Original Research

Spatial Conditions of Environmental Risk Posed by Obsolete Pesticides – Case Study of the "Green Lungs of Poland" Area

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Abstract

Issues related to storage and elimination of obsolete pesticides concern all developing countries. Eastern Europe is a region with the largest stocks in the world. In Poland, the problem with obsolete pesticides has its roots in history. Storage sites and containers in which obsolete pesticides were deposited posed, or continue to pose, a threat to the environment. The spatial conditions, particularly land features and features of the object, can actually increase environment risk. The proposed algorithm makes it possible to distinguish areas where poisonous substances posing the greatest threat to the environment are stored. This knowledge will help to determine the priorities for waste removal and monitoring of environmental receptors.

Keywords: environmental risk, spatial conditions, Green Lungs of Poland

Introduction

The contamination of soil, groundwater, and other environmental receptors by contaminants from historic and existing land use is a complex environmental problem in all developed countries [1, 2]. Contaminated land is most often the heritage of previous negligent industrial practices and improper waste management [2, 3]. Area pollution can pose a threat to people, fauna, and flora, as well as water and property [4-6].

Pesticides, used for a few dozen years to remove and destroy waste, fight parasites and to reduce crop losses in storage, have brought about numerous undesirable results for the environment [7-11] and people's health [12, 13]. Although many of those compounds have been withdrawn from production and used in many countries due to their harmful effects on animal organisms and very low susceptibility to degradation in the environment, they are still manufactured and applied in developing countries. A particular problem has emerged with pesticides that are not suitable for further use and have been deposited in various places – not always intended for this purpose. The method of their storage can pose a threat to the environment, as toxic products erode tanks [14], and they are often placed in shallow pits either covered or uncovered [15].

FAO estimates show 27,395 tons in Africa (9%), 6,463 tons (2%) in Asia, 240,998 tons (83%) in Eastern Europe, 11,284 tons (3.9%) in Latin America and the Caribbean, and 4,528 tons (1.6%) in the Middle East [16]. Definitely the largest stocks are located in Eastern Europe. The estimated cost of their elimination ranges from $722.9 to $1204.9 million USD. Since the amount of stocks gathered in Eastern Europe is huge in relation to the rest of the world, it is important to start to resolve this problem as soon as possible (Fig. 1 presents the estimated quantity of obsolete pesticides in relation to the area of a given Eastern European country).

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In Poland, obsolete pesticides were stored in the so-called pesticide burial areas (in Polish "mogilniki"), referred to as "waste tombs" by Holoubek [17] or as "pesticide tombs" by Manceki and Gałuszka [18]. These are specific places, with various structures made in the form of concrete rings, earthen pits without protection, or in military facilities. Pesticide burial areas were created in Poland in the 1960s and 1970s and, as a result of administrative and ownership changes occurring after that time, they are now situated in areas owned by the treasury, local governments (mainly communes), and private owners. The obstacle connected with removing the substances is their location on private lands or lands of an unregulated legal state, i.e. in Tunisia it is often difficult to ascertain the ownership of old stockpiles as a result of changes in ownership and the status of organizations, or the disappearance of owners. For example, state enterprises that have since been privatized, or organizations that no longer exist, do not retain responsibility for previously accumulated stockpiles of obsolete pesticides [14].

Estimates published by the FAO indicate that there are about 9,000 tons of obsolete pesticides in Poland (Fig. 1). According to reports published by the Ministry of Environmental Protection, almost 100% more obsolete pesticides in comparison to FAO estimates (about 17,400 tons) have been removed or are planned to be removed in Poland (Fig. 2 – the estimated weight of obsolete pesticides originating from documented pesticide burial areas in a specific voivodship of Poland). Often during the removal, new, previously undiscovered, pesticide burial areas are found [19].

The reason for gathering excessive amounts of pesticides in some voivodship of Poland was the ownership system of agricultural land and the character of farming applied. In the 1960s and 1970s state-owned farms were common in this area, for which crop protection chemicals

