Ministry of Education and Science of Ukraine

ODESSA NATIONAL ACADEMY OF FOOD TECHNOLOGIES

International Competition of
Student Scientific Works

BLACK SEA SCIENCE 2020

PROCEEDINGS

ODESSA, ONAFT 2020

Ministry of Education and Science of Ukraine

Odessa National Academy of Food Technologies

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2020

Proceedings

Odessa, ONAFT 2020

UDC 001.8(063)

Black Sea Science 2020: Proceedings of the International Competition of Student Scientific Works / Odessa National Academy of Food Technologies; B. Yegorov, M. Mardar (editors-in-chief.) [*et al.*]. – Odessa: ONAFT, 2020. – 621 p.

Proceedings of International Competition of Student Scientific Works «Black Sea Science 2020» contain the works of winners of the competition.

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5. ECOLOGY AND ENVIRONMENTAL PROTECTION

ENVIRONMENTAL MONITORING AND RECOMMENDATIONS ON DECREASING THE LEVELS OF PESTICIDE POLLUTION IN ZHYTOMYR REGION OF UKRAINE

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Abstract. *Environmental monitoring was conducted of facilities for storage and disposal of banned and unsuitable pesticides. Pesticide content in soil, water and products of agriculture in Zhytomyr region of Ukraine was examined, and accumulation of organochlorine pesticides by freshwater bivalve mollusks was assessed. Storage facilities of Zhytomyr region contain nearly 392.18 t of pesticides in 137 warehouses, of which 11 meet the requirements, 36 are tolerable, and 90 are in poor condition. 39.07 t of pesticides are kept in containers of good quality, 22.43 t are kept in tolerable containers, and storage containers of other pesticides are of poor quality. In 2018−2019, pesticide content (dichlorodiphenyltrichloroethane (DDT), heptachlor, dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD), hexachlorocyclohexane (HCH)) was studied in soil and sediments in Zhytomyr region. The content ranged from 0.0007 to 0.07 mg/kg, which is lower than MPC (0.1 mg/kg). The content of HCH, DDT, DDE, DDD and heptachlor was at 0.0007−0.01 mg/dm^3 levels in water bodies of Zhytomyr region in 2018-2019, also lower than MPC. In a number of samples of soil, water and vegetables, the recorded levels of DDT and organophosphate pesticides Dragon, Dorpan, and Dursban exceeded MPC in 1.5–3.0 times. Traces of organochlorine pesticide Aldrin were found in soft tissues of bivalve mollusks and in the sediments of water bodies they inhabit. Recommendations are proposed to lower the pesticide content in the environment.*

Key words: pesticides, Zhytomyr region, warehouses, *soil****, water,*** *products of agriculture****, mollusks.***

I. Introduction

Relevance of the topic. Ukraine has ratified the Stockholm Convention (23 May 2001) with the Law of Ukraine N 949-V (949-16) of April 18, 2007. According to the Convention, persistent organic pollutants (POP) are recognized as toxic, resistant to decomposition, bioaccumulative, and are subject to transboundary movements by air, water and with migrating species. POP are also deposited at a great distance from the source of their emission, accumulating in terrestrial and aquatic ecosystems [13]. By this convention DDT, aldrin, dieldrin, endrin, chlordane, mirex, toxaphene, heptachlor are included to the list of most dangerous substances.

Long-term application of pesticides has led to large-scale environmental pollution over huge territories. The migration of toxic compounds in ecosystems causes the accumulation of residual amounts of pesticides in natural objects.

Today it is important to monitor both the storage conditions of pesticides, a lot of which are still kept in Zhytomyr Region of Ukraine [7], and the pesticide content in soil, water bodies, products of agriculture, and in aquatic organisms.

Aim and tasks of the study. ***Study aim:*** to conduct ecological monitoring of pesticides in Zhytomyr region and to prepare recommendations on decreasing the pesticide levels in environment.

The following ***tasks*** were chosen to fulfill the study aim:

1. Analysis of storage and utilization of the banned and unsuitable pesticides in warehouses of Zhytomyr region.
2. Determination of pesticide content in soil, water and products of agriculture in Zhytomyr region.
3. Assessment of bioaccumulation of organochlorine pesticides by freshwater bivalve mollusks.
4. Development of recommendations for decreasing the pesticide levels in environment.

Scientific novelty of obtained results. For the first time in Zhytomyr region, monitoring studies were conducted on the problem of pesticide storage and pollution of soils, water bodies, products of agriculture and local aquatic biota.

Theoretical and practical significance of obtained results. Our results contribute to the further development of ecotoxicology. The obtained data is of interest for the regional environmental monitoring. The main results and conclusions of the work can be used in teaching a number of disciplines in higher education institutions.

Author's contribution. The author personally conducted an information search, independently processed own samples, analyzed and summarized the results. Determination of pesticide content was carried out on the basis of the State Institution "Zhytomyr Regional Laboratory Center of the Ministry of Health of Ukraine" together with the laboratory staff and scientific supervisor. Data of the Department of the Department of Ecology and Natural Resources of the Zhytomyr Regional State Administration were processed.

