8. *Дмитренко В.П.* Погода, клімат і урожай польових культур: [монографія] / В.П. Дмитренко; НАН України, Укр. наук.-дослід. гідрометеоролог. ін-т. — К.: Ніка-Центр, 2010. — 620 с.
9. Настанова гідрометеорологічним станціям і постам. — Вип. 11. Агрометеорологічні спостереження. — К.: Державна гідрометеорологічна служба України, 2007. — 303 с.

REFERENCES

1. *Klimatychnyi samit v Paryzhi — naivazhlyvishyi na planeti* [Climate Summit in Paris — the most important in the world]. [Electronic resource]. Available at: http://ua.euronews.com/2015/11/30/world-leaders-as-never-before-kick-start-climate-talks-at-paris-cop21/ (*in Ukrainian*).
2. Tarariko Yu.O. (2011). *Enerhozberihaiuchi ahroekosystemy. Otsinka ta ratsionalne vykorystannia ahroresursnoho potentsialu Ukrainy* [Energy-saving agro-ecosystems. Evaluation and rational use agroresources potential of Ukraine]. Kyiv: DIA Publ., 576 p. (*in Ukrainian*).
3. Liashenko I.M., Korobova M.V., Horitsyna I.A. (2010). *Modeliuvannia ekonomichnykh, ekolohichnykh i sotsialnykh protsesiv: navchalnyi posibnyk* [Modeling of economic, environmental and social processes: textbook]. Kyiv: Vydavnycho–polihrafichnyi tsentr «Kyivskyi universytet» Publ., 320 p. (*in Ukrainian*).
4. Vrublevska O.O., Katerusha H.P., Myrotvorska N.K. (2004). *Klimatolohichna obrobka okremykh meteorolohichnykh velychyn* [Climatology obrobka okremih meteorologichna values]. Odesa: Vydavnytstvo «ТЭС» Publ., 150 p. (*in Ukrainian*).
5. Shalymov N.A. (2009). *Evolyutsiya atmosfernogo klimata Zemli* [Evolution of the Earth for atmospheric climate]. Odessa: Druk Publ., 204 p. (*in Ukrainian*).
6. Kosovets O.O. (2015). *Klimatychni osoblyvosti u 2014 rotsi* [Climatic features 2014]. *Pratsi Tsentralnoi heofizychnoi observatorii* [Proceedings of the Central Geophysical Observatory]. Iss. 11 (25). pp. 14–19 (*in Ukrainian*).
7. Didukh Ya.P. (2011). *Poniattia pro stiikist ekosystem* [Notion of the stability of ecosystems]. *Osnovy bioindykatsii* [Fundamentals of biological indication]. — Kyiv: Naukova dumka Publ., pp. 288–299 (*in Ukrainian*).
8. Dmytrenko V.P. (2010). *Pohoda, klimat i urozhai polovykh kultur: [monohrafiia]* [Weather, climate and harvest field crops: monograph]. *Natsionalna akademiia nauk Ukrainy, Ukrainskyi naukovo-doslidnyi hidrometeorolohichnyi instytut*. Kyiv: Nika-Tsentr Publ., 620 p. (*in Ukrainian*).
9. *Nastanova hidrometeorolohichnym stantsiiam i postam* [Guidelines meteorological stations and posts]. *Ahrometeorolohichni sposterezhennia* [Agrometeorological observation]. Kyiv: Derzhavna hidrometeorolohichna sluzhba Ukrainy (2007). Iss. 11, 303 p. (*in Ukrainian*).

