PROJECT N. 037033

EXIOPOL

A NEW ENVIRONMENTAL ACCOUNTING FRAMEWORK USING EXTERNALITY DATA AND INPUT-OUTPUT TOOLS FOR POLICY ANALYSIS

EXIOPOL DELIVERABLE D II.2.c-1

Report on Unit Values for Pesticides

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Preamble

The present Deliverable D II.2.c-1 contains results to be used as basis for the impact-pathway analysis of the external costs of plant protection products, namely herbicides and insecticides, as applied in current agricultural practice, carried out in workstream WS II.2 of the EXIOPOL project.

As both effects on human health (human toxicity) as well as on the environment (ecotoxicity) have been taken into account, the basic methodology for estimating impacts is based on the following:

- Regarding impacts on human health, the focus has been on the ingestion pathway, i.e. the consumption of effectively harvested and processed agricultural produces, which has been considered the predominant exposure pathway with respect to non-persistent, currently used herbicides and insecticides, respectively.
- Regarding impacts on ecosystems, the focus has been on the fraction of an applied herbicide or insecticide, which undergoes overland flow (run-off) from soil to surface water, groundwater infiltration (leaching) from surface soil to sub-surface soil and further to the groundwater table as well as advective transport from paddy to surface water (only in case of paddy rice).

Note that biodiversity losses have not been taken into account as part of this work stream as this issue is considered to be of significant importance and, hence, impacts on biodiversity have been elaborated in a separate work stream (WS II.3).

Whereas the methodological framework and implications for the implementation into a modelling approach are described in detail in Deliverable D II.2.a-2B, and the linkage between the aggregated unit values per country and the commodity-specific unit values per country are desribed in detail in Deliverable D II.2.c-2, the present Deliverable focuses on the monetary implications by deriving marginal external cost estimates at country level, i.e. damages expressed in monetary terms (Euro) per kg applied herbicide or insecticide, linked to the economic product categories in the EXIOPOL IO-tables. The present deliverable can be read as a relatively raw data protocol for the calculations performed. Different scientific publications on a later stage will include more explanations and justifications for the methodology and approaches.

Peter Fantke

December, 2009

Executive Summary

Overview

This report is the report of the EXIOPOL project on unit values of pesticides for Europe. According to the fact that "it has been common knowledge that many pesticides cause harm to the environment and to human health, it is remarkable that there is an almost complete absence of a full costing of a market product" (Pretty & Waibel, 2005). In order to account for a quantitative assessment of externalities of current agricultural practice at the European scale, it is necessary to select the most relevant plant protection products that are responsible for the major part of the externalities. While according to the DoW of EXIOPOL a lot has been done in the regard of externality estimation from related emissions in the areas of energy production/conversion and transport, there are still significant gaps, e.g. in the agricultural sector. On the basis of a sound gap analysis, EXIOPOL will look at important emission-endpoint pathways for which externalities have not been calculated adequately yet and, thus, is a project of *integrated environmental Health Impact Assessment* (HIA) using the full chain approach.

In line with the overall objective of EXIOPOL, the purpose of work packages WPII.2.a and WPII.2.c is to conceptually develop and adapt the impact-pathway methodology to the impact chain of nutrients and pesticides and provide, as a result, unit values for both substance groups. With respect to pesticides, hereafter referred to as plant protection products, unit values are presented aggregated over all agricultural commodities in the present Deliverable, and, as additional background information, dis-aggregated, i.e. commodity-specific in Deliverable D II.2.c-2.

These unit values are to be further used in Cluster III and Cluster IV of the EXIOPOL project as described in more detail in the subsequent chapters. The EXIOPOL project has started in March 2007 and will run until March 2011.

Approach

With several thousand commercial formulations of several hundred active ingredients currently on the market, plant protection products are widely used in current agricultural practice all around the world (Alloway and Ayres, 1997). The usage of plant protection products and, thus, their dispersion and fate in the environment has mainly occurred in the last six decades and they have become relatively ubiquitous pollutants, especially in technologically advanced countries, such as the U.S. and most countries of the EU. Hence, residues of plant protection products can be found in human as well as in animal tissues, in different agricultural soils and adjacent areas, in groundwater, in rivers and lakes and in various items of the food chain (Arias-Estévez et al., 2008; Hamilton and Crossley, 2004; Juraske, 2007; Margni et al., 2002).

However, the local and transnational transport of plant protection products in the atmosphere, in the oceans and in the marine food chain has resulted in their wider global distribution, all this due to diffuse emission as a function of the method behind the direct application of a product onto the agricultural produce of concern. Hence, concentrations of several plant protection products can even be found in the Arctic snows (Herbert et al., 2005), in Antarctic penguins (Geisz, 2008) and last but not least in the atmosphere all over the world including the polar regions (Li and Macdonald, 2005; Hung et al., 2002).

EXIOPOL as an international and integrated project appropriately addresses the transnational aspects as well as the most important exposure pathways for plant protection products which allows for an assessment in an as comprehensive a way as possible. An example of transnational aspects is long-range transport as a component of the environmental fate of a pesticide that is one part of the transportation processes that lead to its global distribution. However, currently used plant protection products as listed in Chapter 1 are not supposed to undergo long-range transport according to international authorisation guidelines, despite the fact that for most of these substances the long-range transport behaviour is still unclear (Matthies et al., 2009). In addition, the exposure via food products is considered as being predominant with respect to the release of plant protection products into the environment, which is in line with state of the art literature (Juraske et al., 2007; Lu et al., 2008). Therefore, the main focus of the present study is the direct application of plant protection products to the major agricultural commodities, aggregated over all commodities in this Deliverable and dis-aggregated, i.e. commodity-specific in Deliverable D II.2.c-2, for all considered countries. Nevertheless, the exposure from diffuse emissions into the environment has been included based on extensive research by the co-authors of Rosenbaum et al. (2008).

However, the main aim of the EXIOPOL project is to create a monetary input-output table with environmental extensions including externalities resulting from agricultural activities. This input-output table will cover around 130 industrial sectors and products in the 27 Member States of the EU as well as in 16 non-EU countries, such as the U.S., China, or Brazil. The data collected will be based on national supply and use tables which will be linked using trade date for all the countries included in the analysis. Due to this large amount of data requirements, there are a number of criteria that have to be fulfilled to allow for and facilitate the integration of the externalities of different agricultural practices, with plant protection products being a major part of the work in this field of research. This goes along with some constraints and limitations, which will be described in detail in the following chapters.

The main input-output table is basically an economic input-output table to which per sector discerned information about emissions and resource use is added. The database that, in relation to this, is to be developed, will include external costs per sector as calculated in Cluster II, e.g. for the direct application of plant protection products as part of the externalities of current practice in the agricultural sector. The input-output table will be based on data for the year 2000 and will be extrapolated into the year 2005 at a later stage of the project. Thus, data used for the quantification of, e.g. pesticide emissions and modelling their behaviour in the environment and receptors of concern will also be first calculated for the year 2000.

The resulting external costs as main output of the present study will be categorised into 'impacts on human health' and 'impacts on ecosystems'. Data could directly be included into the national supply and use tables and will be aggregated on a European-wide level in a later step. In particular, data related to the application of plant protection products are provided in [kg/year] or [t/year], and external cost values are generally calculated either in [Euro/kg/year] or [Euro/t/year], i.e. given as incremental damages.

In addition to the application of the results of this work stream for the estimation of external cost due to the usage of plant protection products in agricultural practices as well as the inclusion of the results in the final extended input-output table in Cluster III of this project, the information gathered will also be applied in Cluster IV. This cluster focuses on the implications for policy which are to be extracted from the findings of the externality research including agricultural externalities. Therefore, the environmental burden of activities in the agricultural sector will be analysed in different future scenarios and then linked to the use of different agricultural subsidies at the national and/or European scale.

In order to interlink the different aspects concerning policy, economy and the environment including human health, the full chain from policy to external costs must be taken into consideration. Although the full chain approach is much too limited and simplistic to encompass the full complexity of relationships between environmental policies, the environment, and human health, it provides a framework for working through the policies that affect environmental chemicals and physical stressors, and, through these, affect environmental and human health (see Figure 0-1).

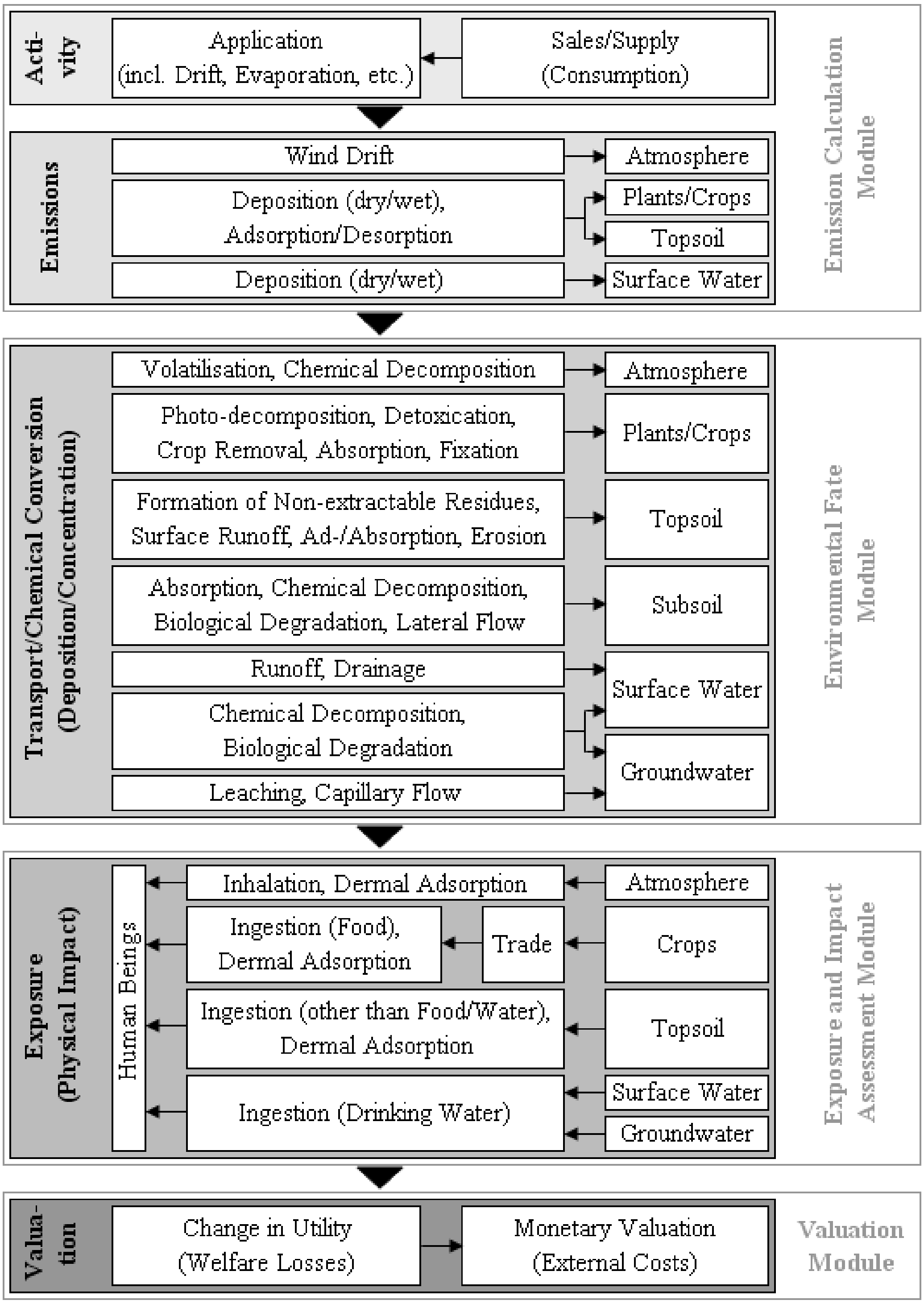

Figure 0-1: Procedural steps in the impact pathway approach to estimate and evaluate impacts on human health and ecosystems due to direct application of plant protection products aggregated over the whole agricultural sector according to current agricultural practice. (1): environmental fate assessment, (2): exposure assessment, (3): human health and ecosystem impact assessment, (4): Severity and external cost assessment.

However, as also mentioned in other projects, such as HEIMTSA, the full chain approach is the methodological framework that is preferred by the European Commission, and which through its name of being an 'Impact Pathway Approach' many of the partners are familiar with, who are involved in the EXIOPOL project. Within EXIOPOL, the general methodology of the full chain approach is used for assessing externalities of different economic sectors and will be adopted as well for the externality assessment of plant protection products released into the environment by current agricultural practice. In general, the full chain approach chronologically follows the pathway of a chemical through the stages of the chain as follows:

- From (changes in) policy; to
- (changes in) emissions to air and/or releases into soil and water; to
- (changes in) concentrations in environmental media (including micro-environments); to
- (changes in) exposures of targeted receptors (e.g. humans: exposure of individuals and populations via inhalation, dermal and/or ingestion routes; to
- (changes in) internal dose at target organs (e.g. lung, liver) in the receptors; to
- (changes in) risks of (human) health effects; to
- (changes in) health impacts ('annual number of incidences'; to
- (changes in) monetary value of health impacts.

Note that actions and policies can change population-attributable health effects not only by directly aiming at a change in emissions or releases of a chemical but also by acting at various other stages of the chain. For example, and in particular, exposure is determined not only by emissions and usage, with consequences for the concentrations of plant protection products in various (micro-) environments. It is also determined by the characteristics and habits of the population at risk. Actions to limit exposure may focus on usage and, thus, on concentrations in (micro-) environments. On the other hand, actions may also focus on, e.g. informing the population so that the total population-weighted exposure is reduced.

The general full chain approach was adapted to meet the specific requirements of an externality assessment of plant protection products at the European scale and follows the methodological concept of the Impact Pathway Approach, according to its definition in Deliverable D II.2.a-2B and its application for an assessment of plant protection products. How the development and application of the presented methodology will be integrated into the overall objective of the EXIOPOL project to finally arrive at unit values for the agricultural sector for each considered country is subject of the following chapters.

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1 Definition of the General Framework

According to the «definition study for EE IO database», Supply and Use Tables (SUT) and Input-Output Tables (IOT) form a key component in national economic accounting systems. Thus, within EXIOPOL, such SUT are provided for each economic sector, e.g. agriculture.

Again, according to the «definition study for EE IO database», the base year for the primary data also with respect to the agricultural sector will be 2000, since for later years not sufficient SUT or IOT are available and staying as close as possible to primary sources is a point of departure on the project. If resources permit this, a data set for 2005 or later will be constructed via simple extrapolation of SUT, and using trade data for this year. However, this is not the case for the present study; hence the unit values have been carried out for the base year 2000 only.

The EE I-O work in EXIOPOL wants to cover the EU-27 and its most important trade partners. Since this will result in a country list that covers most of the global economy, de facto EXIOPOL aims to develop a global, multi-regional input output table with environmental extensions (MR EE IOT). This database will be connected to external costs of emissions as calculated in other parts of EXIOPOL as well. However, due to lack of sufficient data with regard to the application amount of plant protection products, crop-specific property data, etc., the geographical range for the assessment of impacts due to emissions of plant protection products caused by current agricultural activities is strictly limited to the EU-27 countries.

In general, contamination of food products is a major public concern (EFSA, 2006), and thus the impacts on human health and the environment due to direct application of plant protection products in Europe may play a significant role in the present EE I/O framework.

As it is of particular importance in the context of the EE I/O framework of the EXIOPOL project that emissions and, thus, related damages should be connected to industrial sectors rather than to products or commodities, the country-specific unit values with respect to the current agricultural use of plant protection products as calculated in the present Deliverable are aggregated over all agricultural produces. However, as the impacts are originally calculated on the base of individual agricultural commodities, the linkage between the aggregated unit values and the dis-aggregated, i.e. product-specific unit values per country, are presented in Deliverable D II.2.c-2.

1.1 Definition of Substances of Concern

When it comes to the use of plant protection products as part of current agricultural practice in the EU, it is necessary to consider the wide range of different substances that are used for a wide range of target organisms and according to various weather, soil and water conditions, even varying within a country. However, for the purpose of assessing the impacts and related external costs for the EXIOPOL project due to the direct application of plant protection products, it is essential to focus on some particular aspects when defining the list of substances of concern, otherwise the list would easily exceed the scope of the project and the related work to be done. Therefore, the amounts of the five most extensively applied plant protection products, applied to each considered agricultural produce, have been reviewed for all countries of concern and are listed in Table Annex 1 and Table Annex 2 for herbicides and in Table Annex 3 and Table Annex 4 for insecticides, respectively. All four tables show that even among the five most important plant protection products per commodity, the variance between the different countries is huge, i.e. each country uses particular herbicides and insecticides for particular commodities according to specific climate and soil conditions, national economic interests, etc. A short list of all substances of concern is presented in Table 1-1 for herbicides and in Table 1-2 for insecticides (based on application data from Eurostat, 2007).

