence of cultivation factors on the productivity indicators of plants is different and depends on the number of plant stems in a single area, the mass of grain, etc. depends on factors. Changes in fertilizer rates have a significant impact on the productivity of small crop rate variations.

Keywords: *fertilizer norms, soft wheat, productivity, Gobustan, Viktoriya*

Introduction

The food produced from wheat (*Triticum aestivum* L.) is the second largest crop in the world (FAO & WFP, 2015) and human food demand is predicted to double by 2050 (Singh, Kaur, & Majithia, 2015). It is cultivated in wide areas around the world.

The correct determination of cultivation factors plays an important role in increasing the structural elements of the wheat plant and at the same time grain yield, depending on the biological characteristics of the variety, external conditions, cultivation agrotechnics, soil characteristics. Nutrients, humidity, etc. per unit area since it is divided according to the number of plants there, it is necessary to arrange the number of plants in such a way that moisture, nutrients, etc. be sufficiently provided with (Gulyanov, 2003).

Research

The productivity of each variety depends on the number of fertile stems in a single field during harvesting, the density of the spike, the mass of grain in one spike, the number, the mass of 1000 grains (Fatullayev & Mammadov, 2007).

An increase in the number of grains per spike significantly improves the yield potential of the wheat plant. Wheat ears consist of spikelets that form reproductive structures. The number of grains and the weight of 1000 grains in wheat depend on both genetic and environmental influences (Reynolds et al., 2009).

Plant density is an important factor affecting growth and yield formation in wheat (Bustos et al., 2013; Miralles & Slafer, 1995). In wheat, the number of spikes varies at different planting densities (Miralles & Slafer, 1995).

In addition, the application of different fertilizer rates causes significant differences in yield and yield components of common wheat genotypes, which is a logical consequence of the effect of fertilizer rates on the physiological characteristics of plants. R. K. Heydarova notes that because winter wheat germ absorbs nutrients from the early stages of vegetation, it is important to provide nutrients from the early stages of development (Heydarova, 2007). Also, late application of

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additional fertilizers to winter wheat is one of the factors that lowers productivity (Huseynov, A., Huseynov, N., & Mammadova, 2019).

Cultivation of 2-3 varieties in each zone is an important condition to ensure the productivity and good grain quality of winter wheat. In order to reduce the yield loss, it is advisable to cultivate varieties that grow relatively quickly, are resistant to winter and drought, and have different requirements for fertilizers and sowing time in the same farm. Instead of separate varieties, varieties that complement each other, have maximum and stable productivity over the years, and are adapted to local conditions should be used (Miralles & Slafer, 1995).

The Object and Methodology of the Study

In 2023-2024, the Gobustan and Fatima varieties of the Scientific Research Institute of Agriculture and the Victoria variety of the Russian Scientific Research Institute were used. The experiment was conducted in the village of Digah, Guba region.

Field experiments were conducted in 3 replicates of 72 m^2. The field experiment was set up in the following scheme.

1. Sowing norms
1. 4.0 million sprouted grains per hectare
2. 4.5 million sprouted grains per hectare
3. 5.0 million sprouted grains per hectare

2. Fertilizer norms
1. without fertilizer
2. $N_{90}P_{60}K_{60}$
3. $N_{120}P_{90}K_{60}$

Analysis and Discussions

Before the conducted research, a soil analysis was conducted and the amount of nutrients in the soil was evaluated. The average pH of the soils we studied ranges from 7.8 to 7.9, which means that the area is considered to be slightly alkaline.

Table 1.
Main agrochemical analysis indicators of soil samples brought from Digah village, Guba region

No	Depth cm	pH in water	$CaCO_3$ %	Soil organic matter %	Total Nitrogen %	Active phosphorus (P_2O_5)	Exchangeable potassium (K_2O)
						kg/mg	
1	0-30	7.93	5.7	2.45	0.18	4.6	368.5
2	0-30	7.93	5.5	2.49	0.19	5.4	379
3	0-30	7.88	5.25	2.47	0.19	4.6	363.5
4	0-30	7.81	5.55	2.47	0.18	5.2	343.5
5	0-30	7.91	5.7	2.53	0.18	4.7	363.5

