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Dietary Intake of Environmentally Persistent Pesticides in the European Population

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1. Introduction

The pesticide industry has contributed to increase the benefits of the agricultural sector by controlling plagues and vegetable diseases. Moreover, several human diseases as malaria, encephalitis or phylariasis, have been effectively controlled with this type of products (Abhilash & Singh, 2009). The need to increase the food production, due to the fast growth of the global population, involves the use of pesticides to prevent the loss of 45% of global food production due to pests. This fact is more important in tropical countries where humidity and temperature are higher (Abhilash & Singh, 2009). Because the use and abuse of such substances, global pollution has become one of the most important problems of the modern societies and pesticides play a major role among the chemical contaminants that are released to the environment every year. According to the Food and Agriculture Organization (FAO) data, more than 500.000 T of obsolete and non-used pesticides represent a real threat and a risk for environment and global public health. In late 1990, more than 100.000 chemical substances were registered in the European catalogue of commercialized chemical substances (European Environmental Agency, 2007). It must be highlighted that less is known about late toxicity effects of the majority of these compounds. Thus, only the 14% of these 100.000 substances have enough toxicological data to ensure its safety. Several studies have reported that human beings could have 300 synthetic chemical substances in blood and different tissues, some of them clearly established as adverse for health. Some of these adverse effects are:

- In males: testicular cancer, cryptorchidism, lymphoma non-Hodgkin, multiple myeloma, decrease in spermatozoa quality, occupational disease (asthma, some kind of cancer types…), etc.
- In females: breast cancer, lymphoma non-Hodgkin, spontaneous abortion, birth defects (mainly in the genito-urinary tract), occupational disease, etc.
- In children: increment of childhood cancer, immunology impairment, early puberty, learning problems, etc.

These substances act over environment and over living at low concentrations and, more important, in combination. Each mix of substances is different according to many factors, giving to the situation a higher dimension and hindering their understanding and resolution. Obviously, pesticide residues affect not only humans but also wildlife, pets, fish, livestock, and the environment in general. It is the real globalization.

Of all the pesticides, organochlorine compounds, used as insecticides, are particularly relevant from the point of view of waste. Although banned in developed countries, substances as dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexane (HCH), aldrin and dieldrin are used in developing countries because its low costs, efficacy and versatility against pests and disease-carrying insects (Lallas, 2001). Due to their high lipophilicity, stability and resistance to degradation, their levels remain high in the environment as persistent organic pollutants (POPs). Their presence in the environment leads to their introduction into the food chain, especially affecting food of animal origin with higher fat content. These substances tend to be bioaccumulated into the fat tissues of living beings along their entire lives, and to be biomagnificated across trophic levels in the food chain.

The situation has reached a high degree of relevance. In 2006, the European Union started a legislative project entitled "Registration, Evaluation, Authorisation and Restriction of Chemical substances" (REACH), with the aim of to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances (Williams et al., 2009). The new law entered into force on 1 June 2007. Nonetheless, the REACH project does not solve the background of the problem. That is, what can we do with all the persistent substances discharged into the environment for decades?

2. Routes of exposure

The main problem of exposure to pollutants, such pesticides, lies in the chronic nature of it. Humans are exposed to low amounts of several substances for long periods of life. Thus, acute intoxications as well as chronic exposure in certain labours remain less important.

There have been identified different sources of exposure. Without doubt, the way of food should be considered the most important one. Moreover, due to the high lipophility of these substances, foods with higher amounts of fat become the most dangerous. Thus, some products that must be considered essential for life, such as milk, fish or meat, become important risk factors for health (Yaktine et al., 2006). The contribution of specific food groups to daily intake of chemical contaminants may vary by country or geographic region (Sasamoto et al., 2006). Eating habits, the chemical composition of food, and the period in which the studies are done can explain the differences in the contribution of food to the global chemical exposure among different human populations. In this way, the results obtained from different studies are not easily comparable from one region to another. Moreover, there are several social and demographic factors such as sex, age, ethnicity, urban or rural residence and economic status that are strongly associated with changes in eating habits (i.e., fat intake may vary from 30 to 130 g/day (FAO/WHO, 1994)). Furthermore, the levels of residues into food vary in relation to the geographical area. The local pattern of use, the environmental practises and the food security strategies modify this parameter (Chikuni et al., 1997; Koopman-Esseboom et al., 1994). In that way, the levels of DDT, DDE and HCH found in butter from 23 different countries were higher in those countries that used these substances for longer periods of time (Kalantzi et al., 2001). Finally, although the time to do the study may influence the results, when we talk about persistent pollutants, factors such as seasonality become less important (Ryan et al., 1990).

