

UDC 632.95 + 658 + 336

**Roman Petruk**

Vinnitsia National Technical University (Ukraine)  
Ph.D., Associate Professor, [prroma07@gmail.com](mailto:prroma07@gmail.com); [orcid.org/0000-0002-5128-4053](https://orcid.org/0000-0002-5128-4053)

**Yulia Bilichenko**

Vinnitsia National Technical University (Ukraine)  
postgraduate, [jullybilich@gmail.com](mailto:jullybilich@gmail.com); [orcid.org/0000-0002-6034-3924](https://orcid.org/0000-0002-6034-3924)

**Halyna Petruk**

Vinnitsia State Pedagogical University named after Mykhailo Kotsyubynsky (Ukraine)  
Ph.D., Associate Professor, [petrukgd60@gmail.com](mailto:petrukgd60@gmail.com); [orcid.org/0000-0002-8443-6105](https://orcid.org/0000-0002-8443-6105)

## **ECONOMIC CALCULATIONS OF THE CHOICE OF PESTICIDE DISPOSAL METHOD**

**Goal:** *is a brief analysis of the main ways of dealing with unusable pesticides and pesticide-containing wastes and facilities and substantiation of technical and economic parameters of processes of neutralization of unusable pesticides and hazardous waste, as well as establishment of the most optimal methods and ways of their utilization.*

*To establish the most optimal methods and ways of utilization of pesticides and pesticide-containing waste, a financial and economic assessment of pesticide exports from Ukraine to processing plants in Europe was made, the cost of burning pesticides at specialized plants in Ukraine was calculated, the total cost of reclamation works was calculated. on recycling of pesticide containers.*

**Methodology:** *To solve the tasks in the work used modern methods of scientific research: analysis - to summarize modern scientific and technical advances in the prevention of environmental pollution due to pesticides entering the environment; indication methods - for assessment of soil, water and air pollution; methods of reclamation of contaminated areas and incineration of pesticides; methods of analysis of gas mixtures, etc.*

**Scientific novelty:** *for the first time scientific and methodological calculations of environmental safety parameters and management of unusable pesticides and pesticide-containing wastes, the essence of which is to take into account the main components of the cost of pesticide disposal and restoration of contaminated areas, including management actions for all components of pesticide territories and largely solve the problem of pesticide pollution.*

**Conclusions:** *calculations of the cost of recycling various facilities that contain unusable pesticide-containing drugs and waste and established the most optimal methods and ways of recycling pesticides in Ukraine. A brief analysis of the main methods of handling unusable pesticides and pesticide-containing waste and facilities and substantiated the technical and economic parameters of the disposal of unusable pesticides and hazardous waste, as well as the most optimal methods and methods of their disposal.*

**Keywords:** *pesticides, pesticide-containing waste, utilization, processing methods, cost.*

### **Introduction**

At the present stage of development of agricultural production in Ukraine is an extremely acute problem of circulation, export, disposal and processing of residues unusable and prohibited for use chemically hazardous substances and, above all, pesticides and pesticide-containing waste, which include, in particular, used packaging, obsolete structures, chemical warehouses and storage facilities, degraded and contaminated PP above normal soils adjacent to them, etc. At the same time, the implementation of appropriate disposal works requires a lot of effort, the use of the latest technologies for processing and transshipment operations, the need to use significant financial and economic resources, strict compliance with safety rules and sanitary-epidemiological indicators and more. Recently, some state resources have been used to finance neutralization and utilization works, as well as the export of a small part of PP and PVV for processing outside Ukraine, but these amounts of budget funding were and are extremely scarce and insufficient to completely eliminate this problem. To this should be added the almost complete absence in the state of the necessary production capacity for such processing and disposal of accumulated PP and PVV, special transport, trained personnel and so on. In addition, there is no single centralized system of accounting and integrated management of pesticide residues and other agrochemicals, as well as their inventory, proper control over compliance with the requirements in the field of hazardous waste management by both the state and businesses,

The purpose of this work is a brief analysis of the main methods of handling unsuitable pesticides and pesticide-containing waste and facilities and substantiation of technical and economic parameters of disposal of

unusable pesticides and hazardous waste, as well as establishing the most optimal methods and methods of their disposal.

