INTARESE

Project No. 018385
INTARESE
Integrated Assessment of Health Risks of Environmental Stressors in Europe

Integrated Project
Thematic Priority

D24 Agricultural Land Use Policy Assessment Protocol

Due date of deliverable: April 2007
Actual submission date: May 2007

Start Date of Project: 1 November 2005	Duration: 60 Months
Organisation name of lead contractor for this deliverable: CERTH	Revision: Draft 1

Project co-funded by the European Commission with the Sixth Framework Programme (2002-2006)

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	X
CO	Confidential, only for members of the consortium (including the Commission Services	

Table of contents

1. INTRODUCTION

1.1 Issue

To assess, in an integrated manner, the impacts of agricultural land use practices in the EU on public health. The study will focus on how relevant EU policies, mainly those in the context of Common Agricultural Policy (CAP) framework, acting concurrently with other driving forces, can affect Land Use Change (LUC), and in turn what impact such changes would have on human health.

Agriculture can be a significant source of environmental contamination (as indicated in Figure 1) and thus of human exposure to pollutants. The likelihood and magnitude of these exposures is greatest for those in close proximity to agriculture – i.e. farm-workers, their families and bystanders in the local community. Exposures can also occur far more widely, however, as a result of long-distance transport of pollutants by air and water. Pollutants produced by agriculture include pesticide and fertiliser residues, livestock wastes and animal pathogens, dust, spores and gaseous emissions. Levels of these emissions are again dependent on many different aspects of land use practice, including soil tillage and drainage, fertiliser practice, pest control regime, crop choice, grazing practice, harvesting practice and waste management. Important pathways for exposure thus include:

- direct dermal contact with pathogens, pesticides and other chemicals
- inhalation of particulates, spores, pesticide residues, bacteria and endotoxins
- drinking and ingestion of pesticides, fertilisers and pathogens

In Figure 1 the heavy lines designate the main routes of environmental media contamination by the groups of pollutants considered in this study.

This agricultural policy assessment will deal with the integrated risks to the European Union population from pesticides, particulates and allergens and animal wastes, focusing on dermal, ingestion and inhalation exposures. Towards this goal, three regional case studies will be carried out, i.e. in the United Kingdom (UK), Greece and Germany. Existing land use change scenarios will be used to facilitate this assessment.

1.2 General objective

To develop a methodology that would enable an integrated assessment of health risks, helpful in:

- *Critically reviewing* the current agriculture-related sectoral policies at the EU level, and
- *Articulating suggestions* for policy change and/or modifications of mainstream agricultural practices and their monitoring from the competent authorities

The results will also have relevance for several other categories of stakeholders involved in agriculture as well as organizations concerned with the health and environmental impacts of agriculture, outlined in the following.

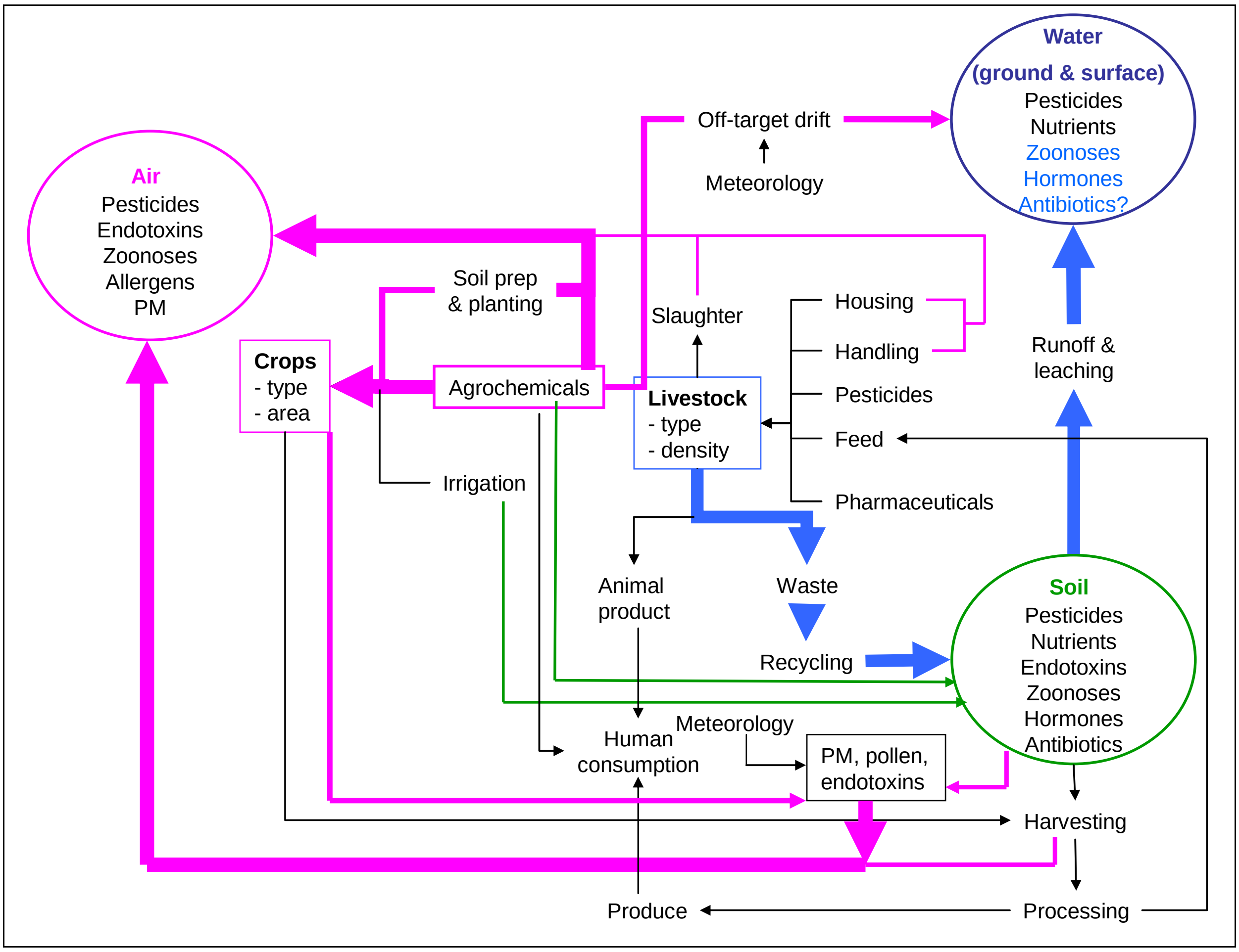


Figure 1. The agricultural system; pollution sources and environmental media. Heavy lines designate the main routes of environmental media contamination by the pollutants considered.