Approbation of results of research. Study materials were presented at the Department of Ecology of the Zhytomyr State Polytechnic University, as well as at the All-Ukrainian scientific and practical conference of graduate students and young scientists "Sustainable development of Ukraine in the framework of European integration" (November 7, 2019, Zhytomyr State Polytechnic University).

Publications. Conference thesis is published on the results of research.

Structure and contents of work. The study consists of the introduction, the main four chapters, conclusions, references (22 sources: 13 in Cyrillic, 7 in English, and 2 Internet sources), 6 figures and 3 Tables.

II. Analytical survey of publications

Organochlorine pesticides (OCP) have been widely used, and some of them still are used in Ukraine [2, 5, 8, 11, 12, 14 and other countries [13, 15−20, 22] to control insect pests of agriculture and protect crops. Such OCP as DDD (dichlorodiphenyldichloroethane), DDT (dichlorodiphenyltrichloroethane), DDE (dichlorodiphenyldichloroethylene), and HCH (hexachlorocyclohexane) are highly persistent, accumulate for a long time in plants, animals, soils, and are poorly soluble

in water. Therefore they usually accumulate in considerable concentration in river sediments and silt.

In Ukraine, OCP have been used most extensively in 1950-1960s. At the beginning of 1970s, OCP were shown to be highly toxic to animal organisms. They are also very persistent. DDT does not decompose in the environment for 10 years [12]. When from the environment (soil, water, sediments) OCP enter the living organisms, the compounds circulate in trophic chains of local ecosystems, climbing the trophic levels. Thus, all these components of ecosystems, from producers to consumers of highest levels, contain pesticides in their bodies. DDT and HCH can accumulate in various organs and tissues (in case of DDT, mostly in fat tissue). OCP are polytropic compounds, thus they are significantly dangerous to human and animal organisms even in small doses. They negatively affect the functional state of the liver, glands, kidneys and other organs. They have also cytotoxic, carcinogenic, mutagenic effects. All this led to the restriction or ban of their use in early 1970s. But even today, OCP belong to the category of widespread pollutants both in Ukraine and abroad.

Content of DDD, DDT, DDE, HCH, DDVP (dichlorvos), 2,4-D (2,4-dichlorophenoxyacetic acid) has been analyzed in rivers of Luhynsky district of Zhytomyr region in 1988-2008. The results of analysis indicated the significant decrease of pesticide content in the two decades [8]. That is linked to the discontinuation of large agricultural enterprises that had used public funds to purchase pesticides. At present, only small farms and private homesteads operate in the district.

The long-term, often uncontrolled and unjustified, use of pesticides in agriculture has led to the contamination of inland water bodies with these dangerous toxicants and the disturbance of natural ecological balance. Pesticides of different chemical origin have a detrimental effect on all representatives of freshwater biota. Due to the cumulative properties, pesticides circulate and accumulate in the organisms of all aquatic organisms, including shellfish. In the early XXI century, a number of scientists [12] have registered persistent OCP (DDT and HCH) in various organs of six freshwater mollusk species of the family Unionidae in rivers of Zhytomyr and Khmelnitsky regions.

In the summer of 2008, several pesticides (DDT, DDE, DDD, HCH, aldrin, dieldrin and hexachlorobenzene) have been found in bivalve mollusks *Colletopterum ponderosum sedakovi* (Siemaschko, 1848) in Lake Baikal [15].

I. A. Fodchenko [14] has found pesticides (DDT, aldrin, HCH, heptachlor) in mussels, produced in Ukraine (the Black Sea coast of Odessa region) and abroad (Chile, China). Pesticides have been found in marine mollusks from other countries: Korea [16], Croatia [18], Italy [19], Asian countries [22] and others.

Today, organophosphate pesticides such as chlorophos, paraoxane, metaphos, carbofos, oxamethyl are used more and more frequently [5]. They are less toxic than OCP, and do not withstand water, i.e. they are subject to rapid decomposition, which eliminates their prolonged impact on the biota of reservoirs.

III. Object, subject and methods of study

Study object is pesticide storage warehouses; samples of water, soil and products of agriculture from Zhytomyr region; freshwater bivalve mollusks of the species *Unio crassus* (Retzius, 1783) from Perga river (Radovel' village, Olevsky district of

Zhytomyr region) (Fig. 1) and *Anodonta anatina* (Linnaeus, 1758) from Irsha river (Khoroshiv village, Zhytomyr region) (Fig. 2).

Fig. 1. The shell of *Unio crassus* (Retzius, 1783) from the Perha river (Radovel' village of Olevsky district, Zhytomyr region).

