

Environmental health in the east Baltic region — pesticides and persistent organic compounds

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Exposure to, and the potential effects of, pesticides and persistent organic pollutants in the East Baltic region are reviewed. Exposure of the average population to chlorinated compounds seems lower than in most of western Europe, and current pesticide use is very low. However, due to infrastructure failures and poor management controls, industrial hot spots and inadequate storage sites exist that cause high risks to small population fractions. The low exposure of the general population is indicated by low concentrations of polychlorinated dibenzo-*p*-dioxins, dibenzofurans and biphenyls in milk fat. Chlorophenol concentrations are also generally lower than in Scandinavia. Some organic pesticides have been found at higher concentrations in Baltic countries and the St Petersburg area than in Norway, but the range is roughly similar to that in central Europe. Thus the overall risk caused by pesticide residues and persistent organic compounds in the Baltic countries and northwestern Russia is low, but local sites of concern exist.

Key terms dioxins, insecticides, organochlorines, persistent pollutants, polychlorinated biphenyls, population exposure, 1,1,1-trichloro-2,2-bis(4-chloro-phenyl)ethane.

Pesticides are controlled chemicals in all European countries, and therefore their risk assessment and its outcome are conceptually different from most other environmental pollutants. The control measures of lead, ozone, or fine particulate matter are based on epidemiologic data or exposure studies with humans, and laboratory studies using experimental animals or cell cultures are used mostly as supplementary data for mechanistic purposes. On the contrary, the risk assessment of preregistered pesticides is almost solely based on toxicologic data and extrapolation using either large safety margins (100 to 1000 or more) or zero-risk extrapolation in the case of cancer risk. In the course of the practical use of a compound, also epidemiologic or clinical data may become available, but such data have rarely led to the liberalization of control measures, although in occasional cases it has led to stricter controls or a ban of the compound.

This practice of using 2 standards, based on an epidemiologic data base and usually rather small safety factors and on a toxicologic data base with large safety factors, has led to different average risk levels. The difference in outcomes using these 2 methods can easily be 100-fold or more. Even a relatively modest violation of

the air quality standard for ozone or the occupational threshold limit of lead exposure may cause health effects, whereas a modest violation of the acceptable daily intake (ADI) of pesticide residues in food usually has no health consequences whatsoever. Since safety is based on extrapolation, however, there is an element of uncertainty in this general truth. While the risk is generally very small, it is more difficult to exclude risk in the case of a particular chemical. An example is phenoxy herbicides, which have been regulated on the basis of the general toxicity in laboratory animals, but whose true risk for humans may be the induction of rare cancers such as lymphomas or soft-tissue sarcomas (1, 2). Often occupational risks are several orders of magnitude higher than consumer risks.

Dietary intake and other exposure data on pesticides have been relatively poorly documented in published literature in Europe (3) although monitoring programs exist in many countries. In general, calculated intakes of pesticides are only 1% or less of the ADI. Therefore the likelihood of toxicity is further diminished. The available data have been insufficient for the World Health Organization (WHO) to conclude that this assumption also

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applies to the countries of central and eastern Europe and the newly independent states (3).

Possible health outcomes caused by pesticides

The most relevant groups of pesticides as to acute effects are insecticides, especially cholinesterase inhibitors with organophosphate or carbamate structure, and some acutely toxic herbicides such as paraquat. However, all of these are either easily broken down in the environment or tightly bound to soil and therefore do not cause appreciable public health risks via residues. Their main risks are occupational, and in some countries the problem is notable (4). These aspects have not been dealt with in this review.

Long-term public health risks can mostly be attributed to pesticides that are persistent in the environment or tend to accumulate in food chains. Historically most publicity has been given to DDT [1,1,1-trichloro-2,2-bis(4-chloro-phenyl)ethane] and its metabolites, but most other organochlorine insecticides such as lindane (γ -HCH), aldrin, dieldrin, toxaphene, and chlordane belong to persistent compounds detected at low concentrations even in countries in which they were never used. In addition, phenoxy acid herbicides, as well as pentachlorophenol and 2,3,4,6-tetrachlorophenol wood preservers, can be included in the group of problem compounds, in part on their own right as possible carcinogens which may pollute ground waters, river sediments, and soil and in part because of their persistent minor impurities, polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/F), some of which are highly toxic.