The final selection of the relevant is based on three consecutive steps:

- we looked at the five most important plant protection products per considered country (regardless if they were herbicides, insecticides, fungicides, growth regulators, etc.) with respect to the amount of direct application,
- we arranged all (sum over all herbicides and insecticides, respectively, over all countries) substances in a matrix in the order of maximal appearance per country (i.e. a substance listed among the five most important plant protection products in one country may be used in other countries as well, but must not necessarily be among the five most important plant protection products in other countries, however – this is why for many countries we arrive at more than five substances to be selected for the present approach; in contrast to that, if the five most important substances in one country were not all either herbicides or insecticides, we have less than five substances in each target class per country, etc.),
- finally, we transpferred the application rate of a particular substance to all countries, were it is reported to be used (regardless whether this substance is among the five most important plant protection products in each of these countries).

Table 1-1: Overview of herbicides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data.

Herbicide			
2,4-D	DICHLORPROP	LINURON	PROMETRYN
ACETOCHLOR	DICHLORPROP-P	MCPA	PROPACHLOR
ACLONIFEN	DIMETHACHLOR	MCPB	PROPANIL
ALACHLOR	DIMETHENAMID	MECOPROP	PROPYZAMIDE
AMITROL	DIMETHENAMID-P	MECOPROP-P	PROSULFOCARB
ATRAZINE	DIQUAT	MESOTRIONE	PYRIDATE
BENTAZONE	EPTC	METAMITRON	QUINMERAC

Herbicide			
BROMOXYNIL	ETHOFUMESATE	METAZACHLOR	S-METOLACHLOR
CHLORBUFAM	FLUAZIFOP-P-BUTYL	METOLACHLOR	SIMAZINE
CLOMAZONE	GLUFOSINATE	METRIBUZIN	SULCOTRIONE
CLOPYRALID	GLYPHOSATE	MOLINATE	TERBUTHYLAZINE
CHLORIDAZON	HALOXYFOP	NAPROPAMIDE	TERBUTRYN
CHLOROTOLURON	IMAZAMETHABENZ	OXYFLUORFEN	TRALKOXYDIM
CYCLOXYDIM	ISOPROTURON	PARAQUAT	TRIFLURALIN
DESMEDIPHAM	ISOXAFLUTOLE	PENDIMETHALIN	TRIFLUSULPHURON
DICAMBA	LENACIL	PHENMEDIPHAM	

Table 1-2: Overview of herbicides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data.

Insecticide		
ALDICARB	DIAZINON	METHOMYL
CARBOFURAN	DICOFOL	OXAMYL
CHLORFENVINPHOS	DIMETHOATE	PARATHION-METHYL
CHLORPYRIFOS	ETHOPROPHOS	PIRIMIPHOS-METHYL
CHLORPYRIFOS-METHYL	FENAZAQUIN	SPINOSAD
BETA-CYFLUTHRIN	FENTHION	TEBUFENPYRAD
LAMBDA-CYHALOTHRIN	IMIDACLOPRID	TERBUFOS
CYPERMETHRIN	METHIDATHION	THIAMETHOXAM
DIAFENTHIURON	METHIOCARB	DIAFENTHIURON

Taking the huge number of contributing herbicides and insecticides as shown in Table 1-1 and Table 1-2 as well as in more detail in Table Annex 1 to Table Annex 4 into account, it becomes obvious that it will be impossible to assess all these substances in a dynamic, crop-specific and holistic way for each country in order to finally estimating unit values for each of the listed countries. Thus, the substances have been aggregated according to the methodology described in the following section.

1.2 Classification and Aggregation of Substances of Concern

The fact that most of the information related to emission inventory data of plant protection products, e.g. European wide sales data, is given aggregated on the basis of the classification according to the target organisms, and in addition the fact that most of the information about pesticides related to human health effects, e.g. derived from occupational studies, is given either for particular active ingredients or aggregated on the basis of the classification according to the mode of action and, thus, of the chemical class, makes it extremely difficult to link emission inventory data to related human health effect data.

An overview of the variety of chemical classes within the two major target organism classes, i.e. herbicides and insecticides, are given with their contribution to the overall amount of plant protection products as used in the present study in Figure 1-1 for herbicides and in Figure 1-2 for insecticides (Eurostat, 2007; Tomlin, 2006).

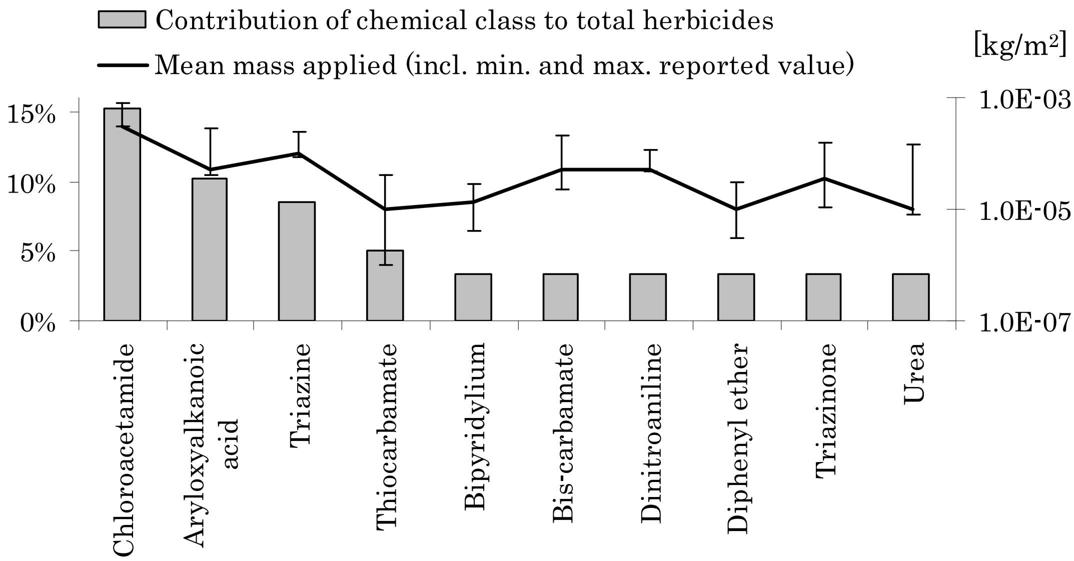

Figure 1-1: Comparison of contribution to overall application amount of selected herbicides as used in the present study [percent contribution] and related typical application dosage of each chemical class including maximum and minimum dosages [$kg_{applied}/m^2$]. Note that due to the variety of included herbicides only chemical classes have been selected for the figure that contribute with more than a single plant protection product to the overall substance number.

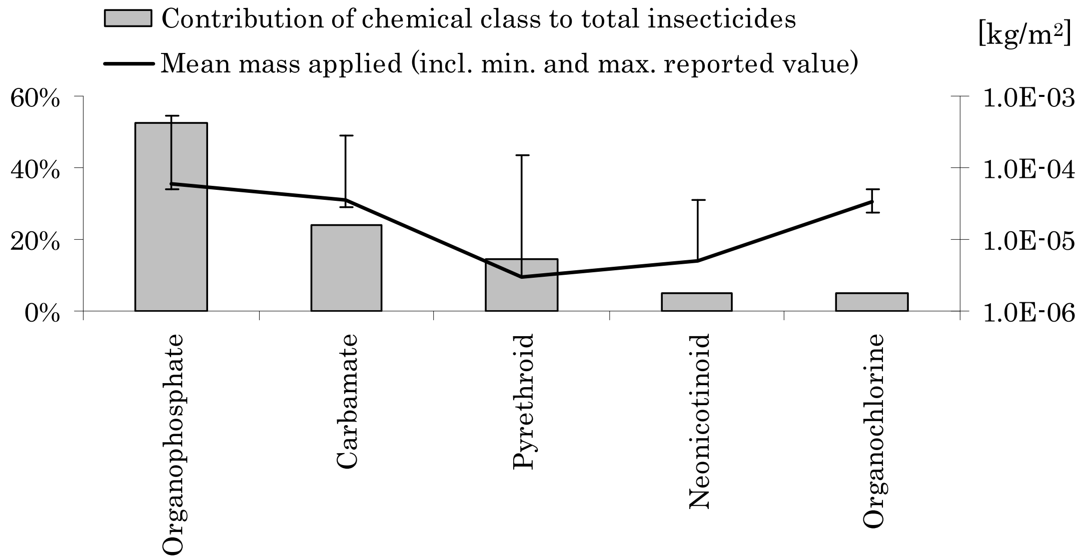

Figure 1-2: Comparison of contribution to overall application amount of selected insecticides as used in the present study [percent contribution] and related typical application dosage of each chemical class including maximum and minimum dosages [$kg_{applied}/m^2$].

However, as the main focus of the present study is on the ingestion of food products as major benefit of the agricultural sector, no diffuse emissions are required for a detailed impact assessment. It is rather necessary to take direct application amounts into account, which are available per plant protection product at least in some of the considered EU-27 countries.

On the other hand, currently used plant protection products, when applied within the frame of good agricultural practice, are not supposed to lead to significant human health effects according to the requirements of international authorisation guidelines, such as the European Coucil Directive 91/414/EEC (European Commission, 1991). Thus, as input from the effect side rather generic characterisation factors, i.e. effect factors with respect to both human health and ecosystem health, as given by Rosenbaum et al. (2008), will be considered instead of rarely, if at all, available much more detailed effect data from occupational exposure studies. This is despite the fact that a maybe not negligible part of the overall human health and ecosystem effects is not due to good agricultural practice but rather due to misuse, i.e. illegally used plant protection products, e.g. as reported for Spain in late 2008 (ECPA, 2008).

Characterisation factors are generally given either for specific active ingredients or, if necessary due to lack of data etc., for representative chemicals of a certain chemical class (see Figure 1-3).

Taking all the aggregated and dis-aggregated data sets into account, it is finally possible to interlink the application inventory data with human and ecosystem health data on the base of individual active ingredients. At the end, only aggregated information regarding the unit values due to agricultural activities are to be considered and, hence, all data sets will finally be merged according to the procedure as presented in Figure 1-3.

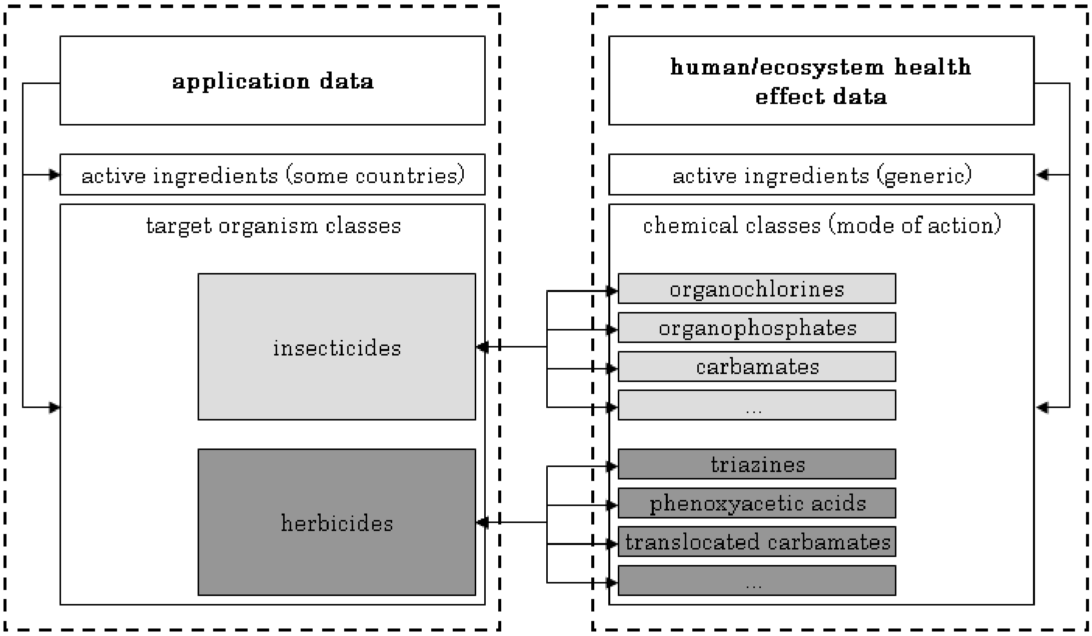

Figure 1-3: Comparison of available data and their classification according to different classification criteria on the one hand with respect to emission/application inventory and on the other hand with respect to human and ecosystem health effects. The possibility to aggregate different data is given via the aggregation of chemical classes to meet classes on the basis of target organism.

Altogether, the classification of plant protection products is performed to simplify the overall impact pathway approach throughout this study and to finally present unit values that are dis-aggregated only according to herbicides and insecticides and provided for each of the considered countries. This is due to the fact that the tables containing the unit values can directly serve as input to Cluster III and IV of the EXIOPOL project and not to confuse by an unnecessary information overload, which would be clearly the case when presenting any substance-specific data set. It would be, in addition, far beyond the scope and the objective of this project.

Information, that instead is required, is the fraction of the total amount of herbicides and insecticides, respectively, that is used in each country in the year 2000 and covered by the present approach by the selection of relevant substances to be included in the assessment. The fractions that are covered by the present approach to the overall amount of used plant protection products are summarised in Table 1-3 for herbicides and in Table 1-4 for insecticides (Eurostat, 2009; FAOSTAT, 2000).

Table 1-3: Fraction of amount of herbicides as used in Europe in year 2000, representing the fraction of the overall applied herbicides due to agricultural practice that is covered by the present study.

Country	Total Use [1000 kg]	Fraction coverd by present approach
Austria	71	96%
Belgium	346	74%
Bulgaria	5*	n/a
Cyprus	2	0%
Czech Republic	205	>95%
Germany (including ex-GDR from 1991)	1,567	>95%
Denmark	174	>95%
Estonia	1	73%
Spain	313	52%
Finland	78	79%
France	1,505	90%
Greece	111	47%
Hungary	110	>95%
Ireland	73	36%
Italy	492	89%
Lithuania	5	33%
Luxembourg (Grand-Duché)	32	74%
Latvia	4	33%
Malta	1	n/a
Netherlands	434	62%
Poland	607	>95%
Portugal	46**	73%
Romania	22	n/a
Sweden	222	73%
Slovenia	8	57%
Slovakia	112	>95%
United Kingdom	635	>95%

* Estimated from the average use per ha in Romania; not included in the model runs.
** Estimated from the average use per ha in Spain; not included in the model runs.

Table 1-4: Fraction of amount of insecticides as used in Europe in year 2000, representing the fraction of the overall applied insecticides due to agricultural practice that is covered by the present study.

Country	Total Use [1000 kg]	Fraction coverd by present approach
Austria	5	>95%
Belgium	62	38%
Bulgaria	1*	n/a
Cyprus	10	>95%
Czech Republic	12	>95%

Country	Total Use [1000 kg]	Fraction coverd by present approach
Germany (including ex-GDR from 1991)	80	>95%
Denmark	4	>95%
Estonia	0	16%
Spain	330	>95%
Finland	5	>95%
France	151	>95%
Greece	137	>95%
Hungary	32	>95%
Ireland	3	16%
Italy	369	>95%
Lithuania	0	75%
Luxembourg (Grand-Duché)	6	38%
Latvia	0	68%
Malta	5	n/a
Netherlands	43	65%
Poland	72	>95%
Portugal	49**	>95%
Romania	6	n/a
Sweden	3	>95%
Slovenia	2	>95%
Slovakia	7	>95%
United Kingdom	38	>95%

* Estimated from the average use per ha in Romania; not included in the model runs.
** Estimated from the average use per ha in Spain; not included in the model runs.

2 The Impact Pathway Approach for Plant Protection Products

For calculating aggregated unit values for the agricultural sector, in particular with respect to the use of plant protection products in good agricultural practice in the year 2000, it is necessary to take the various agricultural commodities, such as wheat and vegetables, into account. This is due to the fact that substances show a different behaviour when it comes to different deposition surfaces (usually the area of the leaves and fruits of a plant), advection uptake pathways into the crop (e.g. deposit onto leaf surface, xylem driven uptake via the root system), etc. (Trapp, 2007; Trapp and Mc Farlane, 1995; Mackova, 2006).