3. Environmentally persistent pesticides

The most important pesticides, from the standpoint of environmental and health, are the persistent ones: DDT (and its metabolismsm, DDE and DDD), HCH, aldrin, dieldrin, ... Those substances, due to their liposolubility, tend to be bioaccumulated into the fat tissues and to be biomagnificated in the food chain (Gray, 2002). The exposure starts even at embryonic stages (Luzardo et al., 2009). It has been reported that Eskimos population, who eat very fatty foods like salmon or seal, ingest levels of these compounds that are well above the acceptable daily intake (ADI) established by the World Health Organization (WHO) (Bonefeld-Jorgensen et al., 2006). The same results have been observed in groups of population who present a high intake of milk (i.e. baby infants) (Trapp et al., 2008). Most POPs are banned, severely restricted or carefully managed in industrialized countries; however, some of them are still manufactured and used in developing countries. The physical and chemical characteristics of these substances make possible that a POP released anywhere, can eventually grow to anywhere in the world. These pesticides are propagated by evaporation into the atmosphere from warmer regions of the world -tropical countries, which is precisely where they are most commonly used- to the cooler regions, where they are deposited by condensation (Scheringer, 2009). Evaporation rates in these cold regions of the planet are very low, therefore, such substances are "trapped" there, and deposited in living organisms (Scheringer, 2009). Anyhow, in contrast to expectations, the levels of POPs in tropical countries are similar to those found in the coolest regions (Weber et al., 2008). This observation could be explained because these types of pesticides are indeed effective, cheap and safe from the point of view of acute poisoning. The cultural level of the user is very low, and the controls to restrict the illegal trade of these substances are ineffective (Ssebugere et al., 2010). The problem grows because some of these substances (i.e. DDT) are extremely effective against certain insect-borne diseases. Thus, it requires the management of pesticides and banned products already manufactured. Some countries, in collaboration with FAO, have made an inventory of obsolete pesticides, which have been subsequently destroyed. Anyway, due to loss of labeling, leakage and poor storage conditions, is impossible to know the real amount of these uncontrolled substances, which thus become a major source of pollution (Felsot et al., 2003; Haylamicheal & Dalvie, 2009). As stated above, it follows that no country can combat the problem independently. A comprehensive strategy is needed to tackle a global problem.

Different governments have developed many projects and agreements in order to control the exposure and emission of POPs. Some of the most important are the following:

- Candidate Substances List for Bans and Phase-Outs (Ontario, Canada; 1992)
- Accelerated Reduction/Elimination of Toxics (ARET) Program (Canada; 1994)
- Toxic Substances Management Program (TSMP) (Canada; 1995)
- Sound Management of Chemicals (SMOC) (North American Commission for Environmental Cooperation; 1995)
- Waste Minimization Program (US Environmental Protection Agency; 1998)

Most of these programs had ambitious goals that were not achieved. On May 23, 2001, more than 90 countries signed the Stockholm Convention on Persistent Organic Pollutants.

Substance	Comments	Commercial use
Aldrin	Annex A *	Pesticide
Chlordane	Annex A *	Pesticide
Chlordecone	Annex A **	Pesticide
DDT	Annex B *	Pesticide
Dieldrin	Annex A *	Pesticide
Endosulfan	***	Pesticide
Endrin	Annex A *	Pesticide
Heptachloro	Annex A *	Pesticide
Hexabromobiphenyl	Annex A **	Industrial chemical
Hexabromocyclododecane	***	Industrial chemical
Hexabromodiphenyl ether and heptabromodiphenyl ether	Annex A **	Industrial chemical
Hexachlorobenzene (HCB)	Annex A *	Pesticide/Industrial chemical
Alpha hexachlorocyclohexane	Annex A **	Pesticide/By-product
Beta hexachlorocyclohexane	Annex A **	Pesticide/By-product
Lindane (γ HCH)	Annex A **	Pesticide
Mirex	Annex A *	Pesticide
Toxaphene	Annex A *	Pesticide
Pentachlorobenzene (PeCB)	Annex A **	Pesticide/Industrial chemical
Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F)	Annex B **	Industrial chemical
Polychlorinated biphenyls (PCB)	Annex A *	Industrial chemical
Polychlorinated dibenzo-p-dioxins (PCDD)	Annex C *	By products
Polychlorinated dibenzofurans (PCDF)	Annex C *	By products
Short-chained chlorinated paraffins	***	Industrial chemical
Tetrabromodiphenyl ether and pentabromodiphenyl ether	Annex A **	Industrial chemical

* Initial POPs from the dirty dozen.
** New substances added on May 2009. *** Chemicals proposed for listing.

Table 1. Complete list of substances included in the Stockholm Convention.

The Convention entered into force on May 17, 2004 with a main goal: "Protecting human health and the environment of persistent organic pollutants, reducing or eliminating their emissions into the environment". The list of POPs that is currently considered is the following:

- Annex A (substances that must be eliminated): pesticides (aldrin, chlordane, dieldrin, endrin, heptachlor, CHC, mirex, hexachlorobenzene or toxaphene) and industrial chemicals (i.e. polychlorinated biphenyls (PCBs)).
- Annex B (restricted substances): pesticides (DDT) and other industrial chemicals included.
- Annex C (reduction of emissions of unintentionally produced substances): industrial sub-products included.

Initially, signatory countries aimed at reducing and / or eliminate the production and use of the most dangerous POPs, known as "Dirty Dozen". It was established a mechanism by which they could add other POPs to the Convention in the future. Thus, in May 2009, nine more dangerous substances were listed. Actually, three new compounds are under revision.