The relevant health outcomes proposed for these compounds can be divided into 3 categories, risk of cancer, risk of developmental effects including hormonal outcomes, and immunologic effects. The strict registration practices in most countries, requiring large safety

margins, have substantially reduced these risks and caused the more dangerous compounds to be withdrawn from the market. Hence exceptional circumstances are a prerequisite for direct risks to the public. They could take place by 2 principal ways, through accidents causing, for example, major pollution of ground waters used for drinking water (5) and through bioconcentration to food items, notably to fish (6, 7). Indirect risks are more difficult to evaluate, the most noteworthy being transfer via milk from mother's adipose tissue to her breast-fed baby. This source concerns especially developmental effects, which can be considered to be the most likely of the mentioned effects (7, 8).

Use of pesticides in the Baltic countries

Herbicides are, by weight, the largest group of pesticides used in the Baltic countries, as they are in the Nordic countries also. An example is Estonia (figure 1). The peak in pesticide use occurred in 1986, and this is true also with Lithuania and Latvia. By European standards the figures are not high, the peak use in 1986 being less than 2 kg/ha (per total agricultural land area) in Estonia, less than 3 kg/ha in Latvia, and somewhat more in Lithuania. The peak levels were, in part, explained by the wide use of trichloroacetic acid, which is used in high doses. In countries of the European Union (EU), the use per hectare varies from about a kilogram or less (Sweden and Finland) to over 10 kg (Belgium and The Netherlands) (9, 10). During the 1990s the use of pesticides in all the Baltic countries has dropped to a small fraction of the former peak use, in part for economic reasons, in part because of "greener" attitudes (The trend in Estonia is representative of all 3 countries, see figure 1.)

All the Baltic countries have applied for membership in the European Union and are working towards

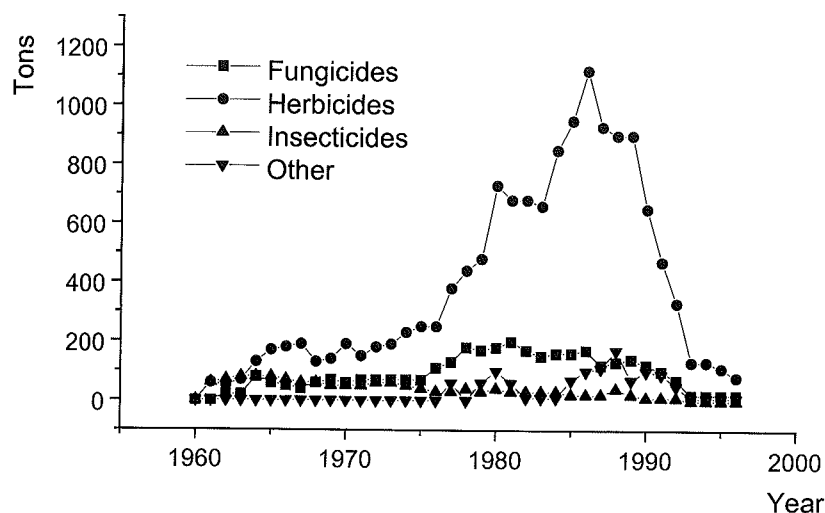


Figure 1. Use of pesticides (tons of active ingredients per year) in Estonia in 1960–1996.

harmonizing their regulations on pesticides and other chemicals accordingly (11). In principle, all new legislation is reviewed in an EU perspective before it is submitted to Parliament for adoption. In the process of drafting new laws, there is a clear trend to harmonize the legislation with corresponding EU legislation or comparable standards (11). Therefore future chemical risks should resemble those in other European countries.

The salient point then is the former use of stable chemicals whose elimination in the environment is slow and which are bioconcentrated along the food chain. They are, therefore, some chlorinated insecticides (such as DDT, lindane and chlordane), phenoxy acids and chlorophenols and their stable microcontaminants (ie, PCDD and PCDF). Disposal of stored pesticides such as DDT, inherited from the Soviet period, is a continuing problem. Other compounds, such as organophosphate insecticides and pyrethroids, can be viewed as occupational rather than environmental risks. Acute risks do not seem to differ from those in other European countries. For example, in Latvia pesticide poisonings comprised 1.6%, 0.8% and 0.6% of all poisonings in 1993, 1994 and 1995, respectively. At the same time drugs caused over 45% and alcohol about 40% of poisonings (12).

Another plausible risk is accidents due to failures in infrastructure and poor management controls. Historically, pesticides have caused a large number of poisoning episodes when deliberately consumed by poorly educated or poorly informed people (13), when stored or transported indiscriminately among flour or other foodstuff (14) or when adulterated food items such as oil were sold to the consumers (15).