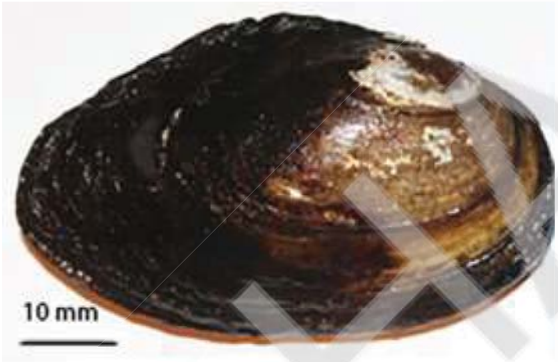

Fig. 2. The shell of *Anodonta anatina* (Linnaeus, 1758) from the Irsha river (Khoroshiv village, Zhytomyr region).

Study subject is ecological monitoring of pesticides in Zhytomyr region.

Methods of study. The content of pesticides in water, soil, agricultural products and tissues of mollusks was determined on the basis of the State Institution "Zhytomyr Regional Laboratory Center of the Ministry of Health of Ukraine" using standard methods of OCP research, gas-liquid chromatography and thin-layer chromatography: DSTU EN 1528-1-2002; EN 1528-2:1996; EN 1528-3:1996; EN 1528-4:1996; DSTU EN 12393-(1;2;3):2003; DSTU 4514:2006 [3, 4, 10].

Information about pesticide storage was given by the Department of Ecology and Natural Resources of Zhytomyr Region State Administration.

Bivalve mollusks were sampled manually at maximum depth 0.5–0.7 m [9]. Most mollusks live on sediments (silt, sandy silt), rarely on sands. Species identification of mollusks was performed on the basis of their conchological features [21].

The results of the study were processed using methods of variation statistics [1].

IV. Results

IV.I. The problem of pesticide storage facilities in Zhytomyr region

Numerous warehouses were built in almost all regions of then-Soviet Ukraine to store various types of pesticides (herbicides, fungicides, insecticides, acaricides, zoocides, etc.). Usually, such pesticides are stored in significantly damaged packages, contaminate the soil and seep into the groundwater. Hence, warehouses that contain pesticides are extremely dangerous. They also have no warning signs and are largely unsecured.

One of the acute environmental problems in the Zhytomyr region is the practice of dealing with unsuitable pesticides and agrochemicals. According to the Department of Ecology and Natural Resources of Zhytomyr Region State Administration, 137 warehouses with unsuitable pesticides and agrochemicals are in the Zhytomyr region, as of 01.01.2018 (Fig. 3). Eleven warehouses meet the requirements, 36 are tolerable, and 90 are in poor condition (Fig. 4, 5). The largest warehouses are located in Yahodynka village (Pulynsky district), with 23.00 tons of pesticides; N. Velidnyky village (Ovrutsky district), with 19.49 tons of pesticides at OJSC "Ovrutsky rajagrokhim"; Koshelivka village (Pulynsky district), with 17.0 tons of pesticides; Veselivka village (Ovrutsky district), with 12.07 tons of pesticides at LLC "Nehodivske" (Table 1).