Plant uptake models are used for predicting environmental fate and exposure behaviour of a wide range of chemicals including currently used plant protection products and for estimating environmental concentrations, food residues and related impacts on humans and the environment. However, most of the available models are rather generic, run in steady state and usually only take diffuse emissions into account rather than directly applied dosages, as for instance described in the Technical Guidance Documents of the current exposure and risk assessment framework for chemicals in the EU (European Commission, 2003). Furthermore, maximum residue levels in (processed) food products, if available, have mostly been set only according to lower determination limits (European Commission, 2009).

A dynamic modelling approach to provide better understanding of the complex behaviour of directly applied plant protection products in the plant-environment system and to estimate residues in food produces effectively harvested and processed for human consumption has been, thus, developed within the frame of the EXIOPOL project. The focus lays on the evolution of the chemical's masses in various compartments over time, which, with respect to plant protection products is the time from the chemical's application to the harvest of the agricultural produce of concern. The model accounts for several crops and their specifics, such as paddy water for rice and the distinction between leaves and fruits for cereals. For further details see foreseen publications and Fantke et al. (2010).

Some of the most important output parameters of the modelling system, i.e. the effective harvest fraction [$kg_{in\ harvest}/kg_{applied}$] and/or the effective intake fraction [$kg_{taken\ in}/kg_{applied}$], are further used to be combined with the total mass of plant protection products applied in each country and human health as well as ecotoxicity effect information to finally arrive at unit values for each considered country (see following chapters).

It is important to note that in the frame of the EXIOPOL project, the focus of the resulting unit values is on the producer's perspective, i.e. the agricultural sector is directly linked to the caused unit value results. This allows a simplified treatment of the modelling output in a sense that national and international trade has not to be accounted for as it would have been from a consumer's perspective.

2.1 Environmental Fate and Exposure of Plant Protection Products

As described in detail in Deliverable D II.2.a-2B, the impact pathway approach has been adopted for assessing the impacts of plant protection products on human and ecosystem health due to direct application methods in agricultural practice.

From the amount of a plant protection product applied per unit value of production area, m_{applied} [$kg_{\text{applied}}/m^2_{\text{production}}$], and the production area in each country, $A_{\text{production}}$ [$m^2_{\text{prodcution}}$], the total mass applied substance(s), M_{applied} [kg_{applied}], can be derived:

$$M_{\text{applied}} = m_{\text{applied}} \cdot A_{\text{production}} \qquad \textbf{Eq. 2-1}$$

Note that it is possible to further derive the mass taken in per country based on the approach as described in Section 2.2, as long as the perspective for arriving at impacts is from the production side. This is the case in the EXIOPOL project, as the final unit values are directly correlated to the production processes of economic sectors, such as agriculture. Whenever it is required to rather take the consumer's than the producer's perspective into account, it would be necessary to also include the import and export of agricultural commodities into account as well as direct consumption data of these commodities. However, as within the present study we exclusively focus on the producer's perspective, the effect can be derived only based on the mass applied to the various commodities (for further details of commodity-specific systems refer to the Deliverable D II.2.c-2).

These data are then incorporated into the dynamic modelling approach. The overall system is divided into environmental compartments (air, root-soil, paddy water) and plant compartments (phyllosphere, i.e. leaf/fruit surface deposit, leaf and fruit interior, stem, thick root and fine root system, i.e. root hairs). We describe transfer processes between and degradation within the plant compartments as well as unilateral losses towards the surrounding environment, such as overland flow, groundwater infiltration and advective transport from paddy to surface water. We give a unique perspective by distinguishing various agricultural produces, such as rice and wheat. We account for formulation types to describe initial losses to non-target compartments after application. A paddy water compartment was introduced as important driver in the paddy rice-environment system. Finally, we account for explicit fruit and root compartments to follow a chemical's pathway up to the plant components that are effectively harvested and consumed by humans or domestic animals, with or without prior food processing. For further details refer to the upcoming related publications as well as to Fantke et al. (2010).

The plant-environment system is mathematically described by a set of linear first order differential equations for the exchange/losses between/in compartments, which is solved analytically by means of matrix algebra containing a matrix exponential. In this system, the application of a PPP reflects the source vector of a non-continuous pulse. Environmental compartments and their characteristics are considered to remain constant, while all plant compartments are considered to evolve over time based on an approach adopting exponential growth.

The whole modelling system is described in more detail in related upcoming publications and in brief in Fantke et al. (2010). As far as it concerns the results of the present study, the modelling framework provides information of the environmental fate and exposure pathways of plant protection products from the application site to the food product on the plate of the consumer. In contrast to the fact that the framework is dynamic with respect to the time from plant growth to the harvest of a crop of interest, it has (so far) not been implemented into a spatially dis-aggregated multi-media model to also account for spatial variability within a country.

However, as the spatial focus in the EXIOPOL project is the country-level, i.e. the countries as in EU-27 for the year 2000, it is not necessary to also include spatial variance into the present approach which significantly decreases the amount of data that would on the other hand be requried to serve as input for the modelling system.

2.2 Effect Assessment with Respect to Human Health

As discussed before, generic effect data for human health have been considered for the present approach rather than endpoint-specific values from epidemiological studies of e.g. occupational health, which is due to the fact that only rare, if at all, data are available for a comprehensive estimation of related health impacts at the European scale. For generic human health effect factors, so-called characterisation factors have been found as result of an extensive literature research.

Characterisation factors for human health are defined as aggregation of inventory results in terms of adequate factors by linearly expressing the contribution of a unit mass of emission [1 kg] to an impact category (Pennington et al., 2004). They are a measure of the relative importance of emissions in the context of the specific environmental impact category 'human toxicity' (Margni, 2003) and are expressed in number of cancer or non-cancer incidences per kg of emitted plant protection product. According to recommendations from experts (Jolliet et al., 2006; McKone et al., 2006), effect indicators for human toxicity in Rosenbaum et al. (2008) are based on best estimate of effect concentrations (ED_{50} or ED_{10}, possibly extrapolated from NOAEL), rather than reference dose that embeds safety factors.

Human effect data in Rosenbaum et al. (2008) build on the workshop recommendations for comparative assessment of McKone et al. (2006). The effect factor takes as a point of departure the effect dose 50% (ED_{50}) from the carcinogenic potency database (CPDB) by Gold et al. (2008, 2005). For cancer, the harmonic mean of all positive ED50 is retained for the most sensitive species of animal cancer tests between mice and rats after application of an allometric factor proportional to bodyweight to the power of 0.25 (Vermeire et al., 2001).

Whereas the full set of human health characterisation factors for all considered plant protection products is given in Table Annex 9 and Table Annex 10, the lowest and highest values for each sub-category are presented in Table 2-1 for herbicides and in Table 2-2 for insecticides, respectively.

Table 2-1: Lowest and highest human health characterisation factors calculated for emissions of plant protection products to continental agricultural soil according to Rosenbaum et al. (2008) for the most important herbicides as used per country in year 2000.

Effect sub-group		$cases/kg_{emitted}$	Substance
Cancer	MIN	1.8E-07	TRIFLURALIN
	MAX	1.3E-06	AMITROL
Non-cancer	MIN	8.5E-09	PARAQUAT
	MAX	3.8E-05	TERBUTRYN

Table 2-2: Lowest and highest human health characterisation factors calculated for emissions of plant protection products to continental agricultural soil according to Rosenbaum et al. (2008) for the most important insecticides as used per country in year 2000.

Effect sub-group		$cases/kg_{emitted}$	Substance
Cancer	MIN	1.5E-05	METHIDATHION
	MAX	1.6E-05	DICOFOL
Non-cancer	MIN	1.1E-07	IMIDACLOPRID
	MAX	4.1E-04	TERBUFOS

It is important to note that in particular with respect to characterisation factors for human health, only few factors are available from Rosenbaum et al. (2008). However, as human health effects might play a minor role compared to the effects on the environment, i.e. ecotoxicity, we also present ecotoxicity characterisation factors for all considered plant protection products in the following section. As a direct result of the application of the human health effect factors we derive number of incidences of cancer and non-cancer, respectively, for the considered countries, as shown in Figure 2-1 and Figure 2-2.

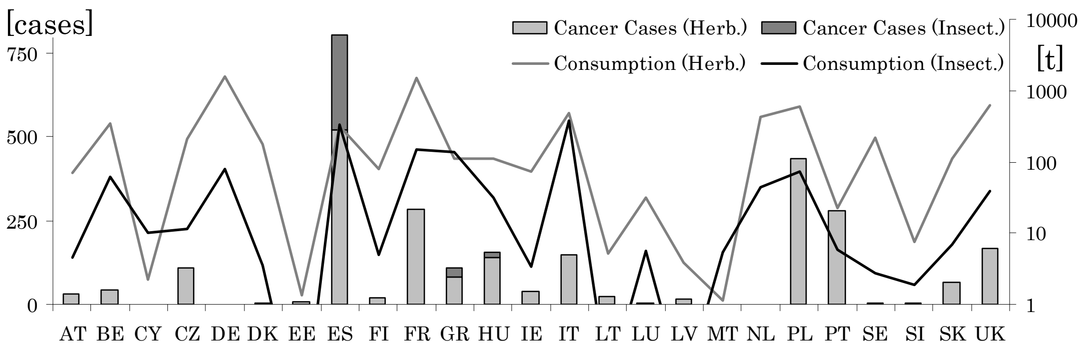

Figure 2-1: Number of cancer incidences per country in year 2000 caused by the direct application of herbicides and insecticides, respectively [cases], and the amount consumed per country in year 2000 [tonnes].

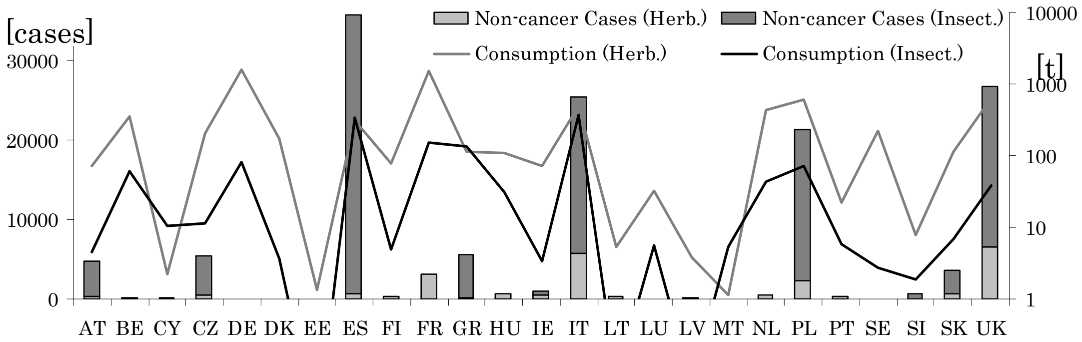

Figure 2-2: Number of non-cancer incidences per country in year 2000 caused by the direct application of herbicides and insecticides, respectively [cases], and the amount consumed per country in year 2000 [tonnes].

The number of cancer, n_{cancer}, and non-cancer, $n_{non\text{-}cancer}$, per country [cases] have been calculated on the base of human effect factors $F_{human,cancer}$ and $F_{human,non\text{-}cancer}$ [cases/kg$_{intake}$] and the total mass of a plant protection product taken in per country, M_{intake} [kg$_{intake}$]:

$$n_{\text{cancer}} = M_{\text{intake}} \cdot F_{\text{human,cancer}}$$
$$n_{\text{non-cancer}} = M_{\text{intake}} \cdot F_{\text{human,non-cancer}}$$

Eq. 2-2

Where the total mass of a plant protection product taken in per country is calculated based on the effective intake fraction, $iF_{effective}$ [dimensionless, kg$_{intake}$/kg$_{applied}$], i.e. the fraction of applied substance that is finally effectively taken in and leading to an adverse health effect, and the total mass applied substance(s), $M_{applied}$ [kg$_{applied}$] according to Eq. 2-3:

$$M_{\text{intake}} = M_{\text{applied}} \cdot iF_{\text{effective}}$$

Eq. 2-3

The mass of a plant protection product applied in the year 2000 per country is calculated as described in Section 2.1. The effective intake fraction is a direct output of the plant uptake model, newly developed for the application within this work stream of the Exiopol project and tested for the plant protection products considered in this study. This means, as the intake fraction is available anyway, it is up to the user to combine this output with more reliable or just a different set of effect factors with respect to human health in order to arrive at either more specific health effects or more accurate results, once he has the respective effect information at hand.

2.3 Effect Assessment with Respect to Ecosystem Toxicity

Rosenbaum et al. (2008) used two databases with ecotoxicity effect data on average EC_{50} values (i.e. HC50s) for calculating ecotoxicity effect factors, covering, respectively, 3,498 (Van Zelm et al. 2007) and 1,408 chemicals (Payet 2004), the first one being based on EC_{50} values from the RIVM e-toxBase (www.e-toxbase.com) and the second one on data mainly from ECOTOX (2001) and IUCLID (2000). Even though there is no consensus on which averaging principles HC50 should be estimated (on basis of trophic levels or single species), the authors of Rosenbaum et al. (2008) pragmatically suggest to use these available HC50 data all based on geometric means of single species tests data according to Larsen and Hauschild (2007).

Further, the authors prioritise chronic values as long as they represent measured EC_{50} values and are not extrapolated from NOEC values (Jolliet et al., 2006; Larsen and Hauschild, 2007). Second priority is given to well documented acute data, applying a best estimate extrapolation factor as an acute-to-chronic ratio (ACR), e.g. 2.2 for plant protection products - except for carbamate and organotin, where no ACR were available from Payet (2004). The HC50 value, which is applied as effect factor, is then pragmatically based on averages of single species test data.

The characterisation factor for aquatic ecotoxicity (ecotoxicity potential) is expressed in comparative toxic units (CTUe) and provides an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted [PAF m^3 day $kg^{-1}_{emitted}$].

Table 2-3: Lowest and highest ecosystem toxicity characterisation factors calculated for diffuse emissions of plant protection products to different compartments according to Rosenbaum et al. (2008) for the most important herbicides as used per country in year 2000.

Emission compartment		PAF m^3 yr/$kg_{emitted}$	Substance
Urban air	MIN	5.1E+00	CYCLOXYDIM
	MAX	4.9E+04	PROPANIL
Continental air	MIN	1.1E+00	CYCLOXYDIM
	MAX	4.5E+04	PROPANIL
Freshwater	MIN	9.3E+01	MCPA
	MAX	6.6E+05	ACLONIFEN
Agricultural soil	MIN	1.1E+00	CYCLOXYDIM
	MAX	6.0E+04	PROPANIL

Table 2-4: Lowest and highest ecosystem toxicity characterisation factors calculated for diffuse emissions of plant protection products to different compartments according to Rosenbaum et al. (2008) for the most important insecticides as used per country in year 2000.

Emission compartment		PAF m^3 yr/$kg_{emitted}$	Substance
Urban air	MIN	1.4E+02	IMIDACLOPRID
	MAX	1.5E+07	BETA-CYFLUTHRIN

Emission compartment		PAF m³ yr/kg$_{emitted}$	Substance
Continental air	MIN	1.0E+02	IMIDACLOPRID
	MAX	7.9E+06	BETA-CYFLUTHRIN
Freshwater	MIN	3.1E+03	IMIDACLOPRID
	MAX	4.9E+08	BETA-CYFLUTHRIN
Agricultural soil	MIN	9.7E+01	IMIDACLOPRID
	MAX	6.8E+05	BETA-CYFLUTHRIN

In the following, we give an overview of the distribution of potentially affected fractions of species as estimate for ecosystem toxicity, expressed in PAF m³ day per kg in freshwater caused by an emission into freshwater and agricultural soil, respectively. In Figure 2-5, the potentially affected fracions of species due to leaching from agricultural soil to groundwater and in Figure 2-6, the potentially affected fractions of species due to surface run-off from soil to surface water are presented. They are compared against the mass of herbicides and insecticides, respectively, in the corresponding surface water fraction.

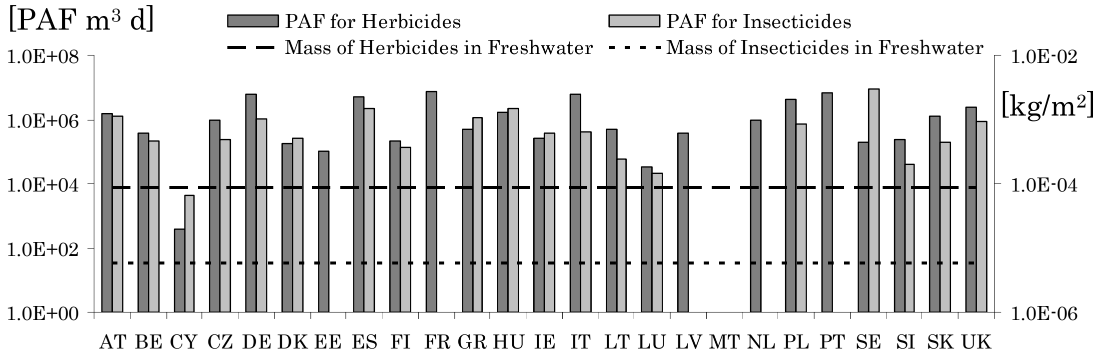

Figure 2-3: Number of PAF m³ day per kg in freshwater due to leaching from soil to surface water per country in year 2000 caused by the direct application of herbicides and insecticides, respectively, and the mass in the corresponding freshwater fraction of the system.

