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Chapter 7

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Changes in Plant Communities Influenced by Pesticide Dump

One of the sources of environmental contamination with pesticides in Poland are leaky pesticide dumps storing pesticide waste, created mainly in the 1960s and 1970s. Waste deposited in pesticide dumps is usually characterized by high durability and toxicity towards people, animals and plants. Pesticides pose a direct threat to the environment due to the leakiness of the pesticide dumps in which they are deposited. This concerns all habitats affected by such contamination, as surface waters, soils and forests. Their low biodegradability, slow decomposition in the environment and long period of half-life result in accumulation of those harmful substances in plants and animals.

The problem of pesticide dump removal is inseparably related to liquidation of the contamination present in the area, which often poses serious problems. Contamination carried by groundwater spreads in the ground over significant distances. In this situation, knowledge concerning the rate and mechanisms of spontaneous disappearance of pesticide pollution in natural environment seems to be of crucial importance. Unfortunately, this phenomenon has not been sufficiently investigated, due to the large variability of properties characterizing biologically active substances and grounds, and to the complexity of biological and physicochemical processes taking place.

Vegetation provides a good bioindicator of contamination spreading in the environment. At the beginning of 2000s, intensive research was started on vegetation in habitats directly neighbouring a pesticide dump in Warlity Wielkie (the area of research is described in details in Chapter 5). The aim of the research was to determine the effect of substances deposited in the pesticide dump on the ecosystem of the anthropogenic wood and the phytolittoral of the lake using phytoindication methods.

Research conditions

Detailed research was preceded by a floristic and phytosociological inventory of the research areas, determination of structural features of the most typical plant communities and species diversity in the analysed area. The research was conducted in 2002-2009. Diversity was assessed on the basis of the Shannon diversity index. Species distribution in the community was described with the use of the Pielou evenness index (Magurran 1988).

The research on vegetation and flora of the pesticide dump area was carried out with the application of a range of methods. Floristic research was conducted on the basis of sensitive bioindicators. Sensitive bioindicators have been widely discussed in the literature (see e.g. Mulgrew, Williams 2000). They are primarily applicable in the monitoring of environmental contamination, although their usefulness in research concerning relations between soil and plants is limited. Therefore, relations between plants and environmental conditions were analyzed with the use of species scales of diversity.

The ecological condition of the ecosystem of Lake Szeląg Wielki was assessed with the application of methods based on the analysis concerning biocenotic diversity of vegetation in the lake phytolittoral.

Detailed conditions of the research - Wood

Relationships between plants of the anthropogenic wood directly neighbouring on the pesticide dump and environmental factors were analyzed using scales of species, with the application of the Ellenberg indicator values. Numerous species of plants serve as good indicators of habitat conditions. The research lasting for a half of the century has resulted in many studies in the form of ecological indicator values for vascular plants in various regions, among others, for Central Europe, Great Britain, Poland and Norway. Additionally, various attempts have been undertaken in order to adapt ecological Ellenberg indicator values to local conditions, e.g. in Holland, Sweden or Estonia.

Ecological Ellenberg indicator values have been applied to interpret results of the research into flora management; they helped to account for plant reactions to environmental changes, carry out classification and assessment of forests based on the effects of humus compounds and to assess ecological risk. Multiple studies have been carried out on the use of indicator values to assess the effects of interrelations between the forest ecosystem and neighbouring habitats, with particular focus on anthropogenic influence or microclimate changes. Application of ecological indicator values supported by phytosociological research has brought good results while assessing climatic and edaphic habitat conditions.

The ecological description is based on 16 phytosociological releves, were performed over an area of 400 – 600 m^2.

Canonical Correspondence Analysis (CCA) was applied in order to determine the variability model of the analysed data, which to the largest extent accounts for the environmental variables taken into consideration.