Use of pesticides in the St Petersburg area

Exact information on the actual use of pesticides in Russia is not available. The Regional Department of Agriculture reports that the use of pesticides by controlled collective farms has dramatically decreased over the last 3 years due to the cut off of governmental subsidies received by agricultural enterprises. The total use of chlorinated and organophosphate pesticides in the region is roughly calculated to be of the order of 1.5 tons per year (30–150 kg per farm), which is low. There are no reliable data on the use in the private sector (Tchachtchine VP, personal communication).

Exposure to chlorinated insecticides

In some samples in Latvia rather high concentrations of DDT were found in plasma (table 1), and the rather high DDT:DDE ratio [DDE = 1,1-dichloro-2,2-bis(4-chlorophenyl)ethene] implies recent exposure. Chlorinated pesticides were found in all the studied milk samples in the Murmansk and Monchegorsk regions (18). The concentrations were higher than in Norway, but similar to those in many western European countries (table 2). The few available measurements in the St Petersburg area give about a similar range of organic chlorinated pesticides, both in blood (table 3) and in breast milk (table 4).

As measured in 1991–1995, surface water concentrations of pesticides in Lake Ladoga and in the upper part of the Neva river were found to be as follows: 2–7

Table 1. Lipid-related plasma levels (ng/g lipid) of p,p'-DDT, p,p'-DDE, and different polychlorinated biphenyl (PCB) congeners in men from Latvia and the east coast of Sweden, with varying intake of fatty fish from the Baltic Sea. [DDT = 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane, DDE = 1,1-dichloro-2,2-bis(4-chlorophenyl)ethene]

Compound	Latvia ^a (consumption of fatty fish)			East coast of Sweden (consumption of fatty fish)						
	Meals per month			Meals per month		None ^b X(N=8)	Moderate ^b X(N=7)	High ^b X(N=11)	Referents ^c	Baltic Sea fishermen ^c
	0	0.5	15	4 ^a	16 ^a					
p,p'-DDT	2613	65	74	75	115	20	45	130	..	..
p,p'-DDE	2214	1688	1282	1250	1193	750	1200	4500	..	..
Mono-ortho-PCB										
CB-118	85	149	60	94	210	41	76	160	55	123
Di-ortho-PCB										
CB-138	109	401	331	457	1148	..	..	..	106	322
CB-153	147	512	430	577	1611	470	580	1000	262	597
CB-170	27	103	93	174	493	..	..	..	103	254
CB-180	57	283	234	376	1238	400	400	600	256	511
Other PCB										
CB-146	17	76	55	69	235	..	..	..	..	..

^a Eva Klasson-Wehler, personal communication. The two Swedish subjects are also included in the study of Asplund et al (16), but separate analyses were performed. Blood samples from the Latvian subjects were drawn in 1993.

^b From Asplund et al (16); "moderate" consumption estimated at 108 (range 20–240) g/week, and "high" at 674 (range 400–1200) g/week. Blood samples were drawn in 1991.

^c From Svensson et al (17); the presented results are the means of 3 analyses of pooled samples from altogether 90 referents or 90 fishermen from the Swedish east coast.

Table 2. Residues of hexachlorobenzene (HCB), sum hexachlorocyclohexane (HCH), p,p'-DDT, p,p'-DDE, sum DDT and the DDT:DDE ratio in human milk from Murmansk and Monchegorsk (18). [DDT = 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane, DDE = 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane]

Residue	Concentration ($\mu\text{g/kg}$ fat weight)							
	Murmansk				Monchegorsk			
	Mean	SD	Median	Range	Mean	SD	Median	Range
Fat (%)	2.77	1.39	2.8	0.75—5.87	3.56	1.29	3.34	1.58—5.7
HCB	129	83	111	51—417	111	47	93	64—253
sum HCH	858	466	664	415—1996	745	295	612	475—1569
sum chlordane	59	38	52	16—167	33	24	21	17—90
p,p'-DDE	1269	530	1159	776—2816	892	220	884	548—1343
p,p'-DDT	178	174	103	17—713	145	71	123	59—242
sum DDT	1615	690	1332	886—3474	1154	265	1109	676—1664
DDT:DDE ratio	0.14	0.11	0.1	0.01—0.38	0.17	0.09	0.15	0.05—0.35

ng/l for total HCH, 0.8—3.0 ng/l for DDT/DDE/DDD [DDD = 1,1-dichloro,2,2-bis(4-chlorophenyl)ethane] and 7.0—17.0 ng/l for tetra-, penta- and hexachlorobenzene (HCB). Towards the inlet higher DDT/DDE/DDD concentrations of 6—10 ng/l were found (V. Tchatchchine, personal communication). Such figures do not indicate appreciable exposure to humans directly through water.

