# THE PROBLEM OF SEEKING ENVIRONMENTALLY SOUND DEVELOPMENT: THE CASE OF OBSOLETE PESTICIDES ASSESMENT MODELS

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**Abstract.** The purpose of this paper is two-fold: firstly, to indicate how the environmental safety issues grow rapidly in the convergence with economic aspects in modern world, and, secondly, to present analyses of implementation of economic-mathematical methods for assessment analysis to OPs management issues. For management (destruction and recycling) of OPs a comprehensive approach is required that includes also modeling, safety assessment and identification of the pesticides, which further will be the determining factor when choosing a method of destruction for the particular region. We offer an economic-mathematical approach to use ecological-economic models, taking into account particularly the density and type of contamination of OPs in synergy with pure economic factors.

**Keywords**: obsolete pesticides, environmental security, sustainable development, model.

## 1. Introduction

*"Appeal to the industrialists and politicians of the world: if you please. Stay the Planet alone, similar to that how it was when you got it."*
*(F. Beigbeder)*

The widespread use of pesticides in agricultural activity has led to the fact that all countries in some extent have problems with pesticide wastes. In highly industrialized countries (Europe, North America), the problem of pesticides wastes are mainly related to waste water, recycling, and (or) the elimination of



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packaging (containers, etc.) after the use of pesticides and the remediation of contaminated soils. For developing countries, the main problem is the elimination of unused (forbidden) and unusable pesticide stocks (Dasgupta et. al., 2009, World Bank, 2002, Louis, 2007).

Thus, environmental pollution by pesticides - one of the major agro-ecological problem – therefore there is degradation of soil, violated environmental and productive functions of soils, reduced productivity and deteriorating quality of plant and animal products. Particular danger goes from prohibited for the use obsolete pesticides (OPs) (Vijgen et. al., 2009). The gap, which has formed between the volume of the waste OPs accumulation after agricultural activities and the measures to prevent its formation, expansion of recycling, disposal and removal OPs, deepens the environmental crisis giving it a progressive nature and is an inhibitory factor for the economy of the region. Therefore urgent environmental problems of recycling and disposal of OPs becomes important for solving and appears to be global challenges. So, it is necessary to choose the right direction to solve this problem and to take into account all impact-factors, including environmental safety, project costs, and environmental, social, legal risks. As any region that has OPs on its territory faces the economic aspects of this problem – costs on re-packaging, storage stocks and remediation/utilization. Most such costs are clearly seen for majority population of the region, than even ecological damages which volume as well is calculated mostly in money indicators (costs). So the assessment tools that could cover all practical aspects of OPs management for a region is in demand from ecological point of view and under terms of sound economic development strategy of the region.

## 2. Ecological-economic Synergism: Ecology, Economy & Environment

Transition to the "environmental" type of economic development requires a review of priorities, fundamental restructuring of the global economy and the transition to a qualitatively new stage of international cooperation (Krabbe, 1996). If in the future the support of conditions for environmentally sound development does not become the primary concern of government, then the ongoing destruction of natural systems that provide the economy brings to naught all their efforts to improve the human life condition. One of the components of solutions to global environmental problems is the need to develop a set of measures for environmental safety and its consistent implementation at various levels - from local to global (Kharlamova, 2011, 2012).

Currently the prime position belongs neither the economy nor the ecology itself but their mix, synergetic combination of effects and impacts, so called

***ecological economics***. Ecological economics is referred to as both a transdisciplinary and interdisciplinary field of academic research that aims to address the interdependence and coevolution of human economies and natural ecosystems over time and space (Jeroen et. al., 2001). The global engine works in the interdependence of economic laws and ecological challenges, what results in the more broad term - Environment (Figure 1).

