ASSESSMENT OF BELGIAN FLORISTS EXPOSURE TO PESTICIDE RESIDUES

K.TOUMI[1], L.JOLY[2], C. VLEMINCKX[2] & B. SCHIFFERS[1]
[1]Gembloux Agro-Bio Tech/ULiege – Pesticide Science Laboratory
Passage des Déportés 2, 5030 Gembloux (Belgium)
[2]Sciensano, SD Chemical and Physical Health Risks
Rue Juliette Wytsman 14, 1050 Brussels (Belgium)
Corresponding author E-mail: khaoula.toumi@doct.uliege.be

SUMMARY

Pesticides are known to be widely used on flowers to control insects and diseases during cropping. As a result, florists who handle daily a large number of flowers can be exposed to their residues. A study was conducted among Belgian volunteer florists to assess their exposure: sampling of flowers, residue analysis, transfer of residues from flowers to hands and their absorption through the skin after contact. 90 bouquets (roses, gerberas, and chrysanthemums) were collected in Belgium to be analysed. Florists were requested to wear during their professional activities two pairs of cotton gloves during two consecutive half days in order to assess the potential transfer to their hands and the dermal exposure. Finally, during the three most important periods for the sale of flowers in Belgium (Valentine's Day, Mother's Day and All Saints' Day), 84 urine samples were collected from florists and control groups (24-hour urine) to assess the total exposure by measuring the concentrations of pesticides (parent compounds and metabolites). A huge variety of pesticide residues were detected: 107 on bouquets and 111 on the gloves. A total of 70 different pesticide residues and metabolites were identified in urine of florists. A vast majority of pesticide residues identified on cut flowers and on cotton gloves were also found in urine samples. A clear relation was then established between dermal exposure and excretion of pesticide residues in florist urines. Exposure was particularly critical for clofentezine with a maximum systemic exposure value four times higher than the acceptable exposure threshold (393% AOEL). Moreover, clofentezine was detected in urine of florists. In conclusion, the study leads to conclude that Belgian florists are exposed daily to pesticide residues, with potential effects on their health. Therefore, there is an urgent need to raise the awareness about pesticides residues among florists who should adopt better personal hygiene rules and among authorities who could strengthen the controls on imported cut flowers and set safety standards such as Maximum Residue Limits for residues on cut flowers.

Key words: pesticide residues, dermal exposure, biological monitoring, risk assessment, florists

INTRODUCTION

Floriculture has become an important agricultural sector and a worldwide commercial activity. It has emerged as a lucrative production with a much higher potential for returns compared to other horticultural crops (Sudhagar, 2013). The flower industry occupies an important place in both developed and underdeveloped countries, with an annual global trade value of more than US$100 billion (Riasi and Amiri, 2013). Developed countries with high per capita incomes obviously are the major consuming markets which imported millions of flowers produced in Africa (Ethiopia, Kenya), Asia (India, Malaysia) or Latin America (Ecuador and Colombia). Cut flowers have a great demand and befit all occasion, therefore they are sold throughout the year with peak periods (Valentine's Day, Halloween, Mother's Day, New Year, etc.). Among continents, European countries accounted for the highest dollar value worth of flower bouquet exports during 2017 with shipments amounting to $4.9 billion or 56% of the global total (Word's Top Export, 2017). With a combination of locally produced flowers and imported flowers, the Netherlands is a dominant central market for global cut flower trade (CBI, 2016; Lichtfouse, 2018). As in any intensive culture, pesticides are deemed necessary by the great majority of flower growers in order to provide high crop yields and to achieve production on a large scale and good quality for competitive prices on both national and international markets (Cooper and Dobson, 2007; Bethke and Cloyd, 2009). Unlike other crops which are harvested for dietary consumption, flowers are usually sprayed at high dosages and with a wide range of pesticides because of the weakness of local regulations, the lack of establishment of maximum residue limits (MRL) for flowers and the lack of controls at the European entry points (Toumi *et al.,* 2016a and 2016b).