УДК 551.521/(633.2+551.435.122)

REGULARITIES OF ^{137}Cs TRANSITION INTO MEADOW VEGETATION IN FLOOD-PLAIN SOILS

V. Feschenko, V. Gurelya

Інститут сільського господарства Полісся НААН

Наведено результати досліджень особливостей проведення докорінного поліпшення забруднених унаслідок аварії на ЧАЕС агроекосистем Полісся України. Встановлено, що основними чинниками впливу на надходження ^{137}Cs із ґрунтів радіоактивно забруднених сільськогосподарських угідь у продукцію є видовий склад рослин, фізико-хімічні властивості ґрунту, а також погодні умови. Обґрунтовано необхідність постійного моніторингу та наукового супроводу розроблення і реалізації контрзаходів. Доведено, що використання сучасних технологій та ведення рентабельного сільськогосподарського виробництва є оптимальним способом реабілітації забруднених територій.

Ключові слова: *радіоактивне забруднення, травостій, реабілітація сільськогосподарського виробництва, Українське Полісся, контрзаходи.*

Meadow is a specific nature object, where the processes of vital activity drawn to biological circulation of biomass substances in grassy vegetation take place very intensively. The size of annual biomass dying off in meadow biocenoses makes up 35–55%, as in forest ones it makes up 5–7%. Firstly, it is connected with variation of meadow vegetation which consists of perennial grasses, where cereal varieties make 85% of the whole grass biomass and, secondly, with presence of meadow sod, which is an active sorbent with especially favourable conditions for reutilization of mineral elements of plant matter and for absorption nutrients coming from outside including radionuclides [1]. Taking into account Chornobyl NPP accident, radioactive contamination of flood plain soils needs reconsideration of agricultural using for receiving ecologically-safe (from radionuclides) agricultural production not exceeding AL-2006 (acceptable contamination level).

The biggest amount of ^{137}Cs comes into grass stand under cultivation in conditions of surplus moistening, especially in peat soils (table 1). Meadows on peaty-gley soils can be used only for feeding cattle [2].

Rational improvement of flood-plain soils is impossible without optimization of a number of negative characteristics. In a complex of agro-measures for soil improvement such measures as radionuclides blocking, surplus acidity removing, improving of physical and agro-chemical characteristics should be foreseen.

The most effective measure of decreasing natural forage lands contamination is their fundamental improvement. Under the first fundamental improvement transition of radionuclides from soil into meadow grasses can decrease by 2–10 times and under the second one — by 2–3 times [3].

After Chornobyl NPP accident 101.285 ha of farmlands in Kyiv and Zhytomyr regions were excluded from economic turnover. Their rehabilitation will be realized according to special projects developed on the base of repeated radiological examination of these territories. Lands set-aside because of low fertility will be returned primarily. They can be used for haymaking and pasture land for feeding young cattle in completing of growing [2].

Radionuclides getting into the soil can be in different forms: water-soluble, exchangeable, non-exchangeable and strongly fixed. Absorption processes of radionuclides in soils influence their forms re-distribution especially under continuance in soil. With the lapse of time their physical and chemical properties change and radionuclides become less accessible for plants — the process of their «aging» in soils takes place.

The forms of radionuclides residence in the soil determine their further conduct in soil coating and migration about soil profile. Their movement about soil profile changes their distribution in root soil layer, which influences their availability to plant root systems.

Scheme of radionuclide availability by plant roots is similar to absorption of basic nutrients — macro- and microelements. The main difference lies in radionuclides presence in the environment in low concentration.

Table 1

^{137}Cs transition into grass stands of natural not improved meadows, TC (Bq/kg / kBq/m^2)

Soil	Type of meadows	TC
Meadow loamy sand	Dry land normal	0.01–0.2
	Flood-plain damp	0.2–1.0
Soddy-podzolic loamy	Dry land normal	0.1–0.2
Soddy-podzoilic sandy	Dry land normal	0.2–0.5
Soddy-podzoilic sandy	Dry land surplus damp	1.0–2.0
Soddy-podzoilic sandy	Flood-plain damp	1.0–2.0
Peaty-gley	Peaty drained	2.0–3.0
	Peaty flood	14.0–21.0
	Peaty lowland	35.0–50.0

Chemical properties of ions influence radionuclides coming into plants out of nutrient medium [4].