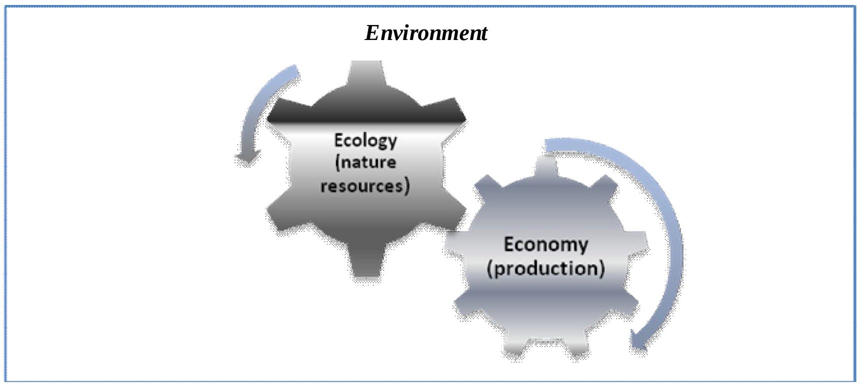


*Figure 1*. The synergism of Ecology and Economy results to Environment.

Healthy ecosystems are the foundation for sound economic development, sustaining and enhancing human life with services ranging from food and fuel to clean air and water. Ecologically sustainable development must maintain ecosystem resilience - the continued ability of ecosystems to provide future generations with easily access to various services (conveniences) in spite of natural and human-driven disturbances. Many current ecosystem management strategies are unsustainable, focusing on a single service/convenience - such as the production of food, fuel, or fiber – in the neglecting of others. Such strategies can reduce biodiversity and ecosystem resilience by eliminating native species, introducing new and harmful species, converting and simplifying habitat, and polluting the surrounding environment.

The agriculture has the tensest connection to the Nature in comparison with other economic fields. From the one side, it uses natural resources (lands, water, etc.), from the other hand – it gives food so the resources for reproduction of human population. But currently, there is a tendency that more yields to agricultures reflects in more ecological damages.

## 3. Obsolete Pesticides and their Specific Features in Aspect of its Management and Estimation

Pesticides are the classic example of the two-fold nature of the Environment as we termed it: here we can clearly see the dichotomy of the ecological-economic process. A man resorts to the help of pesticides in order to save the crop grown. However, pesticides affect the ecology in damaging direction. On the cost side of pesticide use there can be a cost to the environment and human health, as well as the cost of the development and research of new pesticides (Figure 2).

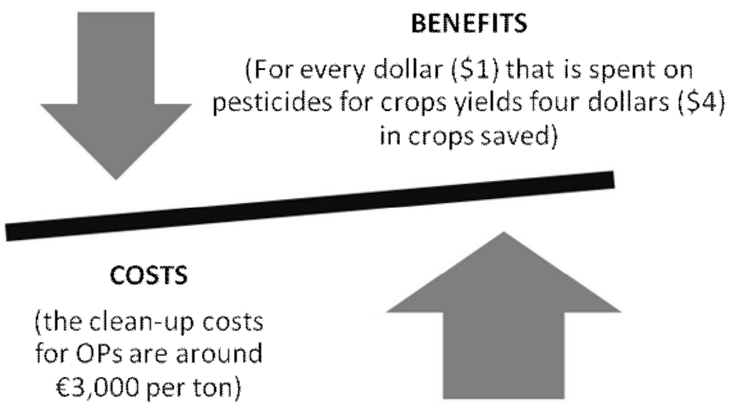


*Figure 2*. Dichotomy effect of OPs: cost weights. Data source: (Pimentel, 2005, Pimentel et. al., 1992)

But the usage of pesticides brings not as much damage to the ecology, than the obsolete pesticides and persistent OPs (POPs). That's why the accumulation of OPs became a XXI century challenge. According to the United Nations' Food and Agriculture (FAO), in developing countries now have accumulated about 100,000 tons of obsolete pesticides (a large group of banned pesticides (so-called "dirty dozen") and a group of POPs). Some pesticides have accumulated for 50 years. The main factors that have led to the accumulation of unusable stocks of pesticides in developing countries are the following:

- Inadequate storage and inventory management;
- Improper handling during transportation;
- Creation over-storage of pesticides;

- Reservation of resources in the event of the need to destroy large quantities of insects;
- Prohibiting the use of certain pesticides;
- The purchase of inappropriate formulations of pesticides;
- Poor quality of purchased pesticides and lack of quality control;
- Excessive donor funding and poor coordination among the sponsoring agencies;
- Change of national policy.