The following is a brief description of the pesticides, as published in the official website of the Stockholm Convention (www.pops.int):

- Aldrin: A pesticide applied to soils to kill termites, grasshoppers, corn rootworm, and other insect pests, aldrin can also kill birds, fish, and humans. In humans, the fatal dose for an adult male is estimated to be about five grams. Humans are mostly exposed to aldrin through dairy products and animal meats. Studies in India indicate that the average daily intake of aldrin and its byproduct dieldrin is about 19 micrograms per person.
- Chlordane: Used extensively to control termites and as a broad-spectrum insecticide on a range of agricultural crops, chlordane remains in the soil for a long time and has a reported half-life of one year. The lethal effects of chlordane on fish and birds vary according to the species. Chlordane may affect the human immune system and is classified as a possible human carcinogen. It is believed that human exposure occurs mainly through the air, and chlordane has been detected in the indoor air of residences in the US and Japan.
- Chlordecone: It was first produced in 1951 and introduced commercially in 1958. Chlordecone is highly persistent in the environment, has a high potential for bioaccumulation and biomagnifications and based on physico-chemical properties and modelling data, chlordecone can be transported for long distances. It is classified as a possible human carcinogen and is very toxic to aquatic organisms.
- DDT: It was widely used during World War II to protect soldiers and civilians from malaria, typhus, and other diseases spread by insects. DDT continued to be used to control disease, and it was sprayed on a variety of agricultural crops, especially cotton. DDT continues to be applied against mosquitoes in several countries to control malaria. Its stability, its persistence (as much as 50% can remain in the soil 10-15 years after application), and its widespread use have meant that DDT residues can be found everywhere; residual DDT has even been detected in the Arctic. The short-term acute effects of DDT on humans are limited, but long-term exposures have been associated with chronic health effects. DDT has been detected in breast milk, raising serious concerns about infant health.
- Dieldrin: Used principally to control termites and textile pests, dieldrin has also been used to control insect-borne diseases and insects living in agricultural soils. The

pesticide aldrin rapidly converts to dieldrin, so concentrations of dieldrin in the environment are higher than dieldrin use alone would indicate. Dieldrin is highly toxic to fish and other aquatic animals, particularly frogs, whose embryos can develop spinal deformities after exposure to low levels. Dieldrin residues have been found in air, water, soil, fish, birds, and mammals, including humans. Food represents the primary source of exposure to the general population, being the second most common pesticide detected in a US survey of pasteurized milk.

- Endosulfan: It is a synthetic organochlorine compound commonly used as an agricultural insecticide. It has been sold from the mid 1950s but it is now banned in at least 60 countries with former uses replaced and its production is decreasing. It has the potential for long-range transport of endosulfan residues. Endosulfan is in the Arctic at increasing levels in water, air and biota.It is highly acutely toxic via oral, dermal and inhalation routes of exposure and it is associated to human poisoning. Contradictory opinions on the potential for endocrine disruption have been presented. a benchmark approach has been performed with lindane having similar toxicity than endosulfan.
- Heptachloro: Primarily used to kill soil insects and termites, heptachlor has also been used more widely to kill cotton insects, grasshoppers, other crop pests, and malaria-carrying mosquitoes. Laboratory tests have shown high doses of heptachlor to be fatal to mink, rats, and rabbits, with lower doses causing adverse behavioral changes and reduced reproductive success.Heptachlor is classified as a possible human carcinogen. Food is the major source of exposure for humans, and residues have been detected in the blood of cattle from the US and from Australia.
- Hexachlorobenzene: First introduced in 1945 to treat seeds, HCB kills fungi that affect food crops. It was widely used to control wheat bunt. It is also a byproduct of the manufacture of certain industrial chemicals and exists as an impurity in several pesticide formulations. Mothers passed HCB to their infants through the placenta and through breast milk. In high doses, HCB is lethal to some animals and, at lower levels, adversely affects their reproductive success. HCB has been found in food of all types. A study of Spanish meat found HCB present in all samples. In India, the estimated average daily intake of HCB is 0.13 micrograms per kilogram of body weight.
- Alpha and beta hexachlorocyclohexane: Although the intentional use of alpha-HCH as an insecticide was phased out years ago, this chemical is still produced as unintentional by-product of lindane. It is highly persistent in water in colder regions and may bioaccumulate and biomagnify in biota and arctic food webs. This chemical is subject to long-range transport, is classified as potentially carcinogenic to humans and adversely affects wildlife and human health in contaminated regions.
- Lindane: It has been used as a broad-spectrum insecticide for seed and soil treatment, foliar applications, tree and wood treatment and against ectoparasites in both veterinary and human applications. The production of lindane has decreased rapidly in the last few years. Lindane is persistent, bioaccumulates easily in the food chain and bioconcentrates rapidly. There is evidence for long-range transport and toxic effects in laboratory animals and aquatic organisms.
- Mirex: This insecticide is used mainly to combat ants and termites. Direct exposure to mirex does not appear to cause injury to humans, but studies on laboratory animals have caused it to be classified as a possible human carcinogen. It is considered to be one of the most stable and persistent pesticides. The main route of human exposure to mirex is through food, particularly meat, fish, and wild game.

