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**INCREASE OF EFFICIENCY
OF SOIL REMEDIATION NEAR ST-
ORES OF RADIOACTIVE WASTES**

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One of bases of the sustainable development of Ukraine is the modern nuclear fuel cycle (complex). But the complex has great potential of pollution in soil resources. The problem in Ukraine can be resolved only on the basis of the European standards by means of wide intrusion of modern procedures of clearing of soil from radioactive pollution (collected during half-century functioning of the nuclear industry of the former Soviet Union). CLEANSOIL is a very simple and cost-efficient modern technology to enable in-situ treatment of hazardous substances in soil, especially targeted for large areas of polluted land and causing minimum site disturbance. The need of viable methods of detecting and evaluating such environmental contamination by objects of nuclear fuel cycle has made the special complex of radiological researches (capacity an exposition doze of γ -radiation, specific activity of soil and vegetation) to be valuable tools, thanks to their non invasive characteristics and low cost investigation.

Одной из основ устойчивого развития Украины является современный ядерно-топливный цикл (комплекс). Но этот комплекс имеет большой потенциал загрязнения ресурсов почвы. Эта проблема в Украине может быть решена только на основе Европейских стандартов посредством широкого внедрения современных процедур очистки почвы от радиоактивного загрязнения (накопленного в течение столетия функционирования ядерной промышленности бывшего Советского Союза). CLEANSOIL - простая и финансово-эффективная современная технология, которая позволяет in-situ извлечение опасных веществ из почвы на достаточно больших площадях загрязненной земли с минимальными нарушениями поверхности. Потребность эффективных методов обнаружения и оценки такого загрязнения окружающей среды объектами ядерно-топливного цикла определила специальный комплекс радиологических исследований (мощность экспозиционной дозы γ -излучения, удельная активность почвы и растительности) как ценный, не агрессивный к окружающей среде и дешевый инструмент.

Introduction

Since 1990-th years Ukraine has been passing to a system of sustainable development, which provides harmonious and rational assistance of economic and ecological spheres. One of bases of the development is the modern nuclear fuel cycle (first of all – mining, processing of uranium raw material and salvaging of radioactive wastes). The present problems of this complex (considerable miscellaneous influence on various spheres of habitability) can be resolved only on the basis of the European standards by means of wide intrusion of modern procedures of clearing of the basic components of an environment from pollution (collected during half-century functioning of the nuclear industry of Soviet Union).

The enterprises of the nuclear fuel cycle are concentrated in the central Ukraine (Dnipropetrovsk and Kirovograd regions). The territory of the regions is marked out to be the Region of uranium ore extraction and primary processing due to its social, economical and environmental peculiarities (Fig.1,a).

But there are many sites of radioactive pollution in territory of the region. The majority of these sites is near the stores of radioactive wastes. Without clearing soil (these sites) from radioactive pollution the sustainable development of the region as a whole is impossible. But the clearing of soil is very expensive procedure. Therefore it is very important to know exact borders of the polluted sites. The complex of radiological researches in the polluted territories is necessary for this purpose.