Detailed conditions of the research - Lake

The ecological condition of Lake Szeląg Wielki was assessed with the use of the Ecological State Macrophyte Index (ESMI) calculated in transects of the lake phytolittoral. The method consists in:

- determining 20-30 m wide transects, perpendicular to the shoreline;
- establishing the maximum depth of plant occurrence (depth range of macrophytes), which determines the length of the transect and defines the area of the research performed;
- assessing total percentage cover of plants in the transect;
- identifying all plant communities occurring in the transect, with assessment of their percentage cover in relation to the total area occupied by plants, converted into the Braun-Blanquet scale.

The number of transects for plant research was determined from the formula proposed by Jensén 1977, modified by Keskitalo and Salonen 1994.

The transect method was also used to assess β-diversity, understood after Whittaker (Magurran 1988) as changes between various communities within one type of landscape. In order to determine whether the pesticide dump affects the ecological condition of the lake, an analysis was conducted to check the existence of statistically significant differences between the analysed transects determined in the phytolittoral of Lake Szeląg Wielki in terms of phytocenotic diversity, diversity index and the share of phytocenoses in transects located in the vicinity of the pesticide dumb and in distant ones. Calculations included determination of the Pielou evenness index.

The first stage of the statistical analysis was to check the distribution of results against normal distribution, using the Shapiro-Wilk [W] test. In case of establishing normal distribution, a parametric t-Student test was used (significance level $\alpha=0.05$), which assumes normal distribution of results or differences between results. The Mann-Whitney U test (significance level $\alpha=0.05$) was applied for determining the significance of differences between variables whose distribution was not consistent with normal distribution. The above described statistical analyses were carried out with the use of Statistica 7.1 software (StatSoft, Inc. 2005). Transects situated at least 2 km from the perpendicular line crossing two points (the point of the Szeląg Wielki shoreline situated nearest the pesticide dump, and the point determined by the centre of the dump) were arbitrarily considered to be distant transects.

Influence of pesticide dump on plants near Warlity Wielkie- Wood

161 species of vascular plants and 24 species of bryophytes were identified over the examined area (Figure 1). Phytosociologically, the examined wood was classified into two syntaxonomic units: a community with *Sambucus nigra-Picea abies* and a complex of *Sambuco racemosi-Pieceetum.* Both communities are of anthropogenic origin. Among the species making up the identified phytocenoses, anthropophytes, growing near human dwellings and such places as dustbins, grounds adjoining fences, roads, etc. constituted a significant share.