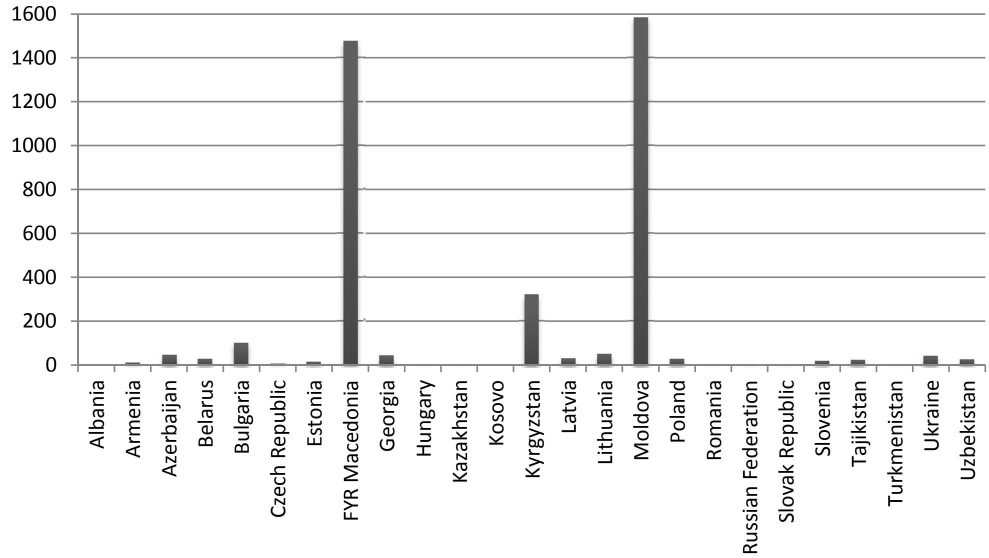

Fig. 1. Quantities of obsolete pesticides (in kg/km^2). Source: own study using [37, 38].

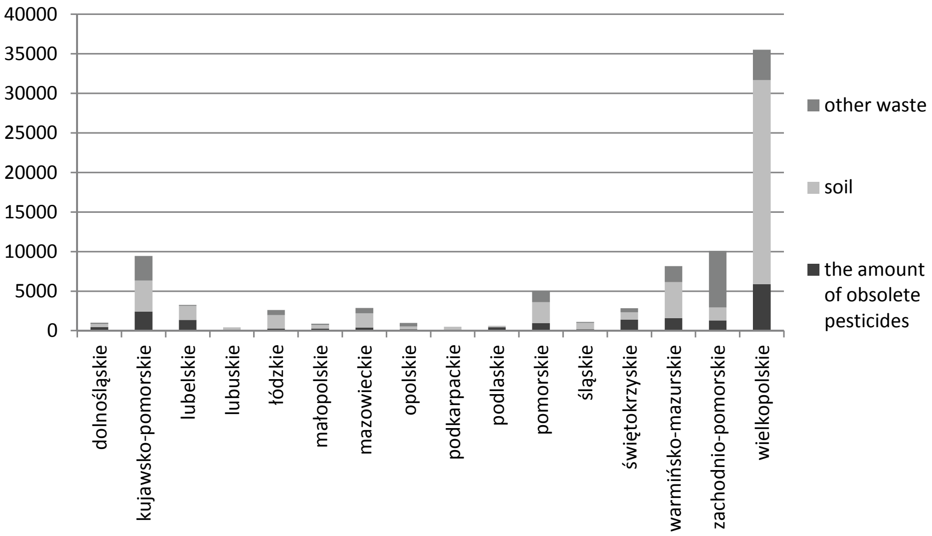

Fig. 2. The quantity of documented obsolete pesticides contaminated surrounding areas and other waste in the voivodship of Poland. Source: own study on the basis of the Pesticide Burial Area Data Integration System [27].

were available at very low prices and no rational management of them was carried out.

A significant problem facing the agricultural environment in Poland is that pesticide burial areas were mostly located at random, without any prior analysis of topographic morphological, geological or hydrogeological conditions. They were situated in exhausted pits (sandpits, gravel pits), on slopes of morphological hills, in the vicinity of rivers, lakes, underground water intakes (drilled wells used for collective supply of drinking water, or municipal water intakes) and in formations characterized by a lack of resistance to vertical penetration of contaminants. Chemicals stored in that way, for many years, caused corrosion of concrete tanks due to the low quality of the concrete used for their construction, and their sealing was prone to dissolving. As a result of damage to the tank, their toxic content was systematically leached into the ground, migrating with precipitation to water-bearing levels and to surface waters (rivers and lakes). Therefore, despite removal of the toxic content itself, contamination of soil, water, flora, and fauna can be extensive.

According to the National Program of Implementing the Stockholm Convention in Poland [19, 20], contamination occurs mainly in the surface area of soil, thus sporadically in deeper layers as a result of the movement of persistent organic pollutants by water. The research in terms of groundwater pollution, including local water intakes covered 14.3% of "pesticide burial areas," and in terms of soil pollution, 10.6%. This is too low an amount to assess the volume of earth mass pollution [21].

According to Wołkowicz [22], in some types of objects contamination can reach the depths of a few to about a dozen meters, their concentration is varied and depends on the lithological formation of subsoil rocks. Such objects are known in which the zone of polluted ground is 100-200 m wide, the length is more than 1 kilometer and the thickness of the polluted layer is 4-6 m, while it occurs at a depth of about a dozen meters. In such cases, it is difficult to even calculate the costs of total reclamation (since they are unimaginable) or consider from a technical point of view (since full reclamation is practically impossible).