1.3 Key stakeholders and their interests

- EU and national policymakers and authorities
- Farmers associations
- Food processors and retailers
- Consumers, NGO, other concerned bodies
- Pesticide manufacturers

Key stakeholders and their interests are included in the tables of **Appendix 1**

In general, stakeholders have not yet been contacted except to enquire about data access. Further consultation with key data providers is planned as part of the first pass assessment. Wider consultation will be carried out in the second iteration.

1.4 The policy context

- **Common Agricultural Policy** (and related instruments)
- **Environment and Health Policy Instruments**
  - Water Framework Directive
  - Waste Directive
  - Pesticides Directive (Plant Protection Products)
  - Proposed Soil Directive
  - Habitats Directive
  - Bathing Waters Directive

In Europe, over the past half century, significant intensification and specialization in agriculture have occurred due to technological progress and targets (set at national and EU level) to establish competitive agricultural production. The latter have been supported and greatly affected by the *Common Agriculture Policy (CAP)*, the strong European policy framework, which at present is comprised of two "pillars" i.e. *market measures* and *rural development.* The variety of measures, incentives and subsidies (in the context of both pillars of CAP) directly and indirectly affect not only agricultural land use but rural landscape as well. In view of the fact that agriculture plays a key role in managing natural resources in rural areas, agricultural policy is increasingly perceived (and occasionally exercised) by governments, politicians and other stakeholders as an integrative part of rural development, complementing other sectoral policies that address the multiple functions of rural areas, such as ecosystem services, recreation, economic infrastructure, etc. Several projects have been recently undertaken to develop a variety of EU-wide LUC scenarios (e.g. PRELUDE, EURURALIS, ATEAM) by placing different emphasis on all these drivers. Obviously, in selecting LUC scenarios for the present study, the focus should be on those scenarios which give prime consideration to CAP policies and to the other environment and health policy instruments (listed above), paying also due attention to factors and drivers foreseen to act at the *global scale*.

1.5 Policy scenarios

Against the above background, a European-wide land use scenario-development study has been selected as the basis for policy assessment. This is the European Environment Agency's PRELUDE (Prospective Environmental analysis of Land Use Development in Europe) study for the assessment of European futures, emphasizing impact on the environment. PRELUDE recognises twenty drivers of land use change, grouped into five categories:

- environmental concern,
- technology and innovation,
- agricultural optimisation,
- governance and intervention, and
- solidarity and equity.

These are then combined into a series of five different scenarios, according to their relative weights (Figure 2). A preliminary assessment of the PRELUDE scenarios, briefly described in **Appendix 2**, suggests that although none is clearly policy driven,

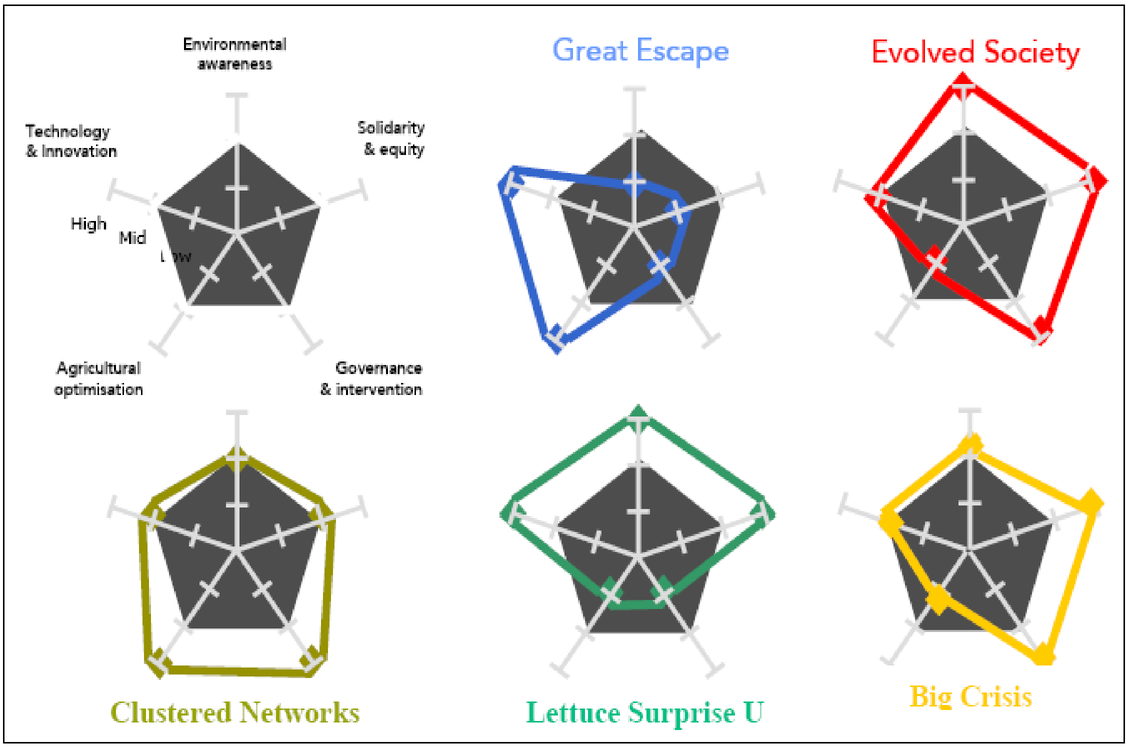


Figure 2. Spider diagrams of the key drivers for each PRELUDE scenario (Hoogeveen et al. 2006)

two of them (referred to as '***Evolved Society*** - *Europe of harmony'* and *'**Big Crisis** - Europe of cohesion'*) attribute comparatively greater weight to European policy interventions, mainly in response to environmental concerns. These two scenarios appear to be compatible with the INTARESE study main objectives.

