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THE ISSUE OF RADIOACTIVE CONTAMINATION IN CONTEXT OF ECOSYSTEM SERVICES DEVELOPMENT

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The **aim** of the article was to define the role of the radioactive environment contamination in the formation of ecosystem services strategy. **Methods**. Monographic, systemic and structural, factor analysis, abstract and logical research methods have been used. The data from the State Statistics Service of Ukraine, the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Ecology and Natural Resources of Ukraine, materials of scientific researches, international materials and reports and other literary sources on the issues investigated have been used as an information base. **Results**. Retrospective analysis of sources and state of radioactive ecosystems contamination was conducted and the priority steps in developing the concept of ecosystem services in conditions of radiation contamination were found. **Conclusions**. The current socio-ecological paradigm of the transition from environmental use to environmental management should be reflected in the relevant environmental management mechanisms. Currently, when assessing the state of ecosystem services in Ukraine and worldwide one must take into account the changes in food demand of residents of radioactively contaminated areas, the exploitation of radioactively safe ecosystems growth, their overload and degradation. All of this requires an inventory of ecosystem services by type, region, consumers, etc. and the formation of a state register of ecosystem services with a clear assignment of area of responsibility for appropriate natural ecosystems. This will help to make the economic evaluation of different ecosystem services and mechanisms of charges for ecosystem services.

Keywords: radiation contamination, ecosystem services, radionuclides, ecosystems degradation.

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INTRODUCTION

Humanity obtains numerous benefits from the environment, including food, timber, clean water, energy, protection from floods and soil erosion, which may conditionally be called “goods” and “services”. The well-being of all the groups of people in the world without exceptions depends on these so called “ecosystem services”. The latter are understood as such functions of ecosystems, which condition specific economic benefits for people, using these services, and are based on the natural provision of different regulatory functions. The users of the mentioned services may be viewed both at the local level (some people or enterprises), and at the regional and global levels – whole countries and regions. In the latter case one should consider global ecosystem services, such as, for instance, consumption of carbon dioxide by forest ranges. Recently more and more people and organizations tend to pay special attention to this issue. At present the Millennium Ecosystem Assessment program is the one to reflect the state of global environment in the finest detail. According to this program, the ecosystem services are classified as follows: supporting services (required for the production of all the other ecosystem services, including the formation of soil, photosynthesis, primary products, circulation of nutrients and water); provisioning services (products, obtained from ecosystems, including food products, fuel, genetic resources, natural medical means and drinking water); regulating services (benefits from regulating ecosystem processes, including control of air quality, regulation of climate, aqueous regime, erosion, water purification, regulation of a num-

ber of diseases and pests, *etc.*); cultural services (non-material services, obtained by people from ecosystem for their cognitive development and health) [1].

During 50 recent years the level of many benefits, which we are used to obtain from the environment, has dropped rapidly due to the catastrophic decrease in biodiversity on the planet. The rate of anthropogenically caused extinction of species was found to be 1,000-fold higher than natural extinction of organisms, remarkable for geologic history. About 60 % of studied ecosystems resources of the Earth have considerably degraded. And it is mainly the anthropogenic impact to blame for it. During recent 300 years the area of forests on the Earth has been reduced by about 40 %. Forests have vanished completely in 25 countries, 29 other countries have lost over 90 % of forest plants. Since 1900 the world has lost about 50 % of wetland [1].

According to scientifically grounded recommendations, natural ecosystems should take at least 2/3 of upland and have their biological performance not lower than the average global index of 7.8 [2]. The ratio of landscapes in Ukraine, where the area of anthropogenic land covers about 80 % of its territory, reflects the state, approaching large scale desertification. The main agent of destroying natural ecosystem in this country is arable agriculture. Our country has one of the highest indices of plough-disturbance of tilled areas in the world, which, by different estimates, is 54–57 % (with the threshold index of 38.2 %) [3]. This figure is considerably smaller even for EU countries, where the population density is higher – 25.6 %. The situation is further deteriorated by removing fertile agricultural lands from active use due to their radionuclides contamination. First of all, these are pollutants of Chornobyl origin, radioactive wastes and wastes of mining industry.