The Customs Laboratory of Finland monitors foodstuffs imported from other countries by multiresidue analysis (200 pesticides, mainly insecticides and fungicides, sensitivity 0.001—0.1 mg/kg depending on the substance), phenoxy acid analysis (2,4-D, MCPA, dichloroprop, mecoprop, sensitivity 0.05 mg/kg), and organochlorine analysis (neutral organochlorine pesticides such as DDT, dieldrin, HCH, sensitivity 0.005 mg/kg, used mainly for fish).

Among vegetable and berry products from Estonia, in 103 samples analyzed by multiresidue analysis, positive samples were found only for cucumber (twice endosulfan, 0.01 and 0.02 mg/kg, and once tolylfluanid, 0.02 mg/kg). Organochlorine analysis in fish revealed p,p'-DDE concentrations of 0.005—0.040 mg/kg. In Russian samples tiabendazole has been found once in watermelon. Hence only low levels of pesticides have been found in products coming from the Baltic countries or Russia, and the Finnish limit values have seldom been exceeded. This situation is in contrast to that for heavy metals, which are often found at concentrations exceeding the limit values (Pyysalo H, Siivinen K, personal communication).

Phenoxy acids

In all Baltic countries herbicides have been the prominent pesticide class by weight, and their use peaked in 1986. In Estonia over 1100 tons were used, in Latvia 3000 tons, and in Lithuania about 7000 tons. Since then the use has been drastically reduced, at least in part due

to economic constraints and difficulties in obtaining them. In the mid-1990s the use was less than 100 tons in Estonia, about 500 tons in Latvia, and less than 1000 tons in Lithuania. At the same time private international suppliers have taken over the market from the Soviet state organizations. Since the application equipment is in poor condition, the prime hazards from these chemicals can be considered to be occupational. Recently there have been some shifts to low-dose herbicides, but for financial reasons phenoxy acids are still generally used.

The Customs Laboratory of Finland has not detected phenoxy acids in forest berry samples imported from Estonia (Pyysalo H, Siivinen K, personal communication). Therefore, the general level of these impurities in the environment is relatively low.

Pentachlorophenol and other chlorophenols

The median lipid adjusted concentration of pentachlorophenol (PCP) in plasma was 475 (range 79—4734) ng/g lipid for 53 Latvian men; this value is significantly lower than the corresponding concentrations for 41 men from the Swedish east coast [median 1243 (range 368—5929) ng/g lipid $P < 0.001$] (Klasson-Wehler E, personal communication). Consumption of fatty fish from the Baltic Sea is not the route of exposure to PCP. In contrast, weak negative correlations between the intake of such fish and PCP in plasma were found for both Sweden and Latvia.

Human levels of polychlorinated dibenzo-p-dioxins and dibenzofurans and polychlorinated biphenyls

There are few studies on human PCDD/F and polychlorinated biphenyl (PCB) concentrations in Baltic

countries and in northwest Russia that would be strictly comparable with the values in other countries. Probably the most reliable data sets are those assays belonging to WHO/EURO studies or performed in laboratories contributing to these analyses, since these laboratories have undergone a meticulous intercalibration process.

WHO/EURO has coordinated 2 rounds of follow-up studies on the levels of PCDD, PCDF, and PCB in breast milk with the aim of evaluating their possible health risks, especially in infants, and preventing and controlling environmental exposure to them. Fourteen countries took part in the first follow-up study (21) in 1987–1988. A total of 30 countries initially expressed their willingness to participate in the second study in 1993, but only 19 countries were able to collect the samples and produce analytical data by the agreed deadline.

The results on the second round show that the levels of PCDD/F in Lithuania, Estonia, and St Petersburg are at the same level as in most European countries, but lower than in Belgium, The Netherlands, United Kingdom, and Spain (table 5). PCB concentrations in St Petersburg and Estonia were one-third the average European level, and at the same level as, for example, in Finland and Canada. The PCB levels in Lithuania were at the average European level.

Previous analyses provide about the same levels in Estonia (21.4 pg/g milk fat in Tartu, 13.5 pg/g in Tallinn) (23).