As a basis for the present assessment (1st pass), two scenarios may be selected, ***Evolved Society*** and ***Great Escape***, representing two rather extreme futures**;** the former is geared towards environmental protection and social well-being characterised by extensification, and the latter is a market and technology driven future characterised by agricultural intensification. However, as noted below, whatever the choice of PRELUDE scenario, it is necessary to employ additional *regional data* in order to develop *specific* LUC scenarios meaningful for health impact assessment.

Specific scenarios for the case studies

The following two-step approach could be taken to select appropriate scenarios for studying the effect of agricultural land use on adverse health effects to the European population.

(i) *Select a particular PRELUDE (EU-wide) scenario; e.g " Evolved Society"*

One would not be able to implement the INTARESE methodology for health impact assessment on the basis of the PRELUDE scenario maps alone, as they do not include sufficiently detailed data regarding foreseen changes of the cropping system and of animal husbandry.

(ii) *Focus at the regional level* (by necessity) to enhance the PRELUDE scenario data. More specifically:

- Select a geographic region, i.e. in Greece, UK, Germany, France
- Determine the **baseline scenario** (base year 2001) in each selected region, in terms of
    - cropping system (typology, area cultivated, yield, etc)
    - animal husbandry (number/type of farms, animals, etc)
    - other relevant factors (farming practices, etc)
- Develop one or more **specific regional scenarios** by adding/overlaying regional information to the PRELUDE scenario (maps). The following type country- or region-specific scenarios may be considered

    - **Regional scenario 1.** It involves a *proportional* change of 'currently' cultivated crops (base year); i.e. no basic change in typology is assumed. New crops (e.g. energy crops) would be added if foreseen by PRELUDE.

    - **Regional scenario 2.** A change of specific crop types is considered depending on EU-wide or regional input data (studies, stakeholder consultation/questionnaires). Such data would be related to, or reflect, EU policy interventions (e.g. CAP, other).

2. SCOPE OF ASSESSMENT

2.1 The assessment framework

The INTARESE full-chain approach will be taken for the agricultural policy assessment, indicated in the scoping diagram (Figure 3). The assessment in the case studies will focus on health risks due to ***Pesticides, Aerosols and Allergens, and Livestock wastes.*** Table 1 summarizes toxic agents, pathways and health effects considered in the scoping report.

Each pollutant group (pesticides, aerosols and allergens, and animals wastes) will be modelled separately. The overall impacts on public health will be assessed by accumulating (e.g. summing) the effects in the form of common indicators of impact at the end of the full chain (i.e. in the impacts box, Figure 3)

2.2 Key elements / relationships to be assessed

To assess health effects caused by pollutants due to

- **Cropping system and related agricultural practices;** i.e pesticides, aerosols (organic, inorganic)
- **Animal husbandry**; pollutants in livestock waste, i.e. zoonotic agents, endotoxins

Key relationships

Figure 1 highlights the key relationships linking sources to environmental media contamination, through various routes, to human exposure. Air is the primary medium of concern in this study and inhalation the main pathway, although dermal contact and ingestion are also important. Another class of key relationships is that linking human exposure to health outcomes, through intake and biologically effective dose.

A summary of pollutant groups, pathways, and health effects, considered in this workpackage, is provided in Table 1.

