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IDENTIFICATION OF HEALTH HAZARDS TO RURAL POPULATION LIVING NEAR PESTICIDE DUMP SITES IN POLAND

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Abstract
Objectives: The aim of the present project was to assess population exposure to pesticides in the vicinity of pesticide dump sites and make a preliminary evaluation of the potential health hazards to humans. **Materials and Methods:** Of the 286 pesticide dump sites registered in Poland, 40 were selected as the largest source of ecological hazard. The application of the Hazard Ranking System made it possible to identify 17 priority dump sites where pesticide wastes are deposited. For population exposure assessment, two dump sites located close to the residence area and drinking water intakes were selected as potentially most hazardous to health. They have a piezometric system installation that enables ground water sampling for analysis. **Results:** In water samples collected from the water-bearing layer in areas adjacent to pesticide dump site, 31 different pesticides in total have been detected (15 organochlorine pesticides, 10 organophosphorous pesticides and 6 phenoxyacids), 12 of which – dichlorvos, mevinphos, endosulfan, dieldrin, heptachlor epoxide, p,p'-DDT, p,p'-DDD, p,p'-DDE, methoxychlor, 2,4-D, MCPA, MCPP – had concentration levels higher than the detection limit. The estimated size of the potentially exposed population approximates 900 inhabitants; 33% of this population are children (aged 0–14 years) and women at reproductive age (aged 15–45 years). Both these target populations are considered particularly susceptible to the adverse health effects of pesticides. Assessment of population exposure to pesticides (p,p'-DDT – 0.15 μg/l; p,p'-DDD – 0.13 μg/l; MCPP – 12.3 μg/l; MCPA – 0.64 μg/l; methoxychlor – 0.31 μg/l; 2,4'-D – 5.4 μg/l) with concentration levels higher than the drinking water standard (0.1 μg/l) was based on pesticide daily intake in drinking water. **Conclusions:** The results indicated a low cancer risk ($R = 10^{-8}$) for people drinking water contaminated with p,p'-DDT and p,p'-DDD as well as low non-cancer risk related to MCPA, MCPP and methoxychlor exposure. At one of the dump sites examined, the level of population exposure to 2,4'-D implies possible hematopoietic, nephrotoxic and hepatotoxic effects as well as reproductive disorders.

Key words:
Pesticides, Pesticide dump sites, Environmental exposure, Health hazards

INTRODUCTION

The dynamic agricultural development in Poland that began in the 1930s with so called "green revolution", based on the use of mineral fertilizers and chemical preparations, resulted in an emergence of new health hazards associated with the application of a new category of chemicals to protect plants from pests and diseases, presently known as pesticides [1].

Pesticides are characterized by a high level of biological activity and a wide spectrum of possible adverse effects to humans and the environment. The most frequently reported health effects and symptoms attributable to the occupational exposure to pesticides include tumors, central and peripheral nervous system impairments, liver and kidney damage, immune dysfunction, disturbed hormonal and enzymatic balance, reproductive disorders, allergy, anemia, sleep disturbances, headache, disturbed vision and nausea [2,3]. Pregnant women and children are particularly susceptible to the harmful effects of pesticides. Research data show an increased risk of cancer