**Theoretical foundations of the study**

There is a scientific, technical and managerial problem of danger and associated risks of storage, processing, transportation, disposal, including: containers of pesticides and pesticide-containing waste, as well as the liquidation of warehouses and storage of HZZR, reclamation and remediation of land around them and others. To solve any applied environmental problem requires the efficient use of available resources (including financial) and a detailed strategy for managing this issue. To understand the optimal environmental and economic solution to the problem of pesticides, it is necessary to calculate the economic parameters of disposal and treatment. For this purpose it is necessary to consider the financial and economic estimation of export of pesticides abroad for processing, to consider a possibility of burning at processing plants of Ukraine,

Undoubtedly, from the beginning of production and use of HZZR for a long time this problem was addressed by domestic and foreign scientists and practitioners [4], in particular: Melnikov MM, Ransky AP, Petruk VG, Patika VP, Krainov IP, Lisichenko GV, Ivanyuta SP, Glukhovskiy IV, Kachinsky AB, Zabulonov YL, Furdychko OI, Moklyachuk LI, Zerkalov D.V. and many other scientists. However, their well-known scientific works are largely dominated by the solution of specific, local problems, rather than solving the problem as a whole [5-6].

Therefore, the scientific substantiation of economic calculations for the disposal of unusable pesticide drugs (expired, mixed, substandard, unidentified, etc.), other chemical plant protection products and hazardous waste is an extremely important issue for science and practice and the environmental sector of Ukraine.

**Results and discussion**

**1. Financial and economic evaluation of the export of pesticides to processing plants in Europe**

**Table 1 - Calculation of the cost of export from Vinnytsia region**

Expense items	Storage location	Quantity, tone	Cost, dollars per ton	Costs, USD	Expenses, UAH
Export of pesticides	Dzhurinsky poison burial ground	2100	3 thousand	6.3 million	163 million
	warehouses of Vinnytsia region	849, 239	3 thousand	2.5 million	65 million
<b>TOTAL</b>				<b>8.8 million</b>	<b>228 million</b>

The table includes the cost of exporting 1 ton of pesticides with all costs within \$ 3,000. US per ton. This average value was calculated based on the statistics of pesticide exports from Ukraine in 2012. Obviously, this cost is somewhat inflated, but in the conditions of non-corrupt exports, this amount may be much lower.

Today in Ukraine there is a resolution of the Cabinet of Ministers №1212 "On Amendments to Clause 11 of the Regulations on Control over Transboundary Movements of Hazardous Wastes and Their Utilization / Disposal", which simplifies the transboundary movement of unusable pesticides. Also, this resolution makes it possible to solve the problem of unusable pesticides directly, without the permission of the Ministry.

**Table 2 - Calculation of the cost of export of pesticides from Ukraine**

Expense items	Storage location	Quantity, tone	Value, dollars per ton	Costs, USD	Expenses, UAH
Export of pesticides	Warehouses of regions of Ukraine	18 thousand	3 thousand	54 million	1404 million

For the state budget, this amount is quite significant and in the current economic situation of the state is unlikely to allocate funds for such a project. However, for regional funds, gradual export is more appropriate, taking into account the fact that the region has an average of 720 tons of pesticides, which will cost for export an average of 56 million UAH.

The total number of unusable pesticides within Ukraine is 18,000 tons. Accurate data are currently not available even in the relevant Ministry of Ecology, as inaccurate accounting is conducted. For example, the Dzhuryn Poison Cemetery estimates that 2,100 tons of pesticides have been stored, but no one has ever repackaged or weighed them, and the estimate has been roughly based on the volume and quantity of pesticides. Therefore, the exact data on the volume of accumulated pesticides are unknown.