But despite the OPs damages there is other source of dramatic side affect – storages of OPs. Thus each stage of the technology of pesticides leads to waste.

Such complex problematic of OPs remediation and utilization reflects in not simple techniques of its management and assessment. The investigation of environmental contamination by OPs consists of three main parts (Česnaitis, 2007):

- Determination of the emission sources,
- Sampling/measurement,
- Modelling.

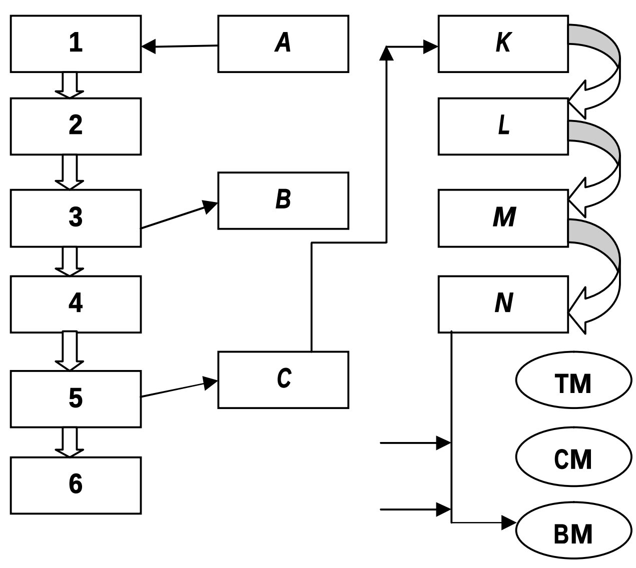


*Figure 3*. The possible strategic plan for the management choice to OPs utilization, where:

1 – modelling of soil (water, etc.) contamination and assessment of environmental safety,

2 – identification of the OPs,
3 – usage/processing,
4 – processing/destruction,
5 – options filtration, taking decision process,
6 – failed options,
A – identification of OPs (POPs) storages,
B – preservation,
C – possible option for taking decision management,
K – human safety and ecology security (risk management),
L – factors of risk management (political, social, economic, legal),
M – costs (project costs),
N – elimination method, which is preferred,
TM – thermal method,
CM – chemical method,
BM – biological method.

The possible strategic plan for the management choice to OPs utilization could be as it is shown on Figure 3.

The modeling of OPs management aims mainly, as any modeling process, to create the model with maximum adequacy to the original process (object). So such model should be homorphic reflection of the object to the reality, which is modeled. According to the main principals of modeling, the OP's management as process is considered as a "black-box", so the classic procedure should be applied:

- identification of controlled variables;
- choosing choice criterion function for variables' problem;
- choosing restrictions via variables' problem.

The specific approach to the OPs assessment and management goes from the complexity, multi-criteria aspect of the problem as well as the necessity to use not only objective calculated variables but also the subjective ones, like the expert estimation, binary data, dummy variables, stochastic variables.
So taking in the account the specific features of OPs for the management and assessment aims, the ecological-economic estimation methods for the case of OPs belongs to:

- applied methods (mission criteria),
- stochastic methods (criteria of cause-and-effect net reflection),
- dynamic methods (criteria of time reflection),
- non-linear (criteria of mathematic forms of interactions),
- aggregated (macro-ecological-economic models) (criteria of resolution).

So the techniques for OPs analyses should be applied in the correspondence with said above. Models are thus useful for testing the hypotheses on the complex system under consideration. By means of a sensitivity analysis, models show the most influential factors that should be thoroughly investigated.

Finally, such models guide our understanding of complex systems that are not fully accessible in the real scale (Oresnes et. al., 1994).

## 4. Models and Economic-ecological Methods of Estimation: Application for the Case of Obsolete Pesticides

The most popular methods in the application to OPs analysis are box models and risk assessment. In addition to the box models, atmospheric transport models with much higher spatial and temporal resolution are also being used for investigating the environmental fate of POPs (Wania et. al., 1999). Multimedia models describing the global transport and fate of POPs basically serve two purposes (Sheringer et. al., 2002, Česnaitis, 2007):

- understanding of the environmental processes leading to global contamination through POPs and development of the indicators that would allow a clear definition of the constituents of a POP (this can be achieved with idealized release scenarios such as a single point source);
- assessment of the actual risk to the environment and human health, requiring the determination of environmental concentrations, based on reliable emission estimates with a view to toxicity thresholds.