According to the amount of calcium carbonate, the soil is considered medium carbonate. Soil fertility is determined by water retention, good quality plowing and the thickness of the humus layer. The amount of soil organic matter varies between 2.5-2.6 % on average at the depth of 0-30 cm from the soils we studied. Such soils are considered of average quality. During the vegetation period of the plant, the provision of basic nutrients in easily assimilated forms (easily hydrolyzable

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nitrogen, mobile phosphorus and exchangeable potassium), determination of fertilizer norms is determined by the stock of easily assimilated basic nutrients in the soil. In the areas of our study, 4.0-5.5 mg of activated phosphorus (P2O5) and 350-400 mg of exchangeable potassium are averaged in 1 kg of soil at a depth of 0-30 cm. The soil is very poorly provided with active phosphorus, because the amount of active phosphorus is considered very poorly provided when the amount of active phosphorus is less than 10 mg per 1 kg of soil. Potassium is provided at an average level. The mentioned evaluations are Azerb. MEA was recommended by the opinions of the Institute of Soil Science and Agrochemistry, Agricultural Research Institute and various decisions of the Scientific Council.

The results of our research reflect the effect of plant productivity on the background of fertilizer and plant density. Thus, it was determined that the level of productivity depends on the number of plants and productive stems located in a single area, the mass of grain produced by those plants, the height of plants and other structural elements. Some sources indicate that the plant density is the main factor for the productivity of the plants included in the agricultural (Duvick et al., 2004). By correctly determining the cultivation factors, it is possible to increase the productivity and economic efficiency of soft wheat varieties against the background of suitable fertilizer norms.

Effect of plant density and different fertilizer rates on structural elements of soft wheat cultivars.

Table 2.
No fertilizer (control)

Varieties	Sprinkle norm million per hectare	1 m^2 out total biomas (gr)	The height of the plant (cm)	The number of productive stems per 1m^2 (number)	The length of the spikes (cm)	Number of grains in 1 spike		The mass of the grain from 1 m^2	Grain yield cent s|ha
						number	Mass of grain (g)		
Gobustan	4,5	1344,6	90,6	313,3	8,8	39.2	0,78	244,1	24,4
	5,0	1374,6	88,8	326,2	8,8	36.2	0,74	241,4	24,1
	5,5	1419,2	78,2	345,5	8,7	31.1	0,69	238,4	23,8
Fatima	4.5	1352.2	91.2	317.2	7.7	38.2	0.76	241.1	24.1
	5.0	1361.2	90.2	332.3	7.6	38.1	0.74	245.7	24.6
	5.5	1366.4	87.6	345.6	7.2	37.3	0.68	234.6	23.5
Victoria	4.5	1412.2	93.3	301.6	8.1	35.5	0.66	198.7	19.9
	5.0	1422.6	90.2	311.7	7.8	34.4	0.64	199.0	19.9
	5.5	1451.2	88.5	346.2	7.7	34.5	0.58	200.7	20.1

Table 3.
$N_{90}P_{60}K_{60}$

Varieties	Sprinkle Norm million per hectare number	1 m^2 out total biomass (gr)	The height of the plant (cm)	The number of productive stems per 1 m^2 (number)	The length of the spikes (cm)	Number of grains in 1 spike		The mass of the grain from 1 m^2	Grain yield cents/ha
						number	Mass of grain (g)		
Gobustan	4.5	1456.2	94.6	323.3	11.1	40.4	1.28	413.4	41.3
	5.0	1486.6	93.1	341.2	10.1	39.6	1.21	412.6	41.3
	5.5	1502.2	93.1	368.2	10.1	33.3	1.16	426.9	42.7
Fatima	4.5	1406.2	92.2	303.2	11.2	38.8	1.28	387.8	38.8
	5.0	1422.2	92.0	331.3	11.3	37.2	1.21	400.5	40.1
	5.5	1462.4	92.0	345.6	11.1	36.6	1.17	403.6	40.4
Victoria	4.5	1509.2	94.3	313.6	11.2	37.1	1.18	369.3	36.9
	5.0	1525.2	94.2	321.2	10.8	36.2	1.15	364.6	36.5
	5.5	1576.3	93.5	352.2	10.6	35.4	1.13	397.7	39.8

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Table 4.
$N_{120}P_{90}K_{60}$