- Toxaphene: This insecticide is used on cotton, cereal grains, fruits, nuts, and vegetables. Toxaphene was the most widely used pesticide in the US in 1975. For humans, the most likely source of toxaphene exposure is food. While the toxicity to humans of direct exposure is not high, toxaphene has been listed as a possible human carcinogen due to its effects on laboratory animals.
- Pentachlorobenzene: PeCB was used in PCB products, in dyestuff carriers, as a fungicide, a flame retardant and as a chemical intermédiate. It also present as impurities in products such as solvents or pesticides. PeCB is persistent in the environment, highly bioaccumulative and has a potential for long-range environmental transport. It is moderately toxic to humans and very toxic to aquatic organisms.

Restrictions on the use of these organochlorine compounds have resulted in a marked decrease in the average concentration of these pesticides in human tissues. Thus, in 1960s the mean concentration of DDT in fat tissue from USA population was 5 ppm, while in 1990s this value decreased one hundred times. However, 35 years after the banned of DDT, is possible to measure residues of this product and DDE in serum from different populations (Jakszyn et al., 2009; Zumbado et al., 2005). Organochlorine pesticides can be classified in order to the chemical structure, the manufacture system, and other factors (O'Neil, 2006). Anyway, all of these substances share a number of common characteristics as its lipid solubility and resistance to degradation. If we consider that the technical pesticides that were applied in past decades was a mixture of isomers among which the most abundant was 4,4 '-DDT, and that the pesticide undergoes slow degradation in the environment to its more persistent metabolite (4.4 '-DDE) (Safe, 1994), it is normal to observe that those countries which had a more controlled use of DDT, and where they were banned for longer, the 4.4 '-DDE is the metabolite found most frequently in foods and in serum of the population.

Pesticide	Approximate half-life
Aldrin	5 years in temperate soil
Campheclor (Toxaphene)	3 months - 12 years
Chlordane	2 - 4 years
DDT	10 - 15 years
Dieldrin	5 years in temperate soil
Endrin	Until 12 years
HCB	3 - 6 years
Heptachloro	Until 2 years
Mirex	Until 10 years
HCH	Days - 3 years

Table 2. Half-life in soil of the POPs listed in Stockholm Convention.

4. Potential adverse consequences of POPs. The phenomenon of endocrine disruption

The US Environmental Protection Agency (EPA) defines an endocrine disruptor (ED) as “an exogenous agent which interferes with the synthesis, secretion, transport, metabolism, binding or elimination of hormones that are naturally present in the body and that are responsible for homeostasis, reproduction and development" (Diamanti-Kandarakis et al., 2009). This phenomenon was first described in 1968, when the 4,4´-DDE (an active metabolite of DDT) was considered responsible for the reproductive abnormalities of birds feeding on fish contaminated with this product (Hickey & Anderson, 1968). Another important fact observed was that occurred with the population of alligators of Lake Apopka in Florida. This animal population was exposed to high levels of dicofol in 1980s due to an accidental release. Ten years later, alligator population had dropped significantly, had increased mortality in eggs and half of newborn languished and died. Moreover, significant sexual abnormalities were observed in both male and females: decreased penis size, increased levels of estrogen, and ovarian malformations (Guillette et al., 1995a; Guillette et al., 1995b). Similar findings have been reported in other species reaching the same conclusion: disorders of sexual phenotype expression (Quintela et al., 2002; Sumpter & Jobling, 1993).

The group of molecules identified as ED is big, and includes several pesticides as DDT, chlordane or methoxychlor. Although some "endocrine disrupters "can be of natural origin, it must be highlighted that the majority of them are anthropogenic substances. Actually, the knowledge about the action mechanisms of ED is deep and wide. First studies reported that ED joined to nuclear receptors related with hormone signalling: estrogen, androgen and progesterone receptors, mainly. Today, it is known that these interactions are more complex. ED join to several membrane receptors for steroid hormones, as well as to orphan receptors (i.e. aryl hydrocarbon receptor), and other types of proteins (i.e. dopamine receptor, serotonine receptor). Thus, from a physiological perspective, an endocrine disruptor is a compound, either natural or synthetic, which through environmental exposure alters hormonal and homeostatic systems that allow the organization to communicate and respond to their environment (Diamanti-Kandarakis, Bourguignon et al., 2009). While most of the effects of ED could be categorized as "estrogenic", there are many substances that have androgenic effects (or more often anti-estrogenics); as well as agonists or antagonists of thyroid hormones. The sources of pollution and exposure to ED are highly variable, but may be considered a global phenomenon that affects all living beings on the planet, that are constantly exposed to mixtures, highly variable from individual to individual and from region to region, of these substances. The situation is also changing, because many of these compounds have been banned decades ago, while others are still permitted for certain uses or have been banned recently. Food and water intake must be considered the main routes of exposure. Different factors must be considered at this point:

- Age of exposure: the substances in the environment in which an organism develops interact with individual genes to determine their propensity to develop a disease or dysfunction in the future (Barker, 2003)
- Latency period from exposure: the consequences of exposure to ED may not appear immediately or early in life (Barker, 2003)
- Importance of mixtures: interactions, potentiation, synergism or addition (Kortenkamp, 2007)
- Non-conventional dose-response effects: in some cases, low doses may produce more powerful effects that higher doses (Boada et al., 2007; vom Saal et al., 2007)
- Trans-generational effects: ED not only can affect the exposed person but also to subsequent generations, possibly through non-genomic pathways (epigenetics)