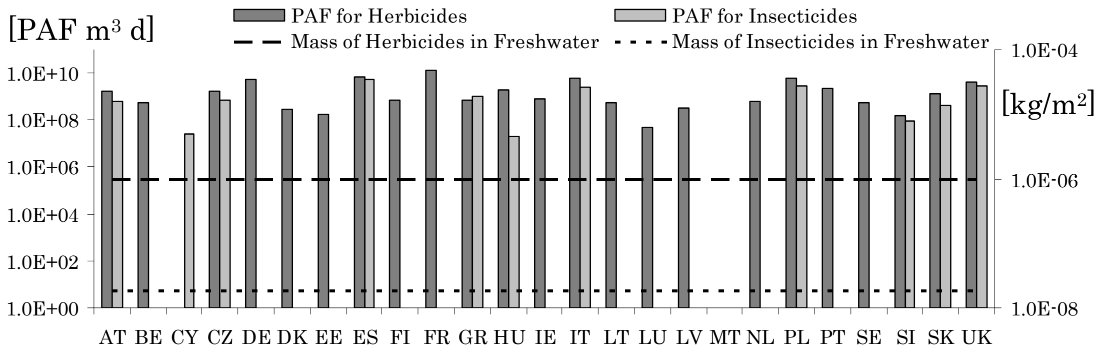

Figure 2-4: Number of PAF m³ day per kg in freshwater due to surface run-off from agricultural soil to groundwater per country in year 2000 caused by the direct application of herbicides and insecticides, respectively, and the mass in the corresponding freshwater fraction of the system.

More detailed information about the country-specific potentially affected fractions of species is presented in the annex in Table Annex 17 for herbicides and in Table Annex 18 for insecticides, respectively.

2.4 Valuation of Human Health Impacts

In order to be able to weight different diseases and human health burdens, the Disabilility Adjusted Life Year (DALY) approach was used to account for both, cancer and non-cancer effects. One DALY represents one year of life lost, or an equivalent in the case of morbidity effects (Murray and Lopez, 1996; Hofstetter, 1998; Hofstetter and Hammitt, 2002).

DALYs per incidence of cancer, based on the approach developed by Crettaz et al. (2002) for cancer and based on the approach developed by Pennington et al. (2002) for non-cancer, have been updated to 11.5 DALY per cancer incidence and to 2.7 DALY per non-cancer incidence, respectively (Huijbregts et al., 2005). The aggregated DALY per country caused by the direct application of plant protection products in agriculture are presented in Figure 2-5 for incidences of cancer and in Figure 2-6 for incidences of non-cancer, respectively.

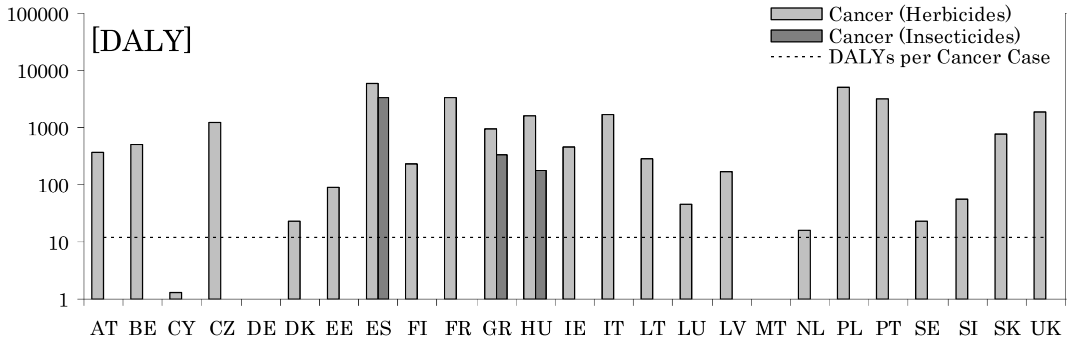

Figure 2-5: Number of DALYs due to cancer incidences per country in year 2000 caused by the direct application of herbicides and insecticides, respectively [DALY], and the number of DALYs that has been used per cancer case [DALY].

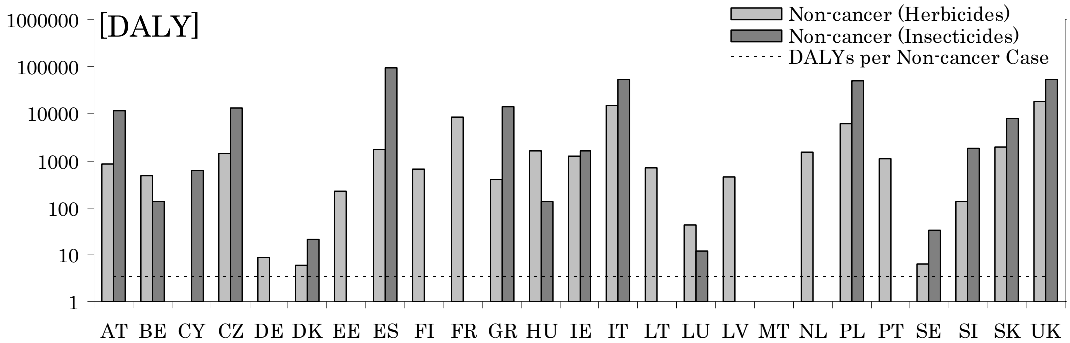

Figure 2-6: Number of DALYs due to non-cancer incidences per country in year 2000 caused by the direct application of herbicides and insecticides, respectively [DALY], and the number of DALYs that has been used per non-cancer case [DALY].

After having derived all basic and intermediate output parameters of the impact assessment of externalities caused by the application of plant protection products, it is the overall goal of work stream WSII.2 to finally end up in the linkage between the human activity, which is herein represented by the amount of released herbicides and insecticides into the environment by current agricultural practice as of the year 2000, and the external effects due to this releases, represented by monetary values.

Monetised externalities are termed external costs when they are negative and external benefits when they are positive. However, as the impacts per released plant protection products are negative, we finally arrive at external costs by multiplying the number of end-point specific incidences with the applied number of a representative severity measure per end-point, i.e. DALY.

The monetary values for the aggregated severity measure DALY are assumed to equal the sum of the monetary values of Years of Life Lost (YOLL) as well as of Years Lived with a Disability (YLD). The units of the costs per unit of severity measure comprise the term $Euro_{2000}$ so far but can, if required, be converted to more up-to-date values, such as $Euro_{2005}$ by means of, e.g. the MethodEx Currency Converter[1]. However, this would maybe not be suitable as long as in Stream 4 (monetary valuation) of the ongoing integrated project HEIMTSA the partners will still work on updating the whole methodology regarding monetary valuation including the DALY approach (for further information see http://www.heimtsa.eu/). In the frame of this work stream, however, only the year 2000 has been considered for the assessment of impacts on human health and the environment due to the application of plant protection products in agriculture, and thus the value $Euro_{2000}$ is used throughout this study. This, of course, may change when dealing with additional scenarios to be places in a different year than 2000 as foreseen at a later stage of the project.

An overall value of 40,000 $Euro_{2000}$ was used throughout this study for one DALY. Note that this value is only valid for Europe as decided in the frame of the NEEDS international project as of 2007 (for further details refer to the final project reports of the NEEDS project, available online at: http://www.needs-project.org/index.php?Itemid=66).

Usually, unless dealing with acute health effects, a delicate question arises when dealing with long time spans that are highly relevant for persistent chemicals. The question is "How can we compare future external costs to present external costs?" Economists usually employ discounting in order to give future benefits or costs present values. In addition, the European Commission recommends the involvement of discounting "whenever positive and negative impacts can be expressed in monetary terms" (European Commission, 2002, p. 16). Thus, the application of different discount schemes to the external cost output of the parameterisation runs have to be discussed.

However, as in the present approach no persistent chemicals have been included, discounting of damages occuring in the far future, as it would be e.g. necessary when assessing non-degradable heavy metals, is not included as it is assumed that the whole bunch of food products contaminated with the plant protection products as considered in the present study for the year 2000 are ingested in the very same year.

The overall estimated costs due to the direct application of plant protection products in agriculture in the year 2000 are the basis for the calculation of the finally important aggregated unit values per country in this project. A unit value, representing the costs per kg applied substance, are calculated according to Eq. 3-1 as given in the following section. Note that dis-aggregated unit values, i.e. specific for each agricultural commodity, as calculated for the present study are given in Deliverable D II.2.c-2.

[1] http://www.methodex.org/CurrencyConversionTool.xls

3 Unit Values per kg applied Plant Protection Product

Based on the total costs due to the direct application of plant protection products according to agricultural practice in the year 2000 in Europe, it is possible to calculate the unit values, i.e. the marginal costs per kg applied herbicides and insecticides, respectively. Unit values, U_{cancer} and $U_{non\text{-}cancer}$ [$Euro_{2000}/kg_{applied}$] can be derived by dividing the total costs, E_{cancer} and $E_{non\text{-}cancer}$ [$Euro_{2000}$], by the total amount applied, $M_{applied}$ [$kg_{applied}$], according to the following equation:

$$U_{\text{cancer}} = \frac{E_{\text{cancer}}}{M_{\text{applied}}}$$
$$U_{\text{non-cancer}} = \frac{E_{\text{non-cancer}}}{M_{\text{applied}}} \qquad \text{Eq. 3-1}$$

An overview of the distribution of aggregated unit values for both cancer and non-cancer cases is presented in Figure 3-1 for herbicides and in Figure 3-2 for insecticides, respectively.

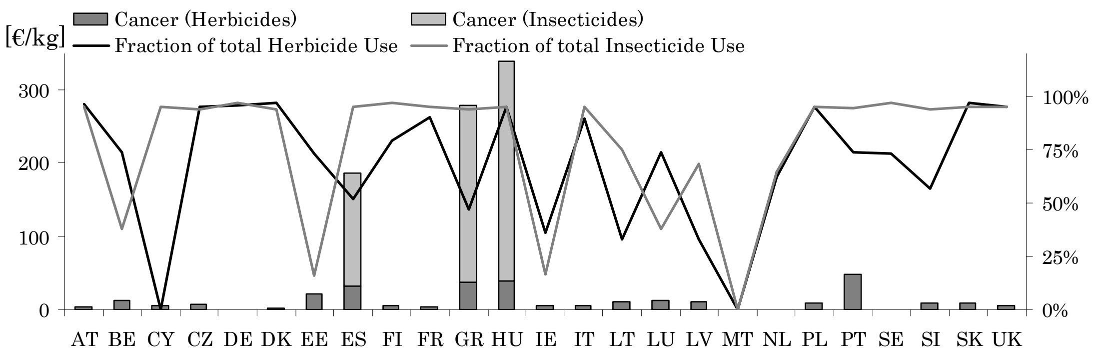

Figure 3-1: Distribution of unit values [$Euro_{2000} \cdot kg^{-1}_{applied}$] for human health cancer cases, aggregated over the whole agricultural sector, for herbicides and insecticides, respectively, in Europe for the year 2000.

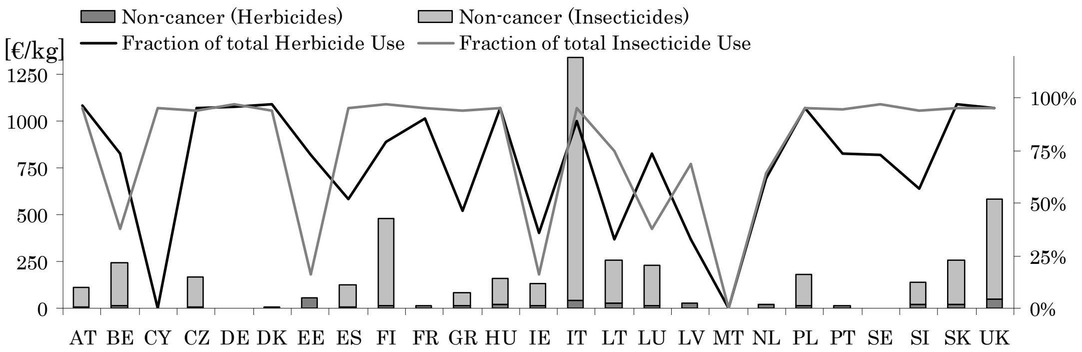

Figure 3-2: Distribution of unit values [$Euro_{2000}\cdot kg^{-1}_{applied}$] for human health non-cancer cases, aggregated over the whole agricultural sector, for herbicides and insecticides, respectively, in Europe for the year 2000.

In the Annex dis-aggregated unit values according to the distinction between cancer and non-cancer cases can be found, i.e. in Table Annex 13 and Table Annex 14 for herbicides and in Table Annex 15 and Table Annex 16 for insecticides, respectively. However, as unit values in this report are preferably given differentiated according to different countries only in order to finally match with the structure of the I/O tables developed in the EXIOPOL project, the aggregated unit values for herbicides are presented in Table 3-1 for herbicides and in Table 3-2 for insecticides, respectively, in the following sub-sections.

3.1 Unit values for Herbicides

In this section, unit values per country for herbicide use in the considered countries according to agricultural practice in the year 2000 are presented. The unit values are expressed in $Euro_{2000}/kg_{applied}$/year. Over all considered countries, the values range from 0.1 Euro in Malta to 340 Euro in Hungary, considering all the selected plant protection products in this study that are herbicides. An overview of all country-specific aggregated unit values for the application of herbicides is given in Table 3-1. Note that for the countries Bulgaria and Portugal no unit values could be calculated as no information of the application of plant protection products in the year 2000 was available from public resources (see Section 1.2 for details).

Table 3-1: Unit values [$Euro_{2000}\cdot kg^{-1}_{applied}\cdot year^{-1}$] for human health aggregated over the whole aricultural sector and all human health end-points for the year 2000 for herbicides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	10.8
2	BE	Belgium	25.0

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
3	BG	Bulgaria	n/a
4	CY	Cyprus	5.2
5	CZ	Czech Republic	16.3
6	DE	Germany	0.0
7	DK	Denmark	1.5
8	EE	Estonia	74.5
9	ES	Spain	43.3
10	FI	Finland	22.6
11	FR	France	15.8
12	GR	Greece	53.8
13	HU	Hungary	62.3
14	IE	Ireland	19.9
15	IT	Italy	48.1
16	LT	Lithuania	35.5
17	LU	Luxembourg	23.4
18	LV	Latvia	36.7
19	MT	Malta	0.0
20	NL	Netherlands	22.2
21	PL	Poland	20.7
22	PT	Portugal	n/a
23	RO	Romania	63.2
24	SE	Sweden	0.7
25	SI	Slovenia	31.4
26	SK	Slovakia	33.0
27	UK	United Kingdom	53.8

3.2 Unit Values for Insecticides

In this section, unit values per country for insecticides use in the considered countries according to agricultural practice in the year 2000 are presented. The unit values are expressed in $Euro_{2000}/kg_{applied}/year$. Over all considered countries, the values range from 0.1 Euro in Malta to 1340 Euro in Italy, considering all the selected plant protection products in this study that are insecticides. An overview of all country-specific aggregated unit values for the application of herbicides is given in Table 3-2. Note that for the countries Bulgaria and Portugal no unit values could be calculated as no information of the application of plant protection products in the year 2000 was available from public resources (see Section 1.2 for details).

Table 3-2: Unit values [$Euro_{2000}\cdot kg^{-1}_{applied}\cdot year^{-1}$] for human health aggregated over the whole aricultural sector and all human health end-points for the year 2000 for insecticides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	100.9
2	BE	Belgium	229.0
3	BG	Bulgaria	n/a
4	CY	Cyprus	0.7
5	CZ	Czech Republic	161.0
6	DE	Germany	1.1
7	DK	Denmark	3.6
8	EE	Estonia	0.0
9	ES	Spain	270.0
10	FI	Finland	460.0
11	FR	France	0.0
12	GR	Greece	310.1
13	HU	Hungary	437.9
14	IE	Ireland	114.9
15	IT	Italy	1296.9
16	LT	Lithuania	229.7
17	LU	Luxembourg	219.2
18	LV	Latvia	0.0
19	MT	Malta	0.0
20	NL	Netherlands	0.0
21	PL	Poland	169.1
22	PT	Portugal	n/a
23	RO	Romania	0.0
24	SE	Sweden	1.8
25	SI	Slovenia	118.4
26	SK	Slovakia	235.1
27	UK	United Kingdom	539.4

The aggregated unit values per country and kg applied plant protection product as presented in the previous sections are to be used as a basis for the externality adders to the agricultural sector in the EXIOPOL project's I/O tables at a later stage. The accuracy and possible use of this unit values is discussed in the following section, where we show effect information corrected aggregated unit values, i.e. what would the final unit values look like when only taking recommended human health effect information into account (see Table 4-1 for herbicides and Table 4-2 for insecticides, respectively).