Varieties	Sprinkle Norm million per hectare number	1 m² out total biomass (gr)	The height of the plant (cm)	The number of productive stems per 1 m² (number)	The length of the spikes (cm)	Number of grains in 1 spike		The mass of the grain from 1 m²	Grain yield cents/ha
						number	Mass of grain (g)		
Gobustan	4.5	1516.6	102.1	355.2	13.6	44.4	1.34	475.7	47.6
	5.0	1619.2	96.2	375.6	13.2	40.4	1.31	491.3	49.1
	5.5	1645.6	98.8	386.2	13.1	39.6	1.29	498.1	49.8
Fatima	4.5	1475.5	98.2	318.8	12.8	40.0	1.31	417.3	41.7
	5.0	1512.2	96.7	326.2	12.8	39.6	1.28	417.3	41.7
	5.5	1566.6	95.4	341.2	12.6	39.6	1.25	426.5	42.6
Victoria	4.5	1598.2	98.9	332.5	12.8	38.8	1.23	408.4	40.8
	5.0	1613.7	98.6	338.5	12.4	37.8	1.21	409.0	40.9
	5.5	1617.2	97.2	356.6	12.3	37.1	1.21	430.1	43.0

The influence of cultivation factors on structural indicators of winter wheat varieties is reflected in tables 2,3 and 4.11 %, 22 % increase in sowing rate in all 3 soft wheat varieties, 2 %-3.1 % in Gobustan variety, 1.1-3.9 % in Fatima soft wheat variety, 1.0-4.4 % in Victoria wheat variety in wheat varieties selected as research material of the total biomass of 1m² caused. Although a shortening of plant heights was observed in all three varieties, the number of productive stems per unit area increased by 5.5-10.8 % in the Gobustan soft wheat variety, 9.2-13.8 % in the Fatima wheat variety, and 2.5-12.4 % in the Victoria soft wheat variety. A decrease in the number of grains in one spike and the mass of the grain is observed if the planting material is too much. The grain yield of soft wheat varieties in the direction of increasing the sowing rate in the control variant without fertilizer was 24.4 centners in the calculation of 4.5 million grains in Gobustan soft wheat variety, 24.1 centners in the norm of 5 million sowings, and 23.8 centners in the norm of 5.5 million sowings. In other soft wheat varieties, Fatima variety had 24.1 centners, 24.6 centners, 23.5 centners, and Victoria soft wheat variety had 19.9 centners, 19.9 centners, 20.1 centners. In the assimilation of nutrients in the soil, the sowing rate in the Gobustan soft wheat variety has already decreased, in the Fatima variety, the highest result is in the variant with the 5 million sowing rate, and in the Victoria variety, the increase in the sowing rate has not made a significant difference in productivity.

11 % and 22 % increase of planting material in N90P60K60 variety resulted in 70 % higher yield of Gobustan soft wheat variety at 4.5 million planting rates compared to the control variant. Thus, in the control variant, the yield was 24.4 centners at the rate of 4.5 million plantings, while the yield at the rate of N90P60K60 fertilizer was 41.3 centners. This increase was 71 % and 79 % at 5.0 million and 5.5 million sowing rates, respectively. In other soft wheat varieties, this increase was 62 %, 61.3 %, and 72 %, respectively, in the rates of 4.5 million, 5 million, and 5.5 million seeds in Fatima, and in the Victoria soft wheat variety, these indicators were 85 %, 83 %, and 98 %.

Certain increases in spike elements were observed in the N120P90K60 variant. If we compare the yield indicators of 4.5 million, 5 million and 5.5 million plantings in the Gobustan soft wheat variety, respectively, 95 % in the norm of 4.5 million seed material compared to controls, 15 % in comparison with the N90P60K60 variety, these figures are 103.7 %, 18.9 % in the norm of 5 million plantings, and at the rate of 5.5 million plantings, these indicators change to 109.2 %, 16.6 %, respectively. The corresponding increases in other cultivars can be compared in Table 3 and Table 4.

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Conclusion

The results of the research show that the influence of cultivation factors on the productivity indicators of plants is different and depends on the number of plant stems in a single area, the mass of grain, etc. depends on factors. Changes in fertilizer rates have a significant impact on the productivity of small crop rate variations.

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Determining the Stability of a Potentially Dangerous Landslide Slope

Abstract

Due to the acceleration of construction of civil, industrial and infrastructure facilities in our republic and the expansion of their area, the construction of many facilities is carried out in mountainous, and foothill areas with complex relief and geomorphological conditions, which in most cases are potentially dangerous landslide slopes.