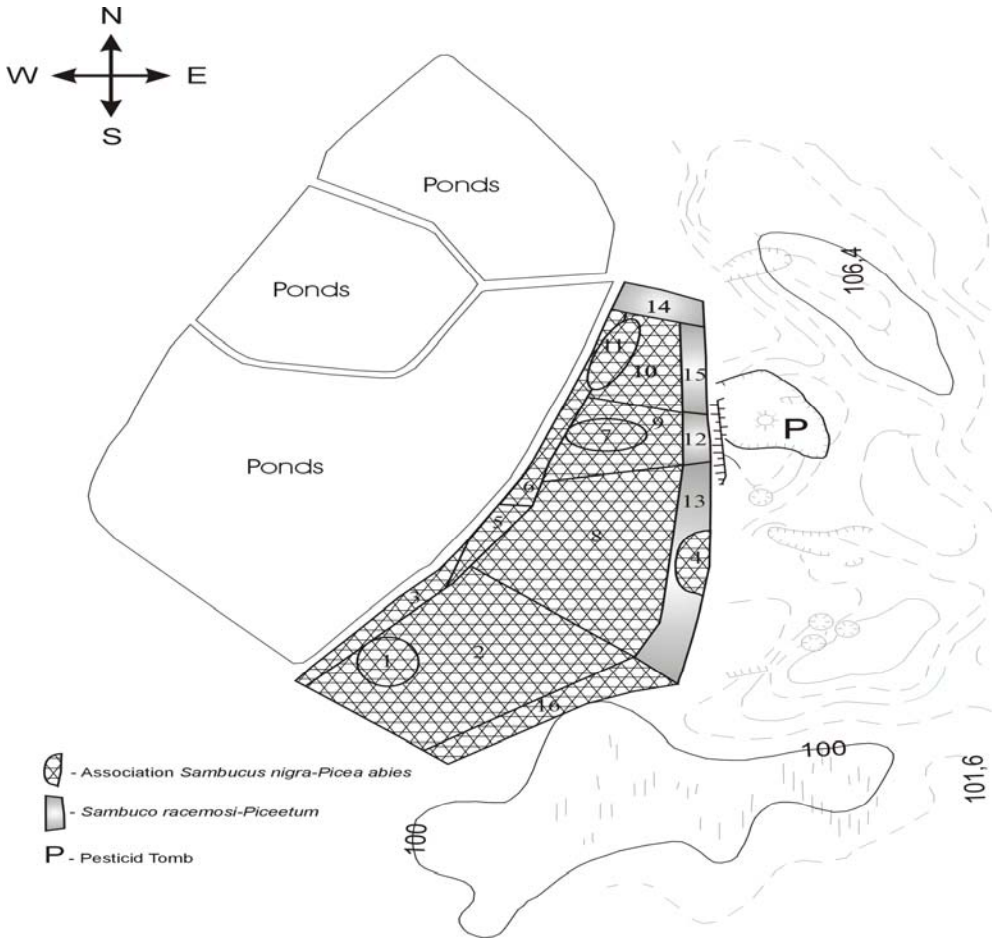

Figure 1. Location of the phytosociological releves within the study area in the vicinity of the pestcide dump

Communities with *Sambucus nigra-Picea abies* usually occupy fertile, humic, wet, and not too insolated habitats, which was also the case in the examined area. The soils of the habitat under examination were artificially processed soils of various stages of the soil-forming process, or soils on soils of the changed soil profile (see Chapter 5).

Sambuco racemosi-Pieceetum, observed most frequently along forest roads and on clear-cuts, also on the examined area occurred near the forest road leading from the pesticide dump to the ponds (Figure 2). Requirements of this species as regards soil and humidity are moderate, therefore it can be most frequently found on fresh, fertile and loamy soils.

The spatial structure of the described communities indicates the clear functional diversification of the identified patches – the outer belt, playing the role of the protection zone, directly adjoining the area occupied by the dump, was formed by *Sambuco racemosi-Pieceetum.*

Indicators of organic matter (H), nitrogen content in soil (N), and soil trophism (Tr), assume higher values in the direct neighbourhood of the dump. This indicates a supply of biogenic compounds from the area of the dump.

The values of edaphic indicators confirm the physico-chemical examinations of soils in this area, indicating fresh, sandy-loamy soils. Soil humidity index (W) and soil dispersion index (D) were the lowest in the direct vicinity of the dump, which could be a barrier for migration of compounds deposited in the dump through potential effluents. A high acidity index (R) indicates the limitation of this barrier due to an active role of hydrogen ions, favouring the migration of numerous compounds.

Table 1

Diversity Indicies in a antropogenic forest neer pesticide dump

Num. Releve	**Index Shannon-Wiener [H]**	**mean**	**Evennes Pielou [J]**	**mean**	**Num. Spec.**	**mean**
Sambuco racemosi-Piceetum						
1	6,06		0,979		73	
7	6,201		0,978		81	
11	5,371		0,978		45	
2	5,944		0,976		68	
3	6,095	5,72325	0,975	0,97542	76	60
9	5,334		0,977		44	
10	5,25		0,974		42	
4	5,942		0,973		69	
5	5,621		0,972		55	
6	5,834		0,972		64	
8	5,843		0,977		63	
16	5,184		0,974		40	
Sambucus nigra-Picea abies						
12	5,15		0,974		39	
13	4,624	5,28075	0,972	0,97625	27	44,25
14	5,596		0,977		53	
15	5,753		0,982		58	

Diversity indices for the examined forest phytocenoses are presented in Table 1. The mean value of the diversity index and the mean value of the number of species were higher for the *Sambuco racemosi-Piceetum* unit as compared to the *Sambucus nigra-Picea abies* complex. On the other hand, the mean value of the evenness index was higher in the *Sambucus nigra-Picea abies* complex than the mean value of the evenness index for the *Sambuco racemosi-Piceetum* complex.