The aim of this study was to analyze the sources and state of ecosystems in terms of radionuclide contamination and to define priority steps regarding the formation of the concept for ecosystem services in conditions of radioactive contamination.

MATERIALS AND METHODS

In terms of theory and methodology this study was based on the fundamental provisions of ecology and environment protection, economy of environmental use and agricultural radiology, highlighted in the works of domestic and foreign scholars. The following methods were used in the work: monographic, systemic and structural, factor analysis, abstract and logical research, *etc*.

The data from the State Statistics Service of Ukraine, the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Ecology and Natural Resources of Ukraine, materials of scientific researches, international materials and reports and other literary sources on the issues investigated have been used as an information base. Retrospective analysis of sources and state of radioactive ecosystems contamination was conducted.

RESULTS AND DISCUSSION

Radionuclides are among 10 most hazardous toxic substances, listed in the report, published by Blacksmith Institute (currently, Pure Earth) – a non-governmental organization, dealing with environment pollution problems, in 2010 [4]. Due to a complex of geological, geochemical, biogeochemical, and other processes, radionuclides migrate along ecosystem components, thus posing as potential threat both to ecosystems, and human health [5]. According to recent estimates, about 0.8–1 mln people worldwide have generally received or are at risk of receiving additional doses of both external and internal radiation due to the mining of radioactive minerals, and over 10.3 mln people – after catastrophes at the Chornobyl and Fukushima-1 Nuclear Power Plants [6]. Penetrating via skin, respiratory organs, drinking water and food, radionuclides get involved in the exchange of substances between environmental components and organisms of humans and animals [7, 8]. The problem of minimizing radioactive burden on the population, residing in the territories, contaminated with radionuclides, mainly relies on the decrease in the radionuclide contamination level of food products and on the restraint of their being absorbed in the digestive tract [9]. In conditions of long-term intake of radionuclides into the human organism, it is recommended to consume dietary fiber, calcium salts, alginic acid, and pectins to decrease absorbing and accumulation of strontium, for instance, and to eat pectins, dietary fibers, and calcium salts to prevent the accumulation of cesium. Thus, supplying the population with a sufficient amount of radiologically safe milk and milk products, fruit, vegetables, sea food (fish, algae, etc.), dried fruit, pulpy juices, peas, kidney beans, and wholemeal bread promotes the reduction of radionuclide accumulation in the organism.

A specific mention should be made of the consequences of catastrophes at Chornobyl and Fukushima-1 nuclear power plants. Even 30 years after the Chornobyl catastrophe the problem of radionuclides accumulation in the organisms of residents of contaminated territories is still urgent. There is increasing sig-