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[4,5] and developmental malformations [6–10] in the progeny of women exposed to pesticides during their pregnancy. The extensive and uncontrolled application of pesticides in Poland in the 1970s with the resultant build-up of obsolete pesticides and their packaging, remains a major public health problem. Pesticides have been stored at dump sites, ground pits, concrete chambers and tanks, concrete bunkers, or in pesticide depositories. The number of these sites varies, depending on the source of information. The National Waste Management Project specifies 340 dump sites for obsolete pesticides. The list of pesticide dumps and other locations of pesticide disposal developed by the Institute of Plant Protection (IPP) in Sośnicowice comprises 303 sites (IPP database). According to these data, an approximate quantity of pesticides deposited at these sites is estimated at 5065 Mg, but for 53 sites no data are available. The update on pesticide dump sites prepared in 2003 by the National Institute of Geology (NIG) Warsaw, specifies 110 remediated sites and about 8640 Mg utilized waste. The number of still existing dump sites is 176, and the quantity of pesticide wastes deposited there is estimated at about 5120 Mg. Most of the dump sites are located in the north-western part of Poland (28 sites) and in central Poland (27 sites), making up more than 31% of all dump sites in Poland. The implementation of the project on pesticide dump site management helped to eliminate all of the 55 sites (50% of the total number of dump sites in Poland) in south-western Poland. In 1995, as a part of the scheduled monitoring of 100 selected dump sites, the Institute of Plant Protection in Poznań performed a quality analysis of the material deposited at dump sites and made a pre-assessment of the related environmental hazards. Of 1000 pesticides registered in 1965–1994 (NIG database), 380 were detected at the dump sites.

All the pesticide dump sites registered in Poland constitute a source of environmental hazard due to improper location, poor technical condition (imperfect design, leakage) and a possible release of their content to the environment. The chemicals released from the dump sites may affect humans through contaminated water, soil and food, but no data have as yet been available on how these chemicals may affect the health of the population living close to dumping sites of obsolete pesticides. This paper reports on the results of the study undertaken to assess pesticide exposure of rural population living in the vicinity of selected dump sites and to make a preliminary evaluation of possible health hazards.

MATERIALS AND METHODS

Subject to the study were 40 pesticide dump sites selected from the 286 sites regarded by the National Institute of Geology as priority facilities. The assessment of population exposure to pesticides released from dump sites was carried out for Kamion Pesticide Dump in central Poland and Krupe Pesticide Dump in eastern Poland.

Ranking of pesticide dump sites

The ranking of 40 pesticide dump sites by health hazard to the community inhabiting adjacent areas was made using an adopted version of The Hazard Ranking System (540-R-92-026) [11] developed by the Environmental Protection Agency (EPA) to identify the most hazardous dump sites as well as priority areas environmentally contaminated. The method consisted in an assessment of environmental and human health hazards from pesticide exposure at particular dump sites by evaluating parameters describing the quantity of deposited wastes, dump site location and the management principles.

Dump site selection criteria

Dump sites satisfying the following criteria were selected for the study:

- high level of potential health hazard to humans and the environment (based on dump site ranking);
- residence areas in the close vicinity of dump site;
- monitoring network (piezometric installations) in operation.

Environmental samples

Since the dump sites under study were of the subsurface landfill type, it was assumed that their major environmental impact was through ground water contamination. The routes of pesticide exposure from dump sites were determined by analyzing the content of pesticide residues in water samples from the used water-bearing layer. Before sampling, the piezometers located near the dump sites were pumped over.

Environmental sample analysis

Water samples from water-bearing layers were analyzed for pesticide residues of organophosphates, organochlorines and phenoxyacids. The analytical work was performed by the NIG Central Chemical Laboratory. The methods included gas chromatography with electron capture detector (5890II GC/ECD Hewlett Packard) for organochlorine and AutoSystem XL with NPD Perkin Elmer for organophosphorous pesticides. Phenoxyacids were extracted from pre-acidified samples using triple liquid-liquid extraction. Then the extracts were concentrated using spiral nitrogen injection and solvent exchange and were subject to HPLC with multiple diode detector (Waters 969, HPLC-DAD).

Identification of potentially exposed population

The population potentially exposed to pesticides from dump sites was identified according to the preliminary indicator of potential exposure, i.e. the distance from the residential area to the waste landfills. Considering literature data on the possible health effects of environmental exposure from hazardous waste landfills, the authors adopted the distance of 1.5 km as the potential impact area. The size of the potentially exposed population was calculated based on demographic data collected via telephone communication with population departments at local administration units.

Exposure assessment

The level of pesticide exposure from dump sites was assessed based on the results of pesticide residue determinations in ground waters used as drinking water supply in the study area within a radius of 1.5 km from dump sites. Mean pesticide concentration in ground water samples was compared with the standards for drinking water quality [12], and daily pesticide intake in drinking water was calculated, assuming the daily water consumption of 2 l/day, body weight of 70 kg, and exposure duration equal to the period the dump site was in existence [13].