Table 2

Test U-Manna-Whitneya and test t-Studenta

U Mann-Whitney. Grouping. var. stadium Marked results are significant at p <.05000										
	Rank sum	Rank sum	U	Z	p level	Z	p level	No. cases per group	No. cases per group	2*1str.
Index [H]	117,0000	19,00000	9,00000	1,819017	0,068910	1,819017	0,068910	12	4	0,078022
Evenness [J]	101,0000	35,00000	23,00000	-0,12127	0,903479	-0,12244	0,902548	12	4	0,952747
Num.Spec.	117,0000	19,00000	9,00000	1,819017	0,068910	1,819017	0,068910	12	4	0,078022
Student's t-test; Grouping: stadium (Sheet1) Group 1: 1 Group 2 2										
	Mean	Mean	t	Df	P	No. cases per group	No. cases per group	SD	SD	F quotient
Index [H]	5,72325	5,28075	1,944655	14	0,072187	12	4	0,35724	0,50689	2,013291
Evenness [J]	0,97542	0,97625	-0,48962	14	0,631987	12	4	0,00243	0,00435	3,205392
Num.Spec.	60,00000	44,25000	1,909717	14	0,076876	12	4	14,35270	14,03270	1,046128

A Mann-Whitney U test and a t-Student test performed during the analysis did not confirm statistical significances of differences between phytocenoses of *Sambuco racemosi-Piceetum* and phytocenoses of *Sambucus nigra-Picea abies* as regards the diversity indicator, species diversity and the share of species in patches (Table 2).

Variables used in the CCA ordination account for about 43.6% of the total plant variability. Canonical indices of all environmental variables, assessed through the measure of the Variance Inflation Factor [VIF < 20], are stable and can be interpreted.

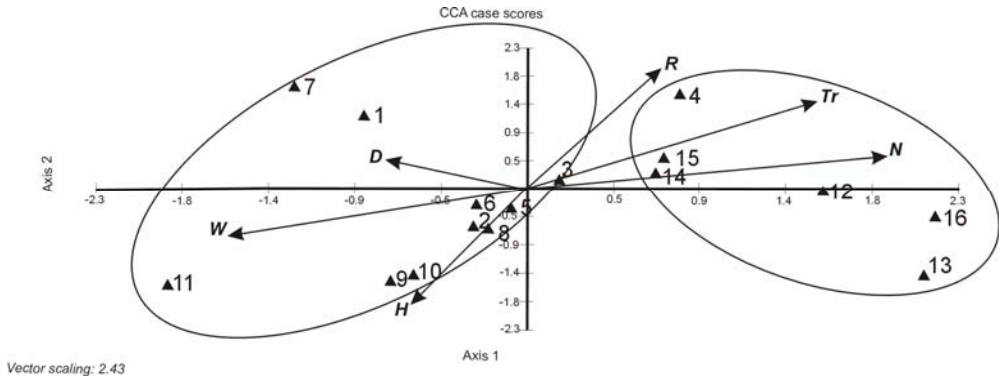

Figure 2. CCA ordination diagram of the phytocenoses threatened by a pesticide dump.
1-16 - releve; W-soil moisure value, Tr-trophy value, R-soil acidity (pH) value, D-soil granulometric value, H-organic matter content value, N - nitrophylity value.

Patches of both examined plant complexes divided along the I axis gradient (Figure 2). On the right side of the ordination space of a higher share of eurytopic, cosmopolitan species, there can be distinguished phytocenoses neighbouring on the pesticide dump (13, 16, 12, 14, 15, 4). This group includes all releves of *Sambucus nigra-Picea abies* (12, 13.14, 15). The left side of the ordination space, characterized by higher humidity, is composed of phytocenoses neighbouring on the drainage ditch, situated closest to fishponds (3, 5, 6, 11) and in the central part of the examined wood (1, 2, 7, 8, 9, 10).