To protect these facilities from the negative impact of dangerous geological, natural-technogenic, and anthropogenic processes, to assess the risks arising from the impact of these processes on building structures, to promptly prevent negative phenomena and dangerous situations, to assess the engineering and geological conditions of the construction area to determine the stability of the slope, conducting research in these areas is of great practical importance.

Mountainous regions are characterized by the complexity and diversity of geological, hydrological, hydrogeological, and tectonic conditions.

Landslides are the most common natural and man-made processes that pose a threat to the safe operation of infrastructure facilities, civil and industrial construction in mountainous and foothill areas.

In addition to infrastructure facilities, landslides can destroy vegetation, destroy the habitat of fauna, and also destroy fertile soils located in the area of their activity (Nikolic, 2015; Krivoguz & Bespalova, 2020).

The main objective of this article is to apply the results of practically implemented and verified studies in other territories of our republic with similar geomorphological structure and engineering-geological conditions, to correctly assess the negative manifestations caused by landslides and other man-made and anthropogenic impacts, as well as to calculate the stability of the slope and scientifically and technically substantiate measures for engineering protection against landslides.

Keywords: *landslide, slope, geological, stability, road, sand, clay, loess, soil, groundwater*

Introduction

In connection with the construction of the state border highway of the Baku-Guba-Russian Federation, when choosing the route for the construction of the road line without entering the city of Shabran, according to the results of the technical and economic evaluation of all options, the option of passing the road through the foothills of the slope located in the northwestern part of the city of Shabran was preferred.

A very important point in the design of embankments and excavations, for example in the construction of railways and highways, is the prediction of the stability of slopes and embankments (Chalkova & Cherepanov, 2007).

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Taking into account the impact of natural factors and processes on a road is one of the fundamental principles in the design of a road both as a transport structure and as an engineering structure (Zhukov, 2019; Makhmudova, 2021).

The probability of landslide development due to road construction, i.e. as a result of man-made impacts on a slope where a landslide process has not yet manifested itself, is not taken into account sufficiently. This is one of the weak links in the design of mountain roads. At the same time, tracing is carried out without quantitative assessments of the degree of stability of the geotechnical complex "slope + roadbed" (Makhmudova, 2021; Khairullaevna & Odilova, 2023).

In order to design the structural elements of the road and, if necessary, anti-slip devices, engineering-geological and hydrogeological studies should be carried out on the slope, the physical and mechanical properties of the soils involved in the geological structure of the slope should be determined, and the stability of the slope should be calculated.

In many cases, the importance of determining the negative manifestations that may arise in the stability of the slope due to the disruption of the natural structure of the slope by drilling and cutting during construction, makes it necessary to carry out relevant research.

For the design of the roadbed, which is the main structural element of the road erected on a slope or on a potential landslide slope, the determination of the slope stability and, accordingly, the slope stability factor is more relevant.

Based on the interpretation of the noted information, it can be concluded that in connection with the passage of a motorway at the foot of the slope, an important design condition is to determine the stability of the soil massif forming the slope. Thus, as a result of construction work, the imbalance on the slopes, accompanied by a landslide of a large soil massif, leads to catastrophic processes leading to the collapse of civil and infrastructural construction projects located on the slope and at the foot of the slope.

Research

The slope with a potential landslide hazard is located in the western part of Shabran city and covers an area of 1000 meters in length and 170 meters in width (along the surface of the slope).

The maximum steepness is 40-450 meters and the height is 120 meters in the parts of the slope considered as a potential landslide zone (Figure 1).

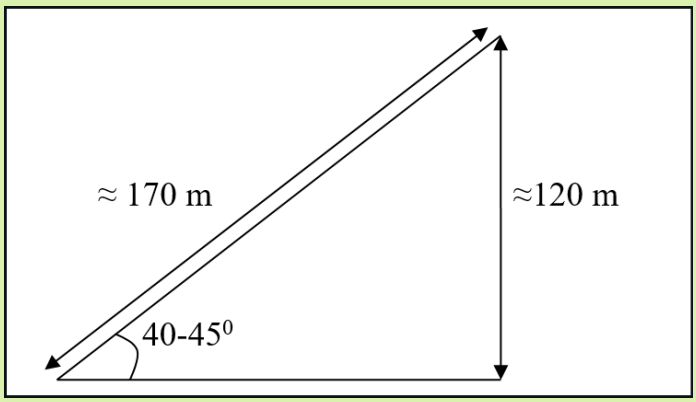

Figure 1. General schematic dimensions of the slope

The upper part of the slope is a large area with a slight slope. Previously, certain protective measures were taken to prevent the risk of landslides in the area of the slope.