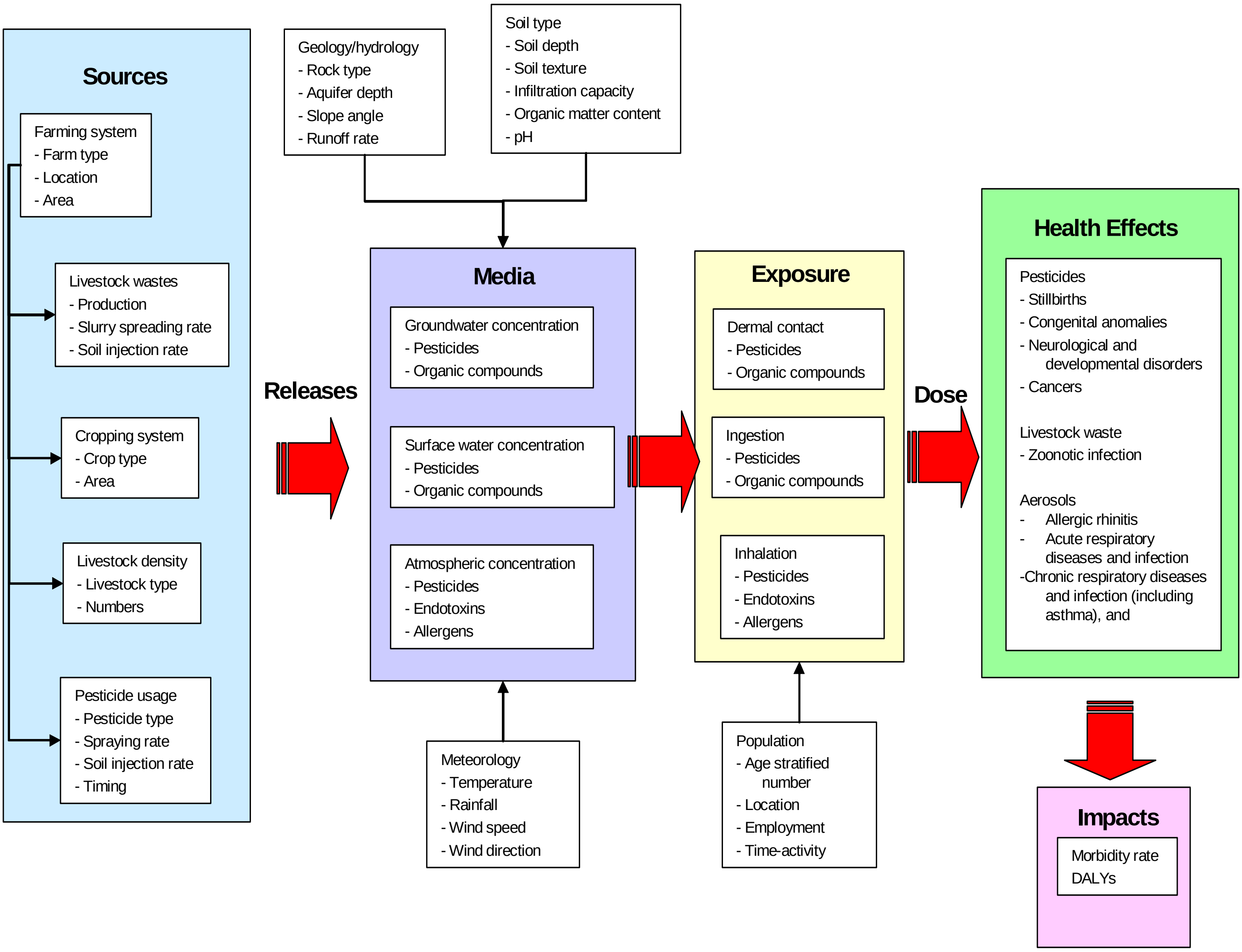


Figure 3. Scoping diagram

Table 1. Summary of pollutant groups, pathways, health effects considered in WP3.3 (Ref. Scoping Report)

	Pollutant groups	Pathways	Health effects
Pesticides	*Active Ingredients (AI) or classes of AI's* (to be determined on the basis of crops considered, i.e. related to geographic region).	Inhalation, Dermal contact	• Childhood and adult cancers • Congenital anomalies • Neurological and neuro-developmental disorders • Stillbirths
Aerosols	*Fine PM, Pollen, Endotoxins*	Inhalation	• Acute respiratory diseases and infection • Allergic rhinitis • Chronic respiratory diseases and infection (including asthma), and
Livestock wastes	*Zoonotic pathogens,*	Ingestion (via water) Inhalation?	• Diarrhea and gastroenteritis

2.3 The study area

- In the 1st pass assessment, the focus will be on regional/country studies in UK, Germany, Greece, France; the number of study areas will depend on data availability and WP3.3 resources. In these study areas, conditions typical of Northern and Southern Europe are encountered.
- The INTARESE target is to extend the assessment to the entire EU in the 2nd pass.

Source areas (and associated releases into the environment) will be determined on the basis of land use, and the target population (bystanders and the general public) will be defined on the basis of the distance of their place of residence from these source areas. For this purpose, buffer zones will be established around the relevant agricultural classes in the land cover map. The EU-wide CORINE land cover 2000 (CLC2000) is available (Table 2) and has EU-wide coverage, which is appropriate for both the 1st and 2nd pass assessment.

Great Britain (England, Scotland and Wales) comprise the study area for the UK policy assessment. Two land cover maps are available for this purpose: (a) CLC2000, and (b) the more detailed UK Land Cover Map 2000 (LCM2000-UK) from which the UK portion of CLC2000 was derived. The advantage of using CLC2000 is that it has EU-wide coverage which could facilitate expansion of the UK case study to the EU during the second pass assessment. LCM2000-UK, however, has higher resolution and the classification of agricultural lands (Table 2) appears a better match to the breakdown in the pesticide usage database.

Table 2. Land cover classifications

CLC2000	**LCM2000-UK**
Non-irrigated arable land	Arable cereals
Permanently irrigated land	Arable horticulture
Rice fields	Non-rotational horticulture
Vineyards	Improved grassland
Fruit trees and berry plantations	Set aside grass
Olive groves	Neutral grass
Pastures	Calcareous grass
Annual crops associated with permanent crops	Acid grass
Complex cultivation patterns	
Land principally occupied by agriculture, with significant areas of natural vegetation	
Agro-forestry	

The regional study in Greece will focus on the Regions of Thessaly and of Central Macedonia (one or both), for which there are available very recently drafted LUC studies, addressing their significant agricultural activity. These studies have been developed using a bottom-up approach by taking into account the views of the main stakeholders related to the agricultural sector.

The regional study in Germany will focus on the Region (German Länder) of Schleswig Holstein and Mecklenburg Vorpommern, for which a LUC study is available. The latter deals with an analysis of the CAP MTR on the Agricultural Sector and AgriBusiness of the Region. The results have been differentiated according to agricultural regions (agroecosystems in SH, counties in MV) within the Länder.

2.4 The study population

- Residents of rural / neighbouring communities (bystanders)
- Children within the rural community will be considered as a special sub-population

The study population comprises all residents of the region or country considered, with the target population being those residing within/near agricultural areas. Distinction between farmers, their families or farm-workers from other residents of the community is difficult. All rural residents are thus considered part of the target population – referred to as the bystanders.

The base year for the studies is 2001; thus 2001 postcode headcount data will be used to define the reference population in the UK case study. The coarser LAU2 (i.e. NUTS 5, ward) level population data for 2001 are also available for all countries considered in this policy assessment. These will be used to provide consistency for the second pass assessment at the EU-scale, and will likely be disaggregated to a finer scale (e.g. 1km level - work undertaken by WP5.1) to better distinguish between bystanders and the general population. Subsets of the bystander population will be selected depending on health outcome.

3. METHODOLOGY

The study aims at implementing a full *source-to-impact chain* assessment, depicted in the scoping diagram (Figure 3), which is subdivided into three main tasks concerning *source-to-exposure, exposure-health effects,* and *secondary impacts and costs*. Table 3 outlines the key data sets for the country/regional case studies. Some of these data are generic (land cover, population statistics, geological, hydrological, meteorological and soil data) and available in house or via WP2.1 and WP5.1. Other data and information particular to this assessment (i.e. pesticides active ingredients used, production of aerosols, endotoxins, etc, livestock waste management) will have to be sourced or estimated from regional/national sources.