Influence of pesticide dump on plants near Warlity Wielkie Lake

The study found that the required number of transects in the phytolittoral of Szeląg Wielki, MLT, was 38 (Table 3). The transects confirmed the presence of 22 plant complexes. The highest range of plant occurrence in Lake Szeląg Wielki was observed for the phytocenosis with *Fontinalis antipyretica*, amounting to 4.8 m.

The ecological condition of the lake, determined on the basis of the ESMI index, was good (Table 4). The results of the tests analysing the normality of distribution as regards phytocenotic diversity variables are presented in Table 5.

A normal distribution was characteristic for a variable: the Shannon–Wiener diversity index. Inconsistency with normal distribution was established in the case of two other variables: the Pielou evenness index and the number of phytocenoses in a transect (Table 5).

The analysis of the Shannon–Wiener index was carried out with the use of the t-Student test. The results obtained were statistically significant ($\alpha=0.05$; $p<0.03$) and they indicate the existence of significant differences between phytocenoses located in transects close to the dump (>2km) and distant ones (<2km) (Figure 3).

The analysis of the number of phytocenoses and the index of phytocenotic diversity was carried out on the basis of the Mann-Whitney U test. The obtained results were statistically insignificant for the number of phytocenoses: ($U= 101.5$; $p= 0.3194$) and the Pielou phytocenotic diversity index ($U= 87.5$; $p= 0.1398$).

Table 3

Phytocoenotic diversity of transects of Lake Szeląg Wielki

Transect	Depth of plants occurrence in a transect	Percentage coverage of transect wth plants	Index Shannon-Wienner	Evenness [J] Pilou	Num. Syntax.	Group
1.	2	90	1,408	0,704	4	2
2.	3,5	90	1,387	0,875	3	2
3.	3,2	100	2,395	0,798	8	2
4.	4,5	90	1,12	0,56	4	2
5.	2	90	1,564	0,674	5	2
6.	4	80	1,244	0,785	3	2
7.	6	100	2,147	0,716	8	2
8.	1,6	90	0,606	0,606	2	2
9.	4,8	100	2,6	0,783	10	2
10.	1,9	95	0,606	0,606	2	2
11.	2,6	80	1,11	0,7	3	2
12.	1,2	90	0,941	0,941	2	1
13.	1,8	90	0,941	0,941	2	1
14.	2,2	100	0,941	0,941	2	1
15.	0,8	90	0,606	0,606	2	1
16.	2	90	0,648	0,409	3	1
17.	1,6	90	0,606	0,606	2	1
18.	2,4	100	0,606	0,606	2	1
19.	3	100	0,781	0,336	5	1
20.	2,6	90	0,994	0,497	4	1
21.	2,8	100	1,408	0,704	4	2
22.	4	90	1,408	0,704	4	2
23.	5,4	95	1,408	0,704	4	2
24.	0,4	100	0	0	1	2
25.	0,6	100	0	0	1	2
26.	1,8	100	0,941	0,941	2	2
27.	2	90	0,941	0,941	2	2
28.	2,2	100	1,727	0,863	4	2
29.	2,4	100	0,941	0,941	2	2
30.	2,6	100	0,941	0,941	2	2
31.	2,6	100	0,941	0,941	2	2
32.	2,9	100	1,11	0,7	3	2
33.	3,4	100	0,973	0,614	3	2
34.	4,8	100	1,13	0,487	5	2
35.	3,4	90	2,025	0,872	5	2
36.	4,8	100	2,6	0,783	10	2
37.	3,2	100	1,408	0,704	4	2
38.	4,2	100	1,564	0,674	5	2

Group: differentiates transects into those located in its proximity at a distance < 2km from pesticide dump (1) and those remote at a distance > 2km from pesticide dump (2)

