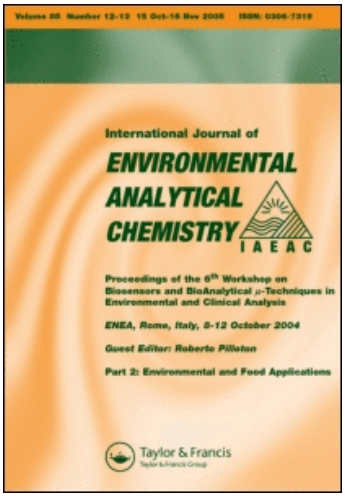

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OCCUPATIONAL EXPOSURE TO PESTICIDES IN FINLAND

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The annual use of pesticides in Finland counted as ingredients has been around 2000 tons from the seventies. Herbicides, which are mostly used in agriculture, are almost 80% of the total use of pesticides. Amount of workers occupationally exposed to pesticides is about 170 000. Farmers are the largest group among exposed persons. Their number is around 50 000 but their exposure periods last only for few days every summer. In greenhouses, around 20 000, and in forestry, nearly 1500 workers are exposed to pesticides with more regular and longer lasting exposure than that of farmers. In the Finnish Register of Occupational Diseases, 79 cases caused by pesticides were reported during the years 1972–1991. Most of the cases were from greenhouses, agriculture and forestry. Typical symptoms in reports were toxic eczema or acute symptoms. Occupational exposure of workers to pesticides in Finland has been mainly studied by the Kuopio Regional Institute of Occupational Health since 1978. Exposure levels have been evaluated by occupational hygienic measurements and biological monitoring. Field studies done in agriculture, forestry and greenhouses revealed that exposure of the workers in most cases is at low level. Skin contamination is the main factor of exposure. Therefore, the use of personal protective clothing is essential for minimising exposure. Situations, where risk for exposure is high, are the dilution of formulation before spraying, preparation of equipment on fields, and contamination of skin when the work is started immediately after applications on fields and in greenhouses.

KEY WORDS: Occupational exposure, biological monitoring, pesticides, Finland.

INTRODUCTION

The annual use of pesticides in Finland counted as active ingredient is about 2000 tons. It has been at this level since 1970 following closely of the area for cultivation of crops. Herbicides are almost 80% of the total amount of pesticides calculated as active ingredients. Phenoxy herbicides are used as active ingredients annually around one thousand tons in agriculture[1]. Fungicides and insecticides are each used about 150 tons. The most important group of chemicals among fungicides are dithiocarbamates. Formulations containing maneb as an active ingredient are annually sold almost 100 tons. Among insecticides, organophosphorous compounds, dimethoate, and malathion are by far most important pesticides used in agriculture[1].

The amount of workers occupationally exposed to pesticides in Finland is about 170 000. Farmers are the largest group. Roughly 50 000 farmers use herbicides every summer during

a few days. Longer lasting and more regular exposure to pesticides occurs in greenhouses where almost 20 000 workers are exposed during applications of pesticides and while handling flowers containing pesticide residues. Forestry workers are exposed to pesticides when coppice is applicated with herbicides or when plant seedlings are sprayed with fungicides and insecticides in forestry nurseries. The amount of workers exposed to pesticides in forestry has been calculated to be about 1500 and exposure periods can last for several weeks during the summertime[2].

EVALUATION OF OCCUPATIONAL EXPOSURE

Occupational exposure of workers to pesticides in Finland has been mainly studied by the Kuopio Regional Institute of Occupational Health since 1978. Exposure levels have been evaluated by occupational hygienic measurements and biological monitoring. Significance of inhalation exposure is estimated by comparing the results from air samples at the breathing zone with occupational exposure limit values. Most of the Finnish values for pesticides are adopted from the ACGIH (American Conference of Governmental Industrial Hygienists).

Inhalation exposure has been studied by collecting air samples at the breathing zone of workers on membrane filters, into solid sorbents or in absorption liquids[3,4]. Skin contamination has been estimated by patch samples and by taking hand wash samples[16]. The penetration of the chemical into a body during exposure was estimated either by determining the concentration of the parent chemical[3,7] or its metabolite[9,11] in urine or measuring the effect of the chemical in biological fluids, e.g., the inhibition of cholinesterase activity in blood after exposure to organophosphorous compounds[17,19]. The analytical methods used were gas chromatographic for phenoxy acids[3] and organophosphates[14,15,16], liquid chromatographic for benomyl[15], and atomic absorption spectrophotometric for maneb[12].