The entire surface of the slope is gradually divided into terraced parts along the bed lines and the boundaries of layers of different lithological composition. In order to eliminate atmospheric precipitation, small trenches were built in these areas, and the stability of the slope was restored by providing a balance between the weight of the soil mass forming the slope and the force of sliding resistance (Figure 2 and Figure 3).

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The slope has a variable relief with convex, flat and protruding shapes in some areas, and the agroforestry reclamation measures carried out in the 1970s are one of the main factors determining the current shape of the slope relief.

Figure 2. Area with potential landslide hazard

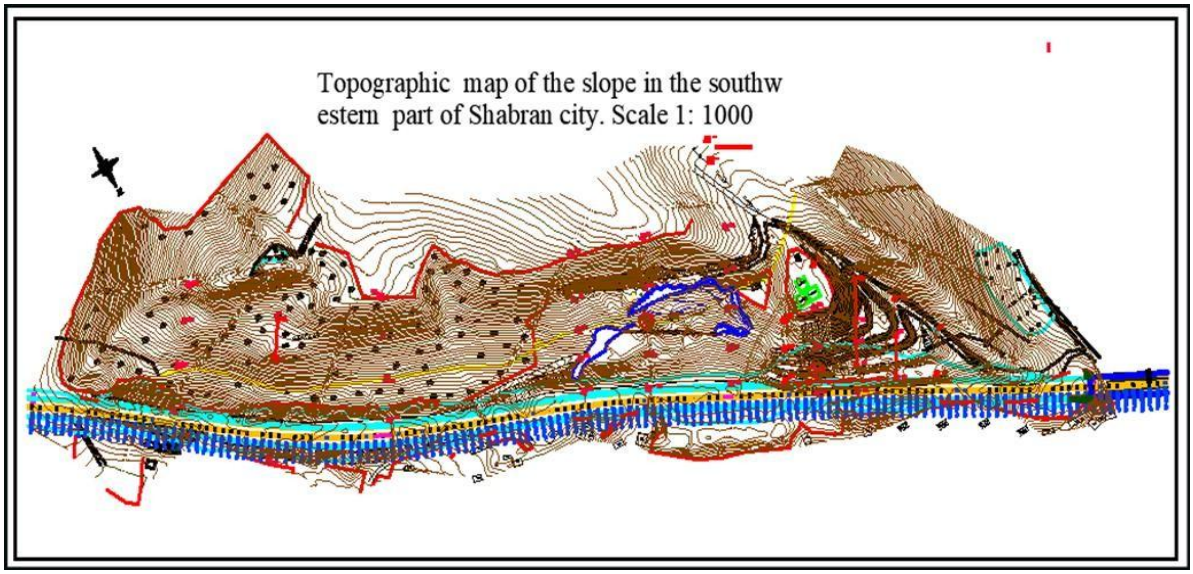

Figure 3. Topographic map of the slope in the southwestern part of Shabran city

The research work was carried out on a 200-meter section of the northern part of the specified territory (Figure 4).

As a result of the research, it was established that the geological structure of the soil massif forming the slope consists of loess semi-hard loams of continental origin, loam of semi-hard consistency, clays of hard and semi-hard consistency, and a layer of fine-grained sand of medium density.

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Figure 4. Research area

At the foot of the slope there is a layer of argillite with a thickness of 15-20 cm, and in the middle part of the geological structure of the slope there is a wet and loose layer of sand. The moisture content of the sand layer allows us to assume the possibility of the presence of a source of nutrition in this layer. Among the mentioned soils, sands, loess loams and loams have the ability to soak and wash away.

According to the results of engineering and geological studies conducted in the initial part of the potentially dangerous landslide zone, the angle of internal friction in clay soils participating in the geological structure is 17-30^0, the adhesion force is 0.36-0.84 kgf/cm^2, the angle of slope of sand is 30^0, and in a water-saturated state – 26^0.