4 Discussion of Uncertainty and Quality of Results

The presented approach comprises a wide range of scientific fields, i.e. from chemistry and applied physics, math and biology to economics and toxicology, after all environmental sciences in the widest sense. Consequently, it is the nature of this integrated approach to try to combine a variety of data at different kind of scales, e.g. from crop-specific conditions of an application of a plant protection product to the aggregated area of the annual production of the same crop, or from the pH dependent behaviour of a contaminant in the field to rather generic effect information with respect to human health and ecosystem toxicity for the whole of Europe.

One of the major source of uncertainty, thus, comes along with data manipulation required as input for the present assessment of impacts due to direct application of plant protection products according to agricultural practice. As a direct consequence of e.g. poor data for either some of the considered countries, some of the considered agricultural commodities or some of the considered plant protection products in the present study, several assumptions have been made in order to be as concise as possible and with respect to all the requirements of a comprehensive impact assessment of substances along the full chain from emissions or application in the environment up to the quantification of related human health and ecosystem impacts.

A detailed description of all the assumptions made in the present assessment for finally arriving at the unit values as required by the I/O methodology is given in Deliverable D II.2.c-2.

Another source of uncertainty is the information available with respect to human health and environmental effects, either based on toxicological studies or, whenever available, based on epidemiology. In the present approach, for instance, an extensive literature review undertaken by Rosenbaum et al. (2008) resulted in a wide range of toxicologically derived effect information regarding human health and ecosystem toxicity. However, not all of the effect factors used in the present study have the status ‘recommended’, but some are set to ‘interim’ or even ‘not available’. The distinction was made between interim and recommended characterisation factors reflecting the level of reliability of the calculations in a qualitative way, while the data have been flagged as not available whenever an uncertainty assessment was not appropriate due to e.g. missing independent data.

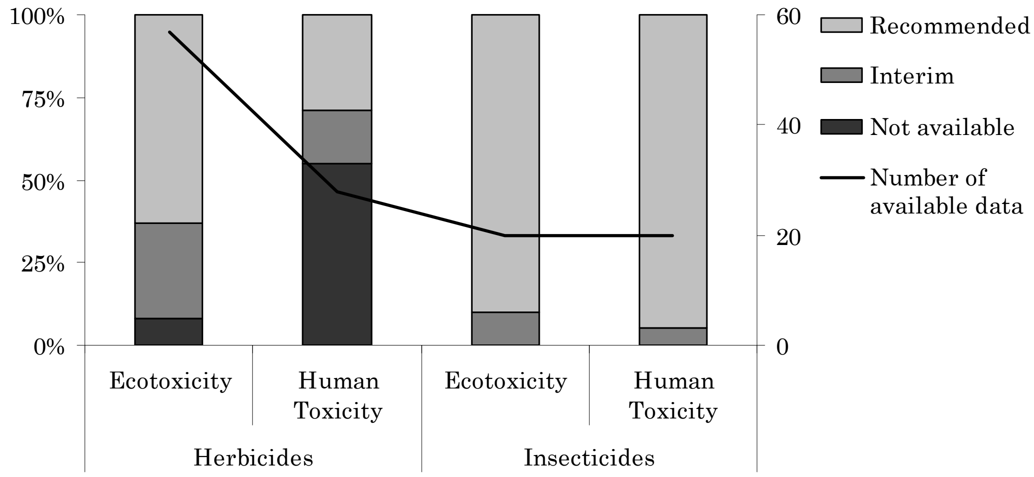

Figure 4-1: Distribution of uncertainty flagging of human toxicity and ecosystem toxicity characterisation factors [percent of flag] according to Rosenbaum et al. (2008) and overall number of available data sets for the most important herbicides and insecticides as used in this study.

When only considering the recommended effect information instead also the information set to status "interim", the distribution of the effect information corrected aggregated unit values would look like in Table 4-1 for herbicides and in Table 4-2 for insecticides, respectively. As can be seen in the following tables, the corrected unit values are only very slightly smaller than the uncorrected unit values, which is due to the fact that the effect information for the most important plant protection products have the status "recommended". Hence, the uncorrected unit values are as representative for the range of the selected substances as the corrected unit values are, as the uncertainty in the whole assessment clearly exceeds the small difference between corrected and uncorrected unit values.

Table 4-1: Effect information corrected unit values [$Euro_{2000}\cdot kg^{-1}{}_{applied}\cdot year^{-1}$] for human health aggregated over the whole agricultural sector and all human health end-points for the year 2000 for herbicides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	10.8
2	BE	Belgium	24.9
3	BG	Bulgaria	n/a
4	CY	Cyprus	5.2
5	CZ	Czech Republic	16.3
6	DE	Germany	0.0
7	DK	Denmark	1.3
8	EE	Estonia	74.5

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
9	ES	Spain	42.2
10	FI	Finland	19.4
11	FR	France	15.8
12	GR	Greece	51.5
13	HU	Hungary	62.2
14	IE	Ireland	19.5
15	IT	Italy	47.3
16	LT	Lithuania	35.5
17	LU	Luxembourg	23.3
18	LV	Latvia	34.0
19	MT	Malta	0.0
20	NL	Netherlands	22.2
21	PL	Poland	19.9
22	PT	Portugal	n/a
23	RO	Romania	61.6
24	SE	Sweden	0.6
25	SI	Slovenia	31.3
26	SK	Slovakia	33.0
27	UK	United Kingdom	53.8

Table 4-2: Effect information corrected unit values [$Euro_{2000}\cdot kg^{-1}{}_{applied}\cdot year^{-1}$] for human health aggregated over the whole agricultural sector and all human health end-points for the year 2000 for insecticides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	100.6
2	BE	Belgium	227.6
3	BG	Bulgaria	n/a
4	CY	Cyprus	0.7
5	CZ	Czech Republic	161.0
6	DE	Germany	1.1
7	DK	Denmark	1.8
8	EE	Estonia	0.0

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
9	ES	Spain	258.3
10	FI	Finland	372.5
11	FR	France	0.0
12	GR	Greece	300.3
13	HU	Hungary	437.8
14	IE	Ireland	111.0
15	IT	Italy	1273.0
16	LT	Lithuania	229.6
17	LU	Luxembourg	217.6
18	LV	Latvia	0.0
19	MT	Malta	0.0
20	NL	Netherlands	0.0
21	PL	Poland	156.9
22	PT	Portugal	n/a
23	RO	Romania	0.0
24	SE	Sweden	0.9
25	SI	Slovenia	117.7
26	SK	Slovakia	235.1
27	UK	United Kingdom	538.7

Along with missing or poor effect information for rather diffuse emissions into the environment, only, if at all, for very few currently used plant protection products additional information is available with respect to occupational health of field workers. This is due to the fact that officially, all plant protection products registered for use within the EU come along with a fact sheet proving that the compound of interest does not harm humans in a significant way. For details please refer to the fact sheets in the frame of the Council Directive 91/414/EEC (European Commission, 1991).

In addition, a maybe not negligible part of the overall human health and ecosystem effects is not due to good agricultural practice but rather due to misuse, i.e. illegally used plant protection products, e.g. as reported for Spain in late 2008 (ECPA, 2008). This can finally not be simply discussed in a policy context as the misuse of plant protection products is already liable to prosecution according to national and international law.

5 Discussion with Respect to Other Approaches

It is stated by the European Partnership for Action Against Cancer of the European Commission that every year 3.2 Million Europeans are diagnosed with cancer, which is also the second most common cause of death in Europe (29% of deaths for men, 23% for women) – a figure that is expected to rise due to the aging European population[2] (please see to the European Cancer Observatory for detailed cancer incidence and mortality data). In fact, it has been predicted that one in three men and one in four women will be directly affected by cancer during the first 75 years of their lives. The most frequently occurring forms of the disease in Europe are breast, colorectal and lung cancers. Although significant advances are being made in the fight against the disease, cancer remains a key public health concern and a tremendous burden on European society.

However, according to the present study, there are estimated 2427 cancer incidences due to the direct application of herbicides and additional 329 cancer incidences due to the application of insecticides in the year 2000, which based on the best available knowledge among the EXIOPOL partners. The sum of 2755 cancer incidences due to the application of plant protection products in Europe would correspond to around 0.09% of the 3.2 Million total cancer incidences estimated by the European Commission.

This goes well in line with estimates of other approaches, e.g. a cancer death rate caused by ingestion of pesticide residues in food of 0.6% of all cancer deaths as an upper bound value (without cocktail effect) according to the "Unfinished business study" of the US-EPA as cited in Gough (1998). On the other hand, more conservative estimates, e.g. on the basis of Ames and Gold (1998) and other sceptics give an estimation of the death rate due to plant protection products use to the overall death rate from cancer as low as 0,001%, mostly based on approaches for some individual compounds only.

With respect to the number of aggregated cancer incidences as estimated in the present study, the values are certainly within the expected range. Nevertheless, many sources of uncertainty, such as more accurate effect information instead of extrapolated toxicological information as base for the effect assessment and comprehensive input data, could lead to results of up to two orders of magnitude.

In addition, it is to be noted that the cancer "incidences" in the present study are not equal to cancer "deaths", which gives another source of uncertainty when applying the present results as this is sometimes not clearly distinguished in current literature. However, a further literature review is necessary to properly evaluate the range of the present results compared to results of other approaches.

[2] http://ec.europa.eu/health/ph_information/dissemination/diseases/cancer_en.htm

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ANNEX

Annex I: Substances of Concern

In the following, a detailed list of which are the herbicides and insecticides that contribute to the five most extensively used plant protection products per country in year 2000 is presented (Eurostat, 2007, AERU, 2009). Note that some of the substances are important in more than one country, while other plant protection products are only relevant in a single country. This means, that the more countries use a single substance, the higher is that substance to be placed when it comes to importance with respect to the amount of application. For a detailed description of the selection of the relevant plant protection products as modelled in the present approach see Section 1.1.

Table Annex 1: Overview of herbicides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data (Part I).

Substance	AT	BE	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU
2,4-D	x			x			x	x			x	x
ACETOCHLOR				x				x		x		x
ACLONIFEN						x			x	x		
ALACHLOR								x		x	x	
AMITROL											x	
ATRAZINE		x		x				x			x	x
BENTAZONE	x	x			x	x			x	x		x
BROMOXYNIL											x	
CHLORBUFAM		x										
CLOMAZONE						x						
CLOPYRALID						x	x		x			
CHLORIDAZON	x	x		x	x					x		x
CHLOROTOLURON												
CYCLOXYDIM												
DESMEDIPHAM	x			x				x	x			
DICAMBA							x					
DICHLORPROP	x											
DICHLORPROP-P									x			x
DIMETHACHLOR				x	x					x		
DIMETHENAMID	x	x										x
DIMETHENAMID-P												
DIQUAT		x				x			x			
EPTC												
ETHOFUMESATE	x			x	x	x		x	x	x		
FLUAZIFOP-P-BUTYL		x					x		x			
GLUFOSINATE									x			
GLYPHOSATE	x		x	x	x	x	x	x	x	x	x	x
HALOXYFOP						x	x					

Substance	AT	BE	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU
IMAZAMETHABENZ											x	
ISOPROTURON	x	x		x	x			x		x		
ISOXAFLUTOLE												
LENACIL								x				
LINURON									x			
MCPA	x	x		x	x	x		x	x	x		x
MCPB	x			x								
MECOPROP	x	x						x			x	
MECOPROP-P					x							
MESOTRIONE												
METAMITRON				x							x	
METAZACHLOR	x	x		x	x			x	x	x	x	
METOLACHLOR										x	x	
METRIBUZIN				x								
MOLINATE												
NAPROPAMIDE										x		
OXYFLUORFEN												
PARAQUAT											x	
PENDIMETHALIN	x			x	x	x		x		x		
PHENMEDIPHAM	x			x	x	x		x	x	x		
PROMETRYN							x					x
PROPACHLOR				x								
PROPANIL												
PROPYZAMIDE		x	x			x						
PROSULFOCARB		x			x	x				x		
PYRIDATE	x											
QUINMERAC	x	x			x							
S-METOLACHLOR	x	x		x	x					x		x
SIMAZINE												
SULCOTRIONE		x								x	x	
TERBUTHYLAZINE	x				x							
TERBUTRYN												
TRALKOXYDIM											x	
TRIFLURALIN	x	x		x			x		x	x		x
TRIFLUSULPHURON												

Table Annex 2: Overview of herbicides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data (Part II).

Substance	IE	IT	LT	LU	LV	NL	PL	PT	SE	SI	SK	UK
2,4-D		x	x		x		x				x	

Substance	IE	IT	LT	LU	LV	NL	PL	PT	SE	SI	SK	UK
ACETOCHLOR							x				x	
ACLONIFEN		x										
ALACHLOR		x						x				
AMITROL						x						
ATRAZINE				x			x	x			x	
BENTAZONE		x		x				x	x			x
BROMOXYNIL												
CHLORBUFAM				x								
CLOMAZONE									x			
CLOPYRALID	x		x		x				x			
CHLORIDAZON	x	x		x		x	x				x	x
CHLOROTOLURON										x		
CYCLOXYDIM		x							x			
DESMEDIPHAM							x				x	
DICAMBA			x		x					x		
DICHLORPROP												
DICHLORPROP-P									x			
DIMETHACHLOR			x		x							
DIMETHENAMID				x								
DIMETHENAMID-P						x						
DIQUAT	x			x	x				x	x		x
EPTC								x				
ETHOFUMESATE		x				x	x	x			x	
FLUAZIFOP-P-BUTYL			x	x	x					x		
GLUFOSINATE												
GLYPHOSATE	x	x	x		x	x	x	x	x	x	x	x
HALOXYFOP			x		x							
IMAZAMETHABENZ												
ISOPROTURON		x		x		x	x	x	x	x		x
ISOXAFLUTOLE										x		
LENACIL	x											
LINURON					x		x					
MCPA	x	x		x		x	x	x	x		x	
MCPB												x
MECOPROP				x								
MECOPROP-P	x					x			x			
MESOTRIONE										x		
METAMITRON		x				x						
METAZACHLOR	x	x		x		x	x		x		x	x
METOLACHLOR		x										
METRIBUZIN											x	
MOLINATE								x				
NAPROPAMIDE												

Substance	IE	IT	LT	LU	LV	NL	PL	PT	SE	SI	SK	UK
OXYFLUORFEN		x										
PARAQUAT	x	x						x				
PENDIMETHALIN		x				x	x		x		x	x
PHENMEDIPHAM		x				x	x	x	x		x	x
PROMETRYN			x		x					x	x	
PROPACHLOR	x						x					x
PROPANIL								x				
PROPYZAMIDE	x			x		x			x			x
PROSULFOCARB				x		x						
PYRIDATE						x						
QUINMERAC				x								
S-METOLACHLOR		x		x		x	x	x		x	x	
SIMAZINE						x						x
SULCOTRIONE				x		x						
TERBUTHYLAZINE		x				x				x	x	
TERBUTRYN											x	
TRALKOXYDIM												
TRIFLURALIN	x	x	x	x	x		x			x	x	x
TRIFLUSULPHURON			x		x							

Table Annex 3: Overview of insecticides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data (Part I).

Substance	AT	BE/ LU	CY	CZ	DE	DK	EE	ES	FI	GR
ALDICARB		x								
CARBOFURAN		x				x				
CHLORFENVINPHOS										
CHLORPYRIFOS	x		x	x				x		x
CHLORPYRIFOS-METHYL	x			x						
BETA-CYFLUTHRIN										
LAMBDA-CYHALOTHRIN										
CYPERMETHRIN	x									
DIAFENTHIURON							x			
DIAZINON										
DICOFOL								x		
DIMETHOATE										
ETHOPROPHOS										x
FENAZAQUIN			x							
FENTHION										x
IMIDACLOPRID										
METHIDATHION										x

Substance	AT	BE/ LU	CY	CZ	DE	DK	EE	ES	FI	GR
METHIOCARB					x				x	
METHOMYL								x		
OXAMYL										
PARATHION-METHYL										x
PIRIMIPHOS-METHYL										
SPINOSAD			x							
TEBUFENPYRAD										
TERBUFOS										
THIAMETHOXAM							x		x	

Table Annex 4: Overview of insecticides that were among the five most importantly used plant protection products per considered country, aggregated over all considered agricultural produces for the year 2000, based on application amount data (Part II).