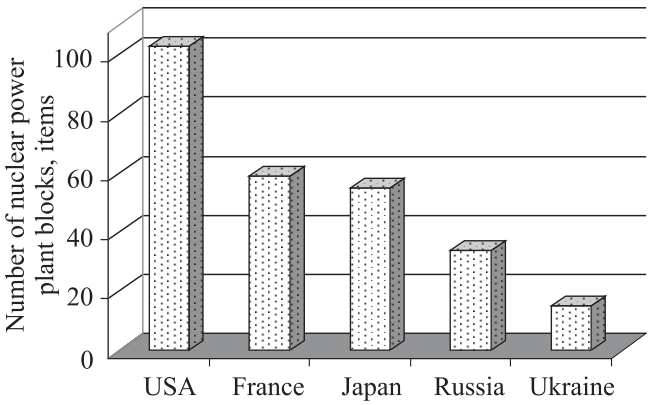

Fig. 1. Nuclear power plants of the world

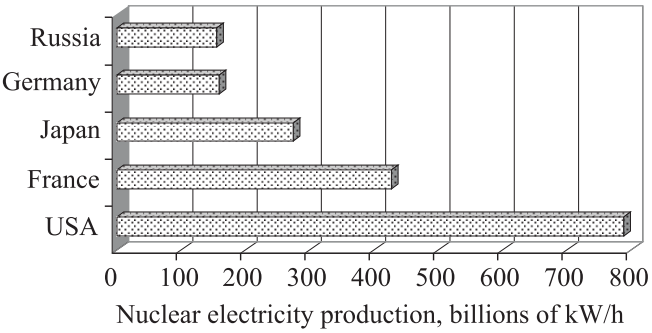

Fig. 2. The volume of nuclear electricity production by leading countries

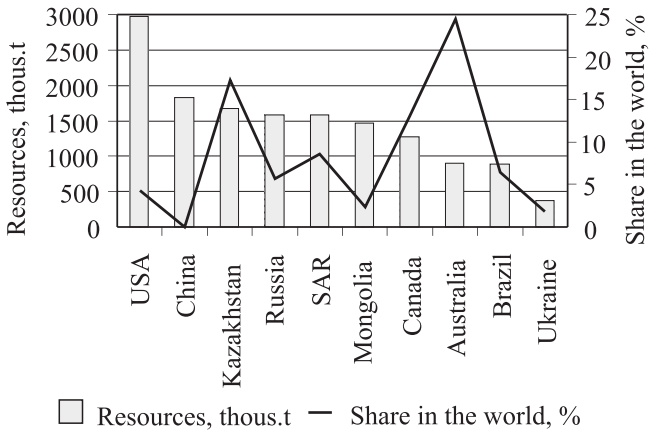

Fig. 3. Uranium resources at the intersection of 20th and 21st centuries (thousand tons)

nificance of people's consuming vitamins, macro- and microelements, especially iodine, selenium, iron, cobalt for unimpaired operation of the thyroid gland. All the abovementioned facts testify to certain specificities of the diet for the residents of radioactively contaminated regions, and thus, to the change in food needs and demand for ecosystem services.

The consequences of the Chornobyl catastrophe are remarkable not only for enormous areas of contaminated territories, but also for the enormous spectrum of radionuclides, which came out of the reactor, and for a considerable power range of chronic exposure doses. Even as of now, the radioecologic situation is complicated and notable for non-homogeneity of territory contamination with α-, β- and γ-radiating radionuclides, the availability of radioisotopes practically in all the ecosystems components and their involvement in geochemical and trophic migration cycles [10, 11].

Regardless of this fact, at the end of the first decade of the 21 century, the world nuclear electricity, produced in over 30 countries (441 nuclear power plants are working worldwide) (Fig. 1) [11], has promising future – its large scale development is planned, in particular, the construction of 300 to 600 new nuclear power reactors as early as by 2030 [12].

In France, nuclear power plants produce over 75 % of electric energy, in Ukraine – over 50 %, in the USA – 20 %, in Great Britain and Belgium – about 60 %, Finland – 27 %. The world leaders in producing nuclear electricity are the USA, France, Japan, Germany, and the Russian Federation (Fig. 2).

According to the MAGATE estimates, over 65 nuclear reactors of power plants and 260 nuclear devices, used in scientific areas, the lifetime of which (30 years) is close to expiration, will have to be removed from active use in the nearest future. This requires considerable financial expenses (sometimes much higher than the construction of new reactors) and envisages a number of serious risks.

Testing of nuclear weapons, catastrophes in the Chornobyl and Fukushima-1 nuclear power plants, active processing of used nuclear fuels and radioactive mineral resources have led to the occurrence of previously unavailable transuranium elements in human environment. Taking into consideration a long half-life period for some of them, they will pose a radiological threat for thousands of years to come. The resources of relatively cheap uranium for nuclear power plants on the planet are about 4 mln tons. Similar to oil, these may be exhausted in 25–30 years. There are uranium ore deposits in Ukraine, the USA, SAR, Canada, Congo, Namibia, Niger, Germany, Kazakhstan, Russia, Australia, Brazil, France, India, Japan, and other countries. The main producing countries are Canada, SAR, the USA, Namibia, Niger, and France. Ukraine has the largest deposits and general uranium reserves in Europe and is among top ten countries of the world by these indices. The State Register of Mineral Reserves of Ukraine enlists 17 ore deposits (Kirovohrad region –

14, Mykolayiv region – 2, Dnipropetrovsk region – 1). 21 ore deposits have been discovered and studied. The share of Ukraine in the world reserves of uranium is 1.8 % (Fig. 3).

Refuse heaps, where the content of uranium isotopes exceeds the bulk earth values manifolds, cover many thousands of square meters in mines and open cuts and are sources of local contamination of the land via wind erosion and washing out with precipitation. The additional sources of environment contamination are liquid wastes, including mine waters, filled with radionuclides.

