Abdibattayeva M.\textsuperscript{1}, Su Xintai\textsuperscript{2}, Almatova B.\textsuperscript{3}, Umbetbekov A.\textsuperscript{4}, Satarbayeva A.\textsuperscript{5}, Asanova G.\textsuperscript{6}

\textsuperscript{1}Faculty of Geography and Environmental Sciences, Al-Farabi Kazakh National University, Kazakhstan, Almaty
\textsuperscript{2}School of Environment and Energy, South China University of Technology, China, Guangzhou
\textsuperscript{3}Baishev University, LLP Technopark «Zerek», Kazakhstan, Aktobe
\textsuperscript{4}Faculty of Geography and Environmental Sciences, Al-Farabi Kazakh National University, Kazakhstan, Almaty
\textsuperscript{5}Faculty of Geography and Environmental Sciences, Al-Farabi Kazakh National University, Kazakhstan, Almaty, e-mail: a.satarbayeva@gmail.com,
\textsuperscript{6}Faculty of Environmental Engineering, Korkyt Ata Kyzylorda State University, Kazakhstan, Kyzylorda

SOIL DEGRADATION DUE TO POLLUTION BY OIL AND OIL PRODUCTS AND THE DEVELOPMENT OF A WAY TO PREVENT THEM

Soil degradation and, as a result, desertification is a global phenomenon, but in Kazakhstan it is felt most acutely. The main causes leading to desertification and adverse environmental changes include chemical contamination of the soil. Local and regional chemical pollution of soils is observed near cities and industrial enterprises, open-pit mining of mineral resources. The dominant group of chemical pollution will be oil itself, gas accompanying it, waste and underground mineralized water. The problem of detoxification, cleaning and restoring the properties and fertility of soils polluted with oil and oil products in order to prevent soil degradation is an important and most pressing issue at present. The main idea of the work is to create a solar complex for processing oil and gas waste with the development of fundamentally new solutions in the technological scheme for processing oily waste.

In world practice, various methods of cleaning soil and water from oil pollution are applied: mechanical, physicochemical and biological. Not all of them are safe and effective. To solve the problems of anthropogenic pollution by oil and petroleum products, photothermal methods during cleaning to remove the hydrocarbon portion of the soil. The authors have created a solar system and developed a way to prevent soil degradation with the production of petroleum products.

The scientific novelty of the work lies in the use of various types of solar constructions in the recycling and utilization of oily wastes, ensuring maximum separation of hydrocarbons from oil wastes, without prejudice to their chemical structure, in the manufacture of modern composite building materials, ensuring the intensification of hardening processes.

The results show that an environmentally friendly method has been developed for cleaning oil-polluted soils, soils and oil sludge. This method solves an important environmental problem of cleaning oil-polluted soils, soils and oil sludge, helps restore and prevent the degradation of natural complexes, reduces pollution of the soil layer and water bodies. This will allow utilizing oil barns and sludge collectors in all oil-producing regions using solar energy.

\textbf{Key words}: soil degradation, technogenic desertification, oil pollutants, land reclamation, soil cleaning.
Топырақ деградациясы және олардың салдарынан шығатын шөлейттену – әлемдік ауқымдағы құбылыс, алайда ол Қазақстанда ерекше сезіліп отыр. Шөлейттену мен жағымсыз экологиялық өзгерістерге алын келетін басқа себептердің бірі. Топырақтың химиялық және жергілікті ластануы қалалар мен өнеркәсіптік кәсіпорындардың, ашық пайдалы кен қазбаларының маңайында байқалады. Химиялық ластану ұсқаға жатады, шөлейттену мен жағымсыз экологиялық өзгерістерге алып келетін басты себептердің бірі. Топырақтың жергілікті және аймақтық химиялық ластануы қалалар мен өнеркәсіптік кәсіпорындар арасында қатысуы мүмкін.

Топырақтың деградациясы және олардың салдарынан шығатын шөлейттену – әлемдік ауқымдағы құбылыс, алайда ол Қазақстанда ерекше сезіліп отыр. Шөлейттену мен жағымсыз экологиялық өзгерістерге алын келетін басқа себептердің бірі. Топырақтың химиялық және жергілікті ластануы қалалар мен өнеркәсіптік кәсіпорындардың, ашық пайдалы кен қазбаларының маңайында байқалады. Химиялық ластану ұсқаға жатады, шөлейттену мен жағымсыз экологиялық өзгерістерге алып келетін басты себептердің бірі.

Мұнай және мұнай ойнаміндерімен ластану есебінен топырақтың деградациялануы және оны бөлдірмә атап тосқа жасау
Локальное и региональное химическое загрязнение почв наблюдается вблизи городов и промышленных предприятий, открытых разработок полезных ископаемых. Доминирующей группой химического загрязнения будет являться нефть, сопутствующий ей газ, сточные и подземные минерализованные воды. Проблемы детоксикации, очистки и восстановления свойств и плодородия почв, загрязненных нефтью и нефтепродуктами, с целью предотвращения деградации почвы является важной и наиболее актуальной в настоящее время. Основная идея работы заключается в создании гелиокомплекса для переработки отходов нефтегазовой отрасли с разработкой принципиально новых решений в технологической схеме переработки нефтесодержащих отходов. В мировой практике применяются различные методы очистки почвы и воды от нефтекоррозий: механические, физико-химические и биологические. Не все они безопасны и эффективны. Для решения проблем техногенного загрязнения почвы нефтью и нефтепродуктами можно использовать фототермические способы, при которых углеводородная часть извлекается из почвы. Авторами создан гелиоустройство и разработан способ предотвращения деградации почвы с получением нефтепродуктов. Научная новизна работы заключается в использовании различных видов гелиоконструкций при переработке и утилизации нефтесодержащих отходов, обеспечивающих максимальное выделение углеводородов из нефтных отходов, без ущерба для их химической структуры, при изготовлении современных композиционных строительных материалов, обеспечивающих интенсификацию процессов твердения. Полученные результаты показывают, что разработанный способ предотвращения деградации природных комплексов, снижает загрязнение почвенного слоя и водосборов. Это позволит утилизировать нефтяные амбары и шламонакопители во всех нефтедобывающих регионах с использованием солнечной энергии.