3.1 Outline of assessment procedure

Baseline scenario (i.e. the exposure scenario referring to the base year 2001)

1. On the basis of available data regarding intensity of pesticide use, aerosol and allergen production, and zoonotic release due to livestock waste, and taking into account the current configuration of the agricultural system in each area under study (in terms of both geographical extent of agricultural land and type of cultivation), calculate spatially resolved environmental load of various agricultural pollutants using the three tiered approach outlined in subsequent Section 3.2.
2. Collect spatially resolved data of population density, stratified by age and sex, and to the extent possible as a function occupation and education level (IC-WP5.1)
3. As per Section 3.3, collate concentration (dose)-response functions available in the scientific literature for the main active ingredients in the pesticides used in the area under study, and for aerosols and allergens and zoonotic organisms (WP1.3 input).
4. Apply the dose-response functions in conjunction with the environmental concentrations reckoned in step 1, and the stratified population density data collected in step 2 (making best-guess assumptions regarding the individual activity patterns, which in turn determine the exposure and intake fractions of the pollutants considered in the study), as outlined in Section 3.3. This will result in spatially resolved maps of potential health effects as foreseen by the literature-based dose-response functions.
5. Collect selected epidemiological data (from local and regional agencies, hospitals or using surrogates, such as purchase of antihistamines) to verify the validity of the health impact estimates obtained in step 4.

6. Correct/adjust the coefficients (slope factors) or other relevant numerical parameters of the dose-response relationships under step 4 to better fit the actual epidemiological data in each region; check for confounders and account for them to estimate the final dose-response formulas.
7. Using the corrected (or developed) dose-response relationships, re-estimate the potential health impact map for each study area and for each health endpoint considered.

Land use change consideration

1. Using the dose-response relationships obtained in step 6 and taking account of the land use change scenario(s) under consideration, estimate the difference in health impact maps due to the variation of the spatial extent and value of the environmental concentrations and the difference in exposure fraction.
2. Run a sensitivity analysis to identify the agricultural policy-related factors that most impinge on potential health impact of agriculture practices locally.
3. Complete the INTARESE full-chain by computing the secondary impacts and costs as per subsequent Section 3.4.

Some or all of the steps 3, 4, 5, 6 may not be possible to implement due to serious data gaps; in that case, the best dose-response relationships obtained from literature and/or developed (e.g. using expert elicitation) will be used to carry out step

Table 3 Key Datasets

Data description	Coverage	Spatial Resolution	Temporal Resolution	Availability - Comments
Land Cover				
CORINE2000 (44 classes)	EU-25	25 ha (notional 100 m grid)	2000	Have
LCM2000-UK (26 classes)	UK	25 m	2000	Have
Pesticide Data				
Pesticide sales (5 active ingredients by main crops)	EU-25	Country	1992-2003	Have (Eurostat, ECPA) New Eurostat report on pesticides sale for 1992 to 2003.
Pesticide usage (chemical group and active ingredient by crop)	UK	County (n = 99)	1998-2001	Will be available (Central Science La DEFRA)
Pesticide data (sales /usages)	DE (Schleswig-Holstein)	For different land use types	Yearly, with and without CAP?	Available as monetary values
Rural land register maps	UK	Farm level (typically 1:5,000)	Up to date	According to land parcels registered f payment scheme (DEFRA)
Farm Business Survey	UK			Reports can be downloaded (DEFRA)
Pesticide residues (Env Agency POPPIE system)	UK			Accessibility?
Agricultural Statistics				
Crop and animal statistics	EU-25			Eurostat
June agricultural returns (farm type & size; crop type & area; herd type & size; employment)	UK	Ward/LAU 2 (n > 6000)	2000-2005	Have (DEFRA)
National statistics (Crop type & area, number of animals, employment)	GR	Prefecture	2000	Have (National Statistical Service of Greece)
Crop type & area, number of animals, employment	DE (Schleswig-Holstein)	Natural regions/landscapes ~ municipalities	Projection 2013 (incl. CAP MTR)	Available (Prof. Henning , CAU Kiel) USTUTT need better reference
Other Agricultural Data				
Statistics (tillage frequency, pollen counts by crop , zoonoses counts by animal)	EU-25			Availability?

Livestock unit conversion ratios	EU-25			
Soils				
European Soils Database	EU-25	1x1km		Can download JRC http://eusoils.jrc.it/data.html
Meteorological Data				
Wind, temperature, etc (parameters needed for dispersion modelling)	EU-25	50x50km or better	2001	IC has access (ECMWF)
Meteorological data, parameters needed for dispersion modelling	DE (Schleswig-Holstein)	10 x 10 km	1997, 2000, 2001, 2003 - hourly	NUTAIR- Will probably be available
Point Sources				
Agricultural point source emissions ?	EU-25			European Pollutant Emission Registry (EPER)? Nace code 01.2 http://eper.ec.europa.eu/eper/default.a
Population				
Age and sex stratified	EU-25	LAU2 level	2001	Have
Age and sex stratified postcodes (headcount)	UK	Postcode level	2001	Have
Age and sex	GR	Prefecture & Municipality	2001	Have (National Statistical Service of Greece)
Age and sex	DE (Schleswig-Holstein)	Länder, municipalities		Destatis-Genesis, have
Health Data				
Background statistics (aggregated)	EU-25		2001	To be provided by WP2.3
Registry data (mortality, cancer incidence, births (congenital anomalies) and hospital admissions)	UK	Postcode level		Have (SAHSU)
Health registry data (mortality, cancer incidence, births (congenital anomalies), hospital releases)	GR	Prefecture	2001	Have (National Statistical Service of Greece)
LUC Scenarios				
PRELUDE	EU-25	10 minute grid for EU scenarios	2005, (2015) and 2035	Have (EEA)
	GR			
	DE			

3.2 Source – exposure

Figure 4 shows a variable linkage diagram, illustrating how the particular variables are related and how they can be used to derive the various indicators for source to dose. Furthermore, the need for relevant models or factors linking the variables are indicated. Figure 4 provides a fairly complete source-to-dose chain for which full implementation may not be possible; indeed, due to lack of data and/or reliable models some intermediate steps may have to be by-passed, effectively omitting one or more links. For instance, depending on the approach taken, it is possible that environmental concentrations of pesticides, aerosols, endotoxins and/or zoonotic pathogens could only be obtained (at least in the 1st pass) from data on source activity, by-passing steps of emission and dispersion modelling.