*Risk management*. Analysis and evaluation of risks in technological safety is the foundation of safety management system of technical and technological systems of different types and levels (Jensen, 1992). The following major tasks are under consideration:

- study goals and objectives of the risk analysis,
- analysis of technological features of production facility and identification of all sources of possible hazards,
- identifying events that could initiate an accident occurring,
- the formation of plausible scenarios of accidents,
- scenario analysis,
- evaluation of the probability of failure for each event that triggers an accident;
- determination of damage factors,
- modeling and predicting the extent of consequences of accidents for human population, environmental scenarios of accidents;
- evaluation of probabilities of external factors that do not depend on the operating conditions of potentially hazardous objects;
- evaluation and risk analysis regarding its admissibility;
- construction of the potential risk field around each of the selected hazards,

- identifying the adequacy of preventive measures to ensure the stability of objects to internal and external impacts.

This list of major tasks look rather general but this approach allows using quantitative safety numbers similar in mathematical terms to the indicators of reliability theory, methods which are sufficiently developed and widely used in practice for the OPs management.

Special approach of the case of OPs reflects that risk assessment should be applied not on the level of OPs identification and following utilization but not less on the level of storage and re-packing, so called *risk assessment of obsolete pesticide storage sites.* Basically all the former pesticides storage sites present a potential contamination risk, but the volume and extent vary a lot. On the basis of the data on the pesticide storage sites the methodology for the risk assessment of the obsolete ones helps develop a priority list of the sites which are potentially most hazardous to the environment and need to be properly managed. According to the methodology each pesticides storage site is assessed by (Česnaitis, 2007):

- technical condition;
- pollution potential;
- factor of groundwater vulnerability;
- land use and environmental value;
- potentiality of pollutant to access the water reservoirs;
- data on the soil and/or groundwater contamination.

The aim of the Environmental risk assessment tool in its application for the case of OPs is to gather sufficient information to provide decision-makers, experts, project managers and planners with the data necessary for:

- ranking the stores and characterizing the situation in each according to simple environmental and public health risk criteria;
- pinpointing the magnitude of the risk and prioritizing practical actions and measures for reducing it;
- devising an implementation plan based on priority actions for the disposal of OPs;
- pre-selecting intermediate and regional collection centres for OPs, for which a separate assessment may be required under national risk assessment procedures;
- final selection of centres is based on additional logistics, economic, public, social or political factors.

Besides, existing computer models of fate of OPs are helpful tools because they make it possible to combine theoretical description of different processes into a consistent mathematical framework that is open to expansion and adoption if new processes are to be included. Models are also the tools supporting the decisions taken while implementing Stockholm Convention requirements. The tools based on a systematic and integrated approach to the POPs management difficulties in the region are deficient (Česnaitis, 2007).

## 5. Model

There exist many different models for the assessment of fate of OPs in the environment; however, the model which could help systematically assess the OPs management situation in a country and develop integrated measures for the OPs risk reduction is deficient.

The aim of the paper is to offer reasonable, from a theoretical and methodological point of view, method of the OPs assessment based on the ranking assessments of its components (toxicity, life-time, storage conditions). Logic of method's developing defines the following stages:

I. Draft components of the OPs assessment.
II. Identify the conceptual range and clarify categories.
III. Match a system of indicators and methods for OPs assessment.
IV. Conduct a comprehensive and systematic monitoring of the OPs with further developing of strategies to strengthen state's ecological policy in its synergism with economic sustainable development.

As to 1$^{st}$ stage: analysis of the structure and function of the various classifications shows that the number of indicators (components) included in the classification is calculated from a few to dozens of tests, which reflects the state of science in this period of time. This was especially evident in the last decade due to severe growth trend of indicators of process of interaction between pesticides (OPs particularly) and the human body.

In the structure of the classifications are essential:

- Informative test;
- Approach to ranking the indicators;
- The assessment of hazard class.