No one can deny that pesticides have been proved to be effective during interventions to prevent possible attacks of pests and diseases. However, despite their popularity and extensive use, it remains important to remember that pesticides could entail risks for human health, mainly when people ignore safety precautions. The relation between exposure to pesticides and possible serious health concerns for exposed floriculturist operators and workers have frequently been reported and well documented (Restrepo *et al.,* 1990a and 1990b; Fleming *et al.,* 1999; Munnia *et al.,* 1999; Bolognesi, 2003; Lu, 2005; Defar and Ali, 2013; Blanco-Muñozet *et al.,* 2016).

Many pesticide applied to cut flowers are persistant, dislodgeable, fat-solubles and absorbed through skin contact. In addition, some pesticides may have a rather high volatility and could be dispersed in the atmosphere of the working area. Consequently, Belgian florists who are in contact with cut flowers, daily and for several hours, can potentially be exposed to residues with potential effects on their health (Toumi *et al.,* 2016a).

Therefore, the exposure assessment of Belgian florists to pesticide residues on cut flowers was deemed necessary to evaluate the potential risk for their health and to be able to recommend measures and efforts to reduce pesticide exposure through better practices.

MATERIALS AND METHODS

To assess the risk of exposure of Belgian florists to pesticide residues, the study was conducted in three stages:

Hazard identification and characterization

To assess the average level of contamination, 90 samples of the most sold cut flowers in Belgium (roses, gerberas and chrysanthemums) were randomly collected in Belgium at the shop level to be analyzed. Simultaneously, a survey (observations and questionnaire) was conducted among 25 florists to define their usual working practices, which helps to establish realistic exposure scenarios.

Potential dermal exposure (PDE)

In order to evaluate the transfer of these residues to hands, cotton gloves (2 pairs / individual) were distributed to 20 volunteer florists and worn for two consecutive half-days (from min 2 h to max 3 h/day) during the handling of flowers and preparation of bouquets to estimate their potential dermal exposure. The pesticide residues in cut flowers and cotton gloves were determinate through a multi-residue method using gas and liquid chromatography coupled to tandem mass spectrometry. Analysis were performed in a laboratory holding a BELAC accreditation to ISO/CEI 17025 for pesticide residues in vegetable products (PRIMORIS, Technologiepark 2/3, 9052 Zwijnaarde – Ghent).

For each active substance (a.s.), a PDE value was calculated as follows (Toumi *et al.*, 2017a, 2018a and 2018b):

$$\text{PDE (in mg a.s./kg bw per day)} = ((C_T \text{ (mg/kg)} \times \text{GW (kg)}) \times 3)/\text{bw (kg)}$$

where C_T is the concentration of active substance in the sub-sample during the task duration of the trial (2 h), GW is the average weight of the cotton gloves samples (57 g ± 0.17 g), 3 is a correction factor (total task duration value equal to 6 h/day) and bw is the body weight (60 kg). A recent publication mentioned that 60% of the Belgian florists worked between 6 and 7 hours/day (Toumi *et al.*, 2016a). A default body weight (bw) value of 60 kg is used in line with the recent EFSA Guidance Document to cover a range of professionally exposed adults (EFSA, 2014).
The PDE values were then converted into systemic exposure values (SE) using an appropriate dermal absorption percentage of 75% (default value) (EFSA, 2012) as follows:

$$\text{SE (mg / kg bw per day)} = \text{PDE (mg / kg bw per day)} \times 0.75$$

The risk characterization is obtained as the ratio of the systemic exposure to the reference threshold value of each active substance, the AOEL (Acceptable Operator Exposure Level; in mg a.s./kg·bw per day).

Total exposure (biomonitoring)

Human biomonitoring represents realistic exposure and provide evidence of human exposure to pesticide residues integrating all routes of exposure (oral, dermal and inhalation) and different sources (feeding, pets, etc.). In order to evaluate the total exposure, urine samples (28 samples per period) from florists and from a reference group (24-hour urine) were collected during the three important periods of sales in Belgium (Valentine's Day, Mother's Day and All Saints'Day).