RESULTS

Dump site characteristics

The pesticide dump sites covered by the pilot study are located over 12 country districts (voivodeships) of Poland. Half of them can be found in the north-western, north-eastern and eastern country districts. The mean exploitation period is 32 years (23–44 years) and the dump sites can be of different type, ranging from concrete chambers (78%) through concrete bunkers (10%) to uncovered ground pits (12%). The largest number of dump sites are those operating for 31–35 years (20 sites, 50%). The total usable area covered by pesticide dumps approximates 8855m^2. As many as 5711 tonnes of obsolete pesticides and their packaging are deposited there. The mean pesticide quantity stored amounts to 143 tonnes (20–974 tonnes). The most prevalent (42%) are dump sites containing between 60 and 100 tonnes of pesticide wastes.

The largest part of the wastes are those of organochlorine pesticides (about 30%), inorganic pesticides (about 15%), dithiocarbamates (about 13%) and organophosphorous pesticides (about 10%).

An analysis of documentation concerning hydrogeological conditions at the dump site areas revealed that at 33% of sites, the depth of geological barrier, i.e. the depth of strata separating the bottom of the dump site from the water-bearing layer, is lower than 6 m. At 51% of the dump sites examined, the geological barrier is highly permeable: the soil filtration coefficient is higher than $1 \cdot 10^{-6}$ m/s, which is inadequate to prevent soil infiltration by the pesticides released from dump sites. At 30% sites, the distance from the bottom of the facility to the water-bearing level does not exceed 5 m. All the dump sites under study are characterized by a relatively small distance to public institutions (from 40 to 1500 m) and drinking water intakes. 40% of them are located at a distance shorter than 500 m from a residential area.

The hazard ranking system made it possible to identify 17 priority dump sites among the 40 facilities where hazardous pesticide wastes are deposited. These were found to pose the highest health hazard to environment and health of people living in their vicinity. Of the 17 priority dump sites, two were selected for further studies: Kamion Pesticide Dump (central Poland) and Krupe Pesticide Dump (eastern Poland) that ceased to be exploited in 2000.

Ground water contamination

As regards the Kamion Dump Site, the evaluation of hydrologic conditions based on the analysis of pesticide content in ground water sampled from piezometric outlets revealed 31 types of pesticide preparations (15 organochlorine pesticides, 10 organophosphorous pesticides, 6 phenoxyacids) four of which: p,p'-DDD – 0.128 µg/dm^3, p,p'-DDT – 0.146 µg/dm^3, MCPA – 0.642 µg/dm^3 and MCPP – 2.95 µg/dm^3 had concentration levels higher than the hygiene standard for drinking water (0.1 µg/dm^3) (Table 1).

The local hydrologic conditions in the areas neighbouring pesticide dump site as well as the high quantity of deposited chemicals (about 70 tonnes) enhance the dissemination of pesticides. This was manifested by the presence of pesticide residues in the water-bearing layer isolated from the bottom line of dump site by a boulder clay layer a few meters deep. The presence of a contaminated stratum under the clay layer is an evidence for a discontinuous hydrogeological structure and enhanced migration of dissolved pesticide contaminants deep into the soil profile.

A relatively high content of pesticide residues in the water-bearing level that was detected in the vicinity of the Kamion dump site indicates that its exploitation should be terminated. Once the source of contamination is eliminated, the emission of hazardous chemicals to the environment will be ended up. However, the environmental contamination from pesticide dumps has been so high that the self-purification of underground waters is expected to be a long-lasting process. Therefore, it will be necessary to monitor the drinking water quality within the study area. Moreover, the dug wells located at a distance

Table 1. Pesticide residues in ground water sampled in the vicinity of the Kamion Pesticide Dump