Substance	HU	IE	IT	LT	LV	PL	SE	SI	SK	UK
ALDICARB										
CARBOFURAN										
CHLORFENVINPHOS		x								
CHLORPYRIFOS			x			x		x	x	x
CHLORPYRIFOS-METHYL									x	
BETA-CYFLUTHRIN							x			
LAMBDA-CYHALOTHRIN								x		
CYPERMETHRIN										
DIAFENTHIURON					x					
DIAZINON	x							x	x	
DICOFOL										
DIMETHOATE	x	x				x	x			
ETHOPROPHOS										
FENAZAQUIN										
FENTHION										
IMIDACLOPRID							x			
METHIDATHION	x									
METHIOCARB										
METHOMYL										
OXAMYL										x
PARATHION-METHYL										
PIRIMIPHOS-METHYL				x						
SPINOSAD										
TEBUFENPYRAD		x								
TERBUFOS	x									
THIAMETHOXAM				x	x					

Annex II: Application Rates of Selected Substances

There exist country-specific application rates for at least some of the considered plant protection products and at least for some countries and last but not least at least for some agricultural produces. However, for most of the selected substances and countries it is hardly ever any specific application rate officially published. Hence, typical application rates as listed in Table Annex 5 and Table Annex 6 (Eurostat, 2007) are used for the present study, referring to aggregated mean values of data available for single countries and agricultural commodities. Note that for the substances Isoxaflutole and Triflusulfuron recommended application values from Tomlin (2006) instead of actual application values have been used due to lack of any applicaion data for the considered countries.

Table Annex 5: Typical application rates of the most important herbicides as used per country in year 2000. Data have been aggregated according to chemical classes.

Substance	CAS RN	Chemical Class	[$kg_{applied}/m^2$]
2,4-D	94-75-7	Alkylchlorophenoxy	1.8E-05
ACETOCHLOR	34256-82-1	Chloroacetamide	3.1E-04
ACLONIFEN	74070-46-5	Diphenyl ether	1.0E-05
ALACHLOR	15972-60-8	Chloroacetamide	3.1E-04
AMITROL	61-82-5	Triazole	6.5E-05
ATRAZINE	1912-24-9	Triazine	1.0E-04
BENTAZONE	25057-89-0	Benzothiazinone	6.2E-06
BROMOXYNIL	1689-84-5	Hydroxybenzonitrile	2.0E-06
CHLORBUFAM	1967-16-4	Carbanilate	4.7E-05
CLOMAZONE	81777-89-1	Isoxazolidinone	2.0E-06
CLOPYRALID	1702-17-6	Pyridine compound	3.4E-06
CHLORIDAZON	1698-60-8	Pyridazinone	4.7E-05
CYCLOXYDIM	101205-02-1	Cyclohexanedione	4.0E-06
DESMEDIPHAM	13684-56-5	Bis-carbamate	5.0E-05
DICAMBA	1918-00-9	Benzoic acid	2.0E-06
DICHLORPROP	120-36-5	Aryloxyalkanoic acid	5.0E-05
DICHLORPROP-P	15165-67-0	Aryloxyalkanoic acid	5.0E-05
DIMETHACHLOR	50563-36-5	Chloroacetamide	3.1E-04

Substance	CAS RN	Chemical Class	[$kg_{applied}/m^2$]
DIMETHENAMID	87674-68-8	Chloroacetamide	3.1E-04
DIMETHENAMID-P	163515-14-8	Chloroacetamide	3.1E-04
DIQUAT	2764-72-9	Bipyridylium	1.3E-05
EPTC	759-94-4	Thiocarbamate	1.0E-05
ETHOFUMESATE	26225-79-6	Benzofuran	5.3E-05
FLUAZIFOP-P-BUTYL	79241-46-6	Aryloxyphenoxypropionate	3.3E-06
GLUFOSINATE	77182-82-2	Organophosphate	2.7E-04
GLYPHOSATE	1071-83-6	Phosphonoglycine	6.0E-05
HALOXYFOP	87237-48-7	Aryloxyphenoxy propionic acid	4.8E-06
IMAZAMETHABENZ	81405-85-8	Imidazolinone	1.0E-06
ISOPROTURON	34123-59-6	Urea	1.0E-05
ISOXAFLUTOLE	141112-29-0	Isoxazole	1.1E-05
LENACIL	2164-08-1	Uracil	2.7E-05
LINURON	330-55-2	Urea	1.0E-05
MCPA	3653-48-3	Aryloxyalkanoic acid	5.0E-05
MCPB	94-81-5	Aryloxyalkanoic acid	5.0E-05
MECOPROP	93-65-2	Aryloxyalkanoic acid	5.0E-05
MECOPROP-P	16484-77-8	Aryloxyalkanoic acid	5.0E-05
METAMITRON	41394-05-2	Triazinone	3.5E-05
METAZACHLOR	67129-08-2	Chloroacetamide	3.1E-04
METOLACHLOR	51218-45-2	Chloroacetamide	3.1E-04
METRIBUZIN	21087-64-9	Triazinone	3.5E-05
MOLINATE	2212-67-1	Thiocarbamate	1.0E-05
NAPROPAMIDE	15299-99-7	Alkanamide	1.7E-05
OXYFLUORFEN	42874-03-3	Diphenyl ether	1.0E-05
PARAQUAT	4685-14-7	Bipyridylium	1.3E-05
PENDIMETHALIN	40487-42-1	Dinitroaniline	5.1E-05
PHENMEDIPHAM	13684-63-4	Bis-carbamate	5.0E-05
PROMETRYN	7287-19-6	Triazine	1.0E-04

Substance	CAS RN	Chemical Class	[$kg_{applied}/m^2$]
PROPACHLOR	1918-16-7	Chloroacetamide	3.1E-04
PROPANIL	709-98-8	Anilide	1.3E-05
PROPYZAMIDE	23950-58-5	Benzamide	2.3E-05
PROSULFOCARB	52888-80-9	Thiocarbamate	1.0E-05
PYRIDATE	55512-33-9	Phenylpyridazine	9.0E-06
QUINMERAC	90717-03-6	Quinoline	7.7E-06
S-METOLACHLOR	87392-12-9	Chloroacetamide	3.1E-04
SIMAZINE	122-34-9	Triazine	1.0E-04
TERBUTHYLAZINE	5915-41-3	Triazine	1.0E-04
TERBUTRYN	886-50-0	Triazine	1.0E-04
TRIFLURALIN	1582-09-8	Dinitroaniline	5.1E-05
TRIFLUSULPHURON	126535-15-7	Sulfonylurea	2.0E-06

Table Annex 6: Typical application rates of the most important insecticides as used per country in year 2000. Data have been aggregated according to chemical classes.

Substance	CAS RN	Chemial Class	[$kg_{applied}/m^2$]
ALDICARB	116-06-3	Carbamate	3.6E-05
CARBOFURAN	1563-66-2	Carbamate	3.6E-05
CHLORFENVINPHOS	470-90-6	Organophosphate	6.0E-05
CHLORPYRIFOS	2921-88-2	Organophosphate	6.0E-05
CHLORPYRIFOS-METHYL	5598-13-0	Organophosphate	6.0E-05
BETA-CYFLUTHRIN	68359-37-5	Pyrethroid	3.0E-06
LAMBDA-CYHALOTHRIN	91465-08-6	Pyrethroid	3.0E-06
CYPERMETHRIN	52315-07-8	Pyrethroid	3.0E-06
DIAZINON	333-41-5	Organophosphate	6.0E-05
DICOFOL	115-32-2	Organochlorine	3.3E-05
DIMETHOATE	60-51-5	Organophosphate	6.0E-05
ETHOPROPHOS	13194-48-4	Organophosphate	6.0E-05
FENTHION	55-38-9	Organophosphate	6.0E-05

Substance	CAS RN	Chemial Class	[$kg_{applied}/m^2$]
IMIDACLOPRID	138261-41-3	Neonicotinoid	5.0E-06
METHIDATHION	950-37-8	Organophosphate	6.0E-05
METHIOCARB	2032-65-7	Carbamate	3.6E-05
METHOMYL	16752-77-5	Carbamate	3.6E-05
OXAMYL	23135-22-0	Carbamate	3.6E-05
PARATHION-METHYL	298-00-0	Organophosphate	6.0E-05
PIRIMIPHOS-METHYL	29232-93-7	Organophosphate	6.0E-05
TERBUFOS	13071-79-9	Organophosphate	6.0E-05

Annex III: Physicochemical Properties of Selected Substances

In this section, the most important physicochemical property data are given for the plant protection products of concern in this study. Note, that other property data can be derived based on the given data in the following tabes and will, thus, not be listed here in addition. These property data are e.g. the Henry law constant [Pa m^3 mol^{-1}], the air-water partition coefficient [–], the molar volume [cm^3 mol^{-1}], the soil organic carbon-water partition coefficient [L kg^{-1}], and the degradation rate constants in various compartments [d^{-1}]. The physicochemical property data were collected from a wide range of avialable resources, e.g. most importantly from AERU (2009), Tomlin (2006), US-EPA (2008) and Mackay (2006).

Table Annex 7: Physicochemical properties of the most important herbicides as used per country in year 2000 including Molecular weight (MW), saturation vapour pressure (P^0), solubility in water (S), N-octanol-water partition coefficient (K_{OW}), and degradation half lives in air ($t_{1/2,a}$), in water ($t_{1/2,w}$) and in soil ($t_{1/2,s}$), respectively.

Substance	MW [g/mol]	P^0 [Pa]	S [g/m³]	K_{OW} [–]	$t_{1/2,a}$ [d]	$t_{1/2,w}$ [d]	$t_{1/2,s}$ [d]
2,4-D	2.2E+02	1.1E-02	6.8E+02	6.5E+02	1.6E+00	3.8E+01	7.5E+01
ACETOCHLOR	2.7E+02	3.7E-03	2.2E+02	1.1E+03	2.2E-01	6.0E+01	1.2E+02
ACLONIFEN	2.6E+02	1.6E-05	2.5E+00	1.1E+04	8.4E-01	6.0E+01	1.2E+02
ALACHLOR	2.7E+02	2.7E-03	2.4E+02	3.3E+03	2.4E-01	6.0E+01	1.2E+02
AMITROL	8.4E+01	5.9E-05	2.8E+05	1.1E-01	1.9E+00	1.5E+01	3.0E+01
ATRAZINE	2.2E+02	3.9E-05	3.5E+01	4.1E+02	3.9E-01	6.0E+01	1.2E+02
BENTAZONE	2.4E+02	4.6E-04	5.0E+02	2.2E+02	1.7E-01	3.8E+01	7.5E+01
BROMOXYNIL	2.8E+02	6.3E-06	1.3E+02	2.5E+03	5.1E+01	3.8E+01	7.5E+01
CHLORBUFAM	2.2E+02	2.1E-03	5.4E+02	1.0E+03	2.3E-01	3.8E+01	7.5E+01
CLOMAZONE	2.4E+02	1.9E-02	1.1E+03	3.2E+02	4.9E-01	3.8E+01	7.5E+01
CLOPYRALID	1.9E+02	1.6E-03	7.9E+03	1.1E+01	2.0E+01	6.0E+01	1.2E+02
CHLORIDAZON	2.2E+02	6.0E-05	4.0E+02	1.4E+01	2.7E-01	3.8E+01	7.5E+01
CHLOROTOLURON	2.1E+02	4.8E-06	7.0E+01	2.6E+02	2.7E-01	3.8E+01	7.5E+01
CYCLOXYDIM	3.3E+02	1.0E-05	4.0E+01	7.6E+03	7.5E-02	3.8E+01	7.5E+01
DESMEDIPHAM	3.0E+02	4.0E-07	7.0E+00	2.5E+03	1.2E-01	3.8E+01	7.5E+01
DICAMBA	2.2E+02	4.5E-03	8.3E+03	1.6E+02	3.6E+00	3.8E+01	7.5E+01
DICHLORPROP	2.4E+02	6.2E-05	3.5E+02	2.7E+03	9.4E-01	3.8E+01	7.5E+01
DICHLORPROP-P	2.4E+02	5.6E-05	5.9E+02	2.8E-01	9.4E-01	2.0E+01	1.4E+01

Substance	MW [g/mol]	P^0 [Pa]	S [g/m^3]	K_{OW} [–]	$t_{1/2,a}$ [d]	$t_{1/2,w}$ [d]	$t_{1/2,s}$ [d]
DIMETHACHLOR	2.6E+02	1.5E-03	2.3E+03	1.5E+02	2.6E-01	6.0E+01	1.2E+02
DIMETHENAMID	2.8E+02	3.7E-02	1.2E+03	1.4E+02	2.0E-01	6.0E+01	1.2E+02
DIMETHENAMID-P	2.8E+02	2.5E-03	1.5E+03	7.8E+01	2.0E-01	2.4E+01	1.1E+01
DIQUAT	1.8E+02	1.3E-06	7.0E+01	2.3E+02	3.0E+00	1.5E+01	3.0E+01
EPTC	1.9E+02	3.2E+00	3.8E+02	1.6E+03	3.4E-01	3.8E+01	7.5E+01
ETHOFUMESATE	2.9E+02	6.5E-04	5.0E+01	5.0E+02	2.0E-01	3.8E+01	7.5E+01
FLUAZIFOP-P-BUTYL	3.8E+02	3.3E-05	2.0E+00	3.2E+04	3.6E-01	6.0E+01	1.2E+02
GLUFOSINATE	2.0E+02	1.2E-09	1.4E+06	1.5E-05	3.5E-01	1.5E+01	3.0E+01
GLYPHOSATE	1.7E+02	2.1E-06	1.1E+04	4.0E-04	1.4E-01	1.5E+01	3.0E+01
HALOXYFOP	4.3E+02	1.6E-09	5.8E-01	2.1E+04	3.0E-01	1.8E+02	3.6E+02
IMAZAMETHABENZ	2.9E+02	1.5E-06	1.0E+03	4.0E+03	6.7E-01	3.8E+01	7.5E+01
ISOPROTURON	2.1E+02	3.3E-06	6.5E+01	7.4E+02	8.9E-01	3.8E+01	7.5E+01
ISOXAFLUTOLE	3.6E+02	1.0E-06	6.2E+00	2.1E+02	1.8E+00	6.0E+01	1.2E+02
LENACIL	2.3E+02	2.0E-07	6.0E+00	1.2E+03	2.3E-01	3.8E+01	7.5E+01
LINURON	2.5E+02	1.9E-04	7.5E+01	1.6E+03	1.0E+00	6.0E+01	1.2E+02
MCPA	2.2E+02	9.7E-09	2.7E+05	5.1E-02	1.1E+00	1.5E+01	3.0E+01
MCPB	2.3E+02	5.8E-05	4.8E+01	3.2E+03	5.3E-01	3.8E+01	7.5E+01
MECOPROP	2.1E+02	4.0E-04	6.2E+02	1.3E+03	6.1E-01	3.8E+01	7.5E+01
MECOPROP-P	2.1E+02	4.0E-04	8.6E+02	1.6E+03	6.1E-01	3.8E+01	7.5E+01
MESOTRIONE	3.4E+02	5.7E-06	1.6E+02	1.3E+00	n/a	5.3E+00	5.0E+00
METAMITRON	2.0E+02	8.6E-07	1.8E+03	6.8E+00	5.5E-01	1.5E+01	3.0E+01
METAZACHLOR	2.8E+02	1.5E-04	4.3E+02	1.3E+02	1.8E-01	6.0E+01	1.2E+02
METOLACHLOR	2.8E+02	4.2E-03	5.3E+02	1.3E+03	1.9E-01	6.0E+01	1.2E+02
METRIBUZIN	2.1E+02	5.8E-05	1.1E+03	5.0E+01	5.9E-01	3.8E+01	7.5E+01
MOLINATE	1.9E+02	7.5E-01	9.7E+02	1.6E+03	3.5E-01	3.8E+01	7.5E+01
NAPROPAMIDE	2.7E+02	2.3E-05	7.3E+01	2.3E+03	4.6E-02	3.8E+01	7.5E+01
OXYFLUORFEN	3.6E+02	2.7E-05	1.2E-01	5.4E+04	9.3E-01	1.8E+02	3.6E+02
PARAQUAT	2.6E+02	1.3E-05	6.2E+05	1.9E-03	5.0E-01	3.8E+01	7.5E+01
PENDIMETHALIN	2.8E+02	4.0E-03	3.0E-01	1.5E+05	3.5E-01	6.0E+01	1.2E+02
PHENMEDIPHAM	3.0E+02	1.3E-09	4.7E+00	3.9E+03	6.9E-02	3.8E+01	7.5E+01