For urine samples, an analytical multi-residue method has been developed, based on the analysis results found from cut flowers and dermal exposure, to measure pesticide residues and their specific metabolites. The residual pesticide excreted in urine samples were identified and analyzed using liquid chromatography coupled to tandem mass spectrometry and according to a validated internal procedure in a Belgian laboratory (SCIENSANO) accredited ISO/IEC 17025:2017 for chemical residues and contaminants.

RESULTS AND DISCUSSION

Contamination of cut flowers

Cut flowers samples appeared to be heavily contaminated by pesticide residues whatever their origin (produced in EU or outside EU). A total of 107 different pesticide residues were detected from all samples, with an average of about 10 pesticide residues per bouquet. The most severely contaminated bouquet accumulated a total concentration of residues up to 97 mg/kg (Toumi *et al.,* 2016a). Results show that roses are the most contaminated cut flowers, with an average of 14 substances detected per sample and an average total concentration per rose sample of 26 mg/kg (Toumi *et al.,* 2016b).

Potential dermal exposure

Exposure scenario

Belgian florists are exposed by three exposure routes that are (1) mainly cutaneous by coming into manual contact with cut flowers and greens previously treated with pesticides, (2) respiratory by breathing volatile active substances (e.g. diazinon, etridiazole, fenpropidin, omethoate, propamocarb, triforine; see table1), especially because the store of florists constitutes a very confined environment and secondarily (3) oral route that occurs accidentally by contact of the mouth with contaminated hands. Especially, bad habits (12% of florists smoke during handling flowers and preparing bouquets) and lack of observation of hygiene rules (88% of the florists eat and drink while working) reported during the survey contribute to increase the risk of exposure of florists to pesticide residues. Behavioral observations of florists made during the survey show that 96% of the florists wear no special clothing during their professional tasks and only 20% of them use occasionally latex gloves when preparing bouquets and handling flowers (Toumi *et al.,* 2016a).

Dermal exposure

A total of 111 different pesticide residues were detected on 20 cotton glove samples, with an average of 37 pesticide residues per sample and an average total concentration per glove sample of 22.22 mg/kg (Toumi *et al.*, 2017b). In the worst case, four active substances (clofentezine, famoxadone, methiocarb, and pyridaben) have values of SE_{MAX} (SE at the maximum concentrations) exceeding their respective AOEL values. Exposure could be particularly critical for clofentezine with an SE_{MAX} value four times higher than the AOEL (393%) (Toumi *et al.*, 2017b). A linear relationship exists between the pesticide residues present on cut flowers and dermal exposure of florists since about 70% of pesticide residues were detected on both cut flowers and on gloves worn by florists during their professional tasks (Table 1).

Total exposure

The skin protects the body against external aggressions. But, it does not constitute a watertight barrier since different elements are able to cross it. The skin may be a target or a preferred entry point for many pesticides, especially for the majority of active substances detected on flowers and florists 'hands which can bioaccumulate (table 1). Therefore, several pesticide residues having an acute and/or chronic toxicity (Table 1), could be absorbed and pass into the human body and be excreted in the urine. A total of 70 pesticide residues and metabolites were identified in urines of florists. It could be shown that a linear relationship existed between dermal exposure and excretion of pesticide residues in urine of florists since the method used for urine analysis is able to detect residues (pesticides residues and their specific metabolites) analysed using liquid chromatography coupled to tandem mass spectrometry and previously found on cut flowers and/or on the hands of florists.