Table 4

The Szeląg Wielki and reference lakes phytocoenotic parameters

Lake Name	Area of 2,5m isobath	Area of phytolittoral (N) (ha)	Number of phytolittoral communities (S)	Index of phytocenotic diversity (H)	Index of colonization (Z)	Index of max. phytocenotic diversity (H_{max})	Synantthropization index (W_s)	Makrofitowy Indeks Stanu Ekologicznego (ESMI)
Szeląg Wielki	144,25	141,9	23	1,94	1,02	3,14	0,53	0,47

Table 5

Shapiro-Wilk's test for variables phytocoenic diversity

	N	W	P	Distribution
Index Shannon–Wiener	38	0,945448	0,063080	N
Evenness Pielou	38	0,856309	0,000185	n.n
Num_Syntax	38	0,828293	0,000042	n.n

W – value of Shapiro-Wilk coefficient; p- level of significance, n-normal distribution W>W (α;n); n.n – not normal distribution W<W (α;n); W_{max} (0.05;38) = 0.863

Water and rush vegetation is of crucial importance for the proper functioning of the entire lake ecosystem. At the same time, it reveals high sensitivity to changes of all environmental factors of the water ecosystem. Higher taxonomic and syntaxonomic diversity of the phytolittorial indicates higher ecological condition of the lake. The mean value of the Shannon-Wiener diversity index (H) for water and rush vegetation in Lake Szeląg Wielki (Table 3), the evenness index (J), as well as the mean number of phytocenoses are typical for poorly eutrophized lakes. The presence of 22 plant complexes established during the research on transects indicates that the transects method fully renders phytocenotic diversity of the lake, and the number of macrophyte phytocenoses in Lake Szeląg Wielki established during phytosociological studies was the same (Grzybowski et al. 2005). Good ecological condition of Lake Szeląg Wielki determined on the basis of the ESMI indicator is

the same as in the case of 39 lakes out of 153 examined so far with the application of this method (Ciecierska et al. 2006). They were also characterized by a similar phytocenotic composition, but differed in the frequent occurrence of stoneworts. Stonewort communities, the presence of which was not established in Szeląg Wielki, are an important indicator of high macrophyte assessment of the ecological condition of the lake.

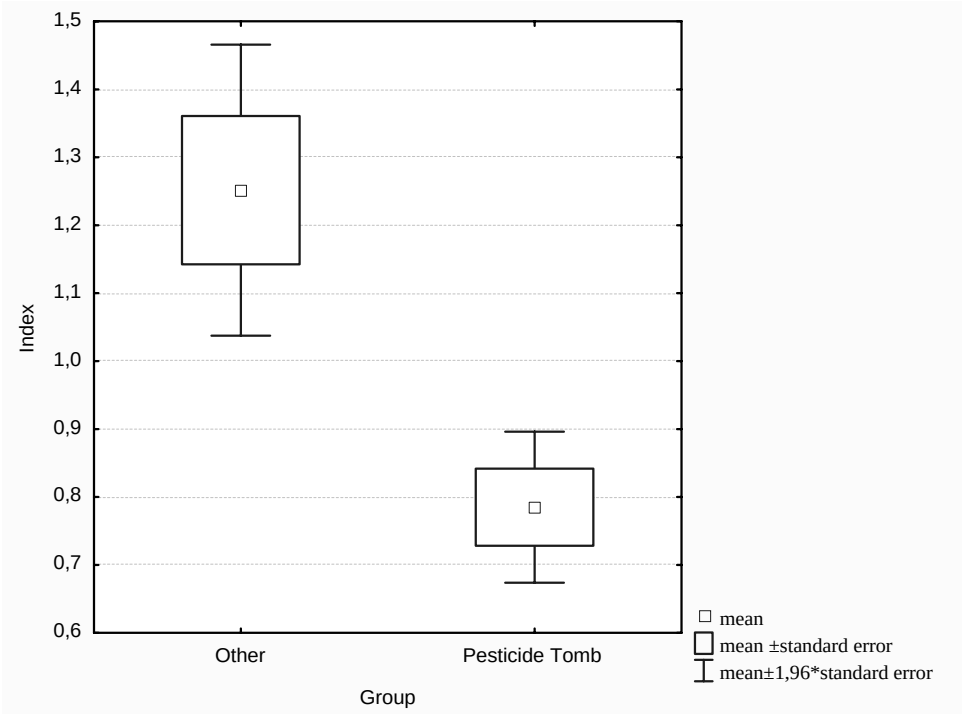

Figure 3. Differences between mean values of Shannon index for phytocoenoses located in the proximity of the pesticide dump and those remote from it (Student's t-test, $\alpha=0.05$; $p<0.03$)