Waleczek et al. [23] claims that even after removal of toxic content from pesticide burial areas, trace amounts of pollution in leachate are observed for many years, which shows that the process of natural soil purification is slow, and after a few years, acceptable concentration levels of active substances characterized by relatively low solubility in water are still considerably exceeded.

Description of Research Area

Poland is situated in central-eastern Europe. The examined area is covered by several programs for the eco-development of the Green Lungs of Poland. It currently occupies 63,235 km^2, which accounts for 20.0% of the national area. It is inhabited by almost 4 million people, which accounts for 9.7% of Poland's population. It is situated in the northeastern part of Poland, covering the voivodships of Warmia and Mazury and Podlaskie and parts of Mazowieckie, Kujawsko-Pomorskie, and Pomorskie. The reason to select this area was based on one of the most precious ecological systems in both Poland and Europe [24]. In these days of widespread globalization and progressive unification, areas characterized by unique features of natural and cultural environment are increasing in importance. Uniqueness has become a value in itself, which should be protected, but also skillfully used as part of regional marketing. The features characterizing the area under examination present a particular, complex, and highly attractive area. This attractiveness is created, among others, by its low population density adjusted to natural conditions, well-balanced settlement network, clean air, good quality of its natural environment, and unique diversity of a natural system and attractive complexes of forests, lakes and grasslands.

Thirty-four catalogued sites where obsolete pesticides had been deposited or are still stored are situated within the area under examination.

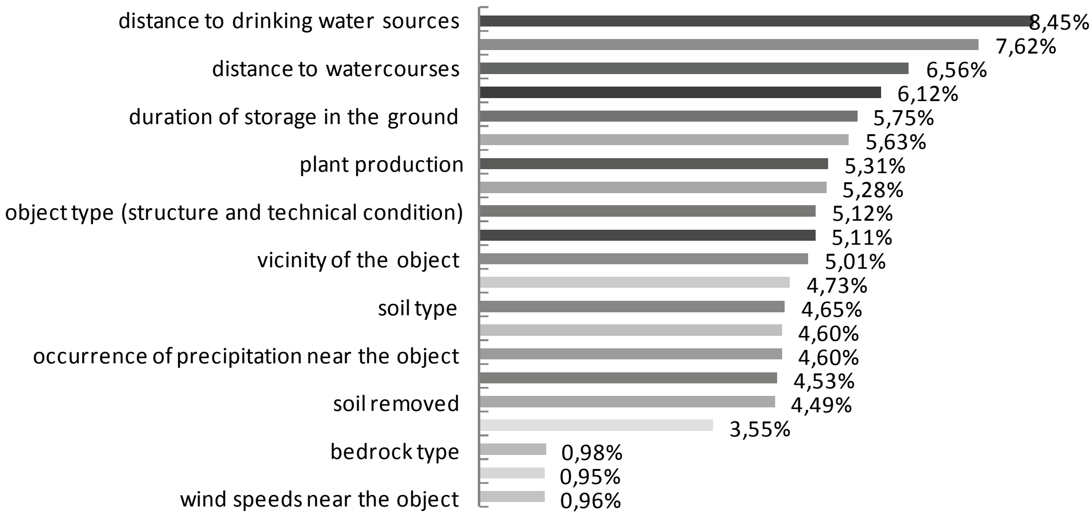

Fig. 3. Survey result. Source: own study.

Table 1. The results of a survey concerning the rank of the analyzed attributes affecting environmental risk.

	Examined attributes	Score	% points obtained	Point group	Feature rank	Feature weight
1.	Distance to drinking water sources	58,582	8.45	1	1	0.84
2.	Type and composition of gathered waste	52,811	7.62	2	2	0.76
3.	Distance to watercourses	45,443	6.56	3	3	0.66
4.	Presence of people near the object	42,398	6.12	3	4	0.61
5.	Time of storage in the ground	39,820	5.75	4	5	0.58
6.	Amount of pesticides and other waste removed	39,042	5.63	4	6	0.56
7.	Plant production in the object or in its vicinity	36,765	5.31	4	7	0.53
8.	Animal production in the object or in its vicinity	36,558	5.28	4	8	0.53
9.	Object type – structure and technical condition	35,498	5.12	4	9	0.51
10.	Distance to residential buildings	35,441	5.11	4	10	0.51
11.	Object surroundings (e.g. forest, agricultural land, other)	34,685	5.01	4	11	0.50
12.	Type of plants overgrowing the object	32,786	4.73	5	12	0.47
13.	Soil type	32,234	4.65	5	13	0.46
14.	Land slope	31,876	4.60	5	14	0.46
15.	Precipitation in the vicinity of the object	31,910	4.60	5	16	0.46
16.	Topographic profile	31,395	4.53	5	15	0.45
17.	Amount of removed land with rubble and other waste	31,145	4.49	5	17	0.45
18.	Existence of environmental monitoring	24,574	3.55	6	18	0.36
19.	Bedrock type	6,785	0.98	7	19	0.00
20.	Mean annual air temperature in the vicinity of the object	6,612	0.95	7	20	0.00
21.	Prevailing wind speeds in the vicinity of the object	6,640	0.96	7	21	0.00
	Total	693,000	100.00			

Source: own study.