HERBICIDES

Farmers are the biggest group of workers who are exposed to chlorinated phenoxy acid herbicides in Finland since phenoxy acid herbicides are largely used as weed killers in agriculture. The study on exposure of Finnish farmers to chlorinated phenoxy acids was performed in 1986[3]. In that study, exposure levels of farmers were evaluated by measuring air concentrations of the pesticides at workers' breathing zone and by urine analysis. Skin contamination was evaluated by patch tests. The field study was made on 17 farms. Sprayed field areas varied from two to twenty-two hectares. Pesticide applications were done by using tractor sprays. The application rate of pesticide was about 1.4 kg/ha. Both liquid and powdered formulations were used. Formulations contained MCPA, (4-chloro-2-methyl (phenoxy) acetic acid, dichlorprop, 2-(2,4-dichlorophenoxy) propanoic acid, mecoprop, 2-(4-chloro-2-methylphenoxy) propanoic acid, and dicampa, 3,6-dichloro-2-methoxybenzoic acid. Herbicides were formulated as either sodium, potassium or dimethylamin salts. The formulations did not contain 2,4-D or 2,4,5-T. Pesticide applica-

Table 1 Exposure of the farmers to phenoxy acid herbicides during application of crop on fields by a tractor spray.

Exposure measurements	*Mean*	*Range*	*No of samples*
Ambient air			
powder formulation	0.06 μg l^{-1}	0.007–0.2 μg l^{-1}	9
liquid formulation	0.01 μg l^{-1}	0.001–0.05 "	16
Skin contamination			
outer side of clothing	26.4 mg h^{-1}	0.22–105 mg h^{-1}	16
inner side of clothing	1.5 mg h^{-1}	0.01–13.9 mg h^{-1}	16
Urine samples			
powder formulation	1.6 mg l^{-1}	0.08–2.5 mg l^{-1}	3
liquid formulation	1.1 mg l^{-1}	0.06–5.7 "	13

tions were made in May and June. Applicators were male farmers or their family members (age 19–65 years). Most of them wore protective clothing, either coveralls or trousers and a jacket. Materials of their protective clothing were cotton and polyester. Respiratory protective devices were used in few cases during the dilution of formulations. The devices were half-face masks or disposable dust masks. Spraying times varied from 0.5 to 5.0 hours in a day[3].

Phenoxy acid concentrations at the breathing zone of workers were low, from 0.001 to 0.2 μg l^{-1}. Exposure levels were significantly higher among those workers who used powdered formulations ($p < 0.01$). Clothing was contaminated according to patch tests, but clothing, however, prevented major part of pesticides from reaching the skin. Exposure was higher through skin than through inhaling. Phenoxy acid concentrations in workers' urine were below 5.7 mg l^{-1} (range from 0.06 to 5.7 mg l^{-1}). These results showed that major route of absorption is the skin (Table 1).

Chlorinated phenoxy acid herbicides are also used in silvicultural clearing work. Exposure of Finnish forestry workers have been evaluated in few studies[4,5]. The concentrations of MCPA and 2,4-D at the breathing zone of workers were below the threshold limit value, 10 μg l^{-1}, ranging from 0.01 to 0.55 μg l^{-1}. Concentrations of MCPA and 2,4-D in workers' urine were below 10 mg l^{-1}. Exposure levels differed from each other depending on the spraying method. The method where a worker carried a power spray on his back caused the highest exposure. Exposure levels of forestry workers were studied two years after that study and were noticed to be slightly lower compared to the afore-mentioned levels, ranging from 0.1 to 0.9 μg l^{-1} at the breathing zone of workers and urine concentrations being below 2 mg l^{-1}. Clinical blood tests showed that no statistically significant differences in haematological parameters and in the enzymes activities of the liver were noticed between the exposed and non-exposed workers.