Ключевые слова: деградация почв, техногенное опустынивание, нефтяные загрязнители, мелиорация, очистка почвы.

### Introduction

In all latitudinal natural-landscape zones of the planet one can observe the existence of processes of degradation of natural components in varying degrees.

The degradation of the components of the natural environment is: the deterioration of the properties of groundwater and surface water, rocks, soils, biota and gas components of the natural environment.

The reasons for the deterioration of these properties are associated with two aspects:

A) the deterioration of the natural environment and human life as a result of natural phenomena (volcanic eruptions, floods, earthquakes, tsunamis, etc.)

B) human activities (destruction of natural ecosystems, pollution, etc.).

In any case, the degradation of the components of the environment leads to a deterioration of the human habitat in the artificially created environment due to increasing environmental pollution (air, water, landscapes, etc.).

Soil degradation and, as a result, desertification is a global phenomenon, but in Kazakhstan it is felt most acutely. We have more than two thirds of the territory exposed to desertification. Of particular danger is the rapidly growing desertification. Desertification is seen as the result of a complex interaction of biological, political, social and economic factors.

It is known that during degradation and desertification almost all components of the landscape are affected. Increased anthropogenic activity can lead to changes in individual properties of soil or soil processes in general.

As a result of identifying diagnostic indicators of aridization and desertification of the soils of the steppe zone, it will be possible to determine the degree of desertification.

Under anthropogenic impact, the soil structure and crust are destroyed, the arable soil horizon is sprayed and the soil becomes susceptible to wind erosion (Table 1.).

According to official data, the area of desertification in Kazakhstan is 179.9 million hectares or 66% of the territory of the republic. The main causes leading to desertification and adverse environmental changes include: massive plowing of soils (including light and unsuitable for use) during the development of virgin lands, overgrazing and failure of pastures, deterioration of their grass stand, secondary salinization of soils during irrigation. There is also cutting down of tree and shrub vegetation along with annually recurring forest fires (especially in the former Semipalatinsk region), as well as chemical pollution of the soil [1].

---

26 Хабарцы. Экология сериясы. №2 (59). 2019
Local and regional chemical pollution of soils is observed near cities and industrial enterprises, open-pit mining of mineral resources. Such pollution of a technogenic type for a long period removes soil cover from use, drastically reduces the biological productivity of the soil, even leads to the unsuitability of vegetation grown on it for use, which is characteristic of very strong desertification.

Local soil contamination is most often associated with oil and petroleum product spills when pipelines are damaged and leaks through equipment leaks. Contamination of large areas is possible with the flow of oil.

Also the main sources of chemical pollution of the soil cover are:

- infiltration of household and technological waste;
- accumulation of products of combustion of fuels and lubricants of motor transport, drilling and diesel installations;
- infiltration and accidental spills of reagents from barns with drilling and cementing solutions;
- infiltration and accidental spills of formation and waste waters;
- freelance and accidental oil spills from the wellhead. The main pollutants in drilling and well testing are drilling fluids, flushing fluids, reagents for affecting the formation, cements, industrial waste, household and technical waste, etc. The dominant group of chemical contamination will be oil itself, its associated gas, wastewater and underground mineralized water. At the same time, there will be an active change in the structure of the soil cover due to secondary salinization, petrochemical pollution and accumulation of heavy metals in soils. In the end, technogenic soil ranges with completely different geochemical properties that are not typical for zonal soils with anomalous, at first aggressive properties will form [2].

The problem of detoxification, purification and restoration of the properties and fertility of soils contaminated with oil and oil products in order to prevent soil degradation is an important and most pressing issue at present.

Materials and Methods

The uniqueness of the work is to create a solar system for the processing of waste oil and gas industry with the development of innovative solutions to prevent soil degradation.

The methodological basis for the experimental study will be:

- analysis of theoretical assumptions;
- the study of the main characteristics of the object under study in the presence of various limitations imposed by the direct tasks of the experiments;
- consideration of the use and technological characteristics of the developed method of processing oily waste.

In the process of developing a methodological substantiation, first of all, the conditions under which it is possible to obtain reliable results are taken into account. Based on the data obtained, experimental models and equipment are selected, simulation parameters are generated, the number of repetitions of individual experiments is calculated.

During the research, both standard and generally accepted non-standard methods of analysis were used. To determine the morphology, structure and chemical composition of the obtained samples, were used various modern new and classical physicochemical methods of analysis. On the basis of the obtained empirical data using the methods of
induction and deduction, theoretical knowledge was formed, which were practically substantiated, which would ensure the removal of their hypothetical nature and transformation into reliable knowledge.

Trial studies were carried out directly on the object of study and ( additionally) on artificial solutions in order to eliminate the influence of side factors on the phenomena under study.

The physical and chemical indicators of oily waste and wastewater are assessed using standard methods. For this purpose used potentiometric, conductometric, colorimetric, spectrophotometric, ionometric and other methods of measurement and appropriate equipment.

For research used oil-contaminated soil and oil sludge from the Atyrau region, where concentrated large oil and gas fields in Kazakhstan. Their composition is given in table 2.

Oil waste was treated to separate the oil components from the main mass of the waste. The oil part of the waste was analyzed for further selection of the conditions for their extraction from waste.