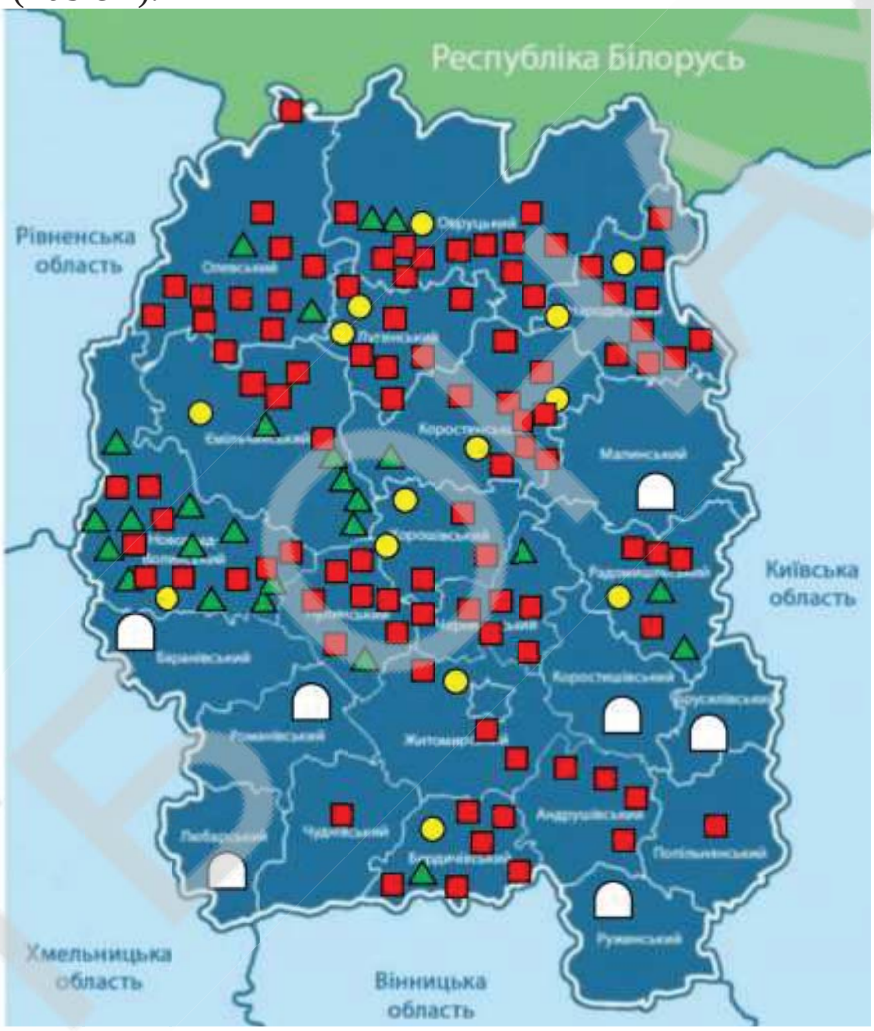

Fig 3. Map of warehouses storing unsuitable pesticides and agrochemicals in Zhytomyr region, as of 01.01.2018 (according to the Department of Ecology and Natural Resources of Zhytomyr Regional State Administration): triangle — under 0.5 t of pesticides; circle — 0.5–1.0 t of pesticides; square — more than 1.0 t of pesticides; horseshoe — pesticides were utilized in 2012.

Fig. 4. Pesticide storage in Toporische village of Khoroshiv district, Zhytomyr region (October, 2019).

Fig. 5. Pesticide storage in Znamianka village of Khoroshiv district, Zhytomyr region (October, 2019).

Table 1

Warehouses of unsuitable pesticides and agrochemicals of Zhytomyr region as of 01.01.2018 (according to the Department of Ecology and Natural Resources of Zhytomyr Regional State Administration)

Settlement	Number of warehouses	Tons in total	Settlement	Number of warehouses	Tons in total
Zhytomyrsky district					
Berezivska village council of Dubovets village	1	4.3	Vertokyivska village council of Vertokyivka village	1	6.8
Sinkhurivska village council of Sinkhuri village	1	3.854	Sadkivska village council of Sadky village	1	0.546
Andrushivsky district					
Yaropovichi village	1	7.0	Zarubyntsi village	1	4.0
Ivankiv village	1	3.0	Volosiv village	1	3.0
Berdychivsky district					
Raykhorodok village	1	3.2	Markushi village	1	2.5
Gordyshivka village	1	0.751	LLC “Shakur”, area of OSCJ “Roduchist”	1	2.2
Buriaky village	1	6.228	Andriyashivka village	1	0.2
Krasivka village	1	2.4	Ivanivtsi village, area of LLC “Fact”	1	4.5

Continuation of Table 1.

Settlement	Number of warehouses	Tons in total	Settlement	Number of warehouses	Tons in total
Pulynsky district					
Ivanovychi village, private enterprise “Ivonovytske”	1	8.0	Yahodynka village	1	23.0
Ten’kivka village	1	9.0	Kolodiyivka village	1	0.3
Huta-Yustynivka village, farm “Poliska nyva”	1	3.0	Khodorivka village, agricultural LLC “Tetirske”	1	4.0
Zelena Poliana village	1	3.0	Koshelivka village	1	17.0
Korostensky district					
Vas’kovychi village, agricultural LLC “Poliska nyva”	1	4.062	Kalenske village, agricultural LLC “Svitanok”	1	8.219
Kapysche village, private rent agricultural enterprise “Hrunty Polissia”	1	3.502	Medynivka village, agricultural LLC “Medynivske”	1	1.696
Sushky village, agricultural LLC “Nove zhyttia”	1	5.655	Khotynivka village, agricultural LLC “Khotynivske”	1	3.393
Khodaky village, private rent agricultural enterprise “Nyva”	1	0.768	Berestovetske village, private rent agricultural enterprise “Nyva”	0	4.124
Meleni village, private rent agricultural enterprise “Meleni”	1	1.256	Novyna village, agricultural LLC “Iskra”	1	0.411
Stremyhorod village, private rent agricultural enterprise “Zoria”	1	0.645	Schorsivka village, Petrovsky agricultural LLC	1	2.0
Luhyncky district					
Chervona voloka village	1	4.0	Private enterprise “Kremnianske”	1	4.1
Velyky Dyvlyn village	1	0.9	Stantsiyne village	1	3.9
LLC “Lypnyky”	1	2.7	Private enterprise “Kalynivske”	1	2.8
Litky village	1	1.7	Zherevtsi village	1	0.8
Topilnia village	1	10.6			
Narodytsky district					
Narodychi village, private enterprise “Berehynia”	1	1.8	Narodychi village, agricultural LLC “Zorya”	1	1.2
Zherev village, private enterprise “Smyka”	1	2.0	Lasky village	1	1.0
Selets’ village	1	1.1	Bolotnytsia village	1	0.7
Sukharivka village, agricultural LLC “Sukharivske”	1	1.2	Zalissia village, Vatutin agricultural LLC	1	3.6
Motiyky village	1	4.97	Lyplianschina village	1	4.7
Novy Dorohyn’ village	1	0.8	Noryntsi village	1	2.2
Novohrad-Volynsky district					
Private rent agricultural enterprise “Kolos”, Pykypovychi village	1	3.0	LLC “Schedry dar”, Kolodianka village	1	0.8
Khmelytsky agricultural LLC, Povchyne village	1	0.6	Private enterprise “Khliborob”, Pyschiv village	0	0.3
Private agricultural enterprise “Granit”, Tokariv village	1	2.0	Private agricultural enterprise “Yavir”, Yavorovka village	1	0.275
private enterprise “Poliana”, Polianivka village	1	1.5	Farm “Adelayida”, Tupaltsi village	1	1.5
LLC “Agrosoyuz”, Orepy village	1	2.9	Agricultural LLC “Rostok”, Kurchytsia village	1	2.1
Procurement and manufacturing plant “N-Volynsky”, Ivashkivka village	1	0.216	Agricultural LLC “Lisove”, Luchytsia village	1	1.7
Korolyov private enterprise, Taraschanka village	1	0.7	private agricultural enterprise “Tserem”, Krasylivka village	1	1.0