Scientists have determined that air temperature and rainfall during the vegetation period play the most important role in ^{137}Cs coming into plants [5]. They found out direct correlative dependence between ^{137}Cs content in plants, amount of atmospheric precipitation (may-august), spring and autumn moisture stocks in one meter soil layer.

Contamination of plant production with radionuclides during their coming out of soil into plants depends on soil surface specificity. The highest contamination level is observed in soddy-podzolic soils especially with light granular content; the less one — in grey forest soils and serozems and the lowest one — in ordinary chernozem [6].

MATERIALS AND METHODS

During 1991–2005 on the base of Institute of Agriculture Polissia NAAS peculiarities of flood-plain soils and influence countermeasures on ^{137}Cs transition into meadow vegetation were studied. Aimed at this monitoring researches and establishment of stationary researches were brought about on the flood plains of the river Mostva near the villages of Nemyrivka and Zubivschyna, Korosten district, Zhytomyr region.

Researches were carried out on the territory of farms in the III–IV zones of radioactive contamination on soddy-podzolic and peat-boggy soils. The object of researches was perennial natural and cultural cenoses, which differed in botanic and biologic peculiarities and level of radioactive contamination.

Meadow vegetation is presented by flood-plain and dry valley meadows. Such bogs as sedge, sedge-hypnum and sedge-sphagnum are spread among the others.

Such plants as meadow June grass, yarrow and bottle brush are the most widespread. Despite the vegetation uniformity, ^{137}Cs accumulation coefficients differ greatly even for one species [5].

When carrying out the analysis, plants were taken out of the plot around the rectangular perimeter from the area of 1 m^2 in 8–10 places. Plants were cut at a height of 3–5 cm from the soil surface and the sample for spectrometric analysis was prepared according to [7].

^{137}Cs specific activity was determined in air-dry soil samples in crop production with gamma-spectrometer SEG-05.

Flood-plain soils improvement lied in deep ploughing and applying mineral fertilizers $N_{60}P_{60}K_{90}$ with liming in the amount of 60 t/ha.

RESULTS AND DISCUSSION

Some meadow and pasture plants differ in higher radionuclides accumulation in comparison with plants on arable lands. It is connected with absorption nutrients by plants from sod layer, where radionuclides are sorbed too. The difference in radionuclides accumulation by plants of different species is defined according to their root system development.

Generally, in the first cutting the coefficient indices of transition were 2–8 times higher than in the second one.

Comparing with average annual data of 1991–2000 we can see that miscellaneous herbs such as meadow foxtail and awnless bromegrass and leguminous plants such as white clover have high level of ^{137}Cs accumulation. Transition coefficients vary from 0.59 to 11.9 (table 2).

Being concentrated in the sod, radionuclides migrate into the soil. Coming of the radionuclides into plants of natural dry land, flood-plain and peaty meadows depends on meadow type, characteristics of soil, which meadows were formed on, and time of their residence in sod. Depending on the meadow type and characteristics of soil, which meadows were formed on, ^{137}Cs coming into meadow natural grasses for certain grass species (forbs) in the first cutting differs by 7 times. The highest ^{137}Cs specific activity was observed among forbs on flood-plain meadow on soddy-podzolic loamy sand soil, the lowest one — on dry land meadow. Accumulation of this radionuclide sharply decreases with every cutting.

Based on the results of researches it was defined that the highest decrease of ^{137}Cs ac-

Table 2

Coefficient of ^{137}Cs transition from flood-plain (peat-boggy) soil into different plant species (first cutting)

Plant	TC
Bulbous bluegrass	0.59
Bladder sedge	1.5
Reed fescue	1.6
Marsh sedge	1.8
Ophiopogon planiscapus	3.1
Yellow dock	3.15
Common timothy	3.2
Orchard grass	4.8
Common yarrow	5.48
Meadow horsetail	5.52
White clover	6.6
Common sedge	8.7
Awnless bromegrass	8.9
Silverweed cinquefoil	11.6
Meadow foxtail	11.9

