The contaminants of the bee colony

Stefan Bogdanov, Anton Imdorf, Jean-Daniel Charrière, Peter Fluri und Verena Kilchenmann
Swiss Bee Research Centre
Dairy Research Station, Liebefeld, CH-3003 Bern

Introduction

Contamination of honey and other bee products has placed the beekeepers in the situation of Hamlet and they lead a "to bee or not bee" fight against the sea of troubles, the contamination sources of bee products. In order to win this struggle, the beekeepers should understand the importance of the different contamination sources. In this short review it will be attempted to discuss the relative importance of the different contamination sources.

The contamination sources can roughly be divided into environmental and apicultural ones. The environmental sources can be further divided in agricultural and non-agricultural ones.

Contamination sources

Contaminants coming from the environment

Bees fly intensively in a radius of up to 3 km. For this reason they and their products can serve as bio-indicators for the contamination this area (Devillers et al., 2002, see there further references). The contamination can reach the beehive:

1. Through air and water they can reach the bee, which will can further transport take them into the colony.
2. Through air, water and soil they can reach plants, which on their part can pass them by nectar and honeydew to the bees.

Non - agricultural sources

Heavy metals in honeys

Air and water contain heavy metals from industry and traffic which can also contaminate the bee colony and its products. The air can contain lead and cadmium, while cadmium can also be transported via water and soil to the plants to reach the nectar and the honeydew. The results, shown in the table 1 illustrate the contamination of honey by of the two most important toxic heavy metals: lead and cadmium. the one of honeys, harvested in normal rural areas. The Pb and Cd values, measured in honey marketed in Switzerland (Bogdanov et al. 1986) and (Wenk, 2002) are well bellow the Maximum Residues Limits (MRL), proposed for the EU. Other investigations show similar results (see for a review Porrini et al., 2002). As showed in this figure, the lead contamination has diminished, due to the increased world-wide use of car-engine catalysts. Heavy metal contamination is increased in areas of industrial and heavy traffic (Höffel 1982). The degree of contamination decreases in the following order: Bees ≥ Propolis > Comb wax > Honey (Höffel, 1982, Altmann 1983). The low contamination of honey is probably due to "filtering" by the bees. Heavy metals will probably be washed off during the process of comb melting to produce pure beeswax.

	Lead mg/kg	**Cadmium** mg/kg
Honeydew honey		
1986 (n = 21)	0.200 (0.020 – 0.520)	0.019 (0.004 – 0.060)
2002* (n = 11)	0.016 (0.000 – 0.048)	0.007 (0.000 – 0.017)
Blossom honey (n = 18)		
1986 (n = 18)	0.090 (0.020 – 0.370)	0.005 (0.002 – 0.020)
2002* (n = 26)	0.021 (0.000 – 0.274)	0.001 (0.000 – 0.019)

average (minimum – maximum) values

after Bogdanov et al. 1986
* after Wenk 2002

MRL proposal for the EU	
Lead: 1 mg/kg	Cadmium: 0.1 mg/kg

Heavy metals in honey

Air and water contain heavy metals from industry and traffic which can also contaminate the bee colony and its products. The air can contain lead and cadmium, while cadmium can also be transported via water and soil to the plants to reach the nectar and the honeydew. The results, shown in the table 1 illustrate the contamination of honey by of the two most important toxic heavy metals: lead and cadmium. the one of honeys, harvested in normal rural areas. The Lead and Cadmium values, measured in honey marketed in Switzerland (Bogdanov et al. 1986) and (Wenk, 2002) are well bellow the Maximum Residues Limits (MRL), proposed for the EU. Other investigations show similar results (see for a review Porrini et al., 2002). As showed in this figure, the lead contamination has diminished, due to the increased world-wide use of car-engine catalysts. Heavy metal contamination is increased in areas of industrial and heavy traffic (Höffel 1982). The degree of contamination decreases in the following order: Bees ≥ Propolis > Comb wax > Honey (Höffel, 1982, Altmann 1983). The low contamination of honey is probably due to "filtering" by the bees. Heavy metals will probably be washed off during the process of comb melting to produce pure beeswax.