In addition, there is a problem of radioactive contamination due to nuclear catastrophes, testing of nuclear weapons, storing radioactive wastes and the activity of nuclear industry, etc. In many cases there are leaks of radionuclides from storages due to different reasons. There are frequent leaks of mine waters and impairments in the integrity of so called tailing dumps. In 1991 Ukraine alone established nine tailing dumps at the total area of 270 ha: seven – with processed uranium ore (about 42 mln t) and two – with uranium production wastes (0.2 mln t). Most wastes are highly radioactive. The storages of uranium production wastes are sometimes located close to human settlements and agricultural lands (for instance, Dniprovske tailing dump in Ukraine is located at the distance of 1 km from the Dnipro river).

The total area of agricultural lands with enhanced level of radioactive contamination in Ukraine is 42.9 mln ha, or 71.0 % of the whole area of the country. The agricultural work in the region, which suffered from the Chornobyl catastrophe the most, amounts to 71 %, and the degree of land tillage – 53.6 % [13]. Removal of radioactively contaminated land from economic use leads to excessive load on radioactively safe lands. The intense exploitation of the latter and the impairment of the recommended ratio of different categories of lands due to increasing food crisis cause progressing degradation of ecosystems.

In the 1990's, Ukrainian scientists developed a program of conserving eroded arable land. However, this was the period when the process of dividing into shares started. The majority of agricultural lands were divided into shares: 270 thousand sq.km (45 % of the country's territory), including a considerable volume of arable land, were at different stages of erosion. Unfortunately, some lands in Ukrainian Polissia with maximal soil-to-plant trancfer factor for 137Cs have been divided. It is legally impossible to force the owners of arable shares to transfer them into natural or seminatural state (to conserve them). The legislation stipulates clear target application of these lands – commercial agriculture, and from the commercial standpoint it is much more beneficial for the owner to exploit his land as arable area. Therefore, the legislation in force practically makes land owners exploit arable lands intensively, as the conservation is viewed as its non-target application and results in punitive sanctions.

Of all the ecosystems of Ukraine, the closest attention is paid to forests, which cover 15.5 % of Ukraine's territory. However, there is also a problem of unavailable scientific substantiation of restoring forest ranges, which results in total decrease of forest biodiversity and large-scale outbreaks of phytophage population and diseases. The extinction of natural ecosystems means degradation of soils, hydrologic regime and water bodies and, as a result, large-scale desertification. The solution to the mentioned problem is returning these territories to their natural state via conservation and recultivation of anthropogenic territories with simultaneous compensation for the shortage of arable fund via returning previously removed radioactively contaminated lands into active use. This idea was somewhat reflected in the Law of Ukraine "On Main Provisions (Strategy) of the State Ecologic Policy of Ukraine for the period till 2020" and in the Resolution of the Cabinet of Ministers No. 675-r dated September 22, 2004 "On Approval of the Concept of the State Biodiversity Preservation Program for 2005–2025".

Therefore, the active development of nuclear energy industry, increasing mining and processing of uranium ores, catastrophes in the Chornobyl and Fukushima-1 nuclear power plants resulted in the occurrence of a new abiotic environmental agent – contamination of natural complexes with radioactive substances. In opinion of the authors of [2], the solution of this problem requires going through three main stages: scientific stage (based on the ecosystem approach), legislative (the increase in the area of government-owned lands, obtaining a permit for conservation of private land and for changing the target application of arable land) and administrative-practical (reforming the executive bodies, including the formation of new departments or state institutions).

As humanity has been successful in eliminating over half of natural upland ecosystems, it is not enough to just protect the remains of natural ecosystems and resources. There is an urgent need of their restoring. At present, the so called "sustainable environment use" is

an archaic term, because first of all natural ecosystems should create healthy environment, i.e. provide ecosystem services, instead of being mere objects of economic activity. The current social-ecologic paradigm of the transition from environmental use to environmental management should be reflected in the relevant management mechanisms, as the development of the organizational and economic forms of ecologic regulation is revealed in environment management the most.