Table 2 – Composition of oil waste

| Oil waste          | Composition, mass.% |
|--------------------|----------------------|
|                    | Organic part | Mechanical impurities | Water   |
| Oil sludge         | 76,8         | 8,0                   | 15,2    |
| Oil Contaminated Ground | 11,6         | 85,4                  | 3,0     |

Results and Discussion

In our country, more than 70 million tons of crude oil are produced annually, oil and gas bearing areas include 172 oil fields, of which more than 80 are under development. Such intensification of oil production and refining is accompanied by industrial pollution of the environment. As a result, the properties of the soil change, it is salinized. Contaminated land is removed from agricultural use as unfit. Also occurs the pollution of the aquatic environment with oil and petroleum products.

The enterprises of the oil and gas complex of the republic occupy one of the leading places in soil pollution with various chemical compounds [3].

Currently, oil and oil products are recognized as priority environmental pollutants. According to the degree of environmental impact, oil-producing enterprises are among the ten most dangerous. The oil and gas production regions are concentrated in the west and south-west of Kazakhstan – in the West Kazakhstan, Aktobe, Atyrau, Mangistau, Kyzylorda regions.

Lately, many oil and gas basins are characterized by an increase in the rates and volumes of oil and gas production. This is achieved either through the introduction of new fields into the development, or, especially for old developed pools, through additional exploration of old fields or the use of enhanced oil recovery technologies. The result is a significant, often uncontrolled, increase in anthropogenic load within the entire basin or its individual parts with irreversible environmental consequences [4].

One of the main sources of soil contamination are oil discharges into earthen barns, oil spills and water-oil mixtures when pipelines are broken, oil leaks onto the ground during an accident, oil production and repair work on wells. The practice of gas flaring in flares also causes significant environmental and economic damage. Increased thermal background and acidification of environmental components around fields during gas combustion have a negative impact on the soil, vegetation, and animal world adjacent to oil complexes, contributing to the increase in the greenhouse effect [5].

During the exploration and exploitation of hydrocarbon deposits around each drilling rig, vegetation is destroyed by 70-80% within a radius of 500-800 meters.

According to the information published by UNDP “Kazakhstan” in the review “Environment and Sustainable Development in Kazakhstan”, technogenic pollution of lands in the form of soil contamination was allowed in Atyrau oblast on an area of more than 1.3 million hectares, in some oil fields it reaches a thickness of 10 meters.

The highest content of oil and oil products in the soil of the Kulsarinskoe field can apparently be explained by the fact that in the old deposits of polluted soils dense bituminous bark is formed, which are impermeable to plant roots and microorganisms. Oil lakes (oil barns) are formed on the territory of the oilfield, the soil of vast areas of the field, mixed with oil, forms oil sludge. In most areas, the soil layer is saturated with crude oil, the thickness of the oil-contaminated layer reaches 10 m
in places. On the territory of the Kulsarinsky field, soil and vegetation cover is severely disturbed and soil deflation processes are noted [6].

Oil differs significantly from other pollutants in the nature of the impact on natural systems. Oil does not have a strictly defined chemical composition. This concept includes many varieties of tar-carbon systems, the properties of which may differ significantly from each other.

In oil pollution, three groups of environmental factors closely interact: 1) complexity, the unique multicomponent composition of oil, which is in the process of constant change; 2) the complexity and heterogeneity of the composition and structure of any ecosystem that is in the process of constant development and change; 3) the diversity and variability of external factors that influence the ecosystem: temperature, pressure, humidity, state of the atmosphere, hydrosphere, etc.

The main characteristics of the composition of oil, which determine its effect on the soil and living organisms, and the peculiarities of transformation in the biosphere depend on the content of: 1) the light fraction; 2) cyclic hydrocarbons; 3) solid paraffins; 4) resins and asphaltenes; 5) sulfur [7].

The light fraction, which includes the most simple in structure and low molecular weight methane (alkanes), naphthenic (cycloparaffinic) and aromatic hydrocarbons, is the most mobile part of oil. Most of the light fraction consists of methane hydrocarbons (alkanes) with the number of carbon atoms C\textsubscript{5} – C\textsubscript{11} (pentane, hexane, heptane, octane, nonane, decane, undecane). Normal (unbranched) alkanes in this fraction are 50 – 70%. Methane hydrocarbons have a strong toxic effect on living organisms, being in soils, water or air. These hydrocarbons are more soluble in water, easily penetrate into the cells of organisms through membranes.

The content of solid methane hydrocarbons (paraffin) in oil is an important characteristic when studying oil spills on soils. Paraffin wax is not toxic to living organisms, but due to high pour points (+ 180 °C and above) and solubility in oil (+ 40 °C) under the conditions of the earth’s surface, it becomes solid, depriving oil of mobility.

The naphthenic (cycloalkanes) and aromatic hydrocarbons (arenes) belong to cyclic hydrocarbons in the composition of oil. The content of aromatic hydrocarbons in oil varies from 5 to 55%, most often from 20 to 40%. The bulk of the aromatic structures are polynuclear hydrocarbons – benzene homologues [8, 9,10].

Aromatic hydrocarbons are the most toxic components of petroleum. At a concentration of only 1% in water, they kill all aquatic plants; oil containing 38% of aromatic hydrocarbons, significantly inhibits the growth of higher plants. Multicore hydrocarbons – have a more rapid toxic effect on organisms than polycyclic hydrocarbons.

Resins are viscous greasy substances, they contain more hydrogen and less carbon than asphaltenes. Asphaltenes are condensation products of 2-3 molecular resins. These are solids that are not soluble in low molecular weight hydrocarbons. Pitches and asphaltenes contain the main part of trace elements of oil, including almost all metals. The total content of trace elements in oil – hundreds and tenths of a percent. From an ecological point of view, trace elements of oil can be divided into two groups: non-toxic and toxic [11].