Purpose and Methods

The main aim of our research was to describe factors affecting environmental risk related to the spatial location of obsolete pesticides and draw up an algorithm that would facilitate the identification of places of the highest risk. The research applied the following methods: analysis and synthesis of the literature, survey research (PAPI), quantitative analysis, ranking method, and point valuation method.

The scope of attributes assumed for the analysis of environmental risk was established on the basis of the analysis of literature and a survey carried out on 345 respondents. The respondents were a group of specialists dealing with the subject matter related to geographical space. The survey was conducted in 2012. The task of the respondents was to indicate features conducive to the risk to the environment resulting from the existence of a pesticide burial area in the neighborhood and to provide the rank (weight) of each feature under analysis. To assess the spatial features contributing to the environmental risk for the given object, the point valuation method was applied. The essence of this method is to bring numerous features to one common denominator using valuation points. However, different qualities of features are not summarized by using absolute values, but only their normalized values. The valuation method assumes the use of information provided in the content of commonly accessible maps from geographical information systems, of a wide range of applications [25, 26]. The study used cadastral, topographic, geophysical, climatic, geological, and soil classification maps, data from the Pesticide Burial Area Data Integration System [27] available at the website of the Ministry of Environmental Protection and data obtained from field stocktaking. These materials made it possible to gather the research material for further analyses. The calculations and the presentation of the questionnaire results were made using Microsoft Office Excell 2000, whereas the map visualization of the location was used in the licensed ArcGIS 10.1 program.

Results

A survey conducted for the study aimed at two goals. The first was to indicate features which, in the opinion of respondents, affected environmental risk. The second task consisted of assigning a rank (weight) of the feature that contributes to the risk to the environment due to the existence of the pesticide burial area. The third stage of the research involved creating an algorithm that would facilitate risk estimation.

In the first part of the survey, the respondents indicated additional features favoring risk to the environment: the type of the object (its structure and technical condition), the amount of pesticides and other waste removed, the presence of environmental monitoring for the surrounding area, and the type of neighborhood of the pesticide burial area.

To summarize this part of the research, the features contributing to the risk for the environment can be divided into two groups. The first group includes features of the examined object and the second includes conditions related to the space in which this object is situated. The features of the examined object include: duration of obsolete pesticide storage in the ground, type of object (its structure and technical condition), the amount of obsolete pesticides removed, the amount of removed rubble, soil and other waste, monitoring the location of the pesticide burial area, and type and composition of waste and the human population in the vicinity of the examined object. The spatial features included: distance to drinking water sources, watercourses, residential buildings, topographic profile, land gradient, animal and plant production near the object, neighborhood of the surrounding pesticide burial area, soil type, bedrock type, and climate at the site where the pesticide burial area is situated (precipitation, temperature, and winds) [10, 28, 29].

In the second part of the survey the respondents were to indicate a rank for each of the features, comparing features in pairs and giving points to them, between 0 and 10. Table 1 presents the results of the first and the second parts of the survey. Respondents, having at their disposal 21 attributes concerning the space and the object itself (the first part of the survey), indicated their rank (in the second part of the survey). The compiled results of respondents' indications were sorted in order of their importance.

The maximum score (8.45% of total points) was given to the feature concerning the distance to drinking water sources. This is the dominating feature and was the most important for all respondents. It was classified into the first point group, with a rank of 1. Another important feature for respondents was the type and composition of the waste gathered (7.62%, rank of 2), distance to watercourses (6.56%), frequency of visits of people in the vicinity of obsolete pesticide stockpiles (6.12%), the duration of storage in the ground (5.75%), amount of removed pesticides and other waste (5.63%), plant production in the object or in its vicinity (5.31%), animal production (5.28%), object type, its structure and technical condition (5.12%), distance to residential buildings (5.11%), vicinity of the object (5.01%), type of plants overgrowing the object (4.73%), soil type (4.65%), land slope (4.60%), occurrence of precipitation near the object (4.60%), topographic profile (4.53%), and the amount of soil removed together with rubble and other waste (4.49%), environmental monitoring in the vicinity of the object (3.55%), bedrock type (0.98%), mean annual air temperature in the vicinity of the object (0.95%), and prevailing wind speeds near the object (0.96%).