	Organochlorine pesticides (µg/dm^3)														
	Alpha-HCH	Beta-HCH	Gamma-HCH (lindan)	Delta-HCH	Heptachlor	Aldrin	Heptachlor epoxide	Endosulfan I	Dieldrin	p,p'-DDE	Endrin	Endosulfan II	p,p'-DDD	p,p'-DDT	Methoxychlor
Ia	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.001	0.001	0.001	0.005	0.005	0.001	0.010	0.10
Ib	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.028	0.001	0.078	0.005	0.005	**0.128**	**0.146**	0.10
IIa	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.033	0.001	0.006	0.005	0.005	0.001	**0.133**	0.10
S	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.001	0.001	0.001	0.005	0.005	0.001	**0.133**	0.10

	Organophosphorous pesticides (µg/dm^3)										Phenoxyacids (µg/dm^3)					
	Dichlorvos	Mevinphos	Thiometon	Diazinon	Metyl parathion	Malathion	Fenthion	Fenitrothion	Chlorfenvinphos	Ethyl parathion	2,4 - D	MCPA	2,4 - DP	2,4,5 - T	MCPP	MCPB
Ia	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.007	<0.009	0.006	0.005	0.007	0.01
Ib	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.007	0.009	0.006	0.005	0.007	0.01
IIa	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.007	**0.642**	0.006	0.005	**2.95**	0.01
S	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.007	0.097	0.006	0.005	**0.82**	0.01

* Single products – 0.100 µg/dm^3 except aldrin, dieldrin, heptachlor and heptachlor epoxide – 0.030 µg/dm^3

Ia – piezometer P-1 at bunker I; Ib – piezometer P-2 at bunker I; IIA – piezometer P-1 at bunker II; S – dug well located 900 m from dump site; Bold – concentration levels higher than the hygiene standard for drinking water (0.1 µg/dm^3);
* Regulation of the Minister of Health on the standards for drinking water quality dated 19 November 2002 [12].

of 1.5 km from the dump site will have to be excluded from exploitation.

As regards the Krupe Pesticide Dump, the contamination of ground waters with pesticide residues was already detected in 1995. Based on the pilot study results pointing to a negative environmental impact of this facility, a decision to close down this dump site was made in 2000. During the liquidation works, it was found that the chambers containing about 140 tonnes of hazardous chemicals were subject to periodical leachate. These conditions, taking place occasionally since 1972, when this dump site was established, caused a cycling dissolution of chemicals and their infiltration to the water-bearing layer. The process resulted in a considerable contamination of underground waters over the area surrounding the dump site. From the time the facility was closed down and pesticide wastes were removed, a gradual dilution of contaminants and self-purification of the water-bearing layer has been observed. The findings of the study indicate that four years after closing down this dump site, the content of pesticide residues in underground waters is still high. In ground water samples, 31 different pesticides were found (likewise at the Kamion site), including p,p'-DDT (0.133 μg/dm^3), methoxychlor (0.31 μg/dm^3), 2,4-D – 5.41 (μg/dm^3) and MCPP (12.30 μg/dm^3) whose concentration levels were higher than the drinking water standard (0.1 μg/dm^3) (Table 2). The results of the study, particularly the very high concentrations of 2,4-D and MCPP that exceed the standard value fifty times and one hundred times, respectively, confirm that the removal of pesticide wastes from this facility does not equal the elimination of pesticides from the former dump site area and that the problem of a possible impact on drinking water quality will continue for many years to come.