Research has established the main features of soil transformation in oil pollution. The processes of degradation of pollutants in soils are carried out against the background of their active interaction with the soil mass. This leads to a directional change in the properties of soils that receive man-made streams, coupled with changes in the chemical composition of introduced substances. The transformation of oil-contaminated soils to local biochemical conditions and changes not only in time but also in space [12].

Oil impregnation of the soil mass leads to active changes in the chemical composition, properties and structure of the soil. First of all, it affects the humus horizon: the amount of carbon in it increases dramatically, but the bituminous substance significantly impairs the property of the soil as a nutrient substrate for plants. In soil, there are changes in redox conditions, an increase in the mobility of humus components from a number of trace elements. If the source of contamination is a production well, then a significant transformation of the soil occurs as a result of salinization by reservoir waters accompanying oil. All this leads to a deterioration of the state of vegetation, a drop in land productivity [13].

Oil pollution of the soil leads to profound changes in all the properties of the soil, as a result of which its fertility is disturbed. This deterioration of water-air, physico-chemical properties of the soil, its absorption capacity, as well as a decrease in the content of elements of mineral nutrition of plants. Data from studies show that about 40–50% of chemical pollutants remain in the soil. Their remnants are combined with humus. Analysis of the literature data showed that humus is lost from an oil spill in the soil, which makes the soil dead and fertility is restored only a few years after the soil is polluted.
At low viscosity, oil has the ability to cover large areas of the earth’s surface with a thin film and affects the oxygen regime of the surface layers.

When the soil is saturated with oil, the phytase activity level of the soil decreases, which causes a slowdown in the mineralization of organophosphorus compounds. As a result, the content of mobile phosphorus decreases and some accumulation of organophosphorus compounds is observed in the soil. All this has a negative effect on the intensity of the microbiological and biochemical processes of soil self-purification. The soil is enriched with carbon disulfide, the number of anaerobic and spore-forming microorganisms increases [14].

Soil is a resource that is overexperienced and polluted. To restore 2-2.5 centimeters of the soil layer, it is necessary from 300 to 1000 years. The recovery period (self-rehabilitation) of soils contaminated with oil is from 1-2 to 10-15 and more years.

Restoration of disturbed soil cover requires a long time and large investments.

In world practice, various methods of cleaning soil and water from oil pollution are applied: mechanical, physicochemical and biological. Not all of them are safe and effective. To solve the problems of anthropogenic pollution by oil and petroleum products, photothermal methods during cleaning to remove the hydrocarbon portion of the soil.

The issue of cleaning oily waste is topical everywhere, but today there is still no effective industrial scheme for their processing, although almost all leading manufacturers of chemical equipment are trying to develop and improve equipment for cleaning and recovery. First in the world separator stations for cleaning oil sludge were designed and installed in Russia. Separators were designed to clean up oil sludge, but they were uneconomical due to the fact that after each work shift it was necessary to disassemble and remove work surfaces from contamination. The project developers made a serious miscalculation: on separators were fed raw materials without prior preparation and purification, while separators should be used only at the final stage of purification of oil sludge. In this regard, the methods of application of these types of separation have not found further application. In other factories for 10-15 years operated installations for the incineration of oil sludge, bottom sediments of sludge collectors and flotopenes. Processing sludge in this way was also uneconomical, since in addition to the loss of oil there was an additional fuel consumption in order to evaporate water and maintain the working temperature in the furnace. Among the disadvantages of the installation can still be inability to clean flue gases, which are formed during the incineration of sludge, from oxides of sulfur and nitrogen, as well as the fact that the raw materials needed to be additionally prepared for incineration [15].

An improved version of the sludge treatment unit was created by the Swedish company AlfaLaval. Cleaning is carried out in this way: the sludge is distilled into the tank and left for several days to settle. The water that has come to the surface is dumped from the tank to the treatment plant, and the oil phase is sent to the AlfaLaval installation. First, the oil phase enters the hydrocyclone, and then into a two-phase centrifuge, in which purification from heavy mechanical particles takes place. Further purification of oil (from water) is performed in a three-phase centrifugal separator. According to the results of the operation, a disappointing conclusion was made: such an installation is only suitable for cleaning fresh, newly formed sludge and, on the contrary, is hardly applicable for cleaning bottom sediments of sludge collectors. In addition, the water obtained in the cleaning process is contaminated with persistent oil emulsions, and it is not possible to process the mechanical impurities (soil) that are discharged from the separators from time to time. It can also be considered a flaw that the destruction of stable oil emulsions and the achievement of higher refining performance does not use chemical reagents [16].

The plant for the purification of oil sludge from the German manufacturer KHD has been proposed to several enterprises in the oil industry. The initial stage of cleaning on this installation is that the sludge is pumped into the tank. From this tank, the oil phase is distilled into a three-phase centrifuge, where the sludge is divided into components: oil, water and mechanical impurities – under the influence of centrifugal forces. To increase the cleaning efficiency, before loading the sludge into the centrifuge, it is treated with a chemical reagent. This installation has the following disadvantages: in order for the oil content in the sludge fed to the installation to be at least 70%, it is necessary to ensure a high degree of separation in the tank, otherwise the purified oil will contain a high percentage of water. In contrast to the centrifugal three-phase separator, the cleaning process in a centrifuge is not carried out automatically. The “KHD” unit can also clean only freshly formed sludge and is not suitable for cleaning deep sediments of sludge collectors. Oil sludge processing using centrifuges requires large quantities of electricity to ensure separation of oil from other components. Along with centrifuges use belt filter presses. However, such equipment allows only
to separate the soil and water. In the resulting soil remains from 20 to 30% of hydrocarbons [17].