The group of three last features was rejected due to their low significance for respondents (Fig. 3). The remaining 18 features were taken into consideration in further stages of the study (Table 1).

The next step was to construct the risk matrix. The basis for the construction of such a matrix was the assumption that a given feature of the land and the object itself contribute to the general magnitude of environmental risk. The result of stock taking of features of the land and the examined objects was the stocktaking matrix whose rows describe the examined object (marked with $A_1, A_2, \ldots, A_n$), and the columns describe the intensity of the examined feature (marked with $Z_1, Z_2, \ldots, Z_n$). Therefore, such a matrix contains information about which features occur in which primary fields (objects). The magnitude of risk in a given primary field is thus the total of "input" values with reference to the features that occur in this field, taking into account the weight describing the rank of the attribute. Intensification of the occurrence in the object of spatial features and the examined attributes make it possible to classify the environmental risk posed by the existence in a given location of objects where obsolete pesticides had been stored in the past or are still deposited. The impact zone was assumed as from the central point (the center of gravity of the object). The last step was the creation of an automated reasoning algorithm (Fig. 4).

Discussion of Results

While assessing each object under examination, the significant features listed in the initial survey by respondents were taken into account. This made it possible to create a matrix reflecting the occurrence of a given feature in all research fields. The magnitude of risk is therefore a sum of the output values in the matrix with regard to the features that occur in a given object. Table 2, the risk matrix, presents the results of environmental evaluation in view of the existence in the location of a pesticide burial area or sites after the storage of persistent organic pollutants in the area of "the Green Lungs of Poland."

Thirty-four objects situated in the region known as "the Green Lungs of Poland" were examined. The majority of them (17 objects) are situated in the voivodship of Warmia and Mazury, 8 in the voivodship of Podlaskie, 2 in the voivodship of Mazowieckie, and 7 in the voivodship of Kujawsko-Pomorskie. Although Pomorskie also belongs to this region, no object from this voivodship was found within the boundaries of the region under analysis.

The category of environmental risk was estimated taking into account the boundaries of ranges: the highest risk

Table 2. Risk matrix.