Protective properties of the materials used for protective clothing in herbicide work in Finland have been studied by Ojanen *et al.*[7]. Best materials for that use were polyurethane-coated polyamide, water-repellent polyester, Gore-Tex® Fabric, cotton, and cotton polyamide (60/40) finished with fluorocompounds. The use of protective clothing made of these materials in silvicultural clearing work reduced the exposure of workers to a lower level than reported in earlier studies[4,5,6].

The use of glyphosate, Roundup® by trade name, has been increased in Finland since the use of chlorinated phenoxy herbicides has been recently reduced among forestry workers. The exposure levels of workers to glyphosate were low, being at its highest 15.7 ng l^{-1} at the breathing zone of a worker. Concentrations of glyphosate in workers' urine were below 0.17 mg l^{-1}[18].

Atrazine containing formulations are also used as herbicides in silvicultural clearing work. Exposure of railway men to atrazine was evaluated in a field study in 1988[9]. Exposure levels during spraying were from 0.2 to 0.8 μg l^{-1} at the breathing zone of workers and from 6.5 to 23.8 mg l^{-1} in urine[9]. The air concentrations are low compared to the occupational exposure limit value, 10 μg l^{-1}.

FUNGICIDES

Dithiocarbamates are the most commonly used compounds among fungicides in Finland. The commercial products of maneb and mancozeb are used in potato farms to control potato late blight and in forestry nurseries mainly against dieback and canker fungus of pines as well as against pine needle cast. Until these days, powder formulations of dithiocarbamates have been used both in forestry nurseries and on potato fields. In forestry nurseries the spraying period starts in June and continues to October depending on climatic conditions. The frequency of applications varies between nurseries, but plants are usually sprayed every second week. In potato fields application of fungicides is not done very often and regularly except during rainy summers. Then potato fields are sprayed several times before harvesting. Tractor sprays are used both in potato fields and in forestry nurseries and the application usually lasts from few hours to one day. Workers' exposure during spraying of maneb in forestry nurseries has been studied by several researchers[10,11,12,13]. Exposure levels calculated from the results of Tervo *et al.*[13] are shown in Table 2. In all studies the ambient air concentrations were low as well as the concentrations of ethylenethiourea (ETU) in urine, a metabolite of dithiocarbamates. ETU has been used as an indicator for the exposure of dithiocarbamates[11]. The exposure of workers on potato fields to dithiocarbamates based on the measurements of ETU concentrations in ambient air was lower than that of workers in forestry nurseries. The ETU concentrations in urine were, however, higher among the potato

Table 2 Exposure of the workers to maneb during applications with a tractor spray in forestry nurseries.

Exposure measurements	*Mean*	*Range*	*N*
Ambient air			
—breathing zone	0.03 μg l^{-1}	< 0.02–0.08 μg l^{-1}	10
—weighing and mixing	0.8 μg l^{-1}	0.03–4.0 μg l^{-1}	10
Contamination of clothes	0.4 mg h^{-1}	0.2–0.6 mg h^{-1}	20
ETU in workers' urine	1.6 μg l^{-1}	0.65–3.7 μg l^{-1}	35

N = number of samples

farmers than among the nursery workers. This is due to a better personal protection of applicators in forestry nurseries than that of workers on potato fields. In greenhouses, occupational exposure of workers to benomyl and sulphur was studied by measuring concentrations of these compounds during and after an application. Sulphur concentrations were high (1–2 μg l^{-1}) in the air of a greenhouse after fumigation causing respiratory symptoms to workers. The average benomyl concentration (0.027 μg l^{-1}) in the air was far below occupational exposure limit value 10 μg l^{-1} during the application according to a study done in 17 greenhouses[14].

INSECTICIDES

Horticulture is continuously growing in Finland. Organophosphates are the most important and the biggest group of insecticides applied in greenhouses. Dichlorvos, dimethoate, and mevinphos are the most usual pesticides but nicotine and aldicarb are also still used. New application methods have increased use of permethrin and deltamethrin.

Pesticide concentrations in greenhouse air depend on the application method. The dichlorvos and nicotine concentrations after fumigation were really high, 5.3 μg l^{-1} (mean) and 9.6 μg l^{-1}, respectively[14,15]. Traditional spraying caused only 6.7 ng l^{-1} of mevinphos in the air and non-thermal foggers 68.8 ng l^{-1}[16]. It is common practice to apply pesticides in the evening and ventilate the greenhouse for a couple of hours in the morning before plant handlers' and harvesters' work[14].