The oil waste treatment method developed by BogartEnvironmentalServices, an American company, has been successfully operating in Kuwait for several years now. This method allows you to clean the sandy soil from oil spills after accidents. To do this, the contaminated soil is removed and formed into high (up to 10 meters) piles. Under its own weight of soil, oil is pressed out. After that, it is sent for cleaning to the centrifuge. The soil is diluted with water to a moisture content of 95% and transported in containers, where the process of biological degradation of hydrocarbons takes place. The use of Bogart equipment and methods for cleaning light soils is associated with certain difficulties. First, such soils are extremely difficult to form into piles. This means that the soil is subjected to biological treatment with virtually no separation of free oil, but microbiological methods are effective only when the concentration of hydrocarbons is not more than 15%. Note also that to ensure the effective operation of microbiological strains, it is required to dilute the soil with clean water. To the downsides of this method, the need for a large amount of pure water and a significant increase in cleaning time are added.

We must remember that microorganisms contain toxic elements and compounds. The volume of microorganisms that are displayed along with the cleaned soil is directly proportional to the volume of the feed (hydrocarbons) introduced into the soil. The more hydrocarbons get into biodegradation, the greater the amount of excess biomass will be obtained as a result of the cleaning process. Purification of soils with a high content of hydrocarbons can lead to an increase in the number of harmful elements contained in the cells, which can lead to biological pollution of the environment.

To maintain the process of biodegradation during biological treatment, it is necessary to update a large amount of biomass. To this end, reactors are installed at landfills for the production of such biomass. This is associated with additional costs for the nutrient medium and supplements for growing biomass. To reduce the amount of biomass, enzymes are used, their cost increases the cost of technology [18].

The multilateral approach to the system of processing oily waste is of great importance for the development of the oil and gas sector in Kazakhstan. The key difference in the idea of creating a solar complex is the use of solar energy in the processing of oily waste. Recycled raw materials on solar systems – cleaned soil – can find its application in the road construction industry. Thus, it is possible to create a demanded technological cycle “waste – feedstock – product”.

The scientific novelty of the work lies in the use of various types of solar constructions in the recycling and utilization of oily wastes, ensuring maximum separation of hydrocarbons from oil wastes, without prejudice to their chemical structure, in the manufacture of modern composite building materials, ensuring the intensification of hardening processes.

In addition, various types of solar constructions have the following advantages:

- environmentally friendly generation of thermal energy;
- total absence of greenhouse gas emissions;
- universality of application, simplicity of design and low weight, mobility at work, modular principle of power gain and high reliability;
- ensured the return of oil from oil sludge into circulation in raw form;
- minimum of oil impurities in the solid residue, as a result of which it is possible to use the solid phase to obtain a modern composite building material;
- oil content at the level of 1.5-2.5% in the aqueous phase, which allows for photochemical purification using ozone technology.

All the shortcomings identified in the above technologies for the processing of oil waste of various companies can be eliminated with the help of the created heliocomplex as part of the proposed method. The proposed effective scheme for the processing of oily waste in the solar complex works as follows. Oily wastes enter the heliocomplex, pass through a sieve, and then go to the solar system with concentrating elements, which is intended to separate the organic and mineral phases and water. The organic phase, i.e., the industrial design of petroleum products, is sent to the oil treatment plant, the mineral phase with a small amount of oil is used as a cleaned soil when obtaining a modern composite building material. In the proposed scheme for processing oil-containing waste, oil is additionally obtained, which is hardly extracted from the depths, instead of burning, which pollutes the environment with flue gases. In purified or pressed soil, a significant amount of hydrocarbons remains, and in our case, the soil contains only 7–8% of oil, which is close in its molecular weight to bitumen. Obtaining a modern composite building material from cleaned soils on the basis of the developed optimal composition is carried out in a solar chamber, which is intended to intensify the processes of hardening.
Table 3 – Total insolation of solar energy by months in Almaty city

| City   | Jan.   | Feb.   | March  | Apr.   | May    | June   | July   | Aug.   | Sept.  | Oct.   | Nov.   | Dec.   |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Almaty | 176·10⁶ | 239·10⁶ | 354·10⁶ | 484·10⁶ | 632·10⁶ | 729·10⁶ | 729·10⁶ | 647·10⁶ | 497·10⁶ | 321·10⁶ | 187·10⁶ | 136·10⁶ |

Experimental studies were conducted in Almaty city. The solar radiation of this area is \(1.343 \cdot 10^{15}\) J per year. Below is a table of total insolation by months in Almaty city.

The device works as follows: in order to create a condition for the displacement of oil from the soil, oil-contaminated soil or oil sludge is mixed with water, for which water is first poured into the device, and oil-contaminated soil or oil sludge is put on top. In the focal part of the body, a parabolic concentrator is installed on the metal frame and equipped with a tracking system behind the Sun, which maximally focuses the direct and scattered solar radiation, collects all the solar energy incident on it and directs it to the focal part of the tank. As a solar energy concentrator, you can use any material that has reflectivity. Figure 1 shows a schematic diagram of the solar system, equipped with matching elements.

The solar system is additionally equipped with a solar panel made from concentrator photovoltaic modules placed on a mechanical system. The module provides additional warmth during the overcast and cold season. Also a thermoelectric heater is additionally installed at the bottom of the tank, which is switched on using additional energy accumulated by the solar panel.

A rotor blades is mounted on the top of the container on the disk, which mixes the mixture as it warms up. Through the formed channels with the help of blades in the process of heating due to solar energy, start to stand out oil fractions. To separate the separated oil from the ground, the disc squeezes the mixture and the resulting productive oil is poured into the reservoir to collect oil through a pipe connected to the body.

During the experiment, when heating oil waste, the temperature in the device was 75-82 °C at an ambient temperature of 33-35 °C. Heating was carried out for 4 hours, and using additional energy accumulated by the solar panel, the heating time is reduced by 2-2.5 times. Loading and unloading of oil-contaminated and cleaned soils and oil sludge is carried out manually or mechanized way, although automation of this process is not excluded.