The exposure to ED has been related with different health problems: testicular cancer, cryptorchidism, lymphoma non-Hodgkin, multiple myeloma, decrease in spermatozoa quality, breast cancer and other cancer types, spontaneous abortion, birth defects, immunology impairment, early puberty, or learning problems. Literature also shows that ED play a role in the aetiology of complex diseases such as obesity, diabetes mellitus or cardiovascular disease, although the scale of its implications are still poorly known. Nonetheless, to find associations between exposure to ED and the development of different pathologies is a very hard and complicate work, taking into account that the extent of chemical compounds in isolation may not give the required information on the biological effect to be surveyed. The evidences obtained from in vitro and animal models are quite concise, not the case of humans. Meanwhile, the precautionary principle should be applied in any case.

5. Legal regulations on waste food for persistent organochlorine pesticides

With the aim to protect the animal and human health, all food intended for human or animal consumption in the European Union is subject to legislation that determines the maximum residue level (MRL) that may be present in its composition. The MRL is defined as the maximum concentration of pesticide residue which is legally permitted or acceptable in food under the laws of the EU, based on good agricultural practices and the lowest consumer exposure necessary to protect all vulnerable consumers. This parameter is based in the acceptable daily intake (ADI) of the regulated substances. Thus, ADI is a measure of the amount of a specific substance in food or drinking water that can be ingested over a lifetime without an appreciable health risk, according to all the facts known at the time of evaluation, taking into account vulnerable groups of population.

Persistent organochlorine pesticides	ADI (mg/kg)	MRL (mg/kg)
Aldrin and dieldrin	0.0001	0.006
Chlordane (sum of *cis*- and *trans*- chlordane)	0.0005	0.002
DDT (sum of 4,4'-DDT, 2,4'-DDT, 4,4'-DDE and 4,4'-DDD)	0.01	0.04
Endosulfan (sum of α- and β- endosulfán and endosulfan sulphate)	0.006	0.05
Endrin	0.0002	0.0008
Heptacloro	0.0001	0.004
HCB	Not available	0.01
HCH (isomere α)	Not available	0.004
HCH (isomere β)	Not available	0.003
HCH (isomere γ) – lindane	0.005	0.001
Metoxicloro	0.1	0.01
Canfeclor (Toxaphene)	Not available	0.01

Table 3. MRL and ADI of the persistent organochlorine pesticides in not concentrated milk and cream (not containing added sugar or other sweetening matter), butter and other fats from milk, cheese and curd.

Laws related to MRL of pesticides were different between countries until 2005. Before this year, the UE had set different limits of pesticide for each type of product: fruit and vegetables (Directive 76/895/EEC), cereals (Directive 86/362/EEC), products of animal origin (Directive 86/363/EEC) and products of plant, including fruit and vegetables (Directive 90/642/EEC). The EC Regulation 396/2005 of the European Parliament and the Council, repeals all previous directives and gathers in one text the limits for various products for human or animal, and sets a default ceiling in the case that no MRL has been fixed. In general, the maximum level of pesticide residues in food is 0.01 mg/kg. However, all the organochlorine compounds have its MRL. Due to its persistent nature, is very important to ensure the protection of all consumers, especially those belonging to the "vulnerable population groups". It follows that MRLs in food must not only ensure the direct protection of the consumer but also to ensure that does not be undesirable accumulation or concentration in the food chain.

6. Current levels of dietary exposure of EU citizens to persistent organochlorine pesticides

Dietary modelling is a scientific method for estimating the levels of pesticide residues, contaminants or other substances that a person or a population may be consuming. Dietary modeling techniques have been used by international food regulators for years to determine whether dietary exposure to pesticide residues, contaminants and other substances represents an unacceptable risk to public health (Kroes et al., 2002; Lopez et al., 2003). In a recent publication, it has been reported an estimation of theoretical maximum daily intake (TMDI) of 421 pesticides, including POPs, among different populations from Europe with several dietary habits (Van Audenhaege et al., 2009). TMDI, expressed as the percentage of the ADI, was estimated taking into account the MRL for each pesticide as well as the dietary habits of each population. It should be noted that this is a theoretical estimate, which means assuming that the controls work perfectly and that it is not marketed in the EU any food

Persistent organochlorine pesticides	ADI (mg/kg)	TMDI (% ADI)
Aldrin	0.0001	348.8
Dieldrin	0.0001	348.8
Chlordane (sum of *cis-* and *trans-* chlordane)	0.0005	38.5
DDT (sum of 4,4'-DDT, 2,4'-DDT, 4,4'-DDE and 4,4'-DDD)	0.01	17.5
Endosulfan (sum of α- and β- endosulfán and endosulfan sulphate)	0.006	27.1
Endrin	0.0002	77.7
Heptacloro	0.0001	331.0
HCH (isomere γ) – lindane	0.005	4.2
Metoxicloro	0.1	0.1

Table 4. Theoretical estimation of the exposure (TMDI) to POPs through the diet in terms of the eating habits in European population.

which present POPs pollution levels exceeding the MRL established. Also, implies assuming that all food consumed have a residue level equal to the MRL for each pollutant. To achieve the real intake of POPs would be necessary to know the data from total diet or to work with a random sampling of foods from all groups.