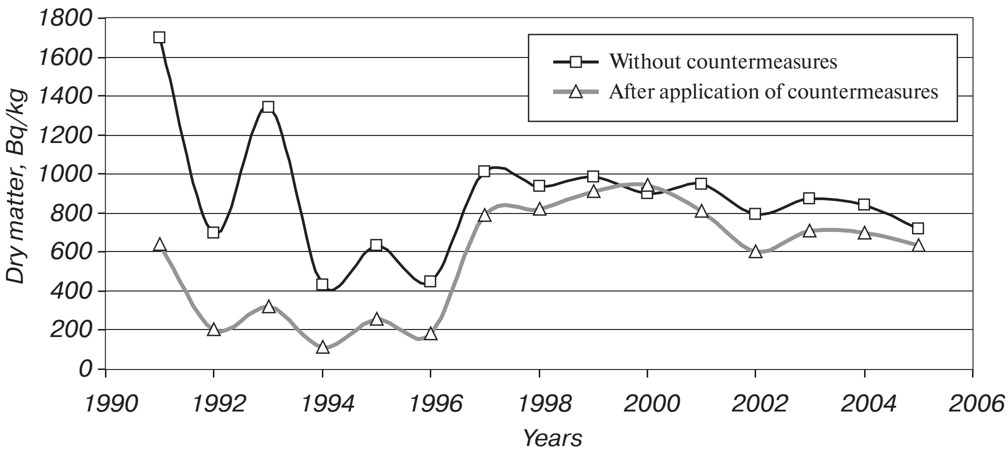
cumulation in hay is observed next year after carrying out root improvement. ^{137}Cs specific activity in hay was approximately 600 Bq/kg. In comparison with the control grass stand activity decreased by 2–5 times.

However, during the next years we can observe fluctuation of radionuclides specific activity in dry matter of plants (pic. 1).

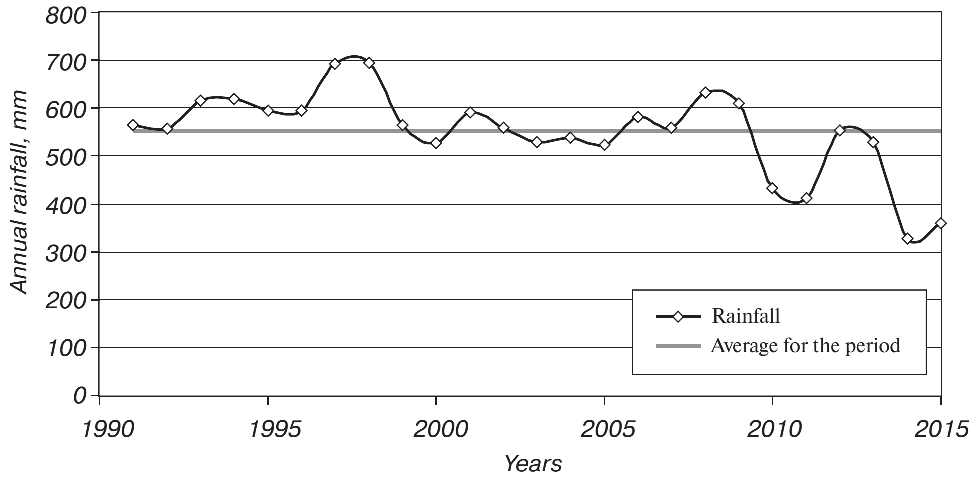
It can be explained by the fact that radionuclides specific activity in vegetation is determined by both their gross content in the soil and amount of mobile forms. So far as defined direct dependence between the main chemical characteristics and radionuclides content in vegetation so hydrolytic acidity increase, sum of exchangeable bases, amount of organic carbon and exchangeable chlorine results in increase of radionuclides accumulation by vegetation.

Taking into consideration the fact that flood-plain soils, depending on rain fall, can change their agro-chemical and agro-physical characteristics, the most intensively, so factor of «weather patterns» can be the most influential on specific activity of radionuclides in dry matter of plants.