Potentially exposed population

The population living in the neighborhood of the Kamion dump site, just like people living near the Krupe site, may be exposed to pesticides released from accumulated wastes only via digestion as a daily intake in drinking water from the wells located up to 1.5 km away from the dump site. Individuals may also be exposed through consumption of farm crops cultivated on contaminated

Table 2. Pesticide residues in ground water sampled in the vicinity area of the Krupe Pesticide Dump

	Organochlorine pesticides (µg/dm^3)															Organophosphorous pesticides (µg/dm^3)										Phenoxyacids (µg/dm^3)					
	Alpha-HCH	Beta-HCH	Gamma-HCH (lindan)	Delta-HCH	Heptachlor	Aldrin	Heptachlor epoxide	Endosulfan I	Dieldrin	p,p'-DDE	Endrin	Endosulfan II	p,p'-DDD	p,p'-DDT	Methoxychlor	Dichlorvos	Mevinphos	Thiometon	Diazinon	Metyl parathion	Malathion	Fenthion	Fenitrothion	Chlorfenvinphos	Ethyl parathion	2,4 - D	MCPA	2,4 - DP	2,4,5 - T	MCPP	MCPB
I	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.001	0.009	0.001	0.005	0.005	0.001	0.010	0.10	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	**5.41**	0.009	0.007	0.005	**12.30**	0.01
II	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.001	0.002	0.001	0.005	0.005	0.001	0.010	**0.31**	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	–	–	–	–	–	–
III	0.01	0.01	0.01	0.01	0.02	0.002	0.002	0.001	0.002	0.001	0.005	0.005	0.003	0.010	**0.31**	0.07	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	–	–	–	–	–	–
IV	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.003	0.002	0.001	0.005	0.005	0.002	**0.133**	0.10	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	–	–	–	–	–	–
V	0.01	0.01	0.01	0.01	0.02	0.002	0.001	0.001	0.001	0.001	0.005	0.005	0.002	0.010	0.10	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	–	–	–	–	–	–
*	Single products – 0,100 µg/dm^3 except aldrin, dieldrin, heptachlor and heptachlor epoxide – 0,030 µg/dm^3																														

I – piezometer P-1 (50 m); II – piezometer P-2 (100 m); III – piezometer P-5 (100 m); IV – piezometer P-6 (200 m); V – piezometer P-8 (200 m); Bold – concentration levels higher than the hygiene standard for drinking water (0.1 µg/dm^3);
* Regulation of the Minister of Health on the standards for drinking water quality dated 19 November 2002 [12].

fields near the dump sites. The number of inhabitants living in the potentially hazardous area, i.e. up to 1.5 km away from the site, is estimated to be about 900 people. The children aged below 14 years, who are thought to be particularly sensitive to the toxic activity of pesticides, make up 17% of the potentially exposed population. The area is also inhabited by 200 women at reproductive age (aged 15–45 years). Several pesticides have been found to affect hormonal balance and produce reproductive disorders. Thus the female inhabitants may suffer from reproductive health effects. Moreover, environmental exposure in pregnancy may have impact on the course and outcome of pregnancy. The occupationally active male population (aged 15–60 years) makes 35%, while respective female population constitutes 31% (in total 66%) of the total population living in the vicinity (up to 1.5 km) of the dump sites. The working population may be additionally exposed to pesticides in the work environment. Assuming that about 300 persons live within a radius of 1.5 km from a dump site, we may estimate the size of the population potentially exposed to pesticides at all dump sites registered in Poland. Taking into account the 286 dump sites (both existing and remediated) contained in the NGI database, the population under conditions of potential exposure to pesticides from dump sites approximates 85 000 people.

Assessment of potential health hazards

Possible health hazards related to environmental exposure to pesticides released from the Kamion and Krupe dump sites were assessed for 11 pesticides, including 2 organophosphorous (dichlorvos, mevinphos), 6 organochlorine (endosulfan, dieldrin, heptachlor epoxide, p,p'-DDT, p,p'-DDD, p,p'-DDE), and 3 phenoxyacids (2,4-D, MCPA, MCPP) whose concentrations in ground water samples were above the detection limit of the analytical methods used (Tables 1 and 2). These pesticides, along with their CAS number, molecular and structural formula, exposure limits and health effects, are listed in Tables 3–5 [2].

Table 6 specifies the estimated levels of exposure to pesticides which showed ground water concentrations higher than the current standards for drinking water (p,p'-DDT, p,p'-DDD, methoxychlor, MCPP, MCPA, 2,4'-D) and displays the pre-assessment data on possible health risk calculated from daily intake in drinking water.