Continuation of Table 1.

Settlement	Number of warehouses	Tons in total	Settlement	Number of warehouses	Tons in total
Bronykivska village council	1	0.27	Maystrivska village council	1	0.2
Private agricultural enterprise “Khmil’”, Klenova village	1	0.45	Private agricultural enterprise “Promin’”, Uzhachyn village	1	0.3
Regional Sanitary-epidemiological station	1	0.488	Shevchenko Private agricultural enterprise, Mala Tsvilia village	1	0.3
Agricultural LLC “Oberih”, Bronyky village	1	2.5			
Ovrutsky district					
Pischanytsia village, agricultural LLC “Polissia”	1	4.2	Private agricultural enterprise “Ukrayina”, Pokaliv village	1	1.474
Khlupliany village, agricultural LLC “Khlupliany”	1	0.8	Levkovychi village, agricultural LLC “Mozharivske”	1	1.8
Mozhary village, agricultural LLC “Mozharivske”	1	3.94	Bihun’ village, private enterprise “Khotynivske”	1	1.9
Cherevky village, agricultural LLC “Cherevky”	1	0.5	Cherevky village, agricultural LLC “Cherevky”	1	0.2
N. Velidnyky village, OJSC “Ovrutsky rayagrokhim”	1	19.49	V. Khaycha village, LLC “Velykokhaychanske”	1	1.5
Sholomky village, agricultural LLC “Nove zhyttia”	1	3.3	Veselivka village, LLC “Nehodivske”	1	12.07
Rakivschyna village, agricultural LLC “Rakivschynske”	1	5.5	Hladkovychi village, farm “Dobrobut-Radychi”	1	1.6
Zaricchia village, agricultural farm “Zorya”	1	5.0			
Olevsky district					
Lopatychi village, private rent aricultural enterprise “Iskra”	1	1.65	Bilokorovychi village, private rent aricultural enterprise “Bilokorovytske”	1	6.35
Kamianka village, aricultural LLC “Svitanok”	1	2.87	Kyshyn village, private rent aricultural enterprise “Kyshynske”	1	1.4
Kopysche village	1	0.5	Majdan village	1	0.48
Zolnia village	1	1.9	Zubkovychi village	1	3.1
Zhubrovychi village	1	2.37	Komsomolsk village	1	1.1
Zamyslovychi village	1	1.3	Suschany village	1	1.907
Tepenytsia village	1	1.5	Olevsk city	1	5.8
Popylniansky sistrict					
Popilnia village	1	5.5			
Radomyshl’cky district					
Kachkyrivska village council	1	0.6	Kocherivska village council	1	0.2
Mirchans’ka village council	1	0.2	Krasnobirs’ka village council	1	2.0
Borschivska village council	1	5.0	Menkivs’ka village council	1	0.3
Vyshevetska village council	1	1.6			
Khoroshivsky district					
Znamianka village	1	0.25	Krayivschyna village	1	8.05
Skolobiv village	1	3.0	Sukhovolia village	1	0.6
Toporysche village	1	2.2			
Cherniakhivsky district					
Okilok village, private rent agricultural enterprise “Okilok”	1	2.59	Styrtynska village council	1	3.0
Zarolivska village council	1	3.3	Andriivska village council	1	3.5
Vysokivska village council, Gorodysche village	1	1.7	Seletska village council, Selets’ village	1	0.5
Смт. Черняхів ДП “Україна”	1	3,0			

Continuation of Table 1.