**2. Incineration of pesticides at specialized plants of Ukraine**

The cost of the specialized Sava plant in Brunsbüttel, where pesticides are burned according to European standards, is about 70 million euros, which is about 1935 million hryvnias. At a specialized plant, pesticides are

burned, and the formed gases undergo multi-stage purification. The cost of treatment equipment alone is about 50 million euros.

There is currently one mini-plant for burning pesticides and containers in Ukraine without standard treatment equipment and without the appropriate licenses. It is also planned to build infrastructure for the disposal of ozone-depleting compounds and persistent organic pollutants in accordance with the projects UNIDO (United Nations Industrial Development Organization) in Cherkasy.

In fact, today in Ukraine there is no possibility to recycle pesticides and containers in accordance with environmental regulations.

**Table 3 - Incineration at a specialized plant Ukraine (estimated cost, taking into account world tariffs)**

Expense items	Storage location	Quantity, tone	Value, dollar per ton	Costs, USD	Expenses, UAH
Repackaging	Warehouses of regions of Ukraine	18 thousand	200	3.6 million	97.2 million
Transportation	Warehouses of regions of Ukraine	18 thousand	100	1.8 million	48.6 million
Total					UAH 145.8 million

From this table it becomes obvious that the procedure of processing and transportation costs about one tenth of the cost of the incineration plant. That is, the main cost item is the construction of a plant, which after processing pesticides can be used further, with a focus on other types of waste and raw materials. Such raw materials can be:

1. Insignificant volumes of unusable pesticides that will be formed in the future as a result of exceeding the shelf life of pesticides. Currently, in our country, such pesticides are sold and used in violation of the law. Expired pesticides can now be found in almost any pesticide warehouse.
2. Incineration of highly toxic organic industrial waste.
3. Incineration of illiquid plastic and non-recyclable recyclables.
4. Burning of rubber products and tires.

**3. Mobile plasma thermal complex for processing unusable and unidentified pesticides and other pesticides**

Currently, there are many examples of successful industrial implementation of the method of plasma thermal processing of a large list of toxic wastes that are recycled by mobile plants in different countries, in particular:

- EA TECHNOLOGY (England): ethanediol, trichloromethane, benzene-alcohol, dichlorobenzene, waste oil distillation, polychlorinated biphenyls (PCBs);
- Alberta Center (Canada): 1 - acetone, gasoline, methyl ethyl ketones, special solvents; 2 - chloroform, dichloromethane, carbon tetrachloride and PCBs;
- PLASCON (Liverton, Australia): toluene and chlorophenol with toxic additives and 2,4-D-butyl ether;
- SOLVAY (Germany): chlorofluorocarbons;
- EST Ltd. (Beersheba, Israel): methylene chloride, polychlorinated carbons and hydrocarbons (C - 60%, C1 - 30%);
- Institute of Heat and Mass Transfer of the National Academy of Sciences of Belarus (Minsk, Belarus) and TVS Merseburg (Germany): methylene chloride, trichlorethylene (C<sub>2</sub>H<sub>3</sub>Cl<sub>3</sub>), alcohol-benzene mixtures (with rosin additives);
- Integrated Environmental Technologies, LLC (PEM - Plasma Enhanced Melter): PCBs, plastics, medical and biological waste;
- WESTINGHOUSE (USA): processing of CCl<sub>4</sub> in a mixture with methyl ethyl ketone, ethanol and water, diphenyl chloride, the degree of decomposition of biphenyls - 99.99%. 160 Dangerous toxic substances (dioxins, dibenzofurans) in gases were not observed;
- PLASMOX (Switzerland, Germany): processing of combat poisons.

The mobile plasma complex, further [7] is intended for utilization (processing) of unsuitable and unrecognizable pesticides and other pesticides located in various places, including on old field warehouses, in the destroyed rooms and other places from where their transportation is dangerous to health. people. The planned productivity of the complex is over 1000 t / year.