Criteria for selection of statistical indicators for further calculation the assessment rating of OPs of regions (states) are following:

1. indicator must be relevant, adequate to the realities;
2. indicator should have a clear quantitative expression, be compact, dynamic, and relatively predictable;

3. indicator should be available for rating-making person. This requirement is, firstly, because of the need to save time and financial costs for monitoring, and secondly, guarantee reliability and adequacy of the results;
4. ability to get "fresh" data for monitoring areas (monthly, quarterly, semi-annually, annually).

The stock of factors can differ according to the aims of the analysis and further decision making but the core factors-indicators could be as shown in Table 1.

TABLE 1. Possible environmental, economic and social factors for the model

| Environmental factors | | | | | | | Economic factors | | Social factors | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diseases | Impact on living organisms | Soil pollution | Air pollution | Water pollution | Waste reduction | Use of natural resources | Investment demand | Risk costs | Innovations | Storage indicators | Image improvement (informative component) |

So the challenge is to model and to optimize (minimize) the function of possible costs from ecothreats and ecoviolence (case of OPs). If to put the latter in math symbols, we can propose some form of function:

$$F(E)=(\text{ecological impact, economic costs}) \rightarrow \min.$$

There should be four main steps within the complex model on 3 levels:

1) state level:

- assessment of the OPs management situation in a country (including assessment of OPs distribution in the environment, wastes, products and POPs pollution sources) (Česnaitis, 2007);
- identification and prioritization of OPs management problems in a country (Česnaitis, 2007);

2) region level:

- development of integrated measures for the solution of prioritized problems and OPs risk reduction (Česnaitis, 2007);
- the first step of the model should be an assessment of OPs current situation in a region. The principal aim of the model application being the reduction of the OPs risk in a region, the result of its application is a developed actions plan;

3) storage level:

- evaluation of the effectiveness of chosen measures in regard with the identified indicators (environmental/economic) (Česnaitis, 2007).

So **the Algorithm for estimation of safety (reliability) of OPs contamination** could be proposed:

1) Analytically calculate the probability of different types of system states:

$H_0$ - serviceability of all sub-systems;

$H_1$ - refusal of exactly one subsystem,

$H_k$ - refusal of exactly k subsystems.

2) The probability of $H_k$ event calculated using the binomial distribution:

$$P_k = C_n^k q^k p^{n-k},$$

where p - the probability of subsystem operability (q = 1 - p).

3) Using the method of statistical tests we can estimate conditional probabilities $\Phi_к$ - that indicate the operation state of the system. Calculate the total probability of operability of the system:

$$h = h_0 + \sum_{k-1}^{n} \Phi_k P_k.$$

4) If the system is constructed so that the refusal j any element does not lead to system failure in general then the full probability of system operability is given by the formula:

$$h - \sum_{k-0}^{j} P_k + \sum_{k=j+1}^{n} \Phi_k P_k$$

The bigger j, the higher efficiency of analytical and statistical evaluation method’s implementation.

5) In quantitative terms the risk is determined by the conditional probability of causing harm to humans (ecosystem) from OPs (W(I)) and by the probability of occurrence of adverse events (P(I)) and is calculated by the formula:

$$R = \sum_{i=1}^{m} [W_i(I_i)] P_i(I_i),$$

where m – the amount of hazards (I) of the same level.

6) In the current risk assessment methodology risk assessment for human health and life under OPs exposed better to use logarithmic-normal distribution of the form:

$$R(Prob_i) = \frac{1}{\sqrt{2\pi}} \int_{\infty}^{Prob_i} [\exp\left(-\frac{t^2}{2}\right)] \, dt$$

7) The upper limit of integration is the so-called probit function ($Prob_i$), which reflects the relationship between the probability of lesions and absorbed (influential) dose (concentration). For its calculation we use the logarithmic dependence:

$$Prob_i = \alpha_i + \beta_i lgC_i,$$

where α and β - parameters that depend on the toxicological properties of the substances (OPs) and types of effects, C – the concentration of harmful substances (OPs).