Settlement	Number of warehouses	Tons in total	Settlement	Number of warehouses	Tons in total
Chudnivsky district					
c. Vil'shanka village, OSCJ "Rayagrokhim"	1	1.2			
Yemilchynsky district					
Gannopilska village council	1	0.5	Maloglumchanska village council	1	1
Mokliakivska village council	1	0.7	Pidlubivska village council	1	0.5
Serhiivska village council	0	0.5	Serednivska village council	1	1.6
Stepanivska village council	1	1	Riasnenska village council	1	0.5
Velykojablunevska village council	1	1	Zelenytska village council	1	0.5

There are a total of 392.18 t of stored pesticides. Of these, 32.450 t are liquid, 24.975 t are solid, and 334.755 t is unknown mixtures. The condition of the storing containers is as follows: 39.07 t of pesticides are kept in good condition, 22.43 t in satisfactory condition, the rest in poor condition. Due to poor storage conditions, toxic pesticides enter the environment including water and air, presenting the risk of poisoning to humans, flora, and fauna.

Only warehouses storing unsuitable chemical plant protection products (CPPP) in Berdychiv and Pulyn districts are protected, the rest of the warehouses are not guarded. In Zhytomyr region, efforts were made of replacing CPPP containers. For example, 33.731 t of unsuitable agrochemicals of the former collective agricultural enterprises were weighed and reloaded in 11 village councils in Korosten district, in October 2014. 37 t of toxic waste were reloaded in sealed containers at the territories of Novovelidnytska, Nevhodivska, Mozharivska and Pokalivska village councils of Ovrutsky district in 2014. Popilnanska united territorial community (UTC) organized reloading at its own expense of 5.5 t of CPPP to sea containers in 13.05.2017.

In 2011–2012, 968.535 t of unsuitable CPPP were reloaded and exported from Ukraine. At present, the territory of Baranivsky, Brusyliv, Lubarsky, Malynsky, Romanovsky, and Ruzhyn districts of Zhytomyr region has been cleared of CPPP.

Expired pesticides are unusable and must be disposed of. Together with storage packaging, they are hazardous waste that must be correctly deactivated by licensed agencies. Currently, in Ukraine, there are no entities licensed to conduct hazardous waste management (collection, transportation, storage, treatment, disposal), including unsuitable pesticides.

The problem also lies in the lack of a scientifically sound concept of pesticide processing and deactivation, imperfect technological processes and the incomplete technological cycles of processing, the lack of safe methods of disposal. The whole range of issues related to the elimination or control of the negative effects of toxic waste on the environment and human health will only be effectively resolved with a national program for waste management.

IV.II. Pesticide pollution of soil, water bodies and products of agriculture in Zhytomyr region

According to State Institution "Zhytomyr Regional Laboratory Center of the Ministry of Health of Ukraine", pesticide (HCH, DDT, DDE, DDD, heptachlor) content was in the range of 0.0007−0.07 mg/kg in soils and sediments of Zhytomyr region in 2018−2019, within the MPC values (0.1 mg/kg) (Table 2).

In February 2015, an excess of **DDT** (0.3 mg/kg, MPC = 0.1 mg/kg) was observed in soil sampled at Romaniv village (Makarenko Street) (report № 1–10 of February 27, 2015). In September 2017, the content of **Dragon** pesticide (0.29 mg/kg) exceeded MPC of 0.2 mg/kg in soil sampled at the boundary of residential development in the Romanivka village of Brusylivsky district (Centralna str., 1.25 m from the corn field) (report № 148−154 of 28.09.2017). The active substance of Dragon is chlorpyrifos. It belongs to organophosphate compounds. It is a modern, broad-spectrum contact insecticide against sucking and biting insects. It has high initial toxicity, blocking primarily acetylcholine esterase enzymes, which play an important role in the transmission of nerve impulses in insects.

Content of HCH, DDT, DDE, DDD and heptachlor was measured in water bodies of Zhytomyr region in 2018−2019. It fluctuated in the range of 0.0007−0.01 mg/dm^3, which is within MPC values (Table 3).

In September, 2017, the content of **Dragon** (0.003−0.004 mg/dm^3) and **Dorpan** (0.003 mg/dm^3) pesticides exceeded MPC values (0.002 mg/dm^3) in waters of private dug out wells on the Centralna and Shevchenko streets of Romanivka village, Brusylivsky district (report № 297−301 of 28.09.2017). The active substance of Dorpan is chlorpyrifos, one of the organophosphate compounds. It is a broad-spectrum insecticide.

In August, 2016, content of **Dursban** pesticide (0.1 mg/kg) exceeded MPC of 0.05 mg/kg in vegetables (zucchini) produced in Yastrubna village of Brusylivsky district (report № 44 of 4.08.2016). The active substance of Dursban is also chlorpyrifos.