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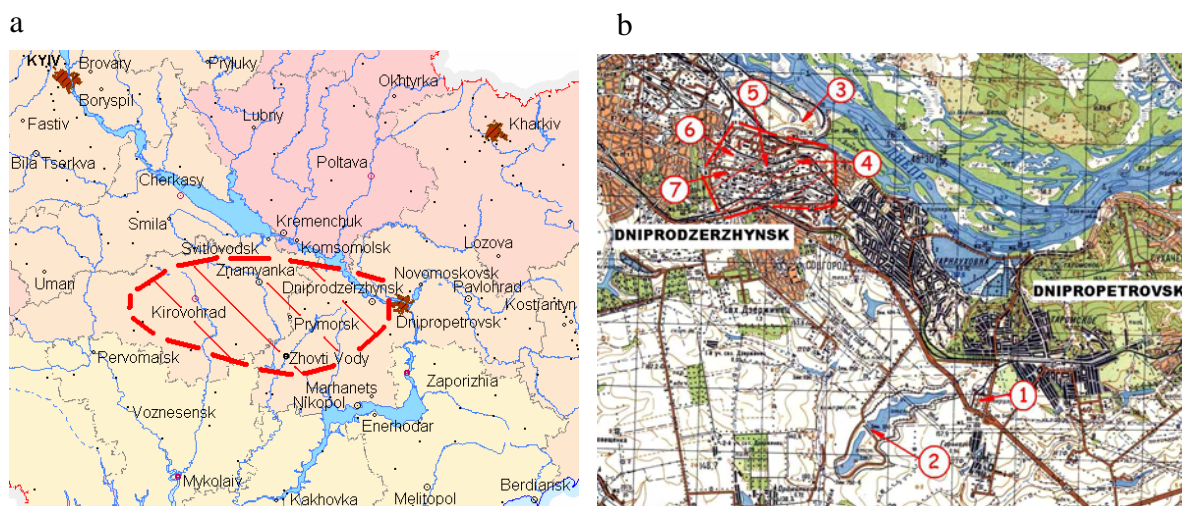


Fig.1. The region of uranium ore extraction and primary processing (a) and the stores of radioactive wastes of Pridniprovsk chemical factory (b): 1 – Base “S”, 2 – Depository “S”, 3 – Depository “Dniprovskoye”, the stores inside the factory: 4 – “Yougo-vostochnoye”, 5 – “Tsentral’nyi Yar”, 6 – “Severo-zapadnoye”, 7 – intermediate warehouse of the production.

General characteristic of the Region of uranium ore extraction and primary processing

The Region has unique powerful industrial potential and development, but radioactive pollution limit its social and economical effect. There were not any adequate activities of social (medical) and environmental protection during half-century functioning of the enterprises of uranium ore extraction and processing. Therefore, the Region is characterized as a territory with negative radioactive and ecological situation, which influences the environment and health, causes negative demographic situation, decrease of the rate of employment and the standard of living.

The Region is located on the southeast part of the Ukrainian Shield (Precambrian bedrock). The granite intrusions with the increased contents of radionuclides: uranium-radium and thorium sets (Proterozoic Kirovogradsky and Dnieprovsko-Tokovsky magmatic complexes) have received rather widespread distribution. These rocks determine local increase of capacity of an exposition doze of γ -radiation (up to

30-50 mcR/hours) in valleys of the rivers and streams, in gorges and ravines. But the regional radioactive background does not exceed 15 mcR/hours. It is determined by the clay overlying (≥ 10 m), which one is “the reliable screen” from radiation influence of Precambrian bedrock on the most part of the region. There are local anomalies (up to 3000 mcR/hours) only near the enterprises of nuclear-fuel cycle. First of all they are the store of liquid radioactive wastes. The huge quantities of liquid radioactive wastes were merged in upper reaches of girders without special antifiltration opening-up of bottom-bed and blocking dams during several decades (Fig.1,b and Tabl.1). These sites are constant sources of contamination of soil “through” superficial and underground waters and lower atmospheric slices – the losses at transportation, temporary storage etc. operations with uranium raw material and wastes [2,5].

Table 1 – The most dangerous sets of stores of radioactive wastes of the Region

	Floor area (m ²)	Weight (tons)	Volume (m ³)	Activity (10 ¹⁵ Bq)
Zhovti Vody (extracting and processing of uranium raw material)	3062000	56300000	34500000	2.79
Dnipropetrovsk-Dniprodzerzhynsk (processing of uranium raw material)	1634600	36346600	18813300	2.58

The large density of the population, objects of an industrial and agricultural infrastructure of Central Ukraine is on the polluted areas. It is

needed for urgent salvation of the regional problems to accelerate the development of effective soil remediation technologies.

Choice of the technology of clearing of soil from radioactive pollution

The most widespread method of soils cleaning from the contaminants includes its complete mining and removal for further cleaning in special areas or store within special sites. As a rule, these methods are very expensive and they cause heavy industrial influence on territory such as influence of long distances transporta-

tion and related high risk of industrial failures and catastrophes.