The magnitude of exposure to pesticides (p,p'-DDT – 0.15 μg/l; p,p'-DDD – 0.13 μg/l; MCPP – 12.3 μg/l; MCPA – 0.64 μg/l; methoxychlor – 0.31 μg/l; and 2,4'-D – 5.4 μg/l) showing mean concentrations in ground water, which exceeded the current standard for drinking water, ranged from 10^{-8} to 10^{-4} mg/kg/day. The relative cancer risk among people using drinking water contaminated with carcinogenic pesticides (p,p'-DDT and p,p'-DDD) was estimated at $R = 10^{-8}$.

The level of population exposure to 2,4'-D in the Krupe neighbourhood was three times as high as the reference dose (RfD) of $5 \cdot 10^{-5}$ mg/kg • day and posed a risk for the possible health effects, including reproductive disorders, nephro- and hepatotoxicity and hematopoietic effects. For the other, non-carcinogenic pesticides (MCPP, MCPA, methoxychlor), the relative risk was lower than unity (HQ < 1), indicating a very low, if any, probability of health effects of pesticide exposure in the population drinking contaminated water.

Table 3. Exposure assessment: organochlorine pesticides

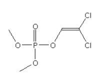
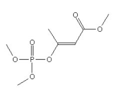
Pesticide	CAS No.	Molecular formula	Structural formula	Health effects (chronic exposure via digestion)	
				Limit values	Effect
Dichlorvos	62-73-7	$C_4H_7Cl_2O_4P$		$RfD = 5 \cdot 10^{-4}$ mg/kg • day	Activity inhibition of cholinesterase, RBC, and brain cells, disturbed hormonal balance
Mevinphos	7786-34-7	$C_7H_{13}O_6P$		$RfD = 2{,}5 \cdot 10^{-4}$ mg/kg • day	Activity inhibition of cholinesterase, plasma cells and brain cells

Tabela 4. Exposure assessment: organophosphorous pesticides

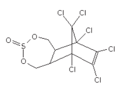
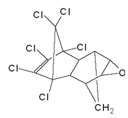
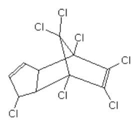
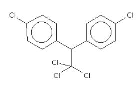
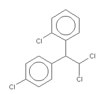
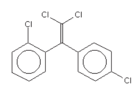
Pesticide	CAS No.	Molecular formula	Structural formula	Health effects (chronic exposure via digestion)	
				Limit values	Effect
Endosulfan	115-29-7	$C_9H_6Cl_6O_3S$		RfD = 6 • 10^{-3} mg/kg • day	Decreased body weight, increased number of cases of glomerular nephritis, liver tumors, disturbed hormonal balance
Dieldrin	60-57-1	$C_{12}H_8Cl_6O$		RfD = 5 • 10^{-5} mg/kg • day SF = 1,6 • 10^{-1} mg/kg • day	Increased liver mass, focal proliferation of the liver parenchymatous cells, disturbed hormonal balance Carcinogenicity: lymphosarcoma, gastric and liver cancers
Heptachlor epoxide	1024-57-3	$C_{10}H_4Cl_6O$		RfD = 1,3 • 10^{-5} mg/kg • day SF = 1,6 • 10^{-1} mg/kg • day	Increased liver mass, increased liver mass/body mass index, disturbed hormonal balance, reproductive disorders Carcinogenicity: liver cancer
p,p'- DDT	50-29-3	$C_{14}H_9Cl_5$		SF = 3,4 • 10^{-1} mg/kg • day	Carcinogenicity: liver cancer
p,p'- DDD	53-19-0	$C_{14}H_{10}Cl_4$		SF = 2,4 • 10^{-1} mg/kg • day	Carcinogenicity: liver cancer
p,p'- DDE	3424-82-6	$C_{14}H_8Cl_4$		SF = 3,4 • 10^{-1} mg/kg • day	Carcinogenicity: hepatocellular carcinoma, liver cancer
Methoxychlor	72-43-5	$C_{16}H_{15}Cl_3O_2$		RfD = 5 • 10^{-2} mg/kg • day	Damage to kidney, liver, and cardiac cells