The total number of plant communities in the lake resulted, among others, from differentiation of habitat conditions of the littoral. The size of the lake, its length and shoreline development affect the number of macrophyte microhabitats. Lake Szeląg Wielki is characterized by favourable habitat conditions. The average number of plant communities in 153 referential lakes from the database of lakes selected for the monitoring of lakes in Poland ranges from 21 to 23, depending on the type of lake. In the case of Szeląg Wielki, the presence of 23 plant complexes was established, which indicates a significant phytocenotic diversity of the phytolittoral of the examined lake.

Summary and conclusions

The obtained results are difficult to be interpreted in details; they reflects overlapping and inseparable processes concerning disappearance of contamination in the ground, accompanied at the same time with accumulation and decomposition of contaminations in effluents gathered in ecosystems neighbouring on the pesticide dump: a wood and an open water reservoir. Nevertheless, they seem to be valuable due to a long period of research (eight years) conducted in a comparable manner. The data collected can be helpful in assessing the ecological condition of ecosystems under the influence of the pesticide dump, the rate of spontaneous disappearance of pesticide pollution of the ground, the assessment of the risk to surface waters in case of contaminating the area with pesticides.

The analysis of the material indicates the following, general conclusions:

1. The processes of biological decomposition taking place in surface waters are so intensive that no pesticide accumulation washed out from the contaminated ground is observed, and initially high concentrations in effluents disappear relatively fast.
2. Trace amounts of contamination in effluents are observed for many years, which indicates that the process of natural ground purification is slow and after several years of waste disposal, the land is still the source of pesticide pollution discharged to neighbouring ecosystems.
3. It is necessary to conduct long-term monitoring of contaminated areas in the vicinity of exiting and liquidated pesticide dumps, taking into consideration the possible direction of groundwater flows, causing migration of pollutants.

Acknowledgements

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Literature

Ciecierska H., Kolada A., Soszka H., Gołub M., 2006: Opracowanie podstaw metodycznych dla monitoringu biologicznego wód powierzchniowych w zakresie makrofitów i pilotowe ich zastosowanie dla części wód reprezentujących wybrane kategorie i typy. T. II Jeziora. IOŚ, UWM. Warszawa-Poznań-Olsztyn.

Grzybowski M., Szarek J., Skibniewska K., Sawicka-Kapusta K., Guziur J., Endler Z. 2005. The characteristics of plants in the littoral zone of lake Szeląg Wielki in the Iława Lake District threatened by pesticide tomb. Fres. Environ. Bull. 14(5): 357-362

Jensén S., 1977. An objective method for sampling the macrophyte vegetation in lakes. Vegetatio 33:107-118.

Keskitalo J., Salonen K., 1994: Manual for integrated monitoring. Subprogramme Hydrobiology of Lakes. National Board of Waters and the Environment, Helsinki, Vesi-Ja Ymparistohallinnon Julkasuja, Seria B, 16: 28-30.Landolt E., 1977. Ökologische Zeigewerte zur Schweizer Flora. Veröff. Geobot. Inst.. ETH, Stifung Rübel 64:1-208.

Magurran, A.1988: Ecological Diversity and its Measurement. Princeton, New Jersey: Princeton University Press.
Mulgrew A., Williams P., 2000: Biomonitoring of air quality using plants. Air Hygiene Report No 10: 1-165. WHO Collaborating Centre for Air Quality Management and Air Pollution Control. Berlin.

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