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	Z14	Z15	Z16	Z17	Z18	P(A)
A25	3.36	0.76	2.64	2.44	1.74	3.36	2.12	1.06	1.53	2.04	2.00	0.47	1.38	0.46	1.38	0.45	2.70	1.44	0.83
A23	3.36	0.76	0.66	1.83	1.74	3.36	1.59	1.06	1.02	2.04	1.50	0.47	0.92	0.46	1.38	0.45	2.70	1.44	0.71
A29	0.84	0.76	1.98	2.44	2.32	0.56	1.59	1.59	1.53	2.04	2.00	1.41	1.38	0.46	1.38	0.45	2.25	1.08	0.69
A14	1.68	0.76	2.64	1.83	2.32	0.56	2.12	0.53	2.04	1.53	1.50	0.47	1.38	0.46	1.38	1.35	2.25	1.08	0.68
A24	1.68	0.76	0.66	1.83	1.74	3.36	2.12	0.53	2.04	1.02	1.50	0.47	0.92	0.46	1.38	0.45	2.70	1.44	0.66
A22	0.84	0.76	2.64	1.83	1.74	0.56	2.12	1.06	2.04	2.04	1.50	0.47	0.92	0.92	1.38	0.45	2.25	1.44	0.66
A30	0.84	0.76	2.64	1.83	2.32	3.36	1.06	0.53	1.53	0.51	1.00	0.47	1.38	0.46	1.38	0.45	2.70	1.08	0.64
A34	0.84	0.76	0.66	1.83	2.32	3.36	2.12	0.53	1.02	0.51	1.50	0.94	0.92	0.92	1.38	0.90	2.70	0.72	0.63
A17	0.84	0.76	1.98	1.83	2.32	0.56	2.12	0.53	1.53	1.02	1.50	0.47	0.92	1.38	1.38	0.90	2.25	1.08	0.62
A28	1.68	0.76	2.64	1.83	1.74	1.68	1.06	1.06	1.53	2.04	1.00	0.94	0.92	0.46	1.38	0.45	0.90	1.08	0.61
A8	1.68	0.76	0.66	1.83	2.32	2.80	2.12	0.53	0.51	0.51	1.50	0.47	0.92	0.92	1.38	1.35	1.80	1.08	0.61
A27	1.68	0.76	0.66	2.44	2.32	0.56	1.06	1.59	1.53	1.53	1.50	0.94	0.92	0.46	1.38	0.45	2.25	1.08	0.61
A15	0.84	0.76	0.66	1.83	2.32	0.56	1.59	0.53	2.04	1.02	1.50	1.41	1.38	0.92	1.38	0.90	2.25	1.08	0.61
A32	0.84	0.76	1.98	1.83	2.32	0.56	1.06	1.06	1.53	2.04	1.50	0.47	1.38	0.46	1.38	0.45	2.25	1.08	0.61
A16	0.84	1.52	0.66	1.83	2.32	0.56	2.12	0.53	2.04	0.51	1.50	0.47	0.92	0.92	1.38	0.90	2.25	1.08	0.59
A6	3.36	0.76	0.66	1.22	2.32	0.56	1.06	0.53	1.53	0.51	1.50	0.47	0.92	0.92	1.38	1.35	1.80	1.44	0.59
A19	2.52	0.76	1.32	1.22	1.74	1.12	0.53	0.53	0.51	1.53	1.00	0.47	1.38	0.92	1.38	0.90	2.25	1.08	0.56
A11	0.84	0.76	1.98	0.61	2.32	0.56	1.06	0.53	1.53	1.53	0.50	0.47	1.38	0.92	1.38	1.35	2.25	1.08	0.56
A31	0.84	0.76	2.64	1.22	2.32	0.56	1.06	0.53	1.53	1.53	1.00	0.47	1.38	0.46	1.38	0.45	1.80	1.08	0.55
A12	0.84	0.76	0.66	1.83	1.74	0.56	2.12	0.53	1.53	0.51	1.50	0.47	0.92	0.46	1.38	1.35	2.25	1.08	0.54
A13	1.68	0.76	0.66	1.83	2.32	0.56	1.06	0.53	1.53	0.51	1.50	0.47	0.92	0.46	1.38	1.35	1.80	1.08	0.54
A4	0.84	0.76	0.66	1.83	2.32	0.56	2.12	0.53	1.53	0.51	1.50	0.47	0.92	0.46	1.38	0.45	1.80	1.08	0.52
A21	0.84	0.76	0.66	1.22	2.32	0.56	1.59	0.53	0.51	0.51	1.00	0.47	1.38	1.38	1.38	0.90	2.25	1.44	0.52
A33	0.84	0.76	2.64	1.83	2.32	0.56	1.59	0.53	0.51	0.51	1.50	0.47	0.92	0.46	1.38	1.35	0.45	1.08	0.52
A2	0.84	0.76	0.66	1.22	1.74	1.68	1.06	0.53	1.53	0.51	1.00	0.47	1.38	0.92	1.38	0.90	0.90	1.44	0.50
A20	2.52	0.76	0.66	1.22	1.74	0.56	0.53	0.53	0.51	0.51	1.00	0.47	1.38	0.92	1.38	0.90	2.25	1.08	0.50
A18	0.84	0.76	0.66	1.22	2.32	1.12	1.06	0.53	0.51	1.02	1.00	0.47	1.38	0.92	1.38	0.45	2.25	0.36	0.48
A3	0.84	0.76	0.66	0.61	1.74	0.56	0.53	0.53	1.53	0.51	0.50	1.41	1.38	0.92	1.38	1.35	1.80	1.08	0.48
A26	0.84	0.76	0.66	1.22	1.74	0.56	1.06	0.53	1.02	0.51	1.00	0.47	0.92	1.84	1.38	0.90	1.35	1.08	0.47
A9	0.84	0.76	0.66	0.61	2.32	0.56	0.53	0.53	1.53	0.51	0.50	0.47	1.38	0.92	1.38	1.35	1.80	1.08	0.47
A10	0.84	0.76	0.66	0.61	2.32	1.68	0.53	0.53	2.04	1.02	0.50	0.47	1.38	0.46	1.38	0.45	0.90	1.08	0.47
A1	0.84	0.76	0.66	1.22	2.32	0.56	0.53	0.53	1.53	1.02	0.50	1.41	0.46	0.46	1.38	1.35	0.45	1.08	0.45
A5	0.84	0.76	0.66	0.61	1.74	0.56	0.53	0.53	0.51	0.51	0.50	0.47	0.92	0.92	1.38	1.35	2.25	1.08	0.43
A7	0.84	0.76	0.66	0.61	2.32	0.56	0.53	0.53	0.51	0.51	0.50	0.47	1.38	0.46	1.38	0.45	2.25	1.08	0.42

Source: own study.

(III category) P(A) – above 0.75, mean risk (II category) P(A) – 0.51-0.74, low risk (I category) – P(A) 0.25-0.50.