Table 2

Levels of pollution of soil and sediments with residual amounts of pesticides (mg/kg, MPC = 0.1 mg/kg) in Zhytomyr region (2018–2019)

Water body	District	HCH MPC = 0.1		DDT MPC = 0.1		DDE MPC = 0.1		DDD MPC = 0.1		Heptachlor MPC = 0.1	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
«Stas'ka hreblia" UT MR	Andruchivka city	0.008	0.008	0.005	0.005						
Unorganized recreational area in Kvitneve village	Andrushivsky	0.01	0.009			0.005	0.004				
Pond of Vchorayshe village	Ruzhyncky							0.01	0.008		
Lake №1	Korostyshivsky	0.004	0.004								
Lake of Glybochok village	Korostyshivsky		0.02								
Quarry (near Zaricchia)	Korostyshiv city		0.07								
Tykhi Verby pond	Brusyliv village	0.0008	0.0007								
Irsha river (unofficial swimming area), Bondaryk str.	Malyn city	0.008	0.007	0.005	0.005						
Confluence of Sluch and Khomora rivers, Baranivka village	Baranivsky	0.07	0.07						0.06		
Pond of Chudniv city	Chudnivsky									0.01	0.01
Floodplain of Kodnianka river	Ozerne village								0.01		

Table 3

Levels of pollution of water bodies with residual amounts of pesticides (mg/dm^3) in Zhytomyr region (2018–2019)

Water body	District	HCH MPC 0.02		DDT MPC 0.002		DDE MPC 0.002		DDD MPC 0.002		Heptachlor MPC 0.001	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
"Stas'ka hreblia"	Andrushivka city	0.009	0.008	0.001	0.0009						
Unava river, Kvitneve village	Andruchivsky	0.009	0.009					0.001	0.0009		
Pond of Popilnia village	Popilniansky	0.01	0.01	0.001	0.001						
Water body of Khodorkiv village	Popilniansky									0.0008	
Pond in Vchorayshe village	Ruzhynsky							0.001	0.0008		
Lake "Skirobjednannia"	Berdychivsky		0.007		0.001						
Irsha river	Khoroshiv city	0.006									
Vodoyma of Guta village	Khoroshivsky	0.001									
Lake № 1	Korostyshivsky	0.008									
Pond of Bezhiv village	Cherniakhivsky	0.002									
Tykhi Verby pond	Brusyliv village	0.0008	0.0007								
Irsha river (unofficial swimming area), Bondaryk str.	Malyn city	0.01	0.01	0.007	0.006						
"Kaliuzha" (unofficial swimming area), Gorodyschanska str.	Malyn city				0.0005	0.0008					
Pond of Malynivka village (unofficial swimming area)	Malynsky						0.0009				
Viznia river, in Rudnia-Gorodyschenska village	Malynsky					0.0008					
Myka river (unofficial swimming area)	Radomyshl'sky	0.008								0.0009	

Teteriv river (250 m downstream of waste-water discharges)	Radomyshl'sky							0.0009			
Sluch river (200 m upstream of waste-water discharges of communal enterprise "Novohrad-Volynsky VUVKH")	Novohrad-Volynsky	0.009									
Sluch river (200 m downstream of waste-water discharges of communal enterprise "Novohrad-Volynsky VUVKH")	Novohrad-Volynsky	0.01									
Sluch river (recreational area near Zaricchia)	Baranivka city	0.005	0.001								0.001
Confluence of Sluch and Khomora rivers, Markivka village	Barankivsky	0.007									0.0008
Pond of brick factory	Pulyny village	0.008	0.009								
Teteriv river (100 m upstream of bridge)	Chudniv city	0.006			0.0009						
Pond of Chudniv city	Chudniv city									0.0007	

IV.III. Accumulation of organochlorine pesticides by freshwater bivalve mollusks

We studied the organochlorine pesticide content in soft tissues of bivalve mollusks of the species *Unio crassus* from Perha river (Radovel' village, Olevsky district) and *Anodonta anatina* from Irsha river (Khoroshiv village, Zhytomyr region), and also in water and sediments of rivers inhabited by the mollusks. OCP enter the mollusk organisms same as other pesticides, either through skin, adsorption with food, or with metabolism. OCP are accumulated most intensively in the body parts of mollusks that are most exposed to the polluted environment (shell, mantle, foot and branchia).

HCH, DDT, DDD, DDE, heptachlor were not detected in water, sediments and tissues of bivalve mollusks by gas-liquid chromatography. Thin-layer chromatography revealed traces of **Aldrin** pesticide in sediments and soft mollusks (Fig. 6).