Substance	MW [g/mol]	P^0 [Pa]	S [g/m³]	K_{OW} [–]	$t_{1/2,a}$ [d]	$t_{1/2,w}$ [d]	$t_{1/2,s}$ [d]
PROMETRYN	2.4E+02	1.7E-04	3.3E+01	3.2E+03	2.8E-01	6.0E+01	1.2E+02
PROPACHLOR	2.1E+02	3.1E-02	5.8E+02	1.5E+02	5.1E-01	3.8E+01	7.5E+01
PROPANIL	2.2E+02	1.2E-04	1.5E+02	1.2E+03	2.8E+00	6.0E+01	1.2E+02
PROPYZAMIDE	2.6E+02	5.8E-05	1.5E+01	2.7E+03	8.1E-01	6.0E+01	1.2E+02
PROSULFOCARB	2.5E+02	6.9E-05	1.3E+01	4.5E+04	3.3E-01	3.8E+01	7.5E+01
PYRIDATE	3.8E+02	1.3E-07	1.5E+00	5.4E+05	6.4E-01	3.8E+01	7.5E+01
QUINMERAC	2.2E+02	1.8E-05	2.2E+02	7.4E+02	2.9E+00	3.8E+01	7.5E+01
S-METOLACHLOR	2.8E+02	4.2E-03	5.3E+02	7.9E+02	1.9E-01	6.0E+01	1.2E+02
SIMAZINE	2.0E+02	2.9E-06	6.2E+00	1.5E+02	9.7E-01	6.0E+01	1.2E+02
SULCOTRIONE	3.3E+02	5.0E-06	1.7E+03	2.0E-02	n/a	9.5E+00	2.5E+01
TERBUTHYLAZINE	2.3E+02	1.5E-04	8.5E+00	1.6E+03	9.7E-01	6.0E+01	1.2E+02
TERBUTRYN	2.4E+02	2.3E-04	2.5E+01	5.5E+03	1.0E+00	6.0E+01	1.2E+02
TRALKOXYDIM	3.3E+02	3.7E-07	6.1E+00	1.3E+02	n/a	6.8E+01	1.9E+00
TRIFLURALIN	3.4E+02	6.1E-03	1.8E-01	2.2E+05	4.5E-01	1.8E+02	3.6E+02
TRIFLUSULPHURON	4.9E+02	2.8E-11	3.4E-01	8.7E+03	2.8E+00	1.8E+02	3.6E+02

Table Annex 8: Physicochemical properties of the most important insecticides as used per country in year 2000 including Molecular weight (MW), saturation vapour pressure (P^0), solubility in water (S), N-octanol-water partition coefficient (K_{OW}), and degradation half lives in air ($t_{1/2,a}$), in water ($t_{1/2,w}$) and in soil ($t_{1/2,s}$), respectively.

Substance	MW [g/mol]	P^0 [Pa]	S [g/m³]	K_{OW} [–]	$t_{1/2,a}$ [d]	$t_{1/2,w}$ [d]	$t_{1/2,s}$ [d]
ALDICARB	1.9E+02	4.6E-03	6.0E+03	1.3E+01	1.2E+00	3.8E+01	7.5E+01
CARBOFURAN	2.2E+02	6.5E-04	3.2E+02	2.1E+02	4.1E-01	3.8E+01	7.5E+01
CHLORFENVINPHOS	3.6E+02	1.0E-03	1.2E+02	6.5E+03	1.9E-01	6.0E+01	1.2E+02
CHLORPYRIFOS	3.5E+02	2.7E-03	1.1E+00	9.1E+04	1.2E-01	1.8E+02	3.6E+02
CHLORPYRIFOS-METHYL	3.2E+02	5.6E-03	4.8E+00	2.0E+04	1.8E-01	6.0E+01	1.2E+02
BETA-CYFLUTHRIN	4.3E+02	2.0E-08	3.0E-03	8.9E+05	8.6E-01	1.8E+02	3.6E+02
LAMBDA-CYHALOTHRIN	4.5E+02	2.0E-07	5.0E-03	1.0E+07	3.4E-01	1.8E+02	3.6E+02
CYPERMETHRIN	4.2E+02	1.7E-01	4.0E-03	4.0E+06	5.0E-01	1.8E+02	3.6E+02
DIAFENTHIURON	3.8E+02	2.0E-06	6.0E-02	5.8E+05	n/a	n/a	5.0E-01
DIAZINON	3.0E+02	1.2E-02	4.0E+01	6.5E+03	1.1E-01	3.8E+01	7.5E+01
DICOFOL	3.7E+02	5.3E-05	8.0E-01	1.0E+05	3.1E+00	1.8E+02	3.6E+02

Substance	MW [g/mol]	P^0 [Pa]	S [g/m^3]	K_{OW} [–]	$t_{1/2,a}$ [d]	$t_{1/2,w}$ [d]	$t_{1/2,s}$ [d]
DIMETHOATE	2.3E+02	2.5E-03	2.3E+04	6.0E+00	1.4E-01	1.5E+01	3.0E+01
ETHOPROPHOS	2.4E+02	5.1E-02	7.5E+02	3.9E+03	1.5E-01	1.5E+01	3.0E+01
FENAZAQUIN	3.1E+02	1.9E-05	1.0E-01	3.2E+05	n/a	n/a	4.5E+01
FENTHION	2.8E+02	1.4E-03	7.5E+00	1.2E+04	1.5E-01	3.8E+01	7.5E+01
IMIDACLOPRID	2.6E+02	2.2E-04	6.1E+02	3.7E+00	7.1E-02	6.0E+01	1.2E+02
METHIDATHION	3.0E+02	4.5E-04	1.9E+02	1.6E+02	7.1E-02	3.8E+01	7.5E+01
METHIOCARB	2.3E+02	3.6E-05	2.7E+01	8.3E+02	7.9E-01	3.8E+01	7.5E+01
METHOMYL	1.6E+02	7.2E-04	5.8E+04	4.0E+00	1.6E+00	1.5E+01	3.0E+01
OXAMYL	2.2E+02	3.1E-02	2.8E+05	3.4E-01	4.7E-01	3.8E+01	7.5E+01
PARATHION-METHYL	2.6E+02	4.7E-04	3.8E+01	7.2E+02	1.8E-01	3.8E+01	7.5E+01
PIRIMIPHOS-METHYL	3.1E+02	2.0E-03	8.6E+00	1.6E+04	6.7E-02	3.8E+01	7.5E+01
SPINOSAD	7.4E+02	2.0E-08	2.4E+02	1.0E+04	n/a	n/a	1.4E+01
TEBUFENPYRAD	3.3E+02	1.6E-06	2.4E+00	8.5E+04	n/a	6.6E+00	1.4E+01
TERBUFOS	2.9E+02	4.3E-02	5.1E+00	3.0E+04	4.4E-02	3.8E+01	7.5E+01
THIAMETHOXAM	2.9E+02	6.6E-09	4.1E+03	7.4E-01	n/a	3.1E+01	5.0E+01

Annex IV: Human Health Effect Factors

In this section, more detailed information with respect to the effects of the direct application of plant protection products on human health toxicity is presented, dis-aggregated according to cancer and non-cancer incidences as distinguished in Rosenbaum et al. (2008) and for all substances as included in the present study.

Table Annex 9: Human health characterisation factors calculated for emissions of plant protection products to continental agricultural soil according to Rosenbaum et al. (2008) for the most important herbicides as used per country in year 2000.

Substance	Human health characterisation factor [cases/kg$_{emitted}$]			Remarks
	cancer	non-cancer	total	
2,4-D	n/a	2.2E-06	2.2E-06	
ACETOCHLOR	n/a	n/a	n/a	
ACLONIFEN	n/a	n/a	n/a	
ALACHLOR	n/a	n/a	n/a	
AMITROL	1.3E-06	1.8E-06	3.1E-06	
ATRAZINE	1.0E-06	1.2E-06	2.2E-06	
BENTAZONE	n/a	6.2E-07	6.2E-07	
BROMOXYNIL	n/a	6.0E-07	6.0E-07	
CHLORBUFAM	n/a	n/a	n/a	
CLOMAZONE	n/a	n/a	n/a	
CLOPYRALID	n/a	n/a	n/a	3,6-DICHLOROPICOLINIC ACID.
CHLORIDAZON	n/a	n/a	n/a	
CHLOROTOLURON	-	-	-	Not available.
CYCLOXYDIM	n/a	n/a	n/a	
DESMEDIPHAM	n/a	n/a	n/a	
DICAMBA	n/a	1.1E-06	1.1E-06	
DICHLORPROP	n/a	n/a	n/a	
DICHLORPROP-P	n/a	n/a	n/a	Adopted from DICHLORPROP.
DIMETHACHLOR	n/a	n/a	n/a	
DIMETHENAMID	n/a	n/a	n/a	
DIMETHENAMID-P	n/a	n/a	n/a	Adopted from DIMETHENAMID.
DIQUAT	n/a	1.6E-07	1.6E-07	
EPTC	n/a	7.9E-07	7.9E-07	
ETHOFUMESATE	n/a	n/a	n/a	
FLUAZIFOP-P-BUTYL	n/a	n/a	n/a	
GLUFOSINATE	n/a	1.1E-07	1.1E-07	Adopted from

Substance	Human health characterisation factor [cases/kg$_{emitted}$]			Remarks
	cancer	non-cancer	total	
				GLUFOSINATE-AMMONIUM.
GLYPHOSATE	n/a	7.6E-08	7.6E-08	
HALOXYFOP	n/a	n/a	n/a	Adopted from HALOXYFOP-ETOTYL.
IMAZAMETHABENZ	n/a	n/a	n/a	
ISOPROTURON	n/a	n/a	n/a	
ISOXAFLUTOLE	n/a	n/a	n/a	
LENACIL	n/a	n/a	n/a	
LINURON	n/a	6.0E-06	6.0E-06	
MCPA	n/a	n/a	n/a	
MCPB	n/a	4.7E-07	4.7E-07	
MECOPROP	n/a	7.4E-06	7.4E-06	
MECOPROP-P	n/a	n/a	n/a	
MESOTRIONE	-	-	-	Not available.
METAMITRON	n/a	n/a	n/a	
METAZACHLOR	n/a	n/a	n/a	
METOLACHLOR	n/a	2.8E-07	2.8E-07	
METRIBUZIN	n/a	5.9E-07	5.9E-07	
MOLINATE	n/a	2.4E-05	2.4E-05	
NAPROPAMIDE	n/a	3.6E-06	3.6E-06	N,N-DIETHYL-2-(1-NAPHTHALENYLOXY)PROPANAMIDE.
OXYFLUORFEN	n/a	3.6E-06	3.6E-06	
PARAQUAT	n/a	8.5E-09	8.5E-09	
PENDIMETHALIN	n/a	1.1E-07	1.1E-07	
PHENMEDIPHAM	n/a	1.5E-08	1.5E-08	
PROMETRYN	n/a	2.7E-07	2.7E-07	
PROPACHLOR	n/a	1.8E-07	1.8E-07	
PROPANIL	n/a	1.4E-06	1.4E-06	
PROPYZAMIDE	9.3E-07	3.9E-07	1.3E-06	PRONAMIDE.
PROSULFOCARB	n/a	n/a	n/a	
PYRIDATE	n/a	n/a	n/a	
QUINMERAC	n/a	n/a	n/a	
S-METOLACHLOR	n/a	n/a	n/a	
SIMAZINE	n/a	8.8E-06	8.8E-06	
SULCOTRIONE	-	-	-	Not available.
TERBUTHYLAZINE	n/a	n/a	n/a	
TERBUTRYN	n/a	3.8E-05	3.8E-05	
TRALKOXYDIM	-	-	-	Not available.
TRIFLURALIN	1.8E-07	1.8E-06	2.0E-06	

Substance	Human health characterisation factor [cases/kg$_{emitted}$]			Remarks
	cancer	non-cancer	total	
TRIFLUSULPHURON	n/a	n/a	n/a	Adopted from TRIFLUSULFURON -METHYL.

Table Annex 10: Human health characterisation factors calculated for emissions of plant protection products to continental agricultural soil according to Rosenbaum et al. (2008) for the most important insecticides as used per country in year 2000.

Substance	Human health characterisation factor [cases/kg$_{emitted}$]			Remarks
	cancer	non-cancer	total	
ALDICARB	n/a	4.4E-05	4.4E-05	
CARBOFURAN	n/a	1.5E-05	1.5E-05	
CHLORFENVINPHOS	n/a	2.4E-04	2.4E-04	
CHLORPYRIFOS	n/a	2.3E-05	2.3E-05	Adopted from CHLORPYRIFOS-METHYL.
CHLORPYRIFOS-METHYL	n/a	2.3E-05	2.3E-05	
BETA-CYFLUTHRIN	n/a	3.9E-07	3.9E-07	
LAMBDA-CYHALOTHRIN	n/a	5.6E-07	5.6E-07	Adopted from CYHALOTHRIN.
CYPERMETHRIN	n/a	2.6E-07	2.6E-07	
DIAFENTHIURON	-	-	-	Not available.
DIAZINON	n/a	3.0E-05	3.0E-05	
DICOFOL	1.6E-05	1.5E-04	1.6E-04	
DIMETHOATE	n/a	1.6E-06	1.6E-06	
ETHOPROPHOS	n/a	1.2E-04	1.2E-04	O-ETHYL S,S-DIPROPYL PHOSPHORODITHIOATE.
FENAZAQUIN	-	-	-	Not available.
FENTHION	n/a	7.0E-06	7.0E-06	
IMIDACLOPRID	n/a	1.1E-07	1.1E-07	
METHIDATHION	1.5E-05	1.4E-05	2.9E-05	
METHIOCARB	n/a	6.1E-07	6.1E-07	
METHOMYL	n/a	4.1E-06	4.1E-06	
OXAMYL	n/a	1.9E-06	1.9E-06	
PARATHION-METHYL	n/a	2.8E-06	2.8E-06	
PIRIMIPHOS-METHYL	n/a	3.2E-06	3.2E-06	
SPINOSAD	-	-	-	Not available.
TEBUFENPYRAD	-	-	-	Not available.

Substance	Human health characterisation factor [cases/kg$_{emitted}$]			Remarks
	cancer	non-cancer	total	
TERBUFOS	n/a	4.1E-04	4.1E-04	
THIAMETHOXAM	-	-	-	Not available.

Annex V: Ecotoxicity Effect Factors

In this section, more detailed information with respect to the effects of the direct application of plant protection products on ecosystem toxicity is presented, disaggregated according to different receiving environmental compartments as distinguished in Rosenbaum et al. (2008) and for all substances as included in the present study. Note that all effect factors are related to the final mass in the freshwater compartment.

Table Annex 11: Ecosystem toxicity characterisation factors calculated for diffuse emissions of plant protection products to different compartments soil according to Rosenbaum et al. (2008) for the most important herbicides as used per country in year 2000.