Contamination by pathogenic bacteria

Honey has a very low water activity, making the growth of bacteria impossible. Indeed, very few pathogens have been found in honey, as they can survive there for a very limited time (see the reviews Snowdon and Cliver, 1996, Snowdown, 1999). The only source of health concern has been the presence of *Clostridum Botulinum.* Spores of this bacterium can survive in honey, but they can not build the toxin. In some rare cases, infant botulism has been explained by ingestion of honey. This has lead some countries as the USA and Great Britain to prescribe a label on honey "not to be eaten by infants until one year old". On the other hand, the presence of this bacterium in natural food is ubiquitous. Recently, a scientific committee of the EU has examined the hazard of *Clostridum Botulinum* in honey (EU report, 2002) It has concluded, that no microbiological examinations of honey are necessary, as the incidence of *Clostridum Botulinum* is relatively low and as such tests will not prevent infant botulism.

Contamination from genetically modified plants

Some genetically modified plants (GMP) as rape and maize are grown in Europe and might pose problems for bees and beekeepers (Williams, 2002). In Europe there is a wide opposition from consumer organisations against the consumption GM derived food, while in North America this kind of food is accepted. In the EU and also in Switzerland there is a MRL level of 1 % for GM content, set for all food. Foodstuff, containing more GMP derived material than this limit should have an appellation indicating the exact GMO content. There are very sensitive methods for the determination of genetically modified plants and their parts, for instance of pollen. Indeed the use of the so called PCR methods allows the determination of only a few genetically modified pollen, which can be contained in honey. Pollen is endangered by GMP, while honey, which contains less than 0.1 % of pollen is not.

Other contaminants

Presently, the radioactive contamination does not present a problem for bees and their hive products (Haarmann, 2002).

Other organic chemicals present in the environment, are the PCB's, (polychlorinated biphenyls) which originate in oil and were used as coolants and lubricants before 1980. These substances are still present in the envorenment and can contaminate food, and thus also the bees and their products. The quantitites, found in honey are low and safe, while those in wax are higher (Jan and Cerne, 1992, Smith et al., 2002). The contamination levels in the bee products are not high.

Agricultural sources

Pesticides

In a recent Swiss study honey and wax were examined for residues of 69 common pesticides (Bogdanov et al., 2003). Non of them were found in the determination range between 5 and 50 µg/kg. Other studies also report that the low level of non-acaricide pesticides in honey is low and safe (Fernandez-Muino et al., 1995, Albero et al. 2001).

	Organochlor-pesticides 37 substances	**Organophosphor-pesticides** 32 substances
Beeswax		
produced 1994-2000	nd	nd
27 honeys		
produced 1997-2001	nd	nd

nd: not detected

Pesticide residues in Swiss beeswax and honey

Pollen is significantly more contaminated than honey (see table, Fleche et al. 1997).

As a whole it can be stated, that the hazard when using insecticides in agriculture lies mostly in the toxicity for the bees (Devillers, 2002). Tests for bee toxicity are carried out in the EU countries before the registration of pesticides. As stated above, the contamination risk on honey is relatively small, but pollen is more heavily contaminated (Kubik 1999 and 2000). Indeed, most of the modern pesticides used today are not stable and will disintegrate quickly after use. However, peasants are advised to use pesticides outside the bloom period or at least, not during the foraging time of bees.

	Period of analysis	n	% positive	mean values
Bees	1987	148	36	0.12
Pollen	1987	146	61	0.50
Honey	1992 - 1996	683	3	0.03

In French bees, pollen and honey (after Fleche et al.)

Streptomycine against fire blight

The fire blight on fruit trees is caused by the bacterium *Erwinia amylovora*. Streptomycin is used in some countries for the control of this disease. The results shown on fig. demonstrate, that there is a great risk of streptomycin residues in honey (Brasse, 2001). That is why streptomycin is not used in most European countries. Indeed there are other effective alternatives for the control of the fire blight.

Trial in Germany 2000	
Number of samples	183
Samples with residues	12
Residues over MRL	12

Residues in honey after use of streptomycin for fire blight control (Erwinia amylovora)

The degree of contamination by pesticides from environmental sources decreases in the following order: propolis ≥ wax > pollen > honey (Fleche et al. 1997).