Table 1. Physicochemical and toxicological properties of pesticide residues and metabolites detected on cut flower samples and / or cotton gloves worn by Belgian florists and/or excreted in urines during handling flowers and preparing bouquets (For flowers and cotton gloves, active substance and its metabolites were counted as one pesticide residue)

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
2CTCA			X	-	-	-
3-hydroxy-carbofuran			X	-	-	-
6-benzyladenine	X			-	-	-
Acephate	X	X		0.226	-0.85	H302
Acetamiprid	X	X	X	1.73×10^{-04}	0.8	H302
Acetamiprid-n-desmethyl			X	-	-	-
Acrinathrin	X	X		4.40×10^{-05}	6.3	-
Ametoctradin	X	X	X	2.1×10^{-07}	4.4	-
Azadirachtin	X	X		-	-	-
Azoxystrobin	X	X	X	1.10×10^{-07}	2.5	H331
Benalaxyl	X			0.572	3.54	-
Benomyl	X	X		0.005	1.4	H315, H317, H335, H340, H360FD

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classifica-tion**
Bifenazate	X	X		1.33 X 10^{-02}	3.4	H317, H373
Bifenthrin	X	X		0.0178	6.6	H300, H317, H331, H351, H372
Bitertanol	X	X		1.36 X 10^{-06}	4.1	-
Boscalid	X	X	X	0.00072	2.96	-
Bupirimate	X	X	X	0.057	3.68	H317, H351
Buprofezin	X	X	X	0.042	4.93	-
Captan		X		0.0042	2.5	H317, H318, H331, H351
Carbendazim	X	X	X	0.09	1.48	H340, H360FD
Carbofuran		X	X	0.08	1.8	H300, H330
Carbosulfan	X			0.0359	7.42	H301, H317, H330
Carboxin	X			0.02	2.3	-
Chlorantraniliprole	X	X	X	6.3 X 10^{-09}	2.86	-
Chlorfenapyr	X			9.81 X 10^{-03}	4.83	H302, H331
Chloridazon	X			1.0 X 10^{-06}	1.19	H317
Chlorothalonil	X	X		0.076	2.94	H317, H318, H330, H335, H351
Chlorpyrifos	X	X		1.43	4.7	H301
Clofentezine	X	X	X	1.40 X 10^{-03}	3.1	-
Cyflufenamid	X			0.0354	4.7	-
Cyflumetofen		X	X	0.0059	4.3	-
Cyfluthrin	X			0.0003	6	H300, H331
Cyhalothrin	X	X		1.00 X 10^{-09}	6.8	-
Cypermethrin	X	X		6.78 X 10^{-03}	5.55	H302, H332, H335
Cyproconazole		X	X	0.026	3.09	H301, H360D, H373
Cyprodinil	X	X	X	5.10 X 10^{-01}	4	H317
Deet		X		-	-	-

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
Deltamethrin	X	X		0.0000124	4.6	H301, H331
DETP			X	-	-	-
Diazinon	X			11.97	3.69	H302
Dicofol	X	X		0.25	4.3	H302, H312, H315, H317
Difenoconazole	X	X	X	3.33 X 10-05	4.36	-
Diflubenzuron		X	X	0.00012	3.89	-
Dimethoate	X	X		0.247	0.75	H302, H312
Dimethomorph	X	X	X	9.85×10^{-04}	2.68	-
Dinotefuran	X		X	0.0017	-0.549	-
Diphenylamine		X		0.852	3.82	H315, H317
Dodemorph	X	X		0.48	4.6	H314, H317, H361d, H373
DMP			X	-	-	
Endosulfan		X		0.83	4.75	H300, H312, H330
Ethirimol	X			0.267	2.3	H312
Etoxazole	X	X		0.007	5.52	-
Etridiazole	X			1430	3.37	H302, H317, H351
Famoxadone	X	X	X	0.00064	4.65	H373
Fenamidone	X	X		0.00034	2.8	-
Fenamiphos	X			0.067	3.3	H300, H310, H319, H330
Fenamiphos sulfone			X	-	-	-
Fenarimol	X			0.065	3.69	H361fd, H362
Fenazaquin		X		1.90×10^{-02}	5.51	H301, H332
Fenhexamid	X	X	X	4.00×10^{-04}	3.51	-
Fenoxycarb		X	X	8.67×10^{-04}	4.07	H351
Fenpropathrin	X			0.76	6.04	H301, H312, H330
Fenpropidin	X		X	17.0	2.6	-
Fenpyroximate		X	X	0.01	5.01	H301, H317, H330