Table 5. Exposure assessment: phenoxyacids

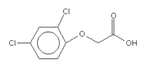
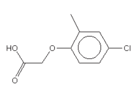
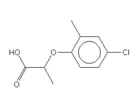
Pesticide	CAS No.	Molecular formula	Structural formula	Health effects (chronic exposure via digestion)	
				Limit values	Effect
2,4- D	94-75-7	$C_8H_6Cl_2O_3$		RfD = 5 • 10^{-5} mg/kg • day	Effect on the hematopoietic system, nephro- and hepatotoxicity, reproductive disorders
MCPA	94-74-6	$C_9H_9ClO_3$		RfD = 5 • 10^{-5} mg/kg • day	Nephro- and hepatotoxicity
MCPP	93-65-2	$C_{10}H_{11}ClO_3$		RfD = 10^{-3} mg/kg • day	Increased kidney mass and creatinine level

Table 6. Estimated exposure to selected pesticides released from the Kamion and Krupe dump sites: relative risk of health effects

Pesticide	Daily intake in drinking water (mg/kg • day)	Relative risk of health effects
	Kamion Dump Site	
p,p'-DDT	$5,4 \cdot 10^{-8}$	$R = 1,83 \cdot 10^{-8}$
p,p'-DDD	$5,2 \cdot 10^{-8}$	$R = 1,24 \cdot 10^{-8}$
MCPP	$8,4 \cdot 10^{-5}$	none (HQ < 1)
MCPA	$1,8 \cdot 10^{-5}$	none (HQ < 1)
	Krupe Dump Site	
p,p'-DDT	$5,4 \cdot 10^{-8}$	$R = 1,83 \cdot 10^{-8}$
Methoxychlor	$8,8 \cdot 10^{-6}$	none (HQ < 1)
MCPP	$3,5 \cdot 10^{-4}$	none (HQ < 1)
2,4'-D	$1,5 \cdot 10^{-4}$	HQ = 3

R – relative cancer risk (absorbed dose • SF);
HQ – hazard index (absorbed dose/RfD) for noncarcinogenic pesticides.

DISSCUSION AND CONCLUSIONS

Numerous epidemiological studies provide evidence that obsolete pesticide dumps pose a significant health hazard to the population of the neighbouring areas [14,15]. Croen et al. [16] in a case-control study on selected malformations in a population living near 746 dump sites of dangerous chemicals (including pesticides) showed an elevated risk of malformations in children whose parents lived within 0.5 km from the study sites. In a cross-sectional study on 49 people drinking water contaminated with organic chemicals from pesticide landfills, Clark et al. [17] showed the liver function impairment (elevated level of liver enzymes) in the control group, which receded two months after exposure cessation. The assessment of drinking water contamination with pesticides, carried out by Munger et al. [18] for the agricultural areas of Iowa, showed 12 pesticides, including 2,4-D, to be present in drinking water intakes, and surface and ground waters. The level of pesticide contamination at drinking water intakes located close to the dump sites points to the potential health effects in people using water from these intakes.

An analysis of the study results for the Kamion and Krupe pesticide dump sites makes us conclude that the populations living in the vicinity of these sites are exposed to pesticides released to the environment. The inhabitants of the areas adjacent to the Krupe dump site are at risk of health effects from 2,4-D exposure. For other pesticides, current exposure levels are not likely to pose a significant health risk to the population living near the dump sites.

It is found that 40% of the major dumping sites of obsolete pesticides are the largest potential hazard to human and environmental health. The sites are located at a relatively short distance from the residential areas, drinking water intakes and farmlands. The most prevalent pesticides detected in the dumps include organochlorine, inorganic, dihtiocarbamate and organophosphorous compounds. The dump sites examined constitute the main source of pesticide emission to the ground water. The main route of exposure is via ingestion of contaminated water from wells dug at 1.5 km away from dump site.