The results of the analysis of extracted oil from oily waste are shown in Tab. 4. From Tab. 4 shows that the content of chloride salts, the water content of the oil and the sulfur content in the electric heating method are much higher than normal, and also leads to a change in the physicochemical properties of the oil.

When using solar energy creates the required conditions for the extraction of oil from the soil. As follows from the above data, the product of cleaning oily waste is a valuable hydrocarbon feedstock that can be recycled or used for other purposes [19, 20].

To clarify the effect of thermal effects of solar energy on the properties of hydrocarbons, a study was conducted of the composition of oil-contaminated soils and sludge and their solid residues after pretreatment using solar energy in the developed device Fig.3.

After heat treatment of oil sludge through the installation, 3 target products are obtained: – product of oil sludge processing;
– water containing petroleum products;
– sludge (cake) with the content of petroleum products.

Thus, after the preliminary purification of oil waste using solar energy in the soil, the content of solid residues does not exceed 8.65–8.79%. After purification, the molecular weight of hydrocarbons is close in absolute value to bitumen, and the ratio of carbon to hydrogen varies according to the following series: bitumen (6.29-10.7) > oily soils or sludge (8.56-8.79). The advantages of this method of cleaning oil waste in order to separate the oil and mineral parts are the simplicity of the device design, its high performance and relative cheapness.
Figure 1 – Device for the extraction of oil and petroleum products during the cleaning of oily waste
1 – solar panel; 2 – parabolic cylindrical concentrator; 3 – solar energy tracking system;
4 – a disk for oil displacement with push-ups; 5 – rotor with blades for moving heated waste;
6 – capacity to drain the displaced oil.

Figure 2 – Dynamics of temperature change of oily waste using solar energy
Row 1 – Ambient Temperature; Row 2 – The temperature of the mixture of waste and water
It is practically possible to apply oil-contaminated soil and oil sludge as secondary raw materials for strengthening road surfaces.

For the manufacture of soil concrete, refined oil-contaminated soil and oil sludge are used as raw materials, which are one of the sources of environmental pollution in oil-producing regions. In the process of production activities in the preparation of oil is generated industrial waste, with containing petroleum products – up to 10%, suspended solids – up to 90%. The main polluting component in the waste is oil, the waste toxicity class is 4. Annual volume is – 4500 tons. The granulometric composition of the soil is determined according to SS 12536 – 79 by sieving the sample in the amount of one kilogram on a standard set of sieves. To implement the problem of disposal of oil-contaminated soil, we carried out experimental studies on the use of previously cleaned oil-contaminated soils and sludge as secondary raw materials as the most rational method of disposal.

The main difference of the organic component of oily waste, which determine physical properties and chemical activity, is a higher content of resins and asphalt, and the mineral part – ion-exchange complexes Ca2+ and Mg2+. Stabilization of oily waste was carried out with Portland cement PC 500. Manufacturing and testing of soil concrete was carried out in accordance with the instructions.

Further, in order to prepare a soil-concrete mixture, the previously cleaned oil-contaminated soil or oil sludge was first mixed, then mixed with sand by dosing, mixed until a homogeneous mixture was obtained, after which the binder was added. again mixed and then injected concrete additive and finally mixed and moistened to molding moisture with the required degree of uniformity. The composition of the investigated composition of soil-concrete based on oil-contaminated soil and sludge: composition – 1: 4: 2. In the compositions based on oil-contaminated soil and sludge used concrete additive based on sulfonic synthetic polymer. Polymer provides superviscosity, reduces to a large extent the water content in reoplastic concretes, does not contain chlorine. Polymer initially accelerates and increases the strength of concrete.

### Table 4 – Physico-chemical properties of recovered oil from oily waste

| Name of properties and methods | Density at 20°C, kg/m³ | Density hand over oil, kg/m³ | Content of chloride salts, mg/l | Oil water cut, % | Content of mechanical impurities | Sulfur content |
|--------------------------------|-----------------------|-----------------------------|---------------------------------|----------------|----------------------------------|---------------|
| Norm ND                        | 830,0                 | 833,7                       | 100                             | 0,5            | 0,05                             | 0,6           |
| 1st method (heating with solar energy) | 948,0                 | 942,7                       | 127,480                         | 18,0           | 0,0349                           | 0,168         |
| 2nd method (heating using electric energy) | 852,1                 | 942,7                       | 407,9                           | 35,0           | 0,0394                           | 0,265         |

---

**Figure 3** – Scheme of passage of sludge through the separator
To conduct an experimental study, we developed experimental and control samples of two compositions for the manufacture of a soil-concrete mixture, using oil-contaminated soil and oil sludge. For the purpose of heat treatment, the experimental samples were subjected to heat treatment in a device with concentrating elements of solar energy, and in the control samples hardening took place in natural conditions (Tab.5-6).

After heat treatment of the soil concrete in a solar system with a translucent shell, the physomechanical parameters of the experimental samples of the soil concrete had the following values given in Tab.6. As can be seen from the results of table 5 and figure 4, the soil concrete composition 2 and 4 in quality meet the requirements of the instructions for the stabilized soil class 2 strength.

The high compressive strength of soil-concrete 2 composition based on oil-contaminated soil and 4 composition based on oil sludge is explained by the following:

– the correct selection of the composition: a complex of sand and additives;
– the presence in the composition of the organic part of compounds with an unsaturated chemical bond, which increases their reactivity;
– using pre-cleaned oil-contaminated soils or oil sludge, since after pre-treatment the molecular weight of hydrocarbons approaches in absolute value to bitumen, and the ratio of carbon to hydrogen varies according to the following series: bitumen ($6.29 – 10.7$) $>$ oil-contaminated soils or oil sludge ($8.56 – 8.79$).

For soil-based concrete made on the basis of oil-contaminated soils or sludge, priority in tensile strength in bending is explained by the content of resins that provide adhesion, cohesive bonds and elasticity (Tab.7).