Apicultural sources

Varroacides

The varroacides are the most important sources for contamination, as they have to be used for long-term varroa control. In the table the most important varroacides are given, but there are many more, used world-wide. The acaricides can be divided basically into three groups:
The first group is the one of the synthetic, lipohilic substances, e.g. fluvalinate. They fatt soluble and persistent in wax, that means they do not disintegrate there for a long period. where they remain nature, they accumulate in wax, and to a lesser extent, also in honey (Bogdanov et al., 1998b; Wallner, 1999). The second group are the group of non-toxic varroacides, which are allowed for use in the frame of organic beekeeping. This group can be sub-divided into two. The first group, to which belongs thymol, are volatile and fat soluble. The second one are the organic acids, are soluble in water. In the bee colony the fat soluble substances will accumulate into the beeswax, while the water soluble will accumulate more into honey. There are many different products on the market. Mites, resistant to pyrethroids and coumaphos have appeared in many countries of the world (Milani, 1999). Thus, natural substances like thymol and organic acids are increasingly used. For many acaricides there are no MRL values, for some of them the MRL values differ from country to country.

Product	Active ingredient	Registration
Folbex VA	bromopropylate	EU
Perizin	coumaphos	EU
Apistan	fluvalinate	EU
Bayvarol	flumethrin	EU
Apitol	cymiazol	EU
Apivar	amitraz	EU
Thymovar, Apilife VAR	thymol	EU*
Formic acid products	formic acid	EU*
Lactic acid, aqueous solution	lactic acid	EU*
Oxalic acid products	oxalic acid	**

* allowed for organic beekeeping **used in EU, but not officially registered

Acaricides against Varroa

The application of different synthetic acaricides result in different contaminatin levels in wax (brood combs and honey combs), sugar feed and honey (The acaricides were applied in normal bee hives according to the Swiss prescription in autumn, after the honey harvest. The residues were measured during the following spring. The acaricide levels, found in the different products after treatment with the different acaricides, decrease in the following order: brood combs > honey combs >> sugar feed ≥ honey. The contamination level of the brood combs, found in our study, is: bromopropylate > coumaphos and fluvalinate. The acaricide levels in feed and honey lied well below the Swiss MRL for honey. For more details on synthetic acaricides and their residues see Bogdanov et al., 1998a and Wallner, 1999.

acaricide	Number of treatments-	brood combs	honey combs	honey	MRL honey
		(averages, mg/kg)			
Brompropylat	1	47.8	2.4	0.01	0.1
Fluvalinat	1	2.9	0.1	nd	0.01
Coumaphos	1	3.8	0.7	0.015	0.05
Flumethrin	2	0.05	-	nd	0.005

nd: not detected

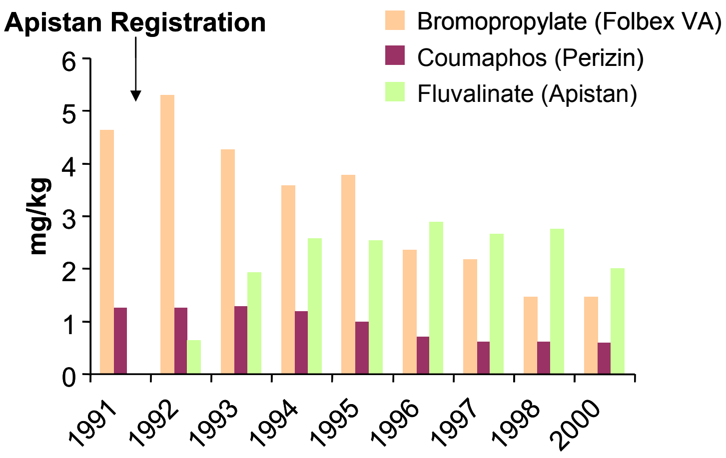
Acaricide residues in wax and honey after normal treatments in autumn after honey harvest

Acaricide residues are also found in propolis (Bogdanov, 1998 a). The fluvalinate residues are 3.4 times higher, the bromopropylate ones two times lower than the corresponding residues found in the commercial Swiss wax of the same year. Only two samples contained flumethrine (3.7 and 1.3 mg/kg), while the other ones did not contain residues higher than the detection limit of 0.4 mg/kg.