Substance	Ecotoxicity characterisation factor for freshwater [PAF·m³·day/kg$_{emitted}$]				Remarks
	urban air	continental air	freshwater	agricultural soil	
2,4-D	1.1E+02	1.0E+02	8.6E+02	1.8E+02	
ACETOCHLOR	2.0E+03	1.4E+03	6.8E+04	7.6E+03	
ACLONIFEN	2.1E+04	1.3E+04	6.6E+05	8.5E+03	
ALACHLOR	2.7E+03	1.9E+03	7.6E+04	9.3E+03	
AMITROL	1.3E+02	1.2E+02	9.8E+02	1.9E+02	
ATRAZINE	4.1E+03	3.3E+03	8.8E+04	1.1E+04	
BENTAZONE	8.8E+00	7.5E+00	2.0E+02	5.0E+01	
BROMOXYNIL	1.4E+03	1.1E+03	1.6E+04	8.7E+02	
CHLORBUFAM	7.2E+01	4.8E+01	2.3E+03	2.2E+02	
CLOMAZONE	2.8E+02	1.9E+02	7.8E+03	4.8E+02	
CLOPYRALID	2.3E+02	2.2E+02	9.1E+02	2.7E+02	3,6-DICHLOROPICOLINIC ACID.
CHLORIDAZON	3.5E+02	2.5E+02	9.3E+03	1.1E+03	
CHLOROTOLURON	-	-	-	-	Not available.
CYCLOXYDIM	5.1E+00	1.1E+00	2.9E+02	1.1E+00	
DESMEDIPHAM	1.6E+03	5.0E+02	8.5E+04	1.1E+03	
DICAMBA	3.5E+02	3.4E+02	1.9E+03	4.8E+02	
DICHLORPROP	4.4E+01	4.1E+01	4.2E+02	8.8E+01	
DICHLORPROP-P	4.4E+01	4.1E+01	4.2E+02	8.8E+01	Adopted from DICHLORPROP.
DIMETHACHLOR	5.0E+02	3.8E+02	1.2E+04	1.7E+03	
DIMETHENAMID	4.2E+03	3.0E+03	1.4E+05	2.0E+04	
DIMETHENAMID-P	4.2E+03	3.0E+03	1.4E+05	2.0E+04	Adopted from DIMETHENAMID.
DIQUAT	3.0E+03	1.9E+03	7.4E+04	1.5E+02	
EPTC	6.9E+00	6.3E+00	1.7E+03	9.7E+01	
ETHOFUMESATE	9.2E+01	4.7E+01	3.9E+03	2.0E+02	

Substance	Ecotoxicity characterisation factor for freshwater [PAF·m^3·day/kg$_{emitted}$]				Remarks
	urban air	continen-tal air	fresh-water	agricul-tural soil	
FLUAZIFOP-P-BUTYL	5.6E+02	2.1E+02	2.9E+04	1.6E+02	
GLUFOSINATE	1.6E+01	8.9E+00	5.8E+02	1.7E+01	Adopted from GLUFOSINATE-AMMONIUM.
GLYPHOSATE	1.5E+01	1.3E+01	3.2E+02	1.0E+02	
HALOXYFOP	5.2E+02	3.5E+02	1.2E+04	1.4E+02	Adopted from HALOXYFOP-ETOTYL.
IMAZAMETHABENZ	1.0E+01	7.1E+00	2.2E+02	2.9E+00	
ISOPROTURON	6.8E+03	5.5E+03	1.2E+05	9.5E+03	
ISOXAFLUTOLE	1.6E+03	9.5E+02	4.2E+04	1.6E+02	
LENACIL	2.1E+03	1.5E+03	6.0E+04	6.4E+03	
LINURON	1.0E+04	7.7E+03	2.0E+05	1.1E+04	
MCPA	1.3E+01	1.2E+01	9.3E+01	1.4E+01	Adopted from MCPA-SODIUM SALT.
MCPB	1.1E+02	9.3E+01	2.0E+03	2.7E+02	
MECOPROP	9.0E+01	8.6E+01	8.6E+02	2.6E+02	
MECOPROP-P	4.4E+01	4.2E+01	4.2E+02	1.2E+02	
MESOTRIONE	-	-	-	-	Not available.
METAMITRON	1.9E+01	1.3E+01	5.0E+02	2.3E+01	
METAZACHLOR	1.6E+02	7.0E+01	7.4E+03	2.2E+02	
METOLACHLOR	1.9E+03	1.2E+03	6.7E+04	6.0E+03	
METRIBUZIN	7.3E+02	6.6E+02	9.5E+03	1.9E+03	
MOLINATE	4.4E+01	3.6E+01	6.0E+03	7.5E+02	
NAPROPAMIDE	1.3E+03	6.6E+02	6.4E+04	9.0E+01	N,N-DIETHYL-2-(1-NAPHTHALENYL OXY)PROPANAMI DE.
OXYFLUORFEN	1.3E+03	6.6E+02	6.4E+04	9.0E+01	
PARAQUAT	2.9E+03	1.3E+03	1.2E+05	1.6E+02	
PENDIMETHALIN	6.6E+03	2.4E+03	4.6E+05	2.9E+03	
PHENMEDIPHAM	1.6E+03	9.7E+02	4.2E+04	2.5E+02	
PROMETRYN	1.5E+04	8.4E+03	5.9E+05	2.4E+04	
PROPACHLOR	1.9E+03	1.2E+03	7.4E+04	4.6E+03	
PROPANIL	4.9E+04	4.5E+04	4.1E+05	6.0E+04	
PROPYZAMIDE	2.8E+02	2.3E+02	4.3E+03	5.0E+02	PRONAMIDE.
PROSULFOCARB	7.3E+02	3.1E+02	3.3E+04	2.0E+02	
PYRIDATE	1.8E+02	1.1E+02	4.8E+03	2.1E+00	
QUINMERAC	3.1E+01	2.4E+01	5.1E+02	2.0E+01	
S-METOLACHLOR	3.2E+03	2.0E+03	1.1E+05	1.0E+04	
SIMAZINE	6.8E+03	6.1E+03	7.8E+04	1.3E+04	

Substance	Ecotoxicity characterisation factor for freshwater [PAF·m³·day/kg$_{emitted}$]				Remarks
	urban air	continen-tal air	fresh-water	agricul-tural soil	
SULCOTRIONE	-	-	-	-	Not available.
TERBUTHYLAZINE	3.2E+04	2.7E+04	4.7E+05	5.4E+04	
TERBUTRYN	2.9E+03	2.1E+03	6.5E+04	2.7E+03	
TRALKOXYDIM	-	-	-	-	Not available.
TRIFLURALIN	2.5E+02	1.9E+02	1.1E+05	5.9E+02	
TRIFLUSULPHURON	1.2E+04	1.2E+04	4.1E+04	1.5E+04	Adopted from TRIFLUSULFURON-METHYL.

Table Annex 12: Ecosystem toxicity characterisation factors calculated for diffuse emissions of plant protection products to different compartments according to Rosenbaum et al. (2008) for the most important insecticides as used per country in year 2000.

Substance	Ecotoxicity characterisation factor for freshwater [PAF·m³·day/kg$_{emitted}$]				Remarks
	urban air	continental air	freshwater	agricul-tural soil	
ALDICARB	6.1E+03	5.8E+03	4.7E+04	1.2E+04	
CARBOFURAN	6.8E+03	5.9E+03	1.1E+05	2.2E+04	
CHLORFENVINPHOS	5.3E+03	3.1E+03	2.0E+05	1.7E+04	
CHLORPYRIFOS	4.3E+03	1.6E+03	7.3E+05	6.6E+03	Adopted from CHLORPYRIFOS-METHYL.
CHLORPYRIFOS-METHYL	4.3E+03	1.6E+03	7.3E+05	6.6E+03	
BETA-CYFLUTHRIN	1.5E+07	7.9E+06	4.9E+08	6.8E+05	
LAMBDA-CYHALOTHRIN	6.7E+04	2.1E+04	5.2E+06	5.0E+03	Adopted from CYHALOTHRIN.
CYPERMETHRIN	9.9E+05	3.8E+05	5.0E+07	7.0E+04	
DIAFENTHIURON	-	-	-	-	Not available.
DIAZINON	3.0E+03	9.1E+02	1.9E+05	6.0E+03	
DICOFOL	2.2E+04	1.5E+04	4.8E+05	9.2E+03	
DIMETHOATE	6.3E+02	5.0E+02	1.8E+04	3.6E+03	
ETHOPROPHOS	4.0E+03	2.0E+03	2.1E+05	1.7E+04	O-ETHYL S,S-DIPROPYL PHOSPHORODITHIOATE.
FENAZAQUIN	-	-	-	-	Not available.
FENTHION	1.6E+03	4.5E+02	2.0E+05	2.4E+03	
IMIDACLOPRID	1.4E+02	1.0E+02	3.1E+03	9.7E+01	
METHIDATHION	4.7E+03	3.6E+03	1.6E+05	3.9E+04	

Substance	Ecotoxicity characterisation factor for freshwater [PAF·m³·day/kg$_{emitted}$]				Remarks
	urban air	continental air	freshwater	agricul-tural soil	
METHIOCARB	9.5E+03	7.5E+03	1.8E+05	1.4E+04	
METHOMYL	3.4E+03	3.2E+03	2.9E+04	5.3E+03	
OXAMYL	1.6E+03	1.6E+03	1.6E+04	5.6E+03	
PARATHION-METHYL	1.2E+03	4.1E+02	6.5E+04	1.2E+03	
PIRIMIPHOS-METHYL	2.2E+03	3.6E+02	2.7E+05	5.0E+03	
SPINOSAD	-	-	-	-	Not available.
TEBUFENPYRAD	-	-	-	-	Not available.
TERBUFOS	1.3E+03	8.6E+02	2.2E+06	5.4E+04	
THIAMETHOXAM	-	-	-	-	Not available.

Annex VI: Disaggregated Unit Values

In this section, more detailed information with respect to the unit values per country for the direct application of plant protection products on human health toxicity is presented, dis-aggregated according to cancer and non-cancer incidences as distinguished in Rosenbaum et al. (2008) and for all substances as included in the present study.

However, these unit values can not be used as input for the I/O table framework of the EXIOPOL project as they have to be aggregated over the various effects. This is due to the fact that within the frame of EXIOPOL, the I/O tables are strictly correlated to the economic sector of concern, i.e. in the case of the present study agriculture, and not to any health effect or commodity.

Table Annex 13: Unit values [$Euro_{2000} \cdot kg^{-1}_{applied} \cdot year^{-1}$] for human health (cancer incidences) aggregated over the whole aricultural sector for the year 2000 for herbicides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	3.3
2	BE	Belgium	12.7
3	BG	Bulgaria	n/a
4	CY	Cyprus	4.8
5	CZ	Czech Republic	7.5
6	DE	Germany	-
7	DK	Denmark	1.1
8	EE	Estonia	22.0
9	ES	Spain	32.8
10	FI	Finland	5.9
11	FR	France	3.8
12	GR	Greece	37.5
13	HU	Hungary	38.9
14	IE	Ireland	5.5
15	IT	Italy	4.8
16	LT	Lithuania	10.5
17	LU	Luxembourg	11.6
18	LV	Latvia	10.1
19	MT	Malta	-
20	NL	Netherlands	0.3

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
21	PL	Poland	9.3
22	PT	Portugal	n/a
23	RO	Romania	47.8
24	SE	Sweden	0.5
25	SI	Slovenia	9.3
26	SK	Slovakia	9.3
27	UK	United Kingdom	5.8

Table Annex 14: Unit values [$Euro_{2000} \cdot kg^{-1}{}_{applied} \cdot year^{-1}$] for human health (non-cancer incidences) aggregated over the whole aricultural sector for the year 2000 for herbicides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	7.6
2	BE	Belgium	12.3
3	BG	Bulgaria	n/a
4	CY	Cyprus	0.5
5	CZ	Czech Republic	8.8
6	DE	Germany	0.0
7	DK	Denmark	0.4
8	EE	Estonia	52.4
9	ES	Spain	10.4
10	FI	Finland	16.8
11	FR	France	12.0
12	GR	Greece	16.3
13	HU	Hungary	23.3
14	IE	Ireland	14.5
15	IT	Italy	43.2
16	LT	Lithuania	25.0
17	LU	Luxembourg	11.8
18	LV	Latvia	26.6
19	MT	Malta	-
20	NL	Netherlands	21.9
21	PL	Poland	11.4

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
22	PT	Portugal	n/a
23	RO	Romania	15.4
24	SE	Sweden	0.2
25	SI	Slovenia	22.1
26	SK	Slovakia	23.7
27	UK	United Kingdom	48.1

Table Annex 15: Unit values [$Euro_{2000}{\cdot}kg^{-1}{}_{applied}{\cdot}year^{-1}$] for human health (cancer incidences) aggregated over the whole aricultural sector for the year 2000 for insecticides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	-
2	BE	Belgium	-
3	BG	Bulgaria	n/a
4	CY	Cyprus	-
5	CZ	Czech Republic	-
6	DE	Germany	-
7	DK	Denmark	-
8	EE	Estonia	-
9	ES	Spain	153.4
10	FI	Finland	-
11	FR	France	-
12	GR	Greece	241.2
13	HU	Hungary	301.3
14	IE	Ireland	-
15	IT	Italy	-
16	LT	Lithuania	-
17	LU	Luxembourg	-
18	LV	Latvia	-
19	MT	Malta	-
20	NL	Netherlands	-
21	PL	Poland	-
22	PT	Portugal	n/a

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
23	RO	Romania	-
24	SE	Sweden	-
25	SI	Slovenia	-
26	SK	Slovakia	-
27	UK	United Kingdom	-

Table Annex 16: Unit values [$Euro_{2000} \cdot kg^{-1}_{applied} \cdot year^{-1}$] for human health (non-cancer incidences) aggregated over the whole aricultural sector for the year 2000 for insecticides.

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
1	AT	Austria	100.9
2	BE	Belgium	229.0
3	BG	Bulgaria	n/a
4	CY	Cyprus	0.7
5	CZ	Czech Republic	161.0
6	DE	Germany	1.1
7	DK	Denmark	3.6
8	EE	Estonia	-
9	ES	Spain	116.6
10	FI	Finland	460.0
11	FR	France	-
12	GR	Greece	68.9
13	HU	Hungary	136.6
14	IE	Ireland	114.9
15	IT	Italy	1296.9
16	LT	Lithuania	229.7
17	LU	Luxembourg	219.2
18	LV	Latvia	-
19	MT	Malta	-
20	NL	Netherlands	-
21	PL	Poland	169.1
22	PT	Portugal	n/a
23	RO	Romania	-

ID	Country Code	Country	Unit Value [Euro/(kg yr)]
24	SE	Sweden	1.8
25	SI	Slovenia	118.4
26	SK	Slovakia	235.1
27	UK	United Kingdom	539.4

Annex VII: Potentially Affected Fractions of Species due to Leaching and Runoff

In this section, more detailed information with respect to the unit values per country for the direct application of plant protection products on human health toxicity is presented, dis-aggregated according to cancer and non-cancer incidences as distinguished in Rosenbaum et al. (2008) and for all substances as included in the present study.

Table Annex 17: Number of PAF m^3 day per kg in freshwater due to leaching from soil to surface water and due to run-off from agricultural soil to groundwater per country in year 2000 caused by the direct application of herbicides.

Country	Number of PAF per country due to Leaching, aggregated [PAF m^3 day / kg]	Number of PAF per country due to Runoff, aggregated [PAF m^3 day / kg]
Austria	1.6E+06	1.6E+09
Belgium	3.6E+05	5.3E+08
Bulgaria	n/a	n/a
Cyprus	3.9E+02	6.5E-05
Czech Republic	9.3E+05	1.7E+09
Germany	6.2E+06	5.4E+09
Denmark	1.7E+05	2.9E+08
Estonia	9.9E+04	1.7E+08
Spain	5.2E+06	6.5E+09
Finland	2.2E+05	7.2E+08
France	7.7E+06	1.3E+10
Greece	4.9E+05	6.9E+08
Hungary	1.6E+06	1.8E+09
Ireland	2.5E+05	7.8E+08
Italy	6.4E+06	6.5E+09
Lithuania	5.0E+05	5.8E+08
Luxembourg	3.3E+04	4.9E+07
Latvia	3.7E+05	3.3E+08
Malta	-	-
Netherlands	9.9E+05	5.9E+08
Poland	4.2E+06	6.4E+09
Romania	n/a	n/a
Portugal	6.7E+06	2.3E+09

Country	Number of PAF per country due to Leaching, aggregated [PAF m^3 day / kg]	Number of PAF per country due to Runoff, aggregated [PAF m^3 day / kg]
Sweden	1.9E+05	5.5E+08
Slovenia	2.3E+05	1.6E+08
Slovakia	1.2E+06	1.3E+09
United Kingdom	2.4E+06	4.2E+09

Table Annex 18: Number of PAF m^3 day per kg in freshwater due to leaching from soil to surface water and due to run-off from agricultural soil to groundwater per country in year 2000 caused by the direct application of insecticides.

Country	Number of PAF per country due to Leaching, aggregated [PAF m^3 day / kg]	Number of PAF per country due to Runoff, aggregated [PAF m^3 day / kg]
Austria	1.3E+06	6.1E+08
Belgium	2.2E+05	-
Bulgaria	n/a	n/a
Cyprus	4.3E+03	2.6E+07
Czech Republic	2.3E+05	6.9E+08
Germany	1.1E+06	-
Denmark	2.7E+05	-
Estonia	-	-
Spain	2.2E+06	5.5E+09
Finland	1.4E+05	-
France	-	-
Greece	1.1E+06	1.0E+09
Hungary	2.2E+06	1.9E+07
Ireland	3.7E+05	-
Italy	4.1E+05	2.5E+09
Lithuania	6.0E+04	-
Luxembourg	2.0E+04	-
Latvia	-	-
Malta	-	-
Netherlands	-	-
Poland	7.0E+05	2.7E+09
Romania	n/a	n/a
Portugal	-	-

Country	Number of PAF per country due to Leaching, aggregated [PAF m^3 day / kg]	Number of PAF per country due to Runoff, aggregated [PAF m^3 day / kg]
Sweden	8.7E+06	-
Slovenia	4.1E+04	9.2E+07
Slovakia	2.0E+05	4.1E+08
United Kingdom	9.1E+05	2.9E+09