Moreover, excavation is unacceptable at all in many cases considering financial or technical state. Thus, an important task is to develop new technology of radioactive pollutants removal from soils.



Fig.2. The circuit of realization of CLEAN SOIL: An Innovate Method for the On-Site Remediation of Polluted Soil Under Existing Infrastructures

The new method of soil clearing (CLEAN SOIL) from different pollutants (heavy metals, hydrocarbons, etc) now actively begins to be applied in Ukraine and Russia. The method of soil cleaning technologically is based on horizontal drilling of bore holes, including territory under the existent infrastructure [1] (Fig.2). The bore holes are afterwards equipped with the system of fabric sleeves capacities filled with some adsorption substance. The method includes the installation systems of horizontal bore holes within the borders of contaminated territory, on a certain depth, with the subsequent adsorption capacities inserted. When pollutants are adsorbed from soil at the

required level, after certain period of time, the system is removed, and adsorption material is regenerated for repeated use. The results of our experimental researches (as the Ukrainian partners of EU Project CLEAN SOIL) in 2006-07 testify that the technology provides extraction of pollution from chernozem of Ukrainian steppe [3]. The technology is more cheaply traditional technology of soil clearing. But for effective remediation of polluted territory the exact finding of radioactive polluted sites is necessary. The positive example of detailed complex radiological researches of territory near one of the largest stores of radioactive wastes is given below.

The example of detailed study of radiological situation near stores of radioactive wastes

We investigate (in details) some stores of radioactive wastes of Pridniprovsk chemical factory (processing of uranium raw material). The enterprise is located in Dniprodzerzhynsk. And the stores are located in (and near) the territory of the enterprise, and near Dnipropetrovsk-city – the regional center with 1,5 million inhabitants (Fig.1,b). The biggest stores are Base "S" (former intermediate warehouse of uranium ore) and Depository "S" (wastes of primary processing of uranium ore) with changeable surface of "mirror" of water, which

does not cover surface of the store completely. The farmland is located around of the stores (Fig.3,a).

The results of our field researches are given in Fig.3,b-d as maps of radioactive anomalies: capacities of an exposition doze of γ -radiation, specific activity of soil and "total" vegetation (the information about specific activity of different kinds of vegetation is submitted in Fig.4,d). The absence of essential spatial pair dependence of these anomalies takes place (Fig.4,a-c)