Confirmation of this fact is rainfall disproportionality in the area of Polissia during 1990–2005 (pic. 2) and similarity of oscillatory amplitude of radionuclides specific activity in plants on improved and unimproved areas (pic. 1), taking into account the fact that the samples per years were taken at stationary fiducially points at the same vegetative stage. Botanical content of selected samples was the same too.



Pic. 1. ^{137}Cs accumulation dynamics by meadow vegetation on soddy-podzolic soil during 1991–2005, depending on using countermeasures, Bq/kg of dry matter

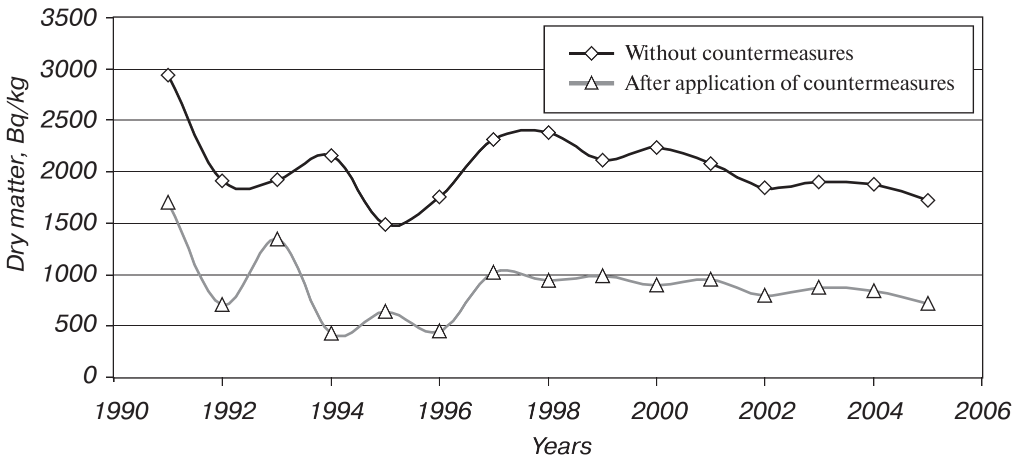


Pic. 2. Annual rainfall dynamics during 1991—2015 in Polissia (according to the data of Korosten meteorological station)

Somewhat different accumulation dynamics of radionuclides in dry matter of plants during the years was observed on peat-boggy soil (pic. 3), which confirms again the hypothesis of dependence radionuclides transition intensity into crop production on soil type and its peculiarities.

When analyzing received results, we can ascertain a fact that the highest decrease of ^{137}Cs accumulation in hay was observed next year, after carrying out root improving. ^{137}Cs specific activity in hay was 181 Bq/kg, which is 10 times less than it was in the control. In comparison with the control ^{137}Cs specific activity in grass stands decreased by 2.3–4.6 times.

For the residents of inhabited localities, where contamination of soils is more than 5 Ci/km^2, critical, as to radiologic relation, ecologic situation arises; it is mainly stipulated by the fact that according to existing crop rotation on the territory of Ukrainian Polissia roughage is grown on drained and,



Pic. 3. ^{137}Cs accumulation dynamics by meadow plants on peat-boggy during 1991—2005, depending on countermeasures using, Bq/kg of dry matter

Table 3

Density of territory contamination of r. Mostva flood plains, depending on soil type and countermeasures

Variant	Inhabited locality	Soil type	Density of territory contamination, Ci/km^2
Without improvement	v. Zubivschyna	Peat-boggy	6.8
After improvement	v. Zubivschyna	Peat-boggy	4.3
Without improvement	v. Nemyrivka	Soddy-podzolic	22.1
After improvement	v. Nemyrivka	Soddy-podzolic	7.1

mainly, peaty and flood-plain (50–60% of the area) lands.