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
Fensulfothion-oxon	X			-	-	-
Fenvalerate	X	X		0.0192	5.01	-
Fipronil	X	X	X	0.002	3.75	H301, H311, H331, H372
Fipronil sulfone			X	-	-	-
Flonicamid	X	X	X	9.43×10^{-04}	-0.24	H302
Fluazinam		X		7.5	4.03	H317, H318, H332, H361d
Flubendiamide	X	X	X	0.1	4.14	-
Fludioxonil	X	X		3.90×10^{-04}	4.12	-
Flufenoxuron	X	X	X	6.52×10^{-09}	5.11	H362
Fluopicolide	X	X		3.03×10^{-04}	2.9	-
Fluopyram	X	X	X	1.2×10^{-03}	3.3	-
Fluoxastrobin		X		5.60×10^{-07}	2.86	-
Flusilazole		X		0.0387	3.87	H302, H351, H360D
Flutolanil		X	X	4.10×10^{-04}	3.17	-
Flutriafol		X	X	4.0×10^{-04}	2.3	-
Fluxapyroxad		X		2.7×10^{-06}	3.13	-
Forchlorfenuron	X			4.60×10^{-05}	3.3	H351
Fosthiazate	X		X	0.56	1.68	H301, H312, H317, H331
Furalaxyl	X		X	0.07	2.7	H302
Hexythiazox	X	X	X	1.33×10^{-03}	2.67	-
Imidacloprid	X	X	X	4.0×10^{-07}	0.57	H302
Indoxacarb	X	X	X	0.006	4.65	H301, H317, H332, H372
Iprodione	X	X		0.0005	3.0	H351
Iprovalicarb	X	X		7.90×10^{-05}	3.2	-
Isocarbophos	X		X	-	2.7	-
Kresoxim-methyl	X	X		2.30×10^{-03}	3.4	H351
Lufenuron	X	X		4.00×10^{-03}	5.12	H317

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
Malathion		X		3.1	2.75	H302, H317
Mandipropamid	X	X	X	9.40 X 10^{-04}	3.2	-
Mepanipyrim	X	X		0.0232	3.28	H351
Metalaxyl	X	X	X	0.75	1.75	H302, H317
Metalaxyl-M				3.3	1.71	H302, H318
Methamidophos	X		X	2.3	-0.79	H300, H311, H330
Methiocarb	X	X	X	1.50 X 10^{-02}	3.18	H301
Methiocarb sulfon			X	-	-	-
Methiocarb sulfoxid			X	-	-	-
Methomyl	X		X	0.72	0.09	H300
Methoxyfenozide	X	X	X	1.33 X 10^{-02}	3.72	-
Metrafenone	X	X	X	0.153	4.3	-
Myclobutanil	X	X		0.198	2.89	H302, H319, H361d
Nitrothal-isopropyl		X		0.01	2.04	-
Novaluron	X	X	X	1.60 X 10^{-02}	4.3	-
Omethoate	X	X		19.0	-0.9	H301, H312
Oxadixyl	X			0.0033	0.65	-
Oxamyl	X		X	0.051	-0.44	H300, H312, H330
Oxycarboxin	X	X		5.60 X 10^{-03}	0.772	H302
Paclobutrazol	X	X		0.0019	3.11	-
Penconazole		X		0.366	3.72	H302, H361d
Permethrin		X		0.007	6.1	H302, H332, H335
Picoxystrobin	X	X		0.0055	3.6	-
Piperonyl butoxide	X	X	X	-	-	-
Pirimicarb	X	X	X	0.43	1.7	H301, H317, H331, H351
Pirimicarb desmethyl			X	-	-	-
Pirimiphos-methyl		X		2.00 X 10^{-03}	3.9	H302