Thus for medical purposes only propolis produced in the frame of certified organic beekeeping should be used.

Long-term monitoring of acaricides in commercial beeswax

The Swiss Bee Research Centre has a monitoring program for a follow up of acaricide residues in Swiss commercial wax. As most of the Swiss producers of beeswax participate in this monitoring, the results can show the long-term behaviour of acaricides in commercial beeswax. The acaricides bromopropylate, coumaphos and fluvalinate are always present, while no flumethrin below the detection limit of 0.25 could be measured. Indeed, from all acaricides, the flumethrin amounts, released into the bee colony are the smallest, with about 16 mg per treatment. Bromopropylate will release 1.6 g of active ingredient during one treatment. Bromopropylate was used until 1991, but 10 years after, it is still present in beeswax. Another 20 years will pass before it can fully disappear from beeswax.



Acaricide residues in wax fondations

On the other hand, if a certain acaricide (e.g. fluvalinate) starts being used, its concentration will rise immediately. During the last years there is no increase in fluvalinate or coumaphos. This can be explained by the increased use of alternative varroa control. For further experimental detals see Bogdanov et al., 1998 a. The results, shown in this figure serve as an example for the wax quality in all countries, where synthetic drugs are used for long-term Varroa control. Indeed, wax analysis in other countries have shown, that similar amounts of acaricides are found in wax (Wallner et al. 1995, Wallner, 1997 b, Bernardini and Gardi, 2001, Menkissoglu et al., 2001).

Thymol residues in honey and wax

Apilife VAR

Brood-combs

500 – 600 mg/kg

Honey-combs

20 – 30 mg/kg

sugar feed

1 – 4 mg/kg

	residues in honey	
Treatment	**minimum**	**maximum**
Apilife VAR (CH)	0.02	0.48
Thymol frame (CH)	0.08	1.1
Thymol frame (D)*	0.09	2.0

► **MRL Switzerland: 0.8 mg/kg**

after Bogdanov et al. 1998,1999
* after Wallner, 1997

Thymol residues in spring honey and wax after treatments with Apilife VAR in autumn or with a thymol frame for the whole season

Bee colonies were treated in August and September with Apilife VAR, which is composed mainly of thymol. During the spring of the next year the thymol residues in honey and wax were measured. The residues in honey and wax did not increase with increasing number of Apilife VAR treatments.

The highest thymol value was 0.5 mg/kg, that means well below the Swiss MRL value of 0.8 mg/kg. The sensory threshold of thymol in honey is 1.1-1.5 mg/kg. The residues in beeswax were much greater, those in the brood combs being much greater than the ones in the honey combs.

The thymol residues will evaporate from foundation upon storage under aeration or 2 weeks after placing them into the bee hive. For details see Bogdanov et al., 1998 b.

If the thymol treatments are carried during the whole bee season, then the honey residues are greater and will in some cases reach levels, that will cause the change of honey taste, which is not permitted according to the international honey regulations (Bogdanov et al. 1998 c and 1999, Wallner, 1997, a).

Residues of organic acids in honey

In a three year trial bee colonies in Swiss apiaries were treated every year with two long duration formic acid treatments and a spray treatment with oxalic acid. The control colonies were treated with Apistan. During the spring of the next year the acid residues were measured in the honey of the treatment and the control apiaries.

	1996		**1997**		**1998**	
	C	**T**	**C**	**T**	**C**	**T**
Formic acid	45	94	31	91	41	71
Oxalic acid	41	33	22	18	19	19

FA treatments in spring (1997, 1999), honeydew honey		
	C	**T**
average mg/kg	61	254
min. – max.	20 - 127	58 - 506

C = control T = treatment preceeding autumn

Natural honey content:	**blossom**	**honeydew**
Formic acid	17 - 85	42 – 284
Oxalic acid	8 - 51	38 - 119

Residues in blossom honey after treatments with formic acid (FA) and oxalic acid (OA) ca. 10 apiaries, averages in mg/kg

The honeys from the treated apiaries had on average higher formic acid content than that of the control apiaries. This increase of formic acid is not important as in lies within the natural variation of this acid. However, if the colonies are treated in spring, the increase of the formic acid concentration in summer honey can be high enough to change honey taste. Thus such treatments should be carried out only in emergency cases.