### Table 5 – Composition of soil-concrete on the basis of oil-contaminated soil and sludge

| number of samples | The composition of soil-concrete (experimental sample-heat treatment with the use of solar energy) | number of samples | The composition of soil-concrete (control – hardening in vivo) |
|-------------------|---------------------------------------------------------------------------------|-------------------|---------------------------------------------------------------------------------|
| 2                 | contaminated soils cement sand water concrete additives | 22                | contaminated soils cement sand water concrete additives |
|                   | using oil sludge                                                              |                   | using oil sludge                                                              |
| 4                 | Oil sludge cement sand water concrete additives                               | 44                | Oil sludge cement sand water concrete additives                               |

### Table 6 – Physical and mechanical properties of the experimental and control samples soil-concrete after 28 days of hardening

| Name indicators                                      | According to building codes and regulations, 2 strength class | The value of technical indicators                                      |
|------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------------------|
|                                                      |                 | contaminated soils | oil sludge | 2 experimental | 22 control | 4 experimental | 44 control |
| The compressive strength of saturated samples, MPa   | 6–4             | 5,73              | 3,1        | 5,33          | 3,70       |                                                             |
| The tensile strength in bending samples saturated with water, MPa, not less | 1,0             | 1,6               | 0,86       | 1,50          | 0,76       |                                                             |
| Coefficient of frost, not less                       | 0,75            | 0,81              | 0,55       | 0,80          | 0,53       |                                                             |
Soil degradation due to pollution by oil and oil products and the development of a way to prevent them

In accordance with the above, the optimal composition can be recommended according to the instructions for the device bases or as a covering of local roads. They can also be recommended as bases acting as crack-breaking layers. At the same time, technological properties are improved: workability, due to the presence of plasticizing additives – oil, and hence homogeneity and easy workability. Increased performance: compressive and tensile strength, frost resistance and deformation capacity due to the use of cement, which provides the crystalline structure of the spatial framework that occurs in fortified soil. This is explained by the fact that oil has a coagulation structure, and the presence of cement in it provides a mixed coagulation-crystalline structure of the soil with a real possibility of obtaining soil concrete with high physico-mechanical properties.

Table 7 – soil-concrete strength by heat treatment using solar energy

| Number of mixture | W/C | Tensile strength in bending | Compressive strength, MPa age day |
|------------------|-----|----------------------------|----------------------------------|
|                  |     |                            | 1  | 7  | 14 | 28 |
| 1                | 2   | 3                          | 4  | 5  | 6  | 7  |
| 2                | 0,5 | 1,6                        | 1,07 | 1,7 | 3,74 | 5,73 |
| 22               | 0,5 | 0,86                       | 0,11 | 0,75 | 1,55 | 3,1 |
| 4                | 0,5 | 1,50                       | 1,01 | 2,36 | 3,70 | 5,33 |
| 44               | 0,5 | 0,76                       | 0,13 | 0,93 | 1,85 | 3,7 |

The results show that an environmentally friendly method has been developed for cleaning oil-polluted soils, soils and oil sludge. This method solves an important environmental problem of cleaning oil-polluted soils, soils and oil sludge, helps restore and prevent the degradation of natural complexes, reduces pollution of the soil layer and water bodies. This will allow utilizing oil barns and sludge collectors in all oil-producing regions using solar energy.

Thus, this method of cleaning oil-contaminated soils, soils and oil sludge will provide, with maximum use of solar energy, a reduction in the level of the negative impact of pollutants on the environment.
References

1. Belzigbaev M.E. Diagnosticкие показатели аридизации и опустынивания почв степной зоны Казахстана // Казахский Национальный Университет имени аль-Фараби, Алматы. Степной бюллетень. – 2002. – №11. – С. 52-55.
2. Diarov M.D. Экология и нефтегазовый комплекс. Tom 1. – Алматы, 2003. – C. 387-391.
3. Smykov V.V., Smykov Yu.V., Torikov A.I. On the problem of utilization of oil-containing wastes // Oil industry. – 2005. – No. 3. – P. 30-33.
4. Середин В.В. Санация территорий, загрязненных нефтью и нефтепродуктами // Геоэкология – 2000. – № 9. – C. 525-540.
5. Valkov V.F., Kazeев K.Sh., Kolesnikov S.I. Ecology of soils: A manual for university students. Part 3 // Pollution of soils. Rostov-on-Don: UPL RSU.- 2004.- P.54.
6. Akpambetova K.M., Musina A.A., Jangzihina D.M., Kalieva T.N. Экологические проблемы аридных территорий Казахстана // Вестник КарГУ. Серия биологическая. – 2007. – №2. – С. 49-54.
7. Salanginas L.A. Change of soil properties under the influence of oil pollution and the development of a system of measures for their rehabilitation // Dis. ... of the Biol. Sciences. Ekaterinburg, 2003. – P. 486.
8. Guangii Hua, Jianbing Li a, Guangming Zengb. Recent development in the treatment of oily sludge from petroleum industry: a review // Journal of Hazardous Materials. - 2013. – № 261. – P.470-490.
9. Карева Н.Ю. Гигиеническая оценка процессов миграции и трансформации нефти в почве // Автореф. дисс. ... канд. биол. наук. – М., 2006. – С. 12-15.
10. Arustamov Э.А. Природопользование // учебник для вузов. – М.: Дашков и Ко, 2000. – С. 302.
11. Геннадьев А.Н., Ju.I.Pikovskii. Карти устойчивости почв к загрязнению нефтепродуктами и полициклическими углеводородами: метод и опыт составления // Почвоведение. – 2007. – N1. – С. 80-92.
12. Баженова О.К. Геология и геохимия нефти и газа // О.К. Баженова, Ю.К. Буллин, Б.А. Соколов, Е. Чейн – М.: МГУ, 2012. – C. 432.
13. Valova V.D. Fundamentals of ecology. – M.: “Dashkov and Co”. 2001. – P. 212.
14. Orlov D.S., Vasilevskaya V.D. Почвенно-экологический мониторинг и охрана почв. – М.: Изд-во МГУ, 1994. – С. 257.
15. Obrevka L.A., Frolova V.A., Darisheva A.M. Environmental problems and utilization of oil industry waste. – Аlmaty: KazgosINTI. – 2002. – Р. 126.
16. Singh P., Ojha A, Borthakur A., Singh R., Lahiry D., Tiwary D., Mishra P.K. Emerging trends in photodegradation of petrochemical wastes // Environmental Science and Pollution research. – 2017. – Part: 23. – Number: 22. – P. 353.
17. Ongarbayev E.K., Mansurov Z.A. Oil waste and ways of their utilization. – Аlmaty: Kazak universiteti, 2003. – P. 160.
18. Yagudin N.G. Processing of sludge from oil production and oil refining into road and aerodrome soil cushions // Environmental protection in the oil and gas sector – 2005. – №3. – P. 77-82.
19. Estrada-Arriaga E.B., Zapeda-Aviles J.A., Garcia-Sanchez L. Post-treatment of real oil refinery using photo-ferrioxalate and Fenton’s reactions with membrane process step // Chemical Engineering Journal. DOI: 10.1016 / j.cej.2015.10.030. Published: FEB 1. – Tom: 285. – 2016. – P. 508-516.
20. Novikov Yu.V. Ecology, environment and people // Textbook, manual for high schools, secondary schools and colleges. – M.: FAIR PRESS, 2005. – P. 736.