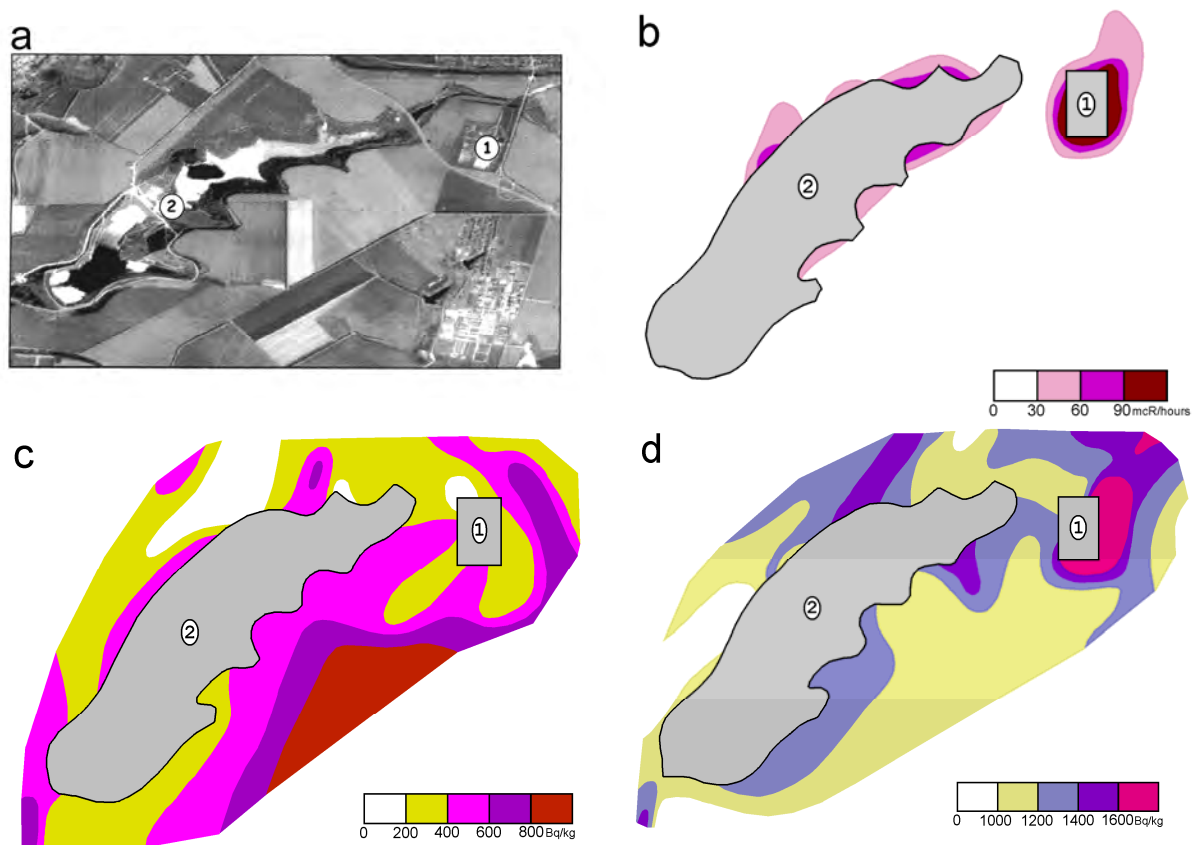


Fig.3. The space photo of territories near the stores of radioactive wastes: 1 – Base "S", 2 – Depository "S" (a) and the results of complex radiological researches – the maps of radioactive anomalies: capacities of an exposition doze of γ -radiation (b), specific activity of soil (c) and "total" vegetation (d).

The following basic spatial features of radiological conditions of investigated territory are revealed:

1) the anomalies of an exposition doze of γ -radiation are located near borders of these stores and consequently they do not give the sufficient information about spatial distribution of radioactive pollution of an environment of the investigated territory;

2) the anomalies of specific activity of soil are result of long-term processes of filling radionuclides of territory near these stores:

- to the northeast (the former demounted access railway ways) – losses of brought uranium raw material,
- to the northwest (pipeline from Pridniпровsk chemical factory) – losses of liquid radioactive wastes,

- to the southeast – wind dust from dry part of surface of the store,

- to the southwest (downwards along a gully) – leakage from the store;

3) the anomalies of specific activity of vegetation partially "correspond" to anomalies of radioactive pollution of soil, but the general tendency is the moving of radioactive anomalies in vegetation to the east and southeast from this sources – the stores of radioactive wastes. It is the result of local influence of the meteorological factors – western winds prevail in the period of vegetation here.

The objects of application of CLEANSOIL technology are not the anomalies of an exposition doze of γ -radiation, but radioactive anomalies (specific activity) of soil and vegetation. Last anomalies are connected to features of tectonic structure of territory.