The level of exposure to 2,4'-D implies that people drinking the contaminated water are likely to develop impairments of hematopoietic system, nephro- and/or hepatotoxic effects and reproductive disorders. The estimated low-level exposure to p,p'-DDT, p,p'-DDD, MCPA, MCPP and/or methoxychlor would rather not produce adverse effects on human health. The closing down of a dump site will not bring an end to environmental emission of the contaminants to the soil and ground water. Therefore, the wells located within the pesticide migration area should be covered by an environmental monitoring system.

REFERENCES

1. Zakrzewski SF. *Principles of environmental toxicology.* Warszawa: Medical Publisher PZWL; 1995 [in Polish].
2. Krieger R.: *Handbook of Pesticide Toxicology*. 2nd ed. California: Academic Press; 2001
3. Hanke W, Jurewicz J. *The risk of adverse reproductive and developmental disorders due to occupational pesticide exposure: An overview of current epidemiological evidence.* Int J Occup Environ Health 2004;17(2):223–43.
4. Zahm SH, Devesa SS. *Childhood cancer: An overview of incidence trends and environmental carcinogens.* Environ Health Perspect 1995;103 Suppl 6:177–84.
5. Ma X, Buffler PA, Gunier RB, Dahl G, Smith MT, Reinier K, et al. *Critical windows of exposure to household pesticides and risk of childhood leukemia.* Environ Health Perspect 2002;110:955–60.

6. Nurminen T, Rantala K, Kurppa K, Holmberg P. *Agricultural work during pregnancy and selected structural malformations in Finland*. Epidemiology 1995;6(1):23–30.
7. Garry M, Schulman J, Cummins S, Harris J. *Pesticide appliers, biocides, and birth defects in rural Minnesota*. Environ Health Perspect 1996;47(2):147–54.
8. Munger R, Isaccson P, Hu S, Burns T, Hanson J, Lynch L, et al. *Intrauterine growth retardation in Iowa communities with herbicide-contaminated drinking water supplies*. Environ Health Perspect 1997;105(3):304–14.
9. Garcia A, Fletcher T, Benavides F, Orts E. *Parental agricultural work and selected congenital malformations.* Am J Epidemiol 1999;151(1):64–74.
10. Loffredo C, Sibergeld E, Ferencz C, Zhang J: *Association of transposition of the great arteries in infants with maternal exposures to herbicides and rodenticides.* Am J Epidemiol 2001;153(6):529–36.
11. Environmental Protection Agency (EPA). *Risk assessment guidance for Superfund*. Vol. I. *Human Health Evaluation Manual* [EPA/540/1-89/002]. Washington: Environmental Protection Agency; 1998.
12. Regulation of the Minister of Health on the standards for drinking water quality dated 19 November 2002. Journal of Laws 2002, 32, 284 [in Polish].
13. Agency for Toxic Substances and Disease Registry (ATSDR). *Public Health Assessment Manual.* Atlanta: Lewis Publication; 1992.
14. Johnson B: *Hazardous waste: human health effects.* Toxicol Ind Health 1997;13:121–41.
15. Johnson B. *Impact of hazardous waste on human health. Hazard, health effects equity and communications issues*. Atlanta: Lewis Publication; 1999.
16. Croen L, Shaw G, Sanbonmatsu L, Selvin S, Buffler P. *Maternal residential proximity to hazardous waste sites and risk for selected congenital malformations.* Epidemiology 1997;8(4):347–54,
17. Clark C, Mayer C, Gartside P, Majeti V, Specker B, Balistreri W, et al. *An environmental health survey of drinking water contamination by leachate from a pesticide waste dump in Hardeman County, Tennessee.* Arch Environ Health 1982; 7:9–18.
18. Munger R, Isacson P, Hu S, Burns T, Hanson J, Lynch C, et al. *Intrauterine growth retardation in Iowa Communities with herbicide-contaminated drinking water supplies.* Environ Health Perspect 1997;105(3):308–14.