The angle of internal friction in the loess clay and clay layers involved in the geological structure of the soil massif can be assumed to be 17-26^0, and the adhesion force is 0.19-0.47 kgg/cm^2 (AzDTN 2.15-1 Soil foundations of buildings and structures).

Landslide processes mainly occur on slopes and embankments with large inclinations, in the geological structure of which clayey and loess-like soils participate (Zuska, 2014).

Landslides that have occurred in nature, depending on the lithological composition of the soil massif, tectonic, physical and engineering-geological, man-made and anthropogenic processes and factors, mainly occur on slopes with an inclination angle of more than 15^0.

In cohesive dispersed soils, the factors that exert opposite influence on displacement are friction and cohesion forces, while in non-cohesive dispersed soils this factor consists only of friction forces. The force of gravity created by the mass of rocks that make up the slope is the force that tries to move the mass of soil in contrast to these forces.

The slope stability was calculated for two soil conditions, since local sections of the slope geological structure involve unbound dispersed soils (sand layer), while the geological structure of the slope geological environment involves predominantly bound dispersed (silty-clayey) soils.

The friction force F and the gravity force P act on each soil particle in loose dispersed soils (sand layers) that participate in the geological structure of the slope (Figure 5). And the gravity force P consists of the force Q, which moves the particles down the slope, and the force N, which pushes the particles toward the slope (Alekseyev, 2007).

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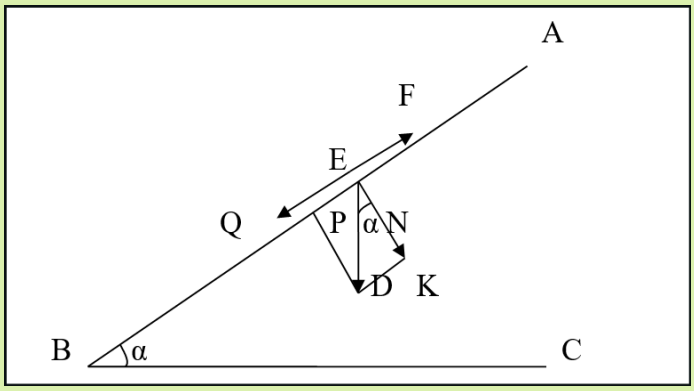

Figure 5. Conditions of stability of uncohesive loose soils

As shown in the picture:

$$Q = P \cdot \sin\alpha$$
$$N = P \cdot \cos\alpha$$

α is the angle between the perpendicular H to the slope surface and the vertical force P. In addition, α is equal to the angle of repose (inclination), since, < ABC= < DEK.

$$\frac{Q}{N} = \frac{P \cdot \sin\alpha}{P \cdot \cos\alpha} = \mathrm{tg}\alpha$$

From here:

$$Q = N \cdot \mathrm{tg}\alpha$$

For soil particles to move, the force Q must be greater than the frictional force F moving in the opposite direction.

It is known from soil mechanics that the frictional force is equal to the product of the internal friction coefficient of the soil and the compressive force:

$$f = \mathrm{tg}\varphi$$

φ – is the angle of internal friction of the soil. From here:

$$F = N \cdot f = N\ \mathrm{tg}\varphi$$

In unstable equilibrium the condition Q=F is satisfied:

$$N \cdot \mathrm{tg}\alpha = N \cdot \mathrm{tg}\varphi \text{ or } \mathrm{tg}\alpha = \mathrm{tg}\varphi$$

In case of stable equilibrium:

$$Q < F,$$
$$N \cdot \mathrm{tg}\alpha < N \cdot \mathrm{tg}\varphi$$

From here:

$$\mathrm{tg}\alpha < \mathrm{tg}\varphi$$

conditions must be met.

Considering that the angle of inclination of the sand layers participating in the geological structure of the slope is 30^0, and in some cases, the slope surface inclination is $40\text{-}45^0$, we can conclude that, directly on the sand layers, the slope is unstable.

It is known that landslides of the konsekvent type occur on any given surface (Pellinen, 2012). In many cases, landslides occur on slopes composed of uniform layers of loess clays, alternating horizontally at a certain angle.

The main causes of landslides are:

- spontaneous undercutting of the slope heel, the balance of natural forces that ensure the stability of the slope is disrupted;
- washing of the surface and base of the slope by atmospheric deposits;
- additional load on the soil mass that forms the slope (construction of artificial structures on the slope, filtration of rain and snow water into the soil layer, etc.);
- violation of the natural structure of the soil as a result of the activity of groundwater and other accompanying factors (Dalmatov, 1988).