A total diet study considers the total number of foods that make up the diet of an individual in the population studied, and analyzes the levels of each chemical contaminant. Thus, it is possible to know the total intake of residues from toxic substances that are commonly present in the food that take part of the diet. Therefore, this kind of studies determines the overall exposure of an individual to contaminants, analyzing whether this exposure has an unacceptable risk to human health. Because the preparation of food affects the concentration of pollutants and other substances, total diet studies use the analyses made over food ready to eat. Actually, there is a lack of total diet studies and global reports in EU regarding to contamination of food by POPs. For this, we can only provide rough estimates based on recently published works (Van Audenhaege et al., 2009). According to this, the levels of ADI for aldrin, dieldrin and heptachlor could be three times over the recommendations made from the WHO. Ten different groups of food were included: fruits, vegetables, cereals, potatoes, vegetable products, milk and dairy products, eggs, meat and other animal products, water and wine. Milk consumption represents about 13% of the total diet in EU countries. Daily contribution intake of milk and dairy products would be around 45% of the ADI for the case of aldrin and dieldrin, and 42% of the ADI in the case of heptachlor.

Dietary modelling is an important part of studies estimating the exposure of a population to a particular group of pollutants. It makes that the analytical results achieved in food dietary exposure can be compared to health benchmarks established. This comparison is crucial in determining whether the estimated dietary exposure to contaminants in food presents an unacceptable risk to the health of any population group (Kroes et al., 2002; Lambe, 2002). In this type of studies, the amount of chemical in each food is multiplied by the amount of food consumed. The sum of the amount raised for all food products determines the exposure to this substance from the total diet. Once the exposure to chemicals is estimated, it is compared with the reference health standards for assessing the potential risk that such exposure poses to human health (Lambe, 2002). The health standards of reference are the ADI for residues of pesticides, and tolerable intake limits for pollutants and other substances. These are the amounts of substance which, according to scientific evidence, can be consumed daily or weekly without posing a significant risk to human health. The levels of chemicals used are representative levels obtained from the analytical testing of food samples in the study. However, one of the most important steps is to match the food samples with more than one-thousand foods that are identified in a food survey. In total/partial diet studies is impossible to analyze all foods consumed, or all which are part of a particular food group. Therefore, each food tested should be considered as representative of a food group, with appropriate adjustments for the concentration (Kroes et al., 2002). The European Food Safety Authority (EFSA) established the Concise European Food Consumption Database in 2008 with the aim of to support estimations of exposure to toxic substances through the diet in the countries of the Union. In order to obtain comparable results, data were aggregated into fifteen major categories, based on the precautionary principle, to provide a conservative estimate of exposure levels. The study also includes subcategories of food in some of the major groups, providing data from consumption of a total of twenty-eight kinds of food. The database was created to provide a tool for exposure assessment, and it allows the evaluation of total exposure of the population groups. Although it has the limitations of categorization in large food groups and differences in methodologies employed for data collection, it is sufficient when calculating exposure based on conservative estimates of concentrations are below the level of concern (ESFA, 2008). Data referred to these fifteen categories are summarized in Table 5. Sixteen countries took part in the study: Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Denmark (DK), Finland (FI), France (FR), Germany (DE), Hungary (HU), Iceland (IS), Ireland (IE), Italy (IT), The Netherlands (NL), Norway (NO), Slovakia (SK), Sweden (SE),

Group	BE	BG	CZ	DK	FI	FR	DE	HU	IS	IE	IT	NL	NO	SK	SE	GB	M
Cereals	245	257	274	217	153	317	287	252	276	227	271	220	192	345	291	249	**257**
Sugar products and chocolate	31	40	39	43	42	31	45	39	31	41	19	43	47	69	28	27	**43**
Fats	46	39	48	36	40	28	29	54	33	36	36	48	41	29	24	20	**38**
Vegetables	230	210	131	166	135	210	252	191	125	244	249	193	140	164	118	163	**194**
Starchy roots and potatoes	95	83	103	112	95	67	125	110	79	229	48	128	133	96	138	112	**129**
Fruits	113	70	122	150	121	132	190	180	71	106	203	107	119	116	119	95	**92**
Fruit juices and soft drinks	945	207	618	340	213	389	947	280	426	179	384	296	491	382	329	325	**439**
Coffee, te and cocoa	432	120	559	836	580	282	691	176	429	714	124	887	604	461	575	724	**601**
Alcoholic beverages	214	102	413	292	139	163	231	76	104	335	126	206	123	64	191	313	**413**
Meat and meat products	121	108	175	128	120	134	127	173	93	122	134	141	103	179	150	49	**234**
Offal	2	7	9	7		8	11	13	6	1	3	5	6	12		2	**12**
Fish and seafood	25	20	19	18	27	37	19	9	37	24	43	13	63	9	34	31	**62**
Eggs	10	21	20	16	17	18	23	27	11	20	18	15	21	13	14	19	**25**
Milk and diary products	203	169	186	386	437	265	313	265	442	306	212	388	522	91	386	251	287
Dietary uses	2	13	15	5	24	2	36	17	23	13	5	6	12	6	16	17	**14**
Tap Water	100		288	840	886	283	71	1	670	284	206	209	312	224	480	205	**349**

Table 5. Average food consumption (g/day) in the total adult population of sixteen EU countries (M, median).

and United Kingdom (UK). Other countries, as Poland (PO), Estonia (ES) and Austria (AU) have sent data, but they are not included in the database, yet. Finally, countries as Spain (SP), Portugal (PT) or Greece (GR) have not sent any data.