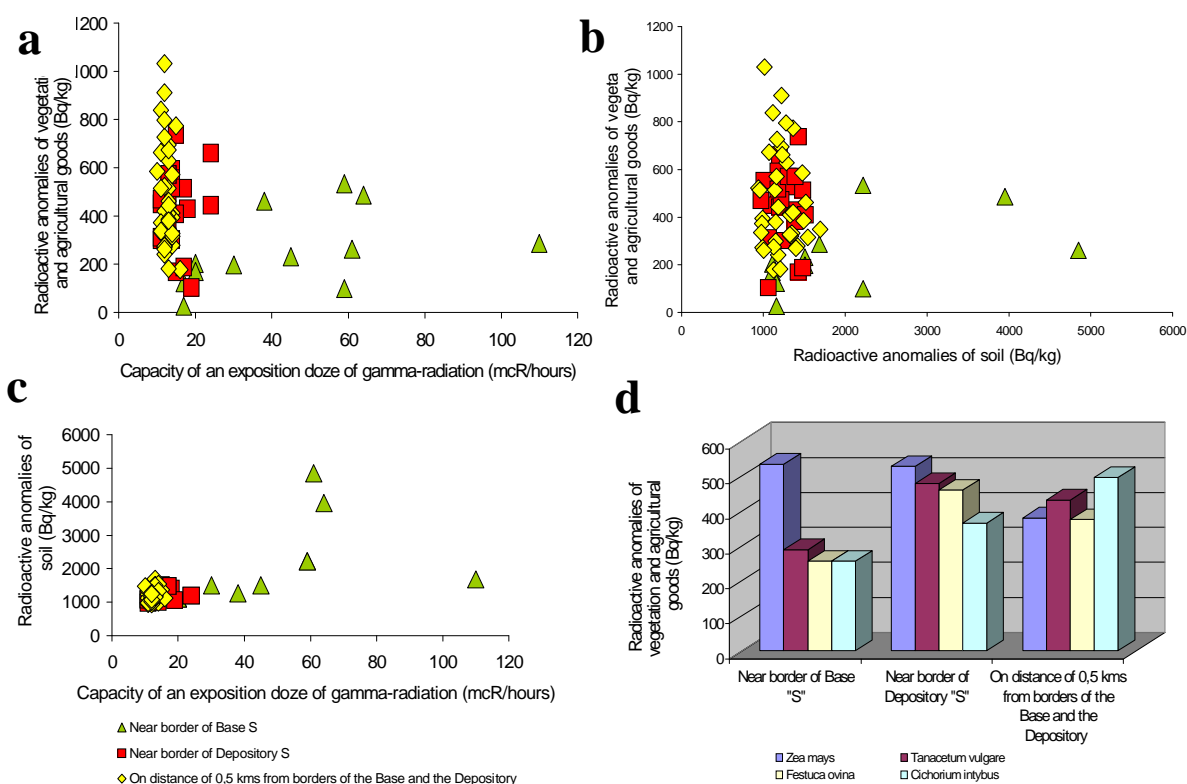


Fig.4. The spatial pair dependence of radiological anomalies of soil, vegetation capacities and γ -radiation, (a-c) and specific activity of different kinds of vegetation (d).

Tectonic preconditions of radioactive contamination

One of the major factors are the faults, which determined as ecological and as radiological situation at any region. The settlements and large industrial manufactures gravitate to the rivers, which network is completely predetermined by systems of faults. The traces of the largest of faults have width from several kilometers up to several tens kilometers on a surface of the Earth. It is well known that no less than 84 % of ore deposits discovered in the Earth are connected-directly or indirectly-with the earth crust faults. Also along faults local structures in sedimentary cover dispose and represent the hydrocarbon traps. All these factors predetermine development of mining and oil industry in the region of faults. Practically all of well-known at this region accumulation of radioactive substances and concentration of radon are bound up with tectonic faults. The faults have ability to concentrate and accumulate radionuclides and that's why its can be ways of migration of radionuclides.

The earth's crust (lithosphere) is cut by the systems of subvertical faults having complicated hierarchy, starting with planetary faults and down to faults confining the blocks to tens

of kilometers and less. The intersection of faults of various ranks and directions results in very mixed picture of lithosphere blocks, the horizontal dimensions of which are incomparably small with respect to the vertical ones.

As the conceptional base for study of a region's tectonics is taken the New rotational hypothesis of structure formation [4]. According to this conception in some tectonic epoch under the influence of forces of planetary stresses it occurs a stirring up of the systems of the earth crust's faults formed earlier. Each such system consists of some faults, hierarchically subordinated, of two mutually orthogonal directions. A system of faults is stirred up, one of its directions coincides with, or is near to, that of the rotation pole's displacement. In other words there is an interrelation between the orientation of the basement faults systems and the time of their stirring up.