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The displacement of the soil mass forming the slope occurs against the background of successive sliding of the mass consisting of blocks on a curved line close to the circular cylindrical sliding surface, and the sliding depth covers the interval from 5 meters to 10-15 meters.

The research area for cohesive dispersed soils occupies an area 80 meters wide, 100-150 meters long, and sometimes more, which has a terraced surface as a result of dissection of the soil mass along certain cracks (Figure 6 and Figure 7).

To calculate the stability of a slope composed of cohesive soils, the method of a circular cylindrical sliding surface was used (Kremnev, Glukhov, & Vishnyakov, 2011).

As the foot of the slope, the length (width) of the slope surface is taken as 115 meters, referring to the natural cut-valley (avalanche) accompanied by the 15 meters from the residential house built at the foot of the slope.

The absolute height of the slope is 81 meters, the radius of rotation at the 0 point of the sliding body R is 76.6 meters (Figure 8).

Taking into account that the slope angle in the area after 115 meters of the slope surface is small, that area was not included in the research object.

The physical and mechanical parameters of the soils used in the report were determined based on the results of the engineering-geological studies conducted in the area and the information of the normative documents.

Figure 6. Research area with potential landslide

Figure 7. Photographs of the research area

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The sum of the forces arising from the weight of the soil mass (Figure 9):

$$\Sigma Ti = 28608 \text{ kN/m}$$

The sum of the forces holding the soil massive of a slope in equilibrium:

$$\Sigma Fi + \Sigma c * Li = 28127 \text{ kN/m}$$

According to the equilibrium formula:

$$\Sigma Ti - \Sigma Fi - \Sigma c_i * L_i = 0$$

It is determined from the formula and the quantities of forces acting on the sliding body that the conditions of the equilibrium formula are not satisfied in our case.

So that:

$$28608 - 21971 - 6156 = 481 \text{ kN/m}$$

As a result of the calculations, it was determined that the forces that try to move the soil mass downwards due to the weight of the soil massif forming the slope are greater than the sum of the resistance forces of the slope against those forces.

The stability coefficient of the slope is calculated by the following formula:

$$\eta = \frac{ZFi + Zc*Li}{ZTi} = \frac{28127}{28608} = 0{,}98$$

As a result of the calculation, the determined stability coefficient of the studied slope (η=0.98) is less than unity, so the slope is evaluated as a potentially dangerous landslide area.

The degree of stability of a slope (slope) is estimated by the value of the stability coefficient (stability, safety margin). A slope, slope or its morphological element is considered stable if its stability coefficient is higher than one (η > 1). The value of the slope (slope) stability coefficient approximately equal to one (η ~ 1) corresponds to the state of limit equilibrium observed at the moments of the beginning and end of a landslide displacement (Matsiy, 2011).