The need for such data at European level was raised at the colloquium on "European Food Consumption Database - Current and medium to long-term strategies" organised by EFSA in Brussels in April 2005. Exposure assessment is a crucial part of the risk assessment and the quality of available data both on food consumption and on occurrence levels may have a major impact on the outcome of the risk assessment. Other European important projects are underway. It is the case of the "Benefit-Risk Assessment for Food" (Beneris). The main objective of the project is to forge major advancements in food benefit-risk analysis on human health. Beneris brings together a team of epidemiologists, toxicologists, nutrition scientists, exposure assessors, risk analysts, and authorities from five European countries (Finland, The Netherlands, Ireland, Denmark and Spain) with crucial access to contacts and data.

The Beneris project forms a cluster with another project in the same call, namely Qalibra. The two projects are tackling the same problems but using complementary methods and approaches. Qalibra is more focused on developing web-based technical tools for risk assessment, while Beneris concentrates on developing useful approaches and strategies (including extensive case studies).

6.1 The potentially hazardous foods: milk and dairy products

Although the POPs can reach humans due to direct environmental exposures (such as occupational exposure), the main source of exposure to these compounds is the consumption of contaminated food. Milk is a food of animal origin where POPs are detected at higher concentrations, making this product a food "at risk" for the consumer (Focant et al., 2002). However, other food groups are involved as sources of exposure, and relevant data have been published recently. Thus, vegetable consumption has been related to lindane, and fruit intake with endosulfan (Mariscal-Arcas et al., 2010)

The concentration of POPs found in the milk brands tested was low and always lower than the MRLs established by the laws. It must be highlighted that, actually, the levels of POPs residues in milk throughout the world have been significantly reduced, as a result of prohibition or restriction of use of this substances (Nag & Raikwar, 2008). In that way, the level of contamination by 4,4′-DDT in the European environment has declined drastically in recent years following the ban on its use forty years ago. In the case of 4,4′-DDE, residue levels of this substance in samples of milk, are similar among different Western countries (U.S. Total Diet Study, 2001). But this does not apply in the developing countries. Both 4,4′-DDE and 4,4′-DDT are routinely detected in 100% of milk and other dairy products sold in China, Ghana and India (Darko & Acquaah, 2008; Nag & Raikwar, 2008; Zhang et al., 2006). In these countries the amounts of these residues are high, and reach worrying levels. In milk samples from India were measured average levels of 4 μg/kg and 5 μg/kg for 4,4′-DDT and 4,4′-DDE, respectively; results that suggest a recent and continued use of the pesticide DDT. The same profile has been observed for lindane (HCH), whose levels in samples of milk from India reached values of 10 μg/kg (Nag & Raikwar, 2008). On the contrary, the higher values of lindane described in the Total Diet Study of the United States in 2001 were 0.00002 μg/kg, which is indicative of the high levels of exposure in the population from developing countries. Thus, current intakes are at least 5- to 100 fold greater than those observed in more developed nations, suggesting a greater risk from organochlorine exposure. Moreover, the estimated intake of DDT by infants from these Asian regions is at least 100 fold greater than the ADI of the FAO/WHO, being the milk a major source of exposure.

Consumption of dairy products in occidental countries has experienced a sharp increase in recent decades. Thus, consumption of cheese, yogurt or butter is vastly superiors who had thirty years ago. Since milk appears to be an important “food of risk” in terms of pesticide residues, it is necessary to study dairy products as sources of exposure to organochlorine pesticides. Just as with milk, the levels of POPs contamination detected in cheese are low, and are always below the maximum residue limit established by law in Western countries (DOUE, 1993 and 1994). However, lindane seems to appear frequently as residue in cheese. Although it levels have decreased in recent years, they vary according to the world region, being highest in developing countries as Jordan or Ghana (Darko & Acquaah, 2008; Mallatou et al., 1997; Salem et al., 2009). Results from Western countries show that HCH pollution is due to the persistence of lindane degradation products (α and β isomers), indicating a past use of the compound. In addition, relationships have been established between high levels of lindane found on products like cheese, and high levels of lindane in the serum of the population consuming these products (Luzardo et al., 2006). It is clearly established in this case a direct connection between the presence of contaminants in food consumption and high pollution levels in the population. Although its use is banned several decades ago, studies have found residues of DDT and its metabolites also in cheese. Again, the relationship between food waste and waste in the population has been established, this time for the case of DDT (Zumbado et al., 2005).