In general, therefore, the following three tiered approach will be used to define the exposure metrics. The number of tiers included for each of the pollutant groups and the exact nature of metrics will depend on the availability of specific data (Table 3) and appropriate models for each case study.

1. *Relative exposure* – Ranked (e.g. high/medium/low or yes/no) based on regional statistics.
2. *Basic modelled exposure* – 'Potential exposure' derived from surface modelling.
3. *Advanced modelled exposure* – Based on simulated movement (convection, dispersion) through environmental media.

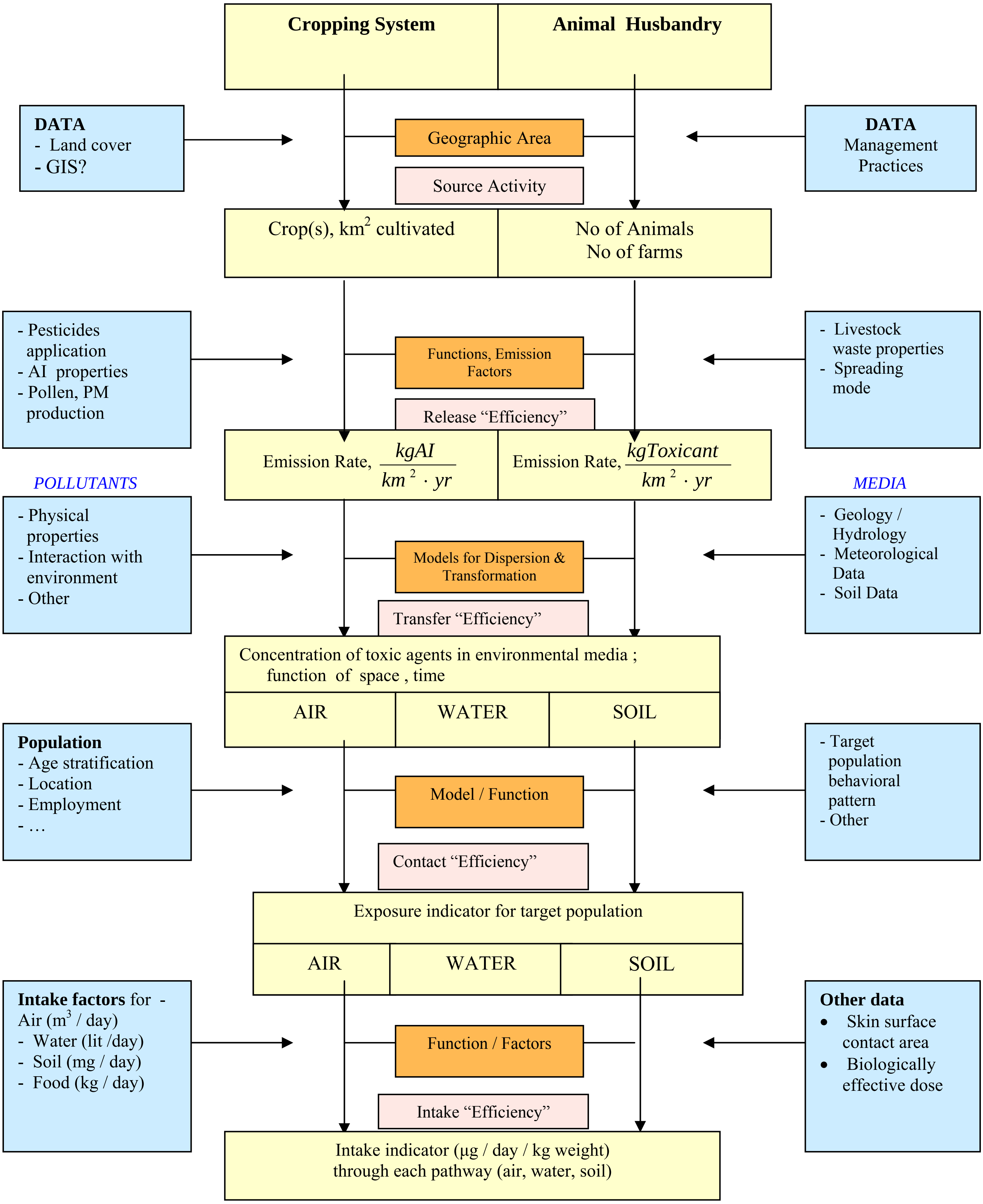
GIS will be used to calculate exposure maps on the basis of these metrics. Table 4 outlines the types of exposure metrics by case study which we aim to derive in the 1st pass assessment.

The aforementioned three approaches for each pollutant group are outlined in the following. The specific exposure indicators to be obtained in this assessment, from approach no 2 and no 3, will depend on the pathway considered, and to a large extent on the type of data available (in particular exposure-dose-outcome relationships). Relating to atmospheric pathway, some simple algorithms to obtain such metrics are given in *Appendix 5(a)* which might be used as a first approximation, or for improved estimates through dispersion modeling. The indicator obtained is the *Average Population Exposure (APE).*

Table 4. Types of exposure metrics by case study – 1st pass assessment

Case Study	Metric	Pesticides	Aerosols/Allergens	Livestock Waste
Greece	1. Relative	X	X	X
	2. Basic modelled	X ?	X?	X
	3.Advanced modelled	X	X	
UK	1. Relative	X	X	X
	2. Basic modelled	X	X	X
	3.Advanced modelled	X	X	
Germany	1. Relative	X	X	X
	2. Basic modelled	X?	X?	X
	3.Advanced modelled	X	X	

Figure 4. Source To Exposure/Dose Chain



Several potential pathways for exposure will not be considered - at least during the first pass assessment. Food is excluded because modern processing and distribution systems mean that there is almost no geographic limit to this exposure pathway. Additionally, food contamination is the subject of several other ongoing EU projects. Exposures to agrochemicals via drinking water will also be excluded considering that in EU the majority of households (e.g. in UK ~ 99%) are serviced with treated or quality-controlled water, and a key public health concern (nitrates, as an indicator for agricultural activity) is being explored in WP3.4. Exposure to zoonoses via surface waters (e.g. via bathing) may, however, be considered.