References

1. Akpambetova K.M., Musina A.A., Dzhangozina D.M., Kaliyeva T.N. (2007) Ecologicheskiye problem aridnyh territoriy Kazakhstana [Ecological problems of arid territories of Kazakhstan]. Vestnik KarGU. Seriya biologicheskaya, №2, pp.49-54.
2. Arustamov E.A. (2000) Prirodopolzovaniye [Nature management]. Uchebnik dliya vuzov, М., “Dashkov and Co.”, pp.302.
3. Bazhenova O.K., Burlin Ju.K., Sokolov B.A., Chain V.E. (2012) Geologiya i geochimiya nefti I gaza [Geology and geochemistry of oil and gas]. М.: MGU, pp. 432.
4. Belgibayev M.E. (2002) Diagnostitcheskie pokazateli aridizacii I opustyniavaniyia potchv stepnoi zony Kazakhstana [Diagnostic indicators of aridization and desertification of soil in the steppe zone of Kazakhstan]. Kazakhskii nationalnyi universitet imeni al-Farabi, Almaty. Stepnoi boltin, №11.-pp.52-55.
5. Gennadiev A.N. Pikovskii Ju.I. (2007) Karty ustoitchivosti potchv k zagriyazneniu nefteproduktami I polichiklicheskimi uglavodorodami: metod i opyt sostavleniya [Soil resistance maps to pollution by petroleum products and polycyclic hydrocarbons: method and experience in compiling]. Potchvovedenie, No1, pp.80-92.
6. Guangii Hua, Jianbing Li a, Guangming Zengb. (2013) Recent development in the treatment of real oil refinery using photo-ferrioxalate and Fenton’s reactions with membrane process step. Chemical Engineering Journal, DOI: 10.1016 / j.cej.2015.10.030. Published: FEB 1. – Tom: 285. – 2016. – P. 508-516.
7. Novikov Yu.V. Ecology, environment and people // Textbook, manual for high schools, secondary schools and colleges. – M.: FAIR PRESS, 2005. – P. 736.
Soil degradation due to pollution by oil and oil products and the development of a way to prevent them

10 Novikov Yu.V. (2005) Ecology, environment and people: Textbook, manual for high schools, secondary schools and colleges. M.: FAIR PRESS, pp.736.
11 Obrevka L.A., Frolova V.A., Darisheva A.M. (2002) Environmental problems and utilization of oil industry waste. Almaty: KazgosINTI, pp. 126.
12 Ongarbayev E.K., Mansurov Z.A. (2003) Oil waste and ways of their utilization. Almaty: Kazak universiteti, pp. 160.
13 Orlov D.S., Vasilevskaya V.D. (1994) Potchvenno-ecologitcheskii monitoring i ochrana potchv [Soil-ecological monitoring and soil protection]. M.: Izd-vo MGU, pp. 257.
14 Salanginas L.A. (2003) Change of soil properties under the influence of oil pollution and the development of a system of measures for their rehabilitation: Dis. ... of the Biol. Sciences, Ekaterinburg, pp.486.
15 Singh P., Ojha A, Borthakur A., Singh R., Lahiry D., Tiwary D., Mishra P.K. (2017) Emerging trends in photodegradation of petrochemical wastes // Environmental Science and Pollution research, Part: 23, Number: 22, pp.353.
16 Seredin V.V. (2000) Sanaciya territorii, zagriyaznennykh neftyu i nefteproductami [Sanitation of the territories polluted by oil and oil products]. Geoecologiya, № 9, pp. 525-540.
17 Smykov V.V., Smykov Yu.V., Torikov A.I. (2005) On the problem of utilization of oil-containing wastes. Oil industry, No. 3, pp. 30-33.
18 Valkov V.F., Kazeev K.Sh., Kolesnikov S.I. (2004) Ecology of soils: A manual for university students, Part 3, Pollution of soils. Rostov-on-Don, pp.54.
19 Valova V.D. (2001) Fundamentals of ecology, M.:»Dashkov and Co», pp.212.
20 Yagudin N.G. (2005) Processing of sludge from oil production and oil refining into road and aerodrome soil cushions. Environmental protection in the oil and gas sector, №3, pp. 77-82.