After the oxalic acid treatments there was no increase of oxalic acid concentration in honey.

From the point of view of residues bee colonies can be treated in late summer with formic acid and with oxalic acid in early winter, in the absensce of brood. For further details about residues of organic acids in honey see Bogdanov et al., 2002.

Antibiotic residues in honey from AFB treatments

Residue studies in different countries show that about 1/3 of the honey on the EU market contains antibiotics. In measurements in Switzerland in 1999 to 2001 one third of the imported contained antibiotics, while 6 to 9 % of the Swiss honeys were contaminated, mostly by sulfathiazol. As the control of AFB by antibiotics is forbidden, honey with antibiotic residues is not permitted to be sold on the EU market. The detection limit of modern determination methods are about 5-10 mg/kg.

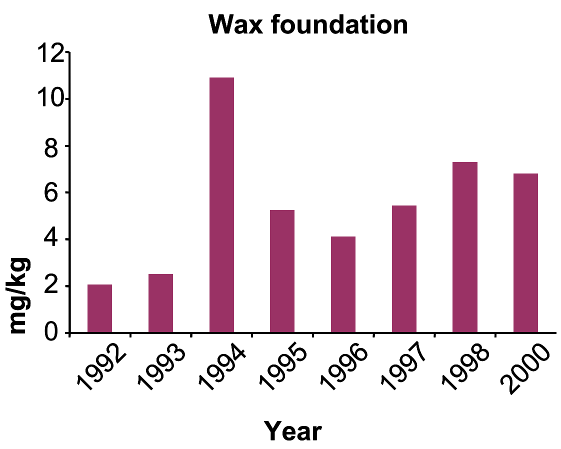
Imported honey		
Year	**% positive**	**n**
1999	34	310
2001	31	91
Swiss honey		
Year	**% positive**	**n**
2000	6	800
2001	9	88

Residues of antibiotics in honey in Switzerland, Result from Swiss Cantonal Laboratories

Recently residues of the antibiotic chloramphencol were found, mostly in Chinese honeys. As there are some doubts that substance might be carcenogenic, even amounts as low as 0.3 µg/kg are prohibited. See for more details on AFB and its treatment in Bogdanov and Fluri, 2000.

Residues in honey and wax of paradichlorbenzene, used for moth control

Some beekeepers use paradichlorbenzene (PDCB) for the control of wax moth. The substance enters the cycle of beeswax and contaminates the whole commercial beeswax. Indeed, as shown in fig. 17, PDCB is present in Swiss beeswax for the whole monitoring period of 10 years. As PDCB is volatile it will evaporate from wax and can contaminate honey (Wallner, 1991). Indeed, on average 30 % of the honeys samples in Switzerland contained PDCB, in 13 % of them the Swiss MRL of 0.01 mg/kg was exceeded (Cantonal laboratories, 2002). PDCB is a toxic substance and is not registered for wax moth control in the EU. Thus , PDCB residues in honey are forbidden in the EU countries.



Honey

year	n	min-max µg/kg	% positive
1997	28	7 - 65	14
1998	13	4 - 114	46
2000	23	4 - 56	26
2001	16	4 - 37	31
2002	11	3 - 13	54

Residues in honey and wax of paradichlorbenzene, used for moth control

Other, even much more toxic substances as naphthaline, are also used for wax moth control. On the other hand (see below), there are other more ecological measures for wax moth control.

Other apicultural contamination sources

Residues coming from wood protectants of bee hive, honey harvest and storage

Wood protectants and paints, used to protect the bee hive against spoilage, should not contain insecticides and fungicides, die might contaminate honey. Indeed, poisonous ingredients of wood protectants and paints have been detected in honey.

When harvesting honey no chemical repellents should be used. The use of different chemical repellants has been reviewed (Jeanne, 1999).

Storage of honey in inconvenient recipients can also lead to undesirable residues. During the storage of honey inorganic and organic components can diffuse from parafinated, corrosive and painted vessels and contaminate it. For optimal vessels see below.