8) So we can calculate for the any state (region) the probit-panel-econometric model:

$$I = f(Prob*Dens, Gov, PP),$$

where I – costs of the utilization, Dens – density of OPs relocation in the state, Gov – costs on governmental project implementation, PP – the price (net cost) of the OPs utilization itself.

For complex modelling process that is proposed here, all statistical indicators of OPs (regions, countries) should be systematized due to 3 components of assessment: human safety and ecology security (risk management) - toxicity, factors of risk management (political, social, economic, legal), economic costs (on detection, elimination and taking decision procedure itself), which in its turn include such relevant factors (mostly binary variables (FAO, 2009)):

- Storage conditions: management procedures,
- Storage conditions: safety,
- Environmental conditions: hazards affecting the store,
- Environmental conditions: human settlements,
- Environmental conditions: water sources and soil,
- Environmental conditions: agriculture, livestock activities, wildlife and biodiversity,
- Store conditions,
- Storage conditions: content of the store,
- Store conditions: security.

As well, in order to make an optimal (benefit-cost) decision on how best to eliminate stockpiles of OPs there is a requirement of data of the qualitative and quantitative composition of the waste.

We offer such procedure for calculating an integral estimation of OPs based on formalizing of operations of comparison, carried out in 9 stages (Table 2) (Kharlamova, 2007, 2010).

TABLE. 2. Procedure of calculating an integral assessment of OPs

| # of a stage | Description |
|---|---|
| Stage 1 | Selection of statistics: $\{x_{ni}\}$ |
| Stage 2 | Standardization of indicators: $x^*_{ni} = \frac{x_{ni}}{x_n}$ |
| Stage 3. | Correlation analysis ($\rho$) as a criterion for selection of indicators: $\rho \geq \pm 0,5$, with exclusion of multicollinearity |
| Stage 4. | Establishment of the database $\{x^*_{ni} \mid \rho_{x^*ni} \geq \pm 0,5\}$ - adjusted and standardized data set |
| Stage 5. | Clustering of objects by each indicator using k-means cluster analysis. Considering singularity of the region, each factor evaluating the option is given the value from 1 to 5. The more the option is friendly to the environment of the region, the more it is acceptable economically and socially, the more points it will be given. |
| Stage 6. | Application of the author's ranking technique for objects on the level of factors |
| Stage 7. | Apply authorial ranking system for giving an integral assessment to each object at the level of three integral components of storage, region, state (human safety and ecology security (risk management) - toxicity, factors of risk management (political, social, economic, legal), economic costs (on detection, elimination and taking decision procedure itself)), putting a certain place in the ranking to each object |
| Stage 8. | Calculation of the effectiveness of OPs management realization for the object ($E$) as the ratio of its costs to its potential hazard. |
| Stage 9. | Presentation of the results, application of a taking decisions approach to develop ecological strategy for further positioning and elimination of rated objects |

Our approach can be considered as adequate to the stated objectives of the study. Not engaging of subjective "expert weights" are the clear advantage in favor of the use of author's ranking system for integral assessment of OPs, because of undoubted objectivity of the results.

From other hand, it’s always possible to include the expert estimation to the objective result of monitoring: to define a subjective assessment (weighting) factors (T-$\lambda_1$) and (C - $\lambda_1$) for a criterion of the test system, which has the form:

$$E = \lambda_1 T + \lambda_2 C,$$

where T - time (duration of the test), and C - the cost of testing; $\lambda_1$, $\lambda_2$ – weights determining influence of T and C on the effectiveness of the tests. We can expect that $\lambda_1$ and $\lambda_2$ will vary according to the setting in which are used the issue and the degree of its influence on the identity of the expert. Thus, the authorial method, despite its simplicity, makes it possible to receive in-line rating product.

## 6. Conclusions

The basis of an extensive factual material proves that all, without exception, global economic problems of today have a definite ecological context. Environmental security cannot be ensured only by means of environmental actions in isolation from social, economic, political and demographic problems. They are all so interconnected and interdependent, that the solution for each of them can be found only in their joint consideration. In future challenging and essential should be issues of not recycling of OPs but preventive methods, such as actions against excessive use of pesticides, promotion of sustainable agriculture and environmentally safe integrated plant protection (IPM).

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