In 1993, 1994, 1997, 2005 agro-ecological situation became worse even more in comparison with other years in consequence of water-related hazards and heavy rains. During some days there was about three months' rainfall over the northern districts of the region. Thousands of hectares of farmlands found themselves under water.

Research results showed that getting ecologically safe production is possible only based on the high level of production culture, introducing achievements in agricultural and land-reclamation science following recommendations according to radiation situation.

The main methods of increasing productivity and quality of natural haylands and pastures are their fundamental and surface improvement. Practical experience of advanced farms and experimental data show that when using the whole complex of works under surface improvement meadow productivity increases by 2–3 times and under fundamental one — by 3–4 times. At the same time intensity of radionuclides transition into crop production changes as well.

However, for different soil types influence of fundamental improvement on radionuclides migration in the system «soil – plant» is different. For example, the best effect as to decreasing soil contamination density under carrying out countermeasures was observed in soddy-podzolic soil in comparison with peat-boggy one (table 3).

It is explained by higher concentration of radionuclides in the upper layer of soddy-podzolic soil, which in consequence of fundamental improvement turns into the depth of 18 cm. In peat-boggy soil radionuclides migration takes place more intensively that is why the content of radionuclides in upper layers is almost the same.

Scientists of the region were offered for decreasing radionuclides accumulation to use agro-technic measures, which increase soil fertility, such as liming, applying necessary amount of mineral and organic fertilizers in favourable relation, selection the crops capable to accumulate radionuclides and applying soil amendments and sorbents (bentonites, zeolites, montmorillonites, sapropels etc.), carrying out decontamination cultivation with ploughing in contaminated soil [5].

CONCLUSIONS

Absorption of radionuclides by plants is mostly determined by their physical and biochemical characteristics, which is defined by their species composition.

In addition to density of territory contamination with radionuclides, ^{137}Cs specific activity is influenced by chemical characteristics of soil, which can be determined by meteorological patterns.

Received data affirm the necessity of constant radiological control of flood plain production, primarily that production which has the highest coefficients of radionuclides transition from soil into plants.

Fundamental improvement carried out in soddy-podzolic soils is more effective (more than 30%) than on peat-boggy ones.

ЛІТЕРАТУРА

1. *Перепелятников Г.П.* Миграция радионуклидов в природных и полуприродных луговых экосистемах / Г.П. Перепелятников // Проблеми екології лісів і лісокористування в Поліссі України. — 2002. — Вип. 3 (9). –С. 85–101.
2. Рекомендації щодо вибору напрямків і порядку проведення реабілітації виведених земель господарств Житомирської та Київської областей з метою повернення цих територій у народногосподарське використання / Б.С. Прістер, Л.В. Перепелятнікова, Л.В. Каліненко та ін. — К., 1998. — 81 с.
3. Шляхи зменшення забруднення радіонуклідами кормів і тваринницької продукції в зоні аварії на ЧАЕС / Ю.І. Савченко, І.М. Савчук, Є.М. Місечко та ін. // Науковий вісник Львівської державної академії ветеринарної медицини імені С.З. Гжицького. — 2000. — С. 155–161.
4. *Кравець О.П.* Радіологічні наслідки радіонуклідного забруднення агроценозів: монографія / О.П. Кравець. — К.: Логос, 2008. — 238 с.
5. *Быстрицкий В.С.* Влияние комплекса агромелиоративных мероприятий на продуктивность лугов и пастбищ и снижение накопления радиоцезия в продукции / В.С. Быстрицкий, Л.Г. Демчук, В.П. Фещенко // Проблемы сельскохозяйственной радиоэкологии. Десять лет спустя после аварии на Чернобыльской АЭС. — Житомир, 1996. — С. 14–16.
6. *Ильин М.И.* Закономерности поведения ^{90}Sr и ^{137}Cs Чернобыльских выпадений в почвенно-растительном покрове кормовых угодий Полесья Украины / М.И. Ильин // Проблемы сельскохозяйственной радиологии: Сб. науч. трудов; под ред. Б.С. Пристера. — Вып. 4. — К., 1996. — С. 159–169.
7. Корма растительного происхождения. Методы отбора проб: ГОСТ 27262–87. — [Введен в действие 01.07.1988]. — М.: Изд-во стандартов, 1987. — 9 с. — (Межгосударственный стандарт).