The results from the Baltic countries and St Petersburg are in agreement with those from other parts of the former Soviet Union. In a WHO/EURO study PCDD/F was 15.2 pg/g I-TEQ (I-TEQ = international toxicity equivalent) in an urban area (Archangelsk) and 5.9 pg/g I-TEQ in a rural area (table 5). In Murmansk and Monchegorsk in the Kola peninsula about 16 pg/g TEQ of PCDD/F and 12 to 14 TEQ of PCB were measured in pooled milk samples (18). However, localized contamination with TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), the most toxic PCDD congener, was seen in some areas of Kazakstan (24, 25), and this finding was associated with high I-TEQ values in breast milk in some persons. Previously similar relatively low levels have been measured in milk (26) and blood (27) in the general population of Russia. PCDD/F levels in food also seem to be relatively low in Russia (28). Local analyses in St Petersburg also support the notion that the PCB levels, although variable to some extent, are not generally higher than in other countries (table 4).

After industrial exposure, very high PCDD/F concentrations have been measured in chemical industrial areas such as Ufa (29). It is likely that contamination of a high degree is seen after large-scale production of 2,4,5-trichlorophenol (2,4,5-T) and other intermediates, pentachlorophenol, and agrochemicals such as 2,4,5-T in Ufa, Chapayevsk, Dzerzhinsk, and other industrial towns

Table 3. Ranges of organic pollutants in maternal plasma in the St Petersburg area (19). [DDT = 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane, DDE = 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane, HCH = hexachlorocyclohexane, HCB = hexachlorobenzene]

Compound	Concentration (ng/g)
DDT	50–280
DDE	90–2280
HCH	50–180
HCB	60–370
<i>trans</i> -Nonachlorine	110–420
Mirex	80–140

Table 4. Chlorinated organic compounds in breast milk in various areas of Russia (20). [HCH = hexachlorocyclohexane, DDT = 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane, DDE = 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane, PCB = polychlorinated biphenyls]

Location	Concentration (ng/g fat)				
	HCH	Chlordane	DDT	DDT/DDE	PCB
Severodvinsk	467	35	1336	0.16	517
Archangelsk	558	27	2088	0.20	516
Murmansk	858	59	1615	0.14	484
Monchegorsk	745	33	1154	0.16	535
Norilsk	..	..	..	..	799
Salehard	..	..	..	..	847
Norway	34	42	328	0.06	383

Table 5. Polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDD/F) and the marker polychlorinated biphenyl (PCB) (sum of IUPAC 28, 52, 101, 138, 153 and 180) concentrations in human milk in 1993 (22).

Country ^a	PCDD/F (pg TEQ/g fat)		Marker PCB (ng/g fat)	
	Urban area	Rural area	Urban area	Rural area
Austria	10.7	10.9	381	303
Belgium	26.6	20.8	261	276
Canada	13.4	10.8	137	86.1
Croatia	13.5	8.4	220	218
Czech Republic	18.4	12.1	1069	532
Denmark	15.2	..	209	..
Finland	21.5	12.0	189	134
Germany	16.5	..	375	..
Hungary	8.5	7.8	61.3	45.0
<i>Lithuania</i>	13.3	14.4	322	287
The Netherlands	22.4	..	253	..
Norway	10.1	9.3	273	265
Pakistan	3.9	..	18.9	..
Russia	15.2	5.9	197	102
Slovakia	15.1	12.6	1015	489
Spain	25.5	19.4	452	461
Ukraine	13.3	..	191	..
United Kingdom	17.9	15.2	130	131
<i>St Petersburg^b region of Russia</i>	16.4	..	190	..
<i>Estonia^b</i>	14.4	12.4	103	136

^a The East Baltic areas are in italics.

^b Unpublished data analyzed simultaneously with the WHO study (courtesy of Professor Terttu Vartiainen)

(30, 31). It is very difficult, however, to reconstruct the transportation of these impurities to other parts of the former Soviet Union, including the present Baltic countries. Undoubtedly both phenoxy acid herbicides and chlorophenol wood preservatives have caused both local and dispersed contamination at the sites of final product use.

All accounts available today point to a relatively low PCDD/F exposure of the general population in the former Soviet Union, but to the existence of a few hot spots where the exposure to dioxins, including TCDD, has been higher than almost anywhere in Europe. These areas can be found especially in the industrial towns between the Volga and the Ural Mountains. The lower general environmental levels of chlorinated compounds in the former Soviet Union than in western Baltic countries are also supported by recent comparative information on halogenated organic material in the bottom sediments of the Gulf of Finland (32).

Concluding remarks

By all measures available today, it seems that the general widespread exposure to pesticide residues or persistent organic compounds from the environment in the Baltic countries and northwest Russia is lower than in most of western Europe. Hence general public health effects are not likely. The most obvious problem is the industrial hot spots in the former Soviet Union, and old storage sites where large amounts of chemicals may not be in proper control and therefore cause health hazards to the near vicinity.

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