The estimated cost of such a complex is about \$ 8 million. But the disadvantage of such a complex is the significant energy costs during the disposal of pesticides, which makes the disposal process extremely expensive.

**4. Reclamation of areas contaminated with pesticides**

There are many areas and lands contaminated with pesticides. Contaminated areas include those where permissible concentrations exceed the standards [8]. Such lands are usually:

- territories of destroyed warehouses and storages of pesticides and adjacent territories within a radius of 50 m;
- agricultural soils, in excess of the MPC;
- territories of industrial enterprises where POPs are stored;

To this list can also be added a number of industrial facilities where some industrial waste is stored.

Among the methods of reclamation of pesticide contaminants are:

- Excavation followed by immobilization or bioremediation;
- Water pumping and treatment of contaminated solutions;
- Soil steam extraction;
- Injection (supply of sprayed air or oxygen) to accelerate the biodegradation of PP;
- Heating of the contaminated area by electric current or radio frequency field (thermal methods);
- Electrokinetic methods (electroosmosis, electrophoresis, electrolysis);
- Bioremediation;
- Plowing;
- Composting and biocup;
- Phytomelioration.

Given the peculiarities of pesticides [9] and their properties for spontaneous decomposition into simpler compounds, some areas of warehouses over time have already cleared themselves of excessive concentrations of pesticides. However, in warehouses where pesticides with a long half-life were stored, there are still exceedances of the MPC. It is obvious that for an accurate answer to this question it is necessary to provide a qualitative analysis of soils in the territory and near the warehouses of pesticides.

Soils with a significant excess of the MPC (over 10) should be disposed of in the same way as pesticides, as biological methods for such contamination will not be effective enough. In addition, biological reclamation is long-lasting, and the reduction to the standard values of the MPC can occur for many years, during which pesticides will adversely affect soils, groundwater and surface water and human health.

As the experience of previous years shows, high-quality reclamation of soil contamination with pesticides in the Ukrainian reality is possible only with the use of biological reclamation and remediation due to their low cost. Therefore, it is necessary to calculate the cost of work on effective biological reclamation of areas contaminated with pesticides within 1-9 MPC.

**Table 4 - Estimation of the cost of works for the area of warehouses 1 ha as of 2021**

cost item	Cost, UAH	
	On 1 hectare	Total
losses from the temporary seizure of land	0	0
costs of mining reclamation, UAH	-	70200
including costs for planning and logistics of works, UAH	13000	13000
including the cost of removing the top layer, transportation, UAH	26000	26000
including the cost of dismantling structures, their removal, UAH	31200	31200
costs of biological reclamation, UAH	39400	39400
The total cost of works for the warehouse area		179800

When calculating the total cost of reclamation works of warehouse plots for Ukraine with a total area of about 6,000 hectares, we will receive a maximum amount of UAH 657 million. For the state, this amount is insignificant and can be allocated to achieve environmental security of the country, and for some of the warehouses certain types of work no longer need to be performed. For example, dismantling of structures or removal of the top layer of soil, and it is necessary to carry out only biological reclamation.

### **5. Disposal of pesticide containers**

Container disposal in Ukraine is currently carried out by Eco Nova and others as intermediaries. Tariffs for this type of processing range from 6 UAH / kg to zero. And there are entrepreneurs who are ready to take free plastic containers from pesticides. Prepared means thoroughly (three times) washed and pressed [10]. Although for small agricultural enterprises with small volumes of pesticide use, the preparation of containers is not economically viable, as it requires the press and skilled workers. In addition to plastic packaging, there are other types of packaging that are impossible to recycle (or impractical), and the only technology treatment (disposal) is high temperature combustion.

The volumes of container formation according to experimental calculations range from 20-50 grams per kilogram (liter) of pesticide, both in retail and wholesale. But in a small container, the total weight of the package is greater.