Beehive
organic chemicals from wood protectants insecticides und fungicides from dyes
Honey harvest
chemical repellents too much smoke
Honey storage in inconvenient vessels
Organic pollutants from paraffinized recipients release Zinc from galvanized vessels Collorants from coloured vessels

Contamination from the hive, harvest and honey storage

Conclusion

The results show that the main contamination danger for bee products originates less from the environment, but from the apicultural practice. Antibiotics are the most likely contaminants of honey. Acaricides are the most most important contaminants of wax and propolis. Pollen quality is mostly endangered by pesticides.

After a lecture at the Apimondia Symposium "Beekeeping without Residues", Celle, 2002

References

Albero B., Sanchez-Brunete C., Tadeo J.L., (2001) Multiresidue determination of pesticides in honey by matrix solid-phase dispersion and gas chromatography with electron-capture detection, Journal of AOAC int. 84, 1165-1171.

Altmann, G.A., (1983), Untersuchung von Honig aus dem Raum Stolberg auf Schwermetalle. Diplomarbeit Fachhochschule Aachen.

Bernardini M., Gardi T., (2001) Influence of acaricide treatments for varroa control on the quality of honey and beeswax, Apitalia 28, 21-24.

Bogdanov S., Fluri P., (2000) Honigqualität und Antibiotikarückstände, Schweizerische Bienen-Zeitung 123, 407-410.

Bogdanov S., Kilchenmann V., Imdorf A., (1998a) Acaricide residues in some bee products, Journal of Apicultural Research 37, 57-67.

Bogdanov S., Imdorf A., Kilchenmann V., (1998b) Residues in wax and honey after Apilife VAR treatment, Apidologie 29, 513-524.

Bogdanov S., Kilchenmann V., Fluri P., Bühler U., Lavanchy P., (1998c) Einfluss von organischen Säuren und Komponenten ätherischer Öle auf den Honiggeschmack, Schweizerische Bienen-Zeitung 121, 581-585.

Bogdanov S., Imdorf A., Kilchenmann V., Fluri P., (1999) Thymolanwendungen zur Bekämpfung der Varroa, Schweizerische Bienen-Zeitung 122, 445-451.

Bogdanov S., Zimmerli B., Erard M. (1986) Schwermetalle in Honig, Mitt. Gebiete Lebensm. Hyg. 77, 153-158.

Bogdanov, S., Charriere J.D., Imdorf A., Kilchenmann V., Fluri P., (2002), Residues in honey after treatments with formic and oxalic acid under field conditions, Apidologie, 33 (4), 399-409.

Bogdanov S., Ryll G., Roth H., (2003) Pesticide residues in honey and beeswax produced in Switzerland, in: Arbeitstagung der Arbeitsgemeinschaft der Bieneninstitute, Schmitten, Deutschland, 2003, Apidologie, in preparation

Brasse D., (2001) Stellungnahme der BBA zum Streptomycin-Problem. Teil 2 Bewertung der Rückstandswerte im Honig, Allgemeine Deutsche Imkerzeitung 35, 24-25.

Cantonal laboraratories of Shaffhausen and Basel (2002) Reports (unpublished).

Devillers J., Pham-Delègue M.H., (2002) .Honey Bees: Estimating the environmental impact of chemicals, Taylor & Francis, London and New York.

EU (1999) Council Regulation No 1804 On organic farming, Chapter Beekeeping and Beekeeping Products. Official Journal of the European Communities of 19 July 1999, L 222, C. Bruxelles, Belgium.

European commission (2002) Opinion of the Scientific Committee on Veterinary Measures relating to Public Health, (adopted on 19-20 June 2002)

EC Commission Regulation (EC) No 49/2000, (2000), Official Journal of the European Communities - 11.1.2000 - No L 6, P. 0013-0014.

Fléché C., (1997) Risques de dissémination des maladies apiaires par les mouvements internationaux des abeilles et de leurs produits, Revue Scientifique et Technique de l'Office International des Epizooties 16, 177-186.

Fernandez-Muino M.A., Sancho M.T., Muniategui S., Huidobro J.F., Simal-Lozano J., (1995) Nonacaricide pesticide residues in honey: Analytical methods and levels found, Journal of Food Protection 58, 1271-1274.