Pesticides

Key data sets for deriving the exposure metrics for Europe will include CORINE Land Cover 2000, pesticide usage/sales data, agricultural statistics (e.g. crop type and area, livestock type and numbers) and meteorological data. In Europe, there is generally no legal requirement for pesticides use reporting as there is in California, but routine reporting is done in some countries (e.g. the UK has pesticide usage and pesticide residue databases). Where pesticide usage data are unavailable or inaccessible (e.g. Greece), pesticide sales data will be used from Eurostat and ECPA. Expert elicitation will be used for estimating the types and quantities of pesticides used for each crop type considered.

For the UK case study, the Rural Land Register maps would be useful for refining the identification of agricultural parcels – though these data are likely proprietary. For the case study in Greece, land cover data from CLC2000 will be enhanced with regional data obtained from the National Statistical Service and other agriculture-related local authorities at the Prefecture level.

For the case study in Germany, land cover data from CLC2000, average pesticide usage data per crop and their monetary values, harvest amounts from DESTATIS (GENESIS) and meteorological data will be used. For the calculation of pesticide data, Eurostat sales data will be included.

The following methods will be used to quantify pesticides in the air (potentially leading to inhalation and dermal exposures) and surface waters.

1. *Relative exposure*

For all case studies, estimation of 'farm-level' pesticide usage will be based on a combination of pesticide sales data, land cover and regional statistics on crop type and cultivation density (percentage area of improved grassland/arable land) as well as livestock units through appropriate conversion from available type/number of animals. Each element (a, b, c below) will be ranked high/medium/low then combined to give an overall indicator score:

a. regional land cover/crop type,

b. grazing intensity (livestock units/hectare)*, and

c. cultivation density (percentage area of improved grassland/arable land).

*Livestock ratios will be sourced and used to convert number of animals (e.g. for UK, cows, sheep available in the JAR) to livestock units.

2. *Basic modelled exposure*

County level pesticide usage data will be disaggregated to the 'farm-level' on the basis of land cover and the regional agricultural statistics (crop type, livestock units). This exposure metric will be assessed for total pesticides and for specific types, for example insecticides (organophosphates, pyrethroids, carbamates), herbicides, and fungicides. If relevant and data available, the disaggregation may also be done for specific active ingredients.

Probability functions could be used to determine the likelihood of crop *c* (from regional statistics) being in field *f* (from land cover); or the likelihood of pesticides *p* (from pesticide usage data) being sprayed on crop *c* and its probability of being in field *f*.

As pesticide usage data are available only in the UK, this tier may not be possible in the other case studies.

3. *Advanced modelled exposure*

Pesticide drift from cultivated land will be simulated in one of two ways:

a) Using GIS techniques such as buffering to determine 'area of influence,' incorporating predominant meteorological conditions as appropriate.

b) Using an established dispersion model such as AgDrift v2.0 (free download http://www.agdrift.com/AgDRIFt2/DownloadAgDrift2_0.htm).

   Partners (TNO) have available air pollution dispersion models including short range 0-25 km, medium range 5 - 100 km, and long range (6 km to European scale), as well as expertise for obtaining emission estimates for pesticides.

Aerosols and allergens

This includes particulates (organic and inorganic dust), spores, pollen and endotoxins. Key data sets for deriving the exposure metrics will include land cover, the regional agricultural statistics, agricultural emission sources and meteorological data.

The following methods will be used to quantify aerosols and allergens in the air (potentially leading to inhalation and dermal exposures).

1. *Relative exposure*

Estimate 'farm-level' level aerosol and allergen production based on a combination of land cover data and the regional agricultural statistics to assess:

a) regional land cover/crop type/tillage,

b) grazing intensity (livestock units/hectare), and

c) cultivation density (percentage area of improved grassland/tilled land).

Each element (a, b, c) will be ranked high/medium/low then combined to give an overall indicator score.

2. *Basic modelled exposure*

Determine indicator of 'potential exposure' using agricultural source emissions and regional crop statistics.

3. *Advanced modelled exposure*

Aerosol drift from farm buildings (if agricultural source emissions data are available) and cultivated land will be simulated in one of two ways:

a) Using GIS techniques such as buffering to determine 'area of influence,' incorporating predominant meteorological conditions as appropriate.

b) Using a combination of established dispersion models to model both the long-range and local components.

   Long-range:

   - CALPUFF is available to partners (http://www.src.com)
   - Other capabilities by partners:

     USTUTT uses a parameterized Lagrangian model for long-range transport modelling. TNO has available several air pollution dispersion models including short range 0-25 km, medium range 5 - 100 km, and long range (6 km to European scale). TNO could also assist in deriving emission estimates for aerosols.

   Local:

   - ADMS-3 for areas and point source modelling in the UK case study, or
   - AERMOD (freely downloadable from the EPA) for the other case studies and second pass assessment. It may be more appropriate than ADMS-3 to other areas of the EU.
   - In the USTUTT, a Gaussian model is used for short-range modelling. This is especially useful for point sources.

Zoonoses

Given the current expertise in WP3.3, exposure modelling related to zoonoses will be exploratory. The following methods will thus be investigated to estimate potential for viable zoonoses contamination in soil, water and air. One or more indicator species (e.g. *E. coli*) will be selected.