CONCLUSIONS

The estimation of the development of ecosystem services in Ukraine and in the world should take into consideration such problems as changes in the food demands of residents of radioactively contaminated territories; removal of radioactively contaminated ecosystems from active use and, as a result, the increased exploitation of radioactively safe ecosystems, their excessive load with the development of degradation processes, including desertification. The estimate should take into account the specifics of ecosystems as well as the primary state of ecosystem services. This principle highlights the absence of universality in approaches to characterization of ecosystem services, each of which is unique. All these require taking inventory of ecosystem services by their kinds, regions, consumers, etc., and establishing a complex state register of ecosystem services with clear assignment of responsibility areas for the state of specific natural ecosystems. This will allow conducting economic evaluation of the services of different ecosystems (water bodies, forests, etc.) and mechanisms of charging for ecosystem services.

The concept, suggested by us, has been presented in the general form, it is yet to be elucidated in detail and discussed, as it relates to a wide range of both ecologic and socio-political issues. However, it should be stressed that the world has passed into the critical phase when economy has to adjust to ecology, not vice versa.

Питання радіоактивного забруднення у контексті розвитку екосистемних послуг

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Мета. Визначення ролі радіоактивного забруднення оточуючого природного середовища у формуванні стратегії екосистемних послуг. **Методи.** Застосовано монографічний, системно-структурний, абстрактно-логічний методи досліджень, а також факторний аналіз. Інформаційною базою слугували дані Державної служби статистики України, Міністерства аграрної політики і продовольства України, Міністерства екології і природних ресурсів України. **Результати.** На основі ретроспективного аналізу джерел і стану радіоактивного забруднення екосистем визначено першочергові кроки щодо формування концепції екосистемних послуг за умов радіаційного забруднення. **Висновки.** Встановлено, що існуюча соціально-екологічна парадигма переходу від природокористування до природогосподарювання потребує відповідних механізмів управління природокористуванням. Наразі при оцінюванні стану екосистемних послуг в Україні та світі необхідно враховувати вплив радіонуклідів на екосистеми, а саме – на зміну та скорочення біорізноманіття, зміну продовольчого попиту мешканців радіоактивно забруднених територій, посилення експлуатації радіаційно безпечних екосистем, їхнє перевантаження та деградацію. Все це вимагає проведення інвентаризації екосистемних послуг за їхніми видами, регіонами, споживачами тощо та формування комплексного державного реєстру екосистемних послуг з чітким закріпленням зон відповідальності за стан певних природних екосистем. Це дозволить оцінити вартість різноманітних екосистемних послуг та створити механізми платежів за них.

Ключові слова: радіаційне забруднення, екосистемні послуги, радіонукліди, деградація екосистем.

Вопрос радиационного загрязнения в контексте развития экосистемных услуг

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Цель. Определение роли радиоактивного загрязнения окружающей среды в формировании стратегии экосистемных услуг. **Методы.** Применены монографический, системно-структурный, абстрактно-логический методы исследований, а также факторный анализ. Информационной базой служили данные Государственной службы статистики Украины, Министерства аграрной политики и продовольствия Украины, Министерства экологии и природных ресурсов Украины. **Результаты.** На основе ретроспективного анализа источников и состояния радиоактивного загрязнения экосистем определены первоочередные шаги по формированию концепции экосис-

темных услуг в условиях радиационного загрязнения. **Выводы.** Установлено, что существующая социально-экологическая парадигма перехода от природопользования к природохозяйствованию требует соответствующих механизмах управления природопользованием. В настоящее время при оценке состояния экосистемных услуг в Украине и мире необходимо учитывать влияние радионуклидов на экосистемы, а именно – на изменение и сокращение биоразнообразия, изменение продовольственного спроса жителей радиоактивно загрязненных территорий, усиление эксплуатации радиационно безопасных экосистем, их перегрузки и деградацию. Все это требует проведения инвентаризации экосистемных услуг по их видам, регионам, потребителями и т. д. и формирования комплексного государственного реестра экосистемных услуг с четким закреплением зон ответственности за состояние соответствующих природных экосистем. Это позволит оценить стоимость разнообразных экосистемных услуг и создать механизмы платежей за них.

Ключевые слова: радиационное загрязнение, экосистемные услуги, радионуклиды, деградация экосистем.

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