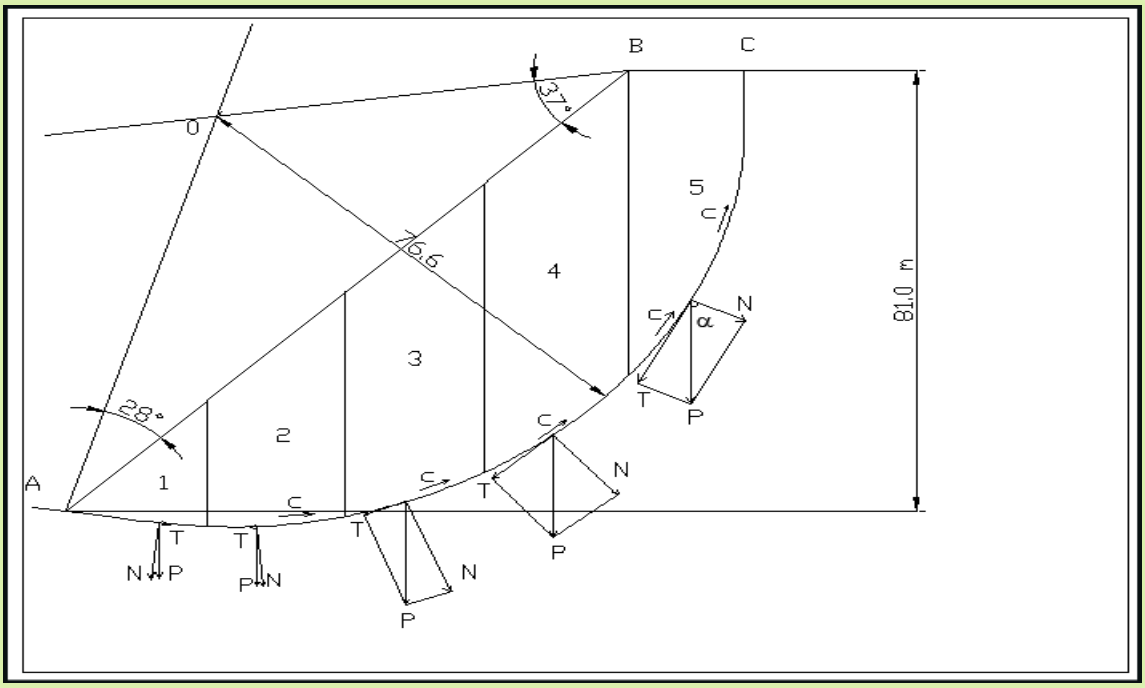

Figure 8. The scheme of calculating the stability of the slope

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s/s	A_i,m^2	γ, kN/m^3	Q_i=γ*A_i, kN/m	α_i, degree	sin α_i	T_i=Q*sin α_i, kN/m	cos α_i	N_i=Q_i*cos α_i, kN/m	φ, degree	tg φ	F_i=N_i*tg φ, kN/m	c, kPa	L_i, m	c*L_i
1	234	17,8	4165	-6	-0,11	-458	0,99	4123	22	0,40	1649	46	20	920
2	845	17,8	15041	5	0,09	1353	1	15041	22	0,40	6016	46	20,1	925
3	946	17,8	16840	21	0,36	6062	0,93	15661	22	0,40	6264	46	21,4	989
4	1153	17,8	20523	40	0,64	13128	0,77	15795	22	0,40	6318	46	28,1	1293
5	538	17,8	9576	63	0,89	8523	0,45	4309	22	0,40	1724	46	44,1	2029
Σ						28608					21971			6156

Figure 9. Slope stability calculation table

The results of calculating the slope stability for two soil conditions showed that the slope under consideration, in the geological structure of which non-cohesive dispersed soils (sands) and cohesive dispersed soils (silty-clayey) participate, is unstable.

In order to avoid negative phenomena taking into account the instability of the slope under study and to prevent catastrophic consequences from dangerous landslide processes when designing infrastructure facilities adjacent to such mountainous areas, a comprehensive engineering and geological study should be carried out, as a result of which designers should design anti-landslide measures based on existing regulatory documents.

Conclusion

To protect infrastructure facilities from the negative impact of dangerous geological, natural-technogenic, and anthropogenic processes, to assess the risks arising from the impact of these processes on building structures, to promptly prevent negative phenomena and dangerous situations, to assess the engineering and geological conditions of the construction area to determine the stability of the slope, conducting research in these areas is of great practical importance.

Landslides are the most common natural and man-made processes that pose a threat to the safe operation of infrastructure facilities, civil and industrial construction in mountainous and foothill areas.

A very important point in the design of embankments and excavations, for example in the construction of railways and highways, is the prediction of the stability of slopes and embankments.

In order to design the structural elements of the road and, if necessary, anti-slip devices, engineering-geological and hydrogeological studies should be carried out on the slope, the physical and mechanical properties of the soils involved in the geological structure of the slope should be determined, and the stability of the slope should be calculated.

The slope stability was calculated for two soil conditions, since local sections of the slope geological structure involve unbound dispersed soils (sand layer), while the geological structure of the slope geological environment involves predominantly bound dispersed (silty-clayey) soils.

The results of calculating the slope stability for two soil conditions showed that the slope under consideration, in the geological structure of which non-cohesive dispersed soils (sands) and cohesive dispersed soils (silty-clayey) participate, is unstable.

The conducted studies give grounds to state that, when designing infrastructure facilities located in mountainous and foothill areas, the scientific and technical approach to assessing the stability of slopes is the only alternative.

For the feasibility study of designing infrastructure facilities located through slopes, the presented methods for calculating the stability of the slope in such geological conditions are sufficient.

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