In the area under examination, no objects scored the maximum or the minimum number of points. A map of researched area locations and their risk group was presented in Fig. 5. Table 3 contains a detailed description of the location of studied objects. Risk category III included one object marked as A25, situated in the area of Łapy in the voivodship of Podlaskie. This is a large object filled with obsolete pesticides, with "to be liquidated" status. It is situated near drinking water intakes, watercourses, residential buildings, and plant production, and is partially

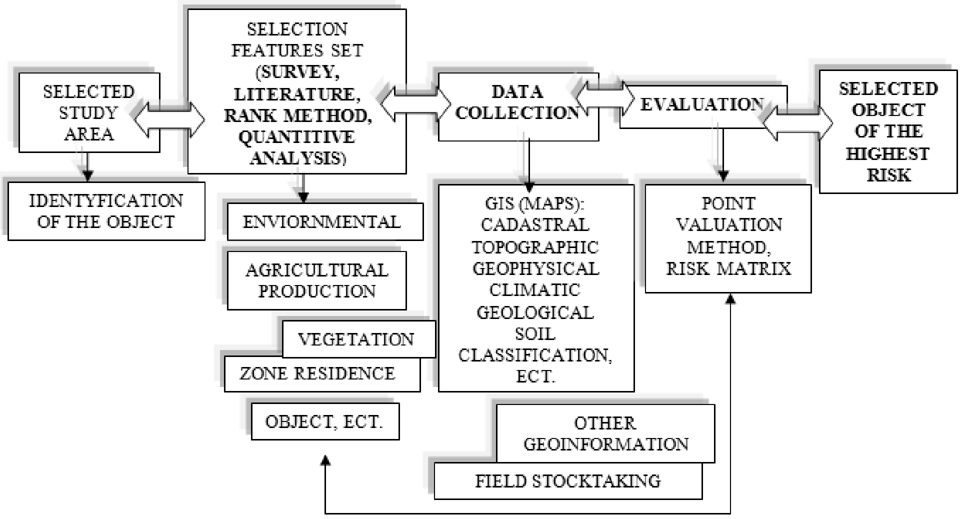

Fig. 4. The proposed algorithm. Source: own elaboration.

immersed in water. The area is not monitored and no control examinations of environmental receptors have been carried out. Obsolete pesticides have been in the ground for more than 30 years and the unsealing structure of the tanks will make it possible for the substance to leak into the environment. Risk category II included 23 objects – 5 situated in the voivodship of Podlaskie (Baciuty, Stelmachowo-Folwarki Tylowickie, Bielany, Wąsosz, Anusin), 10 in the voivodship of Warmia and Mazury (Czerwonka, Wozławki, Konopki Wielkie, Siniec, Matyski, Węgajty, Kobiela, Krosno, Lipowa Góra, Cierzpiety), 6 in the voivodship of Kujawsko-Pomorskie (Grębocin, Małe Pułkowo, Puszcza Miejska, Sokołowo, Piątkowo, Rogowo), and 2 objects in the voivodship of Mazowieckie (Krzywonoś, Podrogów).

I risk category included objects situated in the voivodship of Podlaskie – 2 objects (Słochy Annopolskie, Dębniki), Warmia and Mazury – 7 objects (Rywociny, Kotkowo, Nowe Guty, Warlity Wielkie, Babięta, and Kamiennik Wielki), and Kujawsko-Pomorskie – 1 object (Pokrzydowo). The lowest number of points was obtained by the object named Różyna, situated in the voivodship of Warmia and Mazury. This is an object located in a forest area, far from residential buildings, drinking water sources and watercourses. Despite the good technical condition of the structure of the object where obsolete pesticides had been stored, it was cleaned and the waste liquidated in a manner acceptable for obsolete pesticides.

On the basis of the conducted research, an algorithm was created (Fig. 4). The algorithm consists of 5 stages that include the following steps: choice of research area and identification of objects that threaten the environment; indication of geodata (spatial features) that may condition threats to the environment and people; collecting spatial data (GIS) about the area where the object is located and about the object itself; and evaluation of the researched objects regarding given criteria and selection of objects that require urgent intervention.