REFERENCES

1. Perepelyatnikov G.P. (2002). *Migratsiya radionuklidov v prirodnykh y poluprirodnykh lugovykh ekosistemakh* [The migration of radionuclides in the second semi-natural grassland ecosystems]. *Problemy ekolohii lisiv i lisokorystuvannia v Polissi Ukrainy* [Problems of forest ecology and forest management in Polesie Ukraine]. Iss. 3 (9), Zhytomyr: Volyn Publ., pp. 85–101 (*in Russian*).
2. Prister B.S., Perepeliatnikova L.V., Kalinenko L.V. (1998). *Rekomendatsii shchodo vyboru napriamkiv i poriadku provedennia reabilitatsii vyvedenykh zemel hospodarstv Zhytomyrskoi ta Kyivskoi oblastei z metoiu povernennia tsykh terytorii u narodnohospodarske vykorystannia* [Recommendations by the directions and procedures for land rehabilitation retired households Zhytomyr and Kyiv regions to return these territories in national economic use]. Kyiv, p. 81 (*in Ukrainian*).
3. Savchenko Yu.I., Savchuk I.M., Misechko Ye.M., Stroivans L.T., Feshchenko V.P. (2000). *Shliakhy zmenshennia zabrudnennia radionuklidamy kormiv i tvarynnytskoi produktsii v zoni avarii na ChAES* [Ways to reduce contamination of feed and livestock production in the zone of the Chernobyl accident]. *Naukovyi visnyk Lvivskoi derzhavnoi akademii veterynarnoi medytsyny imeni S.Z. Hzhytskoho* [Scientific Bulletin of Lviv State Academy of Veterinary Medicine named after SZ Gzhytsky]. Lviv, pp. 155–161 (*in Ukrainian*).
4. Kravets O.P. (2008). *Radiolohichni naslidky radionuklidnoho zabrudnennia ahrotsenoziv: monohrafiia* [Radiological consequences of radioactive contamination agrocenoses: monograph]. Kyiv: Lohos Publ., 238 p., Bibliohrafiya: pp. 206–238 (*in Ukrainian*).
5. Bystritskiy V.S., Demchuk L.G., Feshchenko V.P. (1996). *Vliyanie kompleksa agromeliorativnykh meropriyatiy na produktivnost lugov i pastbishch i snizhenie nakopleniya radiotseziya v produktsii* [Influence of complex melioration activities on the productivity of meadows and pastures and reducing the accumulation of radioactive cesium in the product]. Problemy selskokhozyaystvennoy radioekologii [Problems of agricultural radioecology]. *Desyat let spustya posle avarii na Chernobylskoy AYeS* [Ten years after the accident at the Chernobyl AES]. Zhitomir, pp. 14–16 (*in Russian*).
6. Prister B.S., Ilin M.I. (1996). *Zakonomernosti povedeniya ^{90}Sr i ^{137}Cs Chernobylskikh vypadeniy v pochvenno-rastitel-nom pokrove kormovykh ugodiy Polesya Ukrainy* [Laws of behavior ^{90}Sr and ^{137}Cs of Chernobyl fallout in land cover forage land Polesye of Ukraine]. *Problemy selskokhozyaystvennoy radiologii* [Problems of Agricultural Radiology]. Sbornik nauchnykh trudov [Collection of scientific papers]. Iss. 4, Kiev, pp. 159–169 (*in Russian*).
7. *Korma rastitelnogo proiskhozhdeniya. Metody otbora prob* [Foods of plant origin. Sampling methods]. Mezhgosudarstvennyy standart, GOST 27262–87, Moskva: Izdatelstvovo standartov Publ., 1987, 9 p. (*in Russian*).