6.2 The potentially hazardous foods: fish and seafood products. Role of sea and river contamination

Although fish and seafood present detectable levels of organochlorine pesticides, which vary depending on geographic location and other parameters as fat amount, these levels, in Western countries are always below the permitted maximum residue limits for each substance. The National Contaminant Biomonitoring Program periodically determined concentrations of organochlorine chemical residues from the U.S. Fish and Wildlife Service. The mean concentration of total DDT and its homologues (p,p′-constituents) in 1999, declined from 1984 to 1986, thus continuing a trend that began in 1970. Averaged 74% of total DDT residues, up from 70% in 1974-1979, are essentially unchanged from 1984, suggesting a low rate of influx and continued weathering of DDT in the environment (Schmitt et al., 1999). As cited previously, in most Southeast Asian countries DDT was a common contaminant in animal origin foodstuffs. The higher percentage of p,p′-DDT in meat and fish from Southeast Asian countries, except Japan and Korea, indicated the recent use of DDT in vector control operations. Aquatic food products from more industrialized countries, such as Japan, South Korea, Hong Kong, and Taiwan, contained significant levels of other POPs from industrial origin, such as PCBs. In South Pacific countries, particularly in Australia and New Zealand, chlordanes and PCBs were the most prevalent organochlorines in foodstuffs (Kannan et al., 1997), being meat and fish the major sources of organochlorine exposure by Australians. Human dietary intake of organochlorines has been declining more slowly in Asian developing countries (Kannan, et al., 1997).

Sea and river pollution have been extensively studied due to the intrinsic relation with fish and seafood contamination. Several researches have been published reporting levels of contaminations by POPs in different seas and rivers all over the world. In a recent study, it has been estimated the residue levels of organochlorine compounds (and other contaminants as PCBs) in Northwestern Mediterranean Sea from the Ebro River (Gomez-

Gutierrez et al., 2006). Based on the contaminant concentrations and on hydrological data, contaminant discharges into the sea were estimated amounting in total to 167 kg per year of organochlorine compounds. Concentrations ranged from 0.4 to 19.5 ng/l for the organochlorine compounds (Gomez-Gutierrez et al., 2006). Similar data have been reported from other European regions, reporting a modest contaminated status of rivers and seas, that must be under observation (Neamtu et al., 2009).

It has been observed that among several substances, the main contaminants in the muscles of both pikeperch and perch species from the Sulejowski Reservoir in central Poland was p,p'- DDE, reaching an average of 1,072 and 694 ng/g lipid, respectively. Nonetheless, based on the contaminant levels in the sediment and fish, this region compares well with other, freshwater environments relatively uncontaminated with persistent organic pollutants.

In relation to other POPs, temporal trends from ice/snow cores as well as mountain lake sediments reveal a marked increase in endosulfan accumulation from the 1980s onwards. Levels of alpha-endosulfan do not show a decline in atmospheric monitoring data, reflecting ongoing use of this pesticide in the northern hemisphere. Endosulfan is present at low concentrations (relative to the pesticide, lindane) in surface Arctic Ocean waters. Residues of endosulfan have been detected in marine biota for different geographical regions of the Arctic, with higher bioaccumulation factors (>10^3-10^7) for zooplankton and various species of fish, compared to studies in warmer/temperate systems. Endosulfan is present in marine mammals, and biomagnification factors for alpha-endosulfan are >1, notably from fish to seal (Weber et al., 2009).

7. Conclusion

Pollution is inherent to human progress. For decades, persistent pesticides have been used, and actually they are accumulated in the global environment. Food is the main source of exposure to these substances for human beings. Although the exposure levels vary by geographic area, in Europe, levels of organochlorine pesticides detected in foods are below the maximum residue limits established by laws. In general, levels of such waste have been decreasing over the years, mainly due to the creation of laws for the regulation or prohibition of such substances. However, nowadays World population is still environmentally exposed to low levels of these contaminants and the future consequences of such exposure are unknown and a matter of concern.

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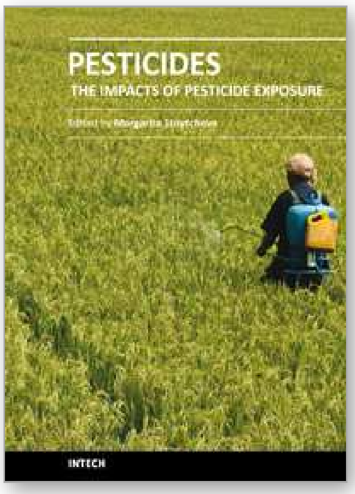

Pesticides - The Impacts of Pesticides Exposure
Edited by Prof. Margarita Stoytcheva

ISBN 978-953-307-531-0
Hard cover, 446 pages
Publisher InTech
Published online 21, January, 2011
Published in print edition January, 2011

Pesticides are supposed to complete their intended function without â€œany unreasonable risk to man or the environmentâ€. Pesticides approval and registration are performed â€œtaking into account the economic, social and environmental costs and benefits of the use of any pesticideâ€. The present book documents the various adverse impacts of pesticides usage: pollution, dietary intake and health effects such as birth defects, neurological disorders, cancer and hormone disruption. Risk assessment methods and the involvement of molecular modeling to the knowledge of pesticides are highlighted, too. The volume summarizes the expertise of leading specialists from all over the world.