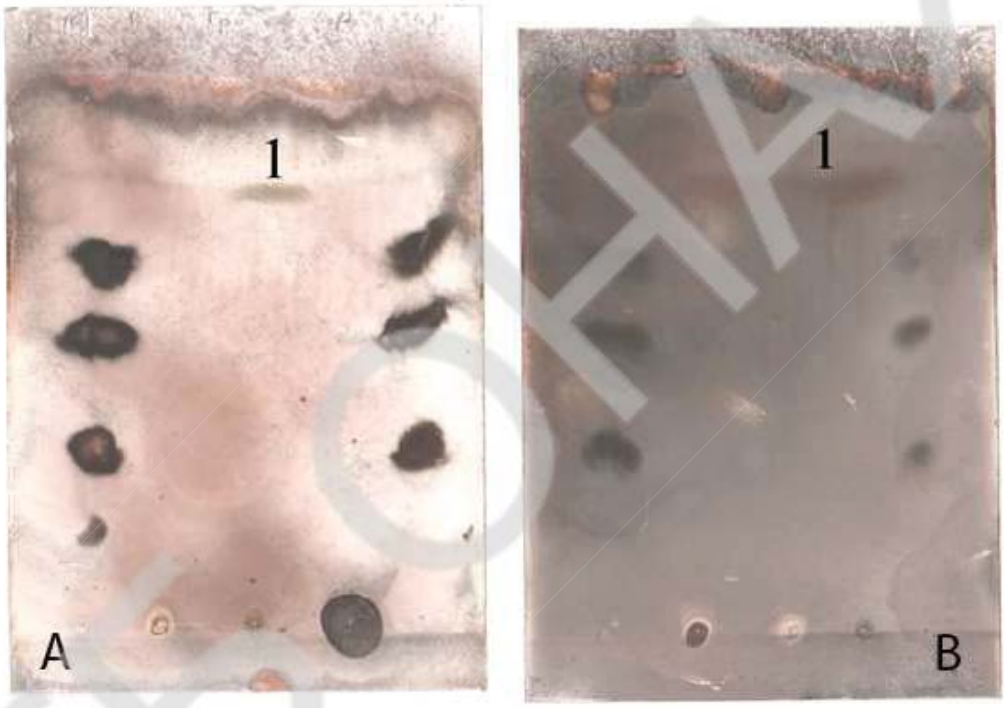

Fig. 6. Chromatogram of distribution of organochlorine pesticides on chromatogramic plate «Silufol», thin-layer chromatography (solvent system hexane, developer silver ammonia, September, 2019): A – foot tissues of *Unio crassus* mollusks from Perha river (Radovel' village, Olevsky district of Zhytomyr region); B – foot tissues of *Anodonta anatina* mollusks from Irsha river (Khoroshiv village, Zhytomyr region), 1 – trace amounts of Aldrin.

Aldrin ($C_{12}H_8Cl_6$) is a pesticide, used in pest control in plant cultures and against termites. Due to its toxic effect, it is banned not only for use but also for production in Ukraine and many other countries of the world. At the same time, it is possible that Aldrin reserves are kept in numerous pesticide storages in Ukraine.

IV.IV. Recommendations for decreasing pesticide content in environment

Development of scientific technologies and legislative framework is important in controlling and lessening the negative effects of pesticides on the environment [2, 6, 11]. Hence, the following recommendations are topical:

- the implementation of the Stockholm Convention on Persistent Organic Pollutants in Ukraine should become a matter of national priority;
- there should be scientific studies and development concerned with determination and monitoring of pesticides;
- system of state monitoring of environment and citizen health under the effect of pesticides should be implemented;
- the infiltration of pesticides into environment should be limited and/or prevented;
- control should be established over economic entities that produce and sell (or otherwise realize) pesticides, and over citizens or other legal entities engaged in activities related to such pesticides;
- people of Ukraine should be informed of the dangers of pesticides;
- training programs should be developed and implemented on pesticide hazards and their implications for the life and health of humans, the environment, and of alternatives to pesticides;
- illegal circulation of pesticides in Ukraine, circulation of banned and overdue pesticides should be prevented, and areas contaminated with pesticides that are unsuitable or banned to use should be detected and cleared.

V. Conclusions

1. In Zhytomyr region, nearly 392.18 t of pesticides are stored in 137 warehouses. Eleven warehouses meet the requirements, 36 are tolerable, and 90 are in poor condition. The quality of storage containers is as follows: 39.07 t are kept in good conditions; 22.43 t are kept in tolerable conditions; other pesticides are stored in containers of poor quality.
2. In 2018−2019, pesticide (HCH, DDT, DDE, DDD, heptachlor) content in soils and sediments of Zhytomyr region was in the range of 0.0007−0.07 mg/kg, i.e. within MPC values (0.1 mg/kg). Content of HCH, DDT, DDE, DDD, heptachlor in water bodies of Zhytomyr was in the range of 0.0007−0.01 mg/dm^3, at the same time, also within MPC.
3. In 2015, DDT content in soil (0.3 mg/kg) exceeded MPC (0.1 mg/kg) in Romaniv village; in 2017, Dragon pesticide content in soil (0.29 mg/kg) exceeded MPC (0.2 mg/kg) in Romanivka village. Also in 2017, Dragon pesticide content (0.003−0.004 mg/dm^3) and Dorpan pesticide content (0.003 mg/dm^3) exceeded MPC (0.002 mg/dm^3 and 0.002 mg/dm^3, respectively) in water samples from wells of Romanivka village. In August, 2016, Dursban pesticide content (0.1 mg/kg) exceeded MPC (0.05 mg/kg) in sampled zucchini produced in Yastrubna village of Brusylivsky district, Zhytomyr region.
4. In soft tissues of bivalve mollusks and sediments of the water bodies which they inhabit, residual traces of the organochlorine pesticide Aldrin were found.
5. Recommendations are developed to decrease the pesticide content in environment.

Prospects for further research. Experimental studies on biological test objects are planned to investigate the likely toxicity of residual OCP.

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