Goodwin M., Van Eaton C., (1999) Elimination of American foulbrood without the use of drugs: a practical manual for beekeepers, National Beekeeper's Association of New Zealand, New Zealand.

Haarmann, T. K., 2000. Honey bees as indicators of radionuclide contamination: A truly useful biomonitor. In: Honey Bees: Estimating the Environmental Impact of Chemicals, eds. J. Devillers and M. H. Pham-Delègue, Taylor & Francis, London and New York, pp. 132–150.

Höffel, I., Apis mellifica L. als Indikator der 'Umweltgüte' im Stadtgebiet von Saarbrücken. (1982) Diplomarbeit Universität Saarbrück.

Jan J., Cerne K., (1993) Distribution of some organochlorine compounds (PCB, CBz, and DDE) in beeswax and honey, Bull. Environm. Contam. Toxicol. 51, 640-646.

Jéanne F., (1999) Le miel. La récolte des hausses. Les répulsifs chimiques, Bull. Tech. Apic. 26, 135-138.

Kubik M., Nowacki J., Pidek A., Warakomska Z., Michalczuk L., Goszczynski W., (1999) Pesticide residues in bee products collected from cherry trees protected during blooming period with contact and systemic fungicides, Apidologie 30, 521-532.

Kubik M., Nowacki J., Pidek A., Warakomska Z., Michalczuk L., Goszczynski W., Dwuznik B., (2000) Residues of captan (Contact) and difenoconazole (Systemic) fungicides in bee products from an apple orchard, Apidologie 31, 531-541.

Menkissoglu-Spiroudi U., Tsigouri A.D., Diamantidis G.C., Thrasyvoulou A.T., (2001) Residues in honey and beeswax caused by beekeeping treatments, FRESENIUS ENVIRONMENTAL BULLETIN 10, 445-450.

Milani N., (1999) The resistance of Varroa jacobsoni Oud. to acaricides, Apidologie 30, 229-234.

Mutinelli F., Irsara A., Cremasco S., Piro R., (1993) Control of varroatosis by means of APILIFE-VAR in the varroa detection tray, Apicoltore. Moderno. 84, 111-117.

Porrini C., Ghini S., Girotti S., Sabatini A.G., Gattavecchia E., Celli G. (2002) Use of honey bees as bioindicators of environmental pollution in Italy, Devillers, J. and Pham-Delègue, M. H., in: Honey bees: Estimating the environmental impact of chemicals, Taylor & Francis, London and New York, 186-247.

Snowdon J.A., Cliver D.O., (1996) Microorganisms in honey, Internat. J. Food Microbiol. 31, 1-26.However, some spore-building bacteria have

Snowdon J.A., (1999) The microbiology of honey - Meeting your buyers' specifications (Why they do what they do), American Bee Journal 139, 51-60.

Smith, G., Bromenshenk, J., Jones, D., Alnasser, G. (2002) Volatile and semi-volatile organic compounds in beehive atmospheres, in: Honey bees: Estimating the environmental impact of chemicals, Taylor & Francis, London and New York, 186-247.

Wallner K., (1991) Das Wachsmottenbekämpfungsmittel Paradichlorbenzol, Schweizerische Bienen-Zeitung 116, 582-587.

Wallner K., Luh M., Womastek R., Pechhacker H., Moosbeckhofer R. (1995) Development of the residue situation at the Institut für Bienenkunde since the beginning of varroa treatment. Entwicklung der Rückstandssituation am Institut für Bienenkunde seit Beginn der Varroabehandlung, Bienenvater 116, 320-329.

Wallner K., (1997 b) The actual beeswax quality in foundations from the market, Apidologie 28, 168-171.

Wallner, K., (1997 a) Bericht der LA für Bienenkunde d. Universität Hohenheim 1996 ADIZ (3), S.XV.

Wallner K., (1999) Varroacides and their residues in bee products, Apidologie 30, 235-248.

Williams I.H., (2002) The EU regulatory framework for GM crops in relation to bees, BEE WORLD 83, 24-35.

Wenk, P. (2002) Report of the Basel-Land canton laboratory, Switzerland (unpublished).