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
Prochloraz	X	X	X	0.15	3.5	H302
Procymidone	X	X		0.023	3.3	-
Profenofos		X		2.53	1.7	H302, H312, H332
Propamocarb	X	X		730	0.84	-
Propiconazole		X		0.056	3.72	H302, H317
Propoxur				1.3	0.14	H301
Pymetrozine	X	X		4.20×10^{-03}	-0.19	H351
Pyraclostrobin	X	X	X	2.60×10^{-05}	3.99	H315, H331
Pyridaben	X	X	X	0.001	6.37	H301, H331
Pyridalyl	X	X		6.24 X 10-05	8.1	-
Pyrimethanil	X	X	X	1.1	2.84	-
Pyriproxyfen		X		1.33 X 10-02	5.37	-
Quinalphos	X		X	0.346	4.44	H301, H312
Simazine		X		0.00081	2.3	H351
Spinetoram	X	X		5.7×10^{-02}	4.2	-
Spinosad	X	X	X	-	-	-
Spirodiclofen		X	X	3.00×10^{-04}	5.83	-
Spiromesifen		X		7.00×10^{-03}	4.55	-
Spirotetramat	X	X	X	5.6×10^{-06}	2.51	H317, H319, H335, H361fd
Spirotetramat-enol			X	-	-	-
Spirotetramat-enol-glucoside			X	-	-	-
Spiroxamine	X	X	X	3.5	2.89	H302, H312, H315, H317, H332, H361d, H373
TCPy			X	-	-	-
Tebuconazole	X	X		1.30×10^{-03}	3.7	H302, H361d
Tebufenozide		X		1.56×10^{-04}	4.25	-
Tebufenpyrad		X	X	0.0016	4.93	H301, H317, H332, H373

Pesticide residues and metabolites	Flowers	Gloves	Urines	[1]Vapour pressure at 25°c (mPa)*	[2]Log Kow (Log P) *	CLP classification**
Tetraconazole		X		0.18	3.56	H302, H332
Tetradifon	X			3.20 X 10^{-05}	4.61	-
Tetrahydrophtalimide		X		-	-	-
Tetramethrin		X		2.1	4.6	-
Thiabendazole	X	X	X	5.30 X 10^{-04}	2.39	-
Thiacloprid	X	X		3.00 X 10^{-07}	1.26	H301, H332, H336, H351, H360FD
Thiamethoxam	X	X		6.60 X 10^{-06}	-0.13	H302
Thiodicarb	X			2.7	1.62	-
Thiophanate methyl	X	X		9.0 X 10^{-03}	1.40	H317, H332, H341
Tolclofos-methyl	X	X		0.877	4.56	H317
Triadimenol		X		0.0005	3.18	H302, H360, H362
Triadimefon		X		0.02	3.18	H302, H317
Trichlorfon	X			0.21	0.43	H302, H317
Trifloxystrobin	X	X		3.40 X 10^{-03}	4.5	H317
Triflumizole	X	X		0.191	4.77	H302, H317, H360D, H373
Triforine	X			26	2.4	-

2CTCA: 2-Chloro-1,3-thiazole-5-carboxylic acid : urinary metabolite of thiamethoxam
TCPy: 3,5,6-trichoro-2-pyridinol: urinary metabolite of both chlorpyrifos and chlorpyrifos-methyl
DMP: Dimethylphosphate: urinary metabolite of organophosphates
DETP: Diethylthiophosphate: urinary metabolite of organophosphates

H300: Fatal if swallowed; **H301:** Toxic if swallowed; **H302:** Harmful if swallowed; **H310:** Fatal in contact with skin; **H311:** Toxic in contact with skin; **H312:** Harmful in contact with skin; **H314:** Causes severe skin burns and eye damage; **H315:** Causes skin irritation; **H317:** May cause an allergic skin reaction; **H318:** Causes serious eye damage; **H319:** Causes serious eye irritation; **H330:** Fatal if inhaled; **H331:** Toxic if inhaled, **H332:** Harmful if inhaled; **H335:** May cause respiratory irritation; **H336:** May cause drowsiness or dizziness; **H340:** May cause genetic defects; **H341:** Suspected of causing genetic defects; **H351:** Suspected of causing cancer; **H360:** May damage fertility or the unborn child; **H360D:** May damage the unborn child;