**Table 5 - Calculation of the cost of recycling containers of different volumes.**

Volume, l	Libra, gr	Package weight per 1 l, g	The cost of disposal at a rate of 6 UAH / kg (average value)
0.25	24-27	96-108	0.612
0.33	21-24	63-72	0.405
0.5	24-28	48-56	0.312 th most common
1	33-36	33-36	0.207
1.5	36-42	24-28	0.156 th most common
2	42-45	21-22.5	0.132
5	91	18.2	0.109
10	157-540	15.7-54	0.024
20	768	38.4	0.023

The most popular in agricultural enterprises is a container of 10-20 liters, due to its convenience and at the same time large areas that can be processed with this volume. There are pesticides in plastic barrels of 200 liters, but as a rule, such barrels are not recycled and reused or for other purposes after steaming. The same applies to steel containers.

#### **Conclusions**

Thus, the cost of disposal of various facilities that contain unusable pesticide-containing drugs and waste was calculated and the most optimal methods and methods of pesticide disposal in Ukraine were established. However, the feasibility of using a particular method of waste disposal should be determined only taking into account the implementation of sanitary and hygienic standards and economic indicators.

#### **List of references**

1. Transportuvannya, zberihannya ta zastosuvannya pestytsydiv u narodnomu hospodarstvi. State sanitary rules. Hkaz MOZY №1 03.08.1998 p.
2. About zatverdzhennya rules dorozhnyoho perevezennya nebezpechnykh vantazhiv. Order of the Ministry of Internal Affairs of Ukraine 26.07.2004 p. №822
3. Law of Ukraine "On pesticides and achrochemicals", (86/95 VR). Closed postanovoyu Verkhovnoyi Rady Ukrayiny vid 02.03.95
4. Petruk RV Naukove obgruntuvannya optimalnykh form intehrovanooho upravlinnya ekolohichnoyu bezpekoyu neprydatnykh pestytsydiv ta pestytsydvmsnykh vidkhodiv: dys... doktora tekhn. Science: 21.06.01 / Petruk Roman Vasilyovych. - K., 2020. –345 p.
5. Arzu Özkara. Pesticides, Environmental Pollution, and Health / Arzu Özkara, Dilek Akyıl and Muhsin Konuk / Environmental Health Risk - Hazardous Factors to Living Species - 2016 [DOI: 10.5772 / 63094]
6. World Bank / WHO / UNEP. 1989. The safe disposal of hazardous wastes: the special needs and problems of developing countries, Vols. I - III. World Bank Technical Paper No. 93. R. Batstone, JE Smith Jr. and D. Wilson. Washington, DC.
7. Mosse AL, Savchenko GE, Savchin VV, Levashov AV Mobile Plasma Systems. Variants of Design, Application and Comparative Analysis. - Journal "Energy technologies and resource saving", Moscov.– 2012. - "4. - p 8-15.
8. US-EPA. 1994a. Innovative site remediation technology; thermal destruction; Volume 7 Pub. No. EPA 542-B-94-003. Washington, DC.
9. M. Gordon, N. Choe, J. Duffy, G. Ekuan, P. Heilman, I. Muiznieks, M. Ruszaj, BB Shurtleff, S. Strand, J. Wilmoth and LA Newman, "Phytoremediation of Trichloroethylene with Hybrid Poplars, "Environmental Health Perspectives Supplements, Vol. 106, no. 4, 1998, pp. 1001- 1004. doi: 10.1289 / ehp.98106s41001
10. Mariam T. Al Khattab, Abdel E. Ghaly. Disposal and Treatment Methods for Pesticide Containing Wastewaters: Critical Review and Comparative Analysis / Mariam T. Al Hattab, Abdel E. Ghaly / Journal of Environmental Protection Vol. 3 No. 5 (2012), Article ID: 19535, 23 pages DOI: 10.4236 / jep.2012.35054