Dermal exposure and the protection efficiency of clothing was evaluated with absorbent pads placed outside and inside of all clothing with an identical location on both sides. In the study where mevinphos was applied, sprayers' exposure was negligible when they used proper protective clothing. The patch samples showed that the plant handlers were exposed to small amounts of mevinphos even during the second day after the application[16]. Foliar samples are collected for establishment of re-entry intervals for workers. A leaf-punch method is usually applied to gauge the amount of dislodgeable residues or degradation products of the pesticides. When dissipitation of dimethoate was followed in the rose greenhouses the maximum amounts were measured 2 to 4 hours after the spraying. The mean half-life of dimethoate was 21 h. Only traces of dimethoxon were detected in the leaf samples[14]. The mevinphos concentrations in the foliar samples depended on the method of

Table 3 Pesticide concentrations in the greenhouse air by different application methods.

Pesticide	*Application method*	*Mean*	*Range*	*No of samples*	*Reference*
Dichlorvos	fumigation	5.3 μg l^{-1}	3.6–7.0 μg l^{-1}	14	(15)
Nicotine	fumigation	9.6 μg l^{-1}	0.2–63.3 μg l^{-1}	28	(14)
Mevinphos	manual spraying	6.7 ng l^{-1}	4.8–8.0 ng l^{-1}	4	(16)
Mevinphos	non-thermal fogger	68.8 mg l^{-1}	60.7–76.9 mg l^{-1}	2	(16)

application. The amount was the highest, 140 ng cm^{-2} in the plant stands where a fogger was used for application. The mevinphos concentration was 140 ng cm^{-2} after the use of a mist blower and only 15 ng cm^{-2} when the application was carried out with a manual sprayer[16]. The results showed that a special attention should be given to plant handlers' exposure and not to concentrate only on evaluation of applicators' exposure.

Reduction of plasma butylcholinesterase (PChE) and red blood cell acetylcholinesterase (AChE) activity was followed when mevinphos was applied in greenhouses. The decrease in red blood AChE was 0–26% and in plasma PChE 2–29% from the initial values of the sprayers. The plant handlers were also exposed as indicated by 0–24% and 0–15% decrease in AChE and PChE, respectively[17].

ASPECTS OF OCCUPATIONAL EXPOSURE TO PESTICIDES

The studies conducted in the Finnish Institute of Occupational Health have revealed that occupational exposure to pesticides is generally low. One reason might be that northern climate gives special protection against plant diseases and insects. Therefore, pesticides are not needed to use as much as in southern European countries. Much more important reason is that workers are well educated and experienced in safety work habits. The Finnish population exposed to pesticides is not big enough by numbers for the evaluation of health effects by epidemiological studies.

In the Finnish Register of Occupational Diseases there are 79 cases of occupational diseases caused by pesticides during the years 1982–1991. Most of the cases were greenhouse workers or workers from agriculture or forestry. Typical symptoms reported were toxic eczema, headache, vomiting or nausea[18].

An important result of our studies is that the most dangerous work phases; the dilution of formulations and applications immediately after spraying and application methods have been found and workers and safety personnel have been properly advised. Skin contamination is the main factor of exposure. Therefore, the use of protective clothing is also essential for minimising exposure. The most contaminated skin areas during spraying and nursing the plant stand are arms and legs, which are the most likely skin areas to come in contact with the foliage during plant handling and collection of flowers.

The Institute provides biological monitoring services to the occupational health care stations. More than one thousand samples are routinely analysed for continuos follow-up of pesticide exposure of sprayers and other workers. Samples for blood cholinesterase activities from about 500 greenhouse workers are annually followed in out laboratory. Reduction of the activity of more than 30% is not noticed in more than 1–2% of samples. Biological monitoring is according to our experience proved to be the most convenient method for the estimation of workers' exposure to pesticides.

The calculation of the re-entry interval according to the present methods produces inadequate values, most likely due to dermal exposure and complexicity of the relative parameters[14,16]. Our approach has been to calculate the theoretical value and reconsider it for practical work before recommendations to the field.

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