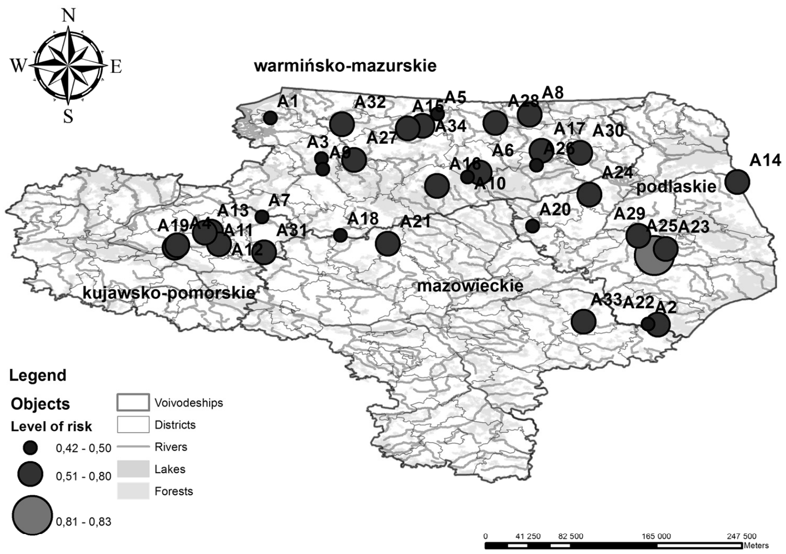

Fig. 5. Object locations (obsolete pesticides). Source: own study.

Table 3. The list of tested objects with their locations.

	Name of place	Name of community	Voivodship
A25	Łapy	Łapy	podlaskie
A23	Baciuty	Turośń Kościelna	podlaskie
A29	Stelmachowo – Folwarki Tylowickie	Tykocin	podlaskie
A14	Bielany	Nowy Dwór	podlaskie
A24	Wąsosz	Wąsosz	podlaskie
A22	Anusin	Siemiatycze	podlaskie
A30	Czerwonka	Biskupiec	warmińsko-mazurskie
A34	Wozławki	Bisztynek	warmińsko-mazurskie
A17	Konopki Wielkie	Miłki	warmińsko-mazurskie
A28	Siniec	Srokowo	warmińsko-mazurskie
A8	Matyski	Węgorzewo	warmińsko-mazurskie
A27	Węgajty	Jonkowo	warmińsko-mazurskie
A15	Kobiela	Kiwity	warmińsko-mazurskie
A32	Krosno	Orneta	warmińsko-mazurskie
A16	Lipowa Góra	Szczytno	warmińsko-mazurskie
A6	Cierzpięty	Piecki	warmińsko-mazurskie
A19	Grębocin	Lubicz	kujawsko-pomorskie
A11	Małe Pułkowo	Dębowa Góra	kujawsko-pomorskie
A31	Puszcza Miejska	Rypin	kujawsko-pomorskie
A12	Sokołowo	Golub Dobrzyń	kujawsko-pomorskie
A13	Piątkowo	Kowalewo Pomorskie	kujawsko-pomorskie
A4	Rogowo	Lubicz	kujawsko-pomorskie
A21	Garlino – Krzywonoś	Szydłowo	mazowieckie
A33	Podrogów	Sokołów Podlaski	mazowieckie
A2	Słochy Annopolskie	Siemiatycze	podlaskie
A20	Dębniki	Zbójna	podlaskie
A18	Rywociny	Działdowo	warmińsko-mazurskie
A3	Kotkowo	Łukta	warmińsko-mazurskie
A26	Nowe Guty	Orzysz	warmińsko-mazurskie
A9	Warlity Wielkie	Ostróda	warmińsko-mazurskie
A10	Babięta	Piecki	warmińsko-mazurskie
A1	Kamiennik Wielki	Milejewo	warmińsko-mazurskie
A5	Różyna	Sępopol	warmińsko-mazurskie
A7	Pokrzydowo	Zbiczno	kujawsko-pomorskie

Source: own study.

Conclusions

The analysis included features directly related to the object itself and features related to the surrounding area. The examined features of the objects were divided into three categories of risk. The study found that the highest risk is posed by objects that have not been emptied from toxic substances and are situated near water intakes, watercourses, and houses, and are visited by people. The least harmful are objects situated in forest areas with spatial features posing no threat to the environment. Because of their content, pesticide burial areas are environmentally hazardous. Spatial features may actually increase environmental risk – making biological time-bombs out of old pesticide stocks. It is important not only to remove them and to eliminate their toxic content, but also to monitor the environment in the neighborhood of their location. Toxins that may have leached to the environment are dangerous due to their accumulation in plants and human organisms and their persistence and resistance to biological decomposition processes [30-33].

The proposed algorithm that uses information included in a geographical information system (cadastral, topographic, geophysical, climatic, geological, soil classification maps) and other sources makes it possible to examine environmental risk for the select group of objects and to identify those that pose the greatest threat. Numerous researchers that deal with issues connected with threats caused by obsolete pesticides use data included in GIS to estimate the risk and to visualize the situation of toxic objects [34-36]. However, Głuszka et al. [10] suggest a similar scope of operations essential in the researched objects' spatial analysis. The suggested algorithm indicates on a specific methodology that may be used in initial risk evaluation without having soil chemical analyses.

The costs of elimination and environmental monitoring are high. Therefore, this method allows the objects that pose the greatest risk to the environment due to environmental conditions to be identified.

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