H360FD: May damage fertility. May damage the unborn child; **H361d:** suspected of damaging the unborn child; **H361fd:** suspected of damaging fertility. Suspected of damaging the unborn child; **H362:** May cause harm to breast-fed children; **H372:** Causes damage to organs through prolonged or repeated exposure; **H373:** May cause damage to organs through prolonged or repeated exposure

* Classification according The PPDB - Pesticides Properties DataBase
** CLP classification according the EU Pesticides database

[1] **Vapour pressure at 25°c (mPa) (EFSA, 2014)**, significance of indicator:
< 5.0 mPa = low volatility,
5.0 – 10.0 mPa = moderately volatile,
> 10 mPa = highly volatile

[2] **Octanol-water Partition Coefficient (Log P)** (PPDB - Pesticides Properties Data-Base, 2018), significance of indicator:
< 2.7 = Low bioaccumulation
2.7 – 3 = Moderate
> 3.0 = High

CONCLUSION

The analysis of the best selling cut flowers in Belgium (roses, gerberas and chrysanthemums) on the one hand, and the determination of the potential transfer of residues present on the flowers to the hands through the analysis of cotton gloves worn by florists during their professional activities on the other hand, enable to conclude that their potential exposure to pesticide residues is very important and astounding (different pesticide residues, banned active substances, and high concentrations). This appears to reflect the extensive use of different pesticides by growers and might be explained by the susceptibility of cut flowers to insect attacks, diseases and weeds proliferation, the poor dissemination of alternative methods and the absence of maximum residue limits that could leads to control at the entry points.

Subsequently, biological monitoring (biomonitoring by urine analysis of exposed and unexposed groups) has proven to be an excellent tool for confirming exposure and assessing a realistic total systemic exposure level. There is a very good correlation between substances detected on cut flowers, measured on cotton gloves and also found in urine samples, demonstrating the transfer and absorption of these substances, and therefore the exposure.

The variety and amounts of pesticide residues to which florists are exposed, are very high compared to workers re-entering greenhouses where edible crops were previously treated with pesticides. Indeed, flower supply sources are widely diversified: cut flowers are imported into Belgium from producing countries all over the world where a wide variety of products are used, often containing active substances no longer approved in Europe and where the GAP (Good Agricultural Practices) are different.

Florists represent a very vulnerable and not informed category of workers. A lack of information about the risk of repeated exposure to pesticide residues on cut flowers emerged during the interviews. Consequently, this is very challenging both for the sector and for the Belgian authorities (no official recommendations issued to date). This study confirms that florists should be considered (especially with regard to risk assessment during the marketing of plant protection products (PPP) for use on flowers) as "workers" (persons who, as part of their employment, enter an area that has been treated previously with a PPP or who handle a crop that has been treated with a PPP, EFSA 2014).

In conclusion, the exposure of florists seems to be an example of a single employment status, at risk for several reasons: florists are regularly exposed to important numbers and significantly high amounts of pesticide residues. The majority of these pesticide residues have potentially acute and / or chronic toxicity (Table 1) according CLP classification. As a result, the combination of all factors can lead to significant long-term negative effects on their health.

Future works (risk assessment considering the oral and inhalation exposure routes, analyse of greens, cumulative risk assessment, development of a pesticide residue transfer model applied on cut flowers, assessment of the capabilities of personal protective equipment, biological monitoring considering other matrices such as hair and blood, epidemiological studies, etc.) should be done to better document the exposure problem of Belgian florists to pesticide residues and to recommend mitigation measures to reduce the exposure. Meanwhile simple and inexpensive rules should be respected: use of appropriate personal protective equipment, trainings on integrated pest management, setting up of a harmonized traceability system, stronger quality controls of imported cut flowers (opinion request to experts to know if it will be helpful to set up a Maximum Residue Limits for cut flowers).

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