In establishing and studying faults of the crystalline basement in the Industrial Pridneprov'e the geophysical methods, gravity and magnetic surveys in particular, were of predominant value. For this aim, the following three groups of indicators were used:

- the linear steps in the levels of the gravity and magnetic fields, corresponding to the linear tectonics and stratigraphic basement rocks contacts of different physical properties;
- the linear local gravity and magnetic anomalies of both signs caused, within the fault structures of basement, by the newly formed geological objects of the magmatic, metamorphic and tectonic composition;
- the linear irregularities in the behaviour of the isoanomalies or the linear boundaries between the zones with the isolines of different configurations of these fields owing to different types of contacts of the contiguous geological formations of the basement.

In the limits of Industrial Pridnieprov'e as well as on all territory of the Ukrainian Shield there are clearly fixed six systems of faults with the following stretching azimuths: 0° and 270°, 17° and 287°, 35° and 305°, 45° and 315°, 62° and 332°, 77° and 347°.

The analysis of geomorphological indications of the revealed faults has allowed to determine their fragments, which stirring up at the newest time.

That's why the greatest radioactive pollution in all environments of the Earth are connected to faults.

Conclusions

The present Ukrainian nuclear fuel cycle (mining, processing of uranium raw material and salvaging of radioactive wastes) not only provides the social and economic development of the state, but it's the source of radioactive pollution of an environment in the large territories of central Ukraine.

The new technology of soil clearing (CLEANSOIL) is adapted for soil conditions of central Ukraine. It is an innovative method of soil purification from radioactive contaminating (simple in use, applicable for existing infra-

The map of density of indicators of faults of different ranks – as the basis of the characteristic of sustainable of an environment in causal relation to most intensive natural and technogenic processes have been constructed [5]. The maps is the basis of the prediction of sharp disturbances of geologic environment, which causing to accident on enterprises of nuclear fuel cycle and their consequences.

The sites with radioactive pollution of vegetation in many cases are badly correlated with anomalies of capacity of dose γ -radiation, but its are supervised precisely by features of tectonic structure. The rocks of the Ukrainian Shield, which leaving on a day time surface within the limits of faults, was the sources of radioactive contamination of plants. The anomalies of volumetric activity of radon are dated for the systems of faults in region. The greatest concentration radionuclides in superficial and underground waters and the greatest quantity of radioactive anomalies in vegetation are dated for blocks of the rocks, which limited by these systems of faults [6].

The information about local features of tectonic structure helps more precisely to define borders of the polluted sites and the directions of radionuclide "distribution".

structure, cost-justifiable, neither excavation nor soil transferring). The complex of radiological researches is necessary for effective application of this technology (it's not measurement of capacity an exposition dose of γ -radiation, but specific activity of soil and vegetation). Last anomalies are connected to features of tectonic structure of territory. Therefore the information about local features of tectonic structure helps more precisely to define (spatially - temporary) borders of the radioactive polluted sites.

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**ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ
ВІДНОВЛЕННЯ ҐРУНТУ БІЛЯ СХОВИЩ
РАДІОАКТИВНИХ ВІДХОДІВ**

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Однієї з основ сталого розвитку України є сучасний ядерно-паливний цикл (комплекс). Але цей комплекс має великий потенціал забруднення ресурсів ґрунту. Ця проблема в Україні може бути вирішена тільки на основі Європейських стандартів за допомогою широкого впровадження сучасних процедур очищення ґрунту від радіоактивного забруднення (накопиченого протягом півстоліття функціонування ядерної промисловості колишнього Радянського Союзу). CLEANSOIL - проста і фінансово-ефективна сучасна технологія, що дозволяє in-situ витяг небезпечних речовин із ґрунту на досить великих площах забрудненої землі з мінімальними порушеннями поверхні. Потреба ефективних методів виявлення й оцінки такого забруднення навколишнього середовища об'єктами ядерно-паливного циклу визначила спеціальний комплекс радіологічних досліджень (потужність експозиційної дози γ -випромінювання, питома активність ґрунту і рослинності) як цінний, не агресивний до навколишнього середовища і дешевий інструмент.

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