1. *Relative exposure*

Estimate 'farm-level' zoonoses production based on a combination of land cover data and regional agricultural statistics to assess:

a) regional land cover/pasture,

b) grazing intensity (livestock units/hectare), and

Each element (a, b) will be ranked high/medium/low then combined to give an overall indicator score.

2. Basic modelled exposure

Typical slurry spreading rates and pathogen release/survival rates, along with relevant meteorological and hydrological parameters will be incorporated to step 1 above, to refine the estimation of 'farm-level' zoonoses and transport to air and surface water.

3. Advanced modelled exposure

At this stage, advance modelling is not anticipated for any of the case studies.

3.3 Exposure – health effects

This section outlines the health outcomes we aim to investigate and the approach to be taken. As pesticide poisonings and accidents are excluded, the mortality rates due to agricultural exposures are expected to be low. The largest burden of disease will be morbidity; thus the focus will be on incidence (e.g. based on hospital admissions) or prevalence to facilitate comparison and integration of the risks at the next stage of the chain. The specific health outcomes of interest in this workpackage (ICD-10 codes), for which background disease rates will be sought, are listed in **Appendix 3.**

Health effects due to each pollutant group will be treated separately.

Exposure - response relationships

The availability of exposure-response relationships will be investigated using procedures outlined by WP1.3. The order of preference for deriving exposure-response relationships for the health outcomes of interest is as follows:

1. Systematic review of scientific literature
2. Meta-analysis (if appropriate)
3. Use of toxicological information
4. Expert elicitation

For the various case studies, the target population (i.e. age/sex stratified for specific subgroup), at the available level of aggregation, will be intersected with the exposure maps to identify those who are exposed (and exposure classes if appropriate). The postcode headcount data will be used for the UK case study, for example, while spatially disaggregated LAU2 level data will likely be used for the other case studies and EU-wide second pass assessment.

Where available and applicable, the exposure-response relationships will be applied to the exposed population to estimate the burden of disease (BoD) for each outcome, as follows:

$$BoD = (\sum EM \times P) \times ER \times BkR \qquad (1)$$

where EM is the exposure from metric 2 or 3.

P is the population by exposure class

ER is the exposure-response function or relative risk

BkR is the background rate of disease

This equation can be applied to population exposure distributions for each of the exposure indicators of interest, expressed in μg per day, for a single exposure-response function (i.e. slope factor) and a representative mean background rate of disease. There is a need to clarify the applicability of Equation (1) to the case of exposure metric 1, and to health outcomes characterized by a threshold dose.

Pesticides

The main health outcomes that will be investigated include:

- congenital anomalies
- neurological and neuro-developmental disorders, and
- child and adult cancers.

A literature survey suggests that there is no general method available that can be used to obtain exposure-response relationships for pesticide exposure. Therefore, the exposure- response relationships have to be retrieved or developed from evaluation of epidemiological and/or toxicological data. A preliminary review of epidemiological studies has identified serious gaps in the availability of dose-response relationships. These gaps as well as significant sources of uncertainty that have been identified stem from lack of good exposure data and proper exposure indicators. In the months to follow a thorough review will be completed of relevant epidemiological studies.

In conjunction with WP3.3, an epidemiological study related to bystander exposure to pesticides will be undertaken by SAHSU (IC), with the aim of improving the estimates of dose-response functions and providing a 'reality-check' on the risk assessment.

If epidemiological data are inadequate, we will aim to derive dose-response relationships from toxicological studies (number 3 above), although extrapolation of relationships from animal studies to humans and from high doses to low doses can introduce significant uncertainty into the assessment. The US EPA has provided guidelines (USEPA reports, 2002, 2005) for risk assessment methods for quantitative dose response assessment when only animal data are available. These are guidelines for exposure to a single agent and to mixtures of ingredients only if the individual chemicals (for example class of organophosphates) have the same mechanisms of action and toxicity, for the same health outcome. In accordance with the WP1.3 guidelines, a systematic review (including meta-analysis) of animal studies will only be undertaken if no other data are available (WP1.3 third draft protocol, 2007).

The use of toxicological data necessitates a different approach for carcinogenic and non carcinogenic health effects due to the possible existence of a threshold in the latter case. In particular, risk is usually calculated for carcinogenic health outcomes, while a hazard indicator may be calculated for a non carcinogenic disease:

Carcinogenic health outcomes Risk = Intake x slope factor

Non carcinogenic health outcomes Hazard= Intake / reference concentration

In Appendix 4 a methodology is summarized for a) Single active ingredient intake estimation, and b) Single active ingredient risk/hazard estimation based on toxicological data, for pesticides. Data requirements, limitations and uncertainties are also indicated therein. The use of toxicological data poses a series of limitations and uncertainties, which are outlined in Section 4.3. Some guidance is expected from WP1.3 in this area.

Aerosols and allergens

The main health outcomes to be investigated will be those related to respiratory health, including:

- acute respiratory diseases and infection
- allergic rhinitis
- chronic respiratory diseases and infection (including asthma)

For particulate matter, we will mainly focus on existing exposure-response relationships paying special attention to the source, type and size fraction of particulate matter in the selected epidemiological studies. Effort will be made to identify exposure-response relationships for allergens (e.g. pollen) and endotoxins by continuing the review of relevant epidemiological studies.

Zoonoses

The main health outcomes that will be investigated include:

- diarrhea
- gastroenteritis and

Dose-response relationships will be sought for selected zoonotic agents. Sources of dose-response relationships will be sought in epidemiological studies.

Appendix 5(b) provides a simple expression (compared to Equ. 1) for estimating health outcome indicators *(Attributable Body Burden-ABB)* which, however, have limitations. ABB can be obtained through the Average Population Exposure (APE).

3.4 Secondary impacts

The relationships and possible interactions between agricultural exposures will be clearly defined, so that the burden of disease for each outcome can be appropriately combined (e.g. additive). Expert advice will be solicited to develop a procedure for dealing with interactions and non-additive effects. The aim is to make an impact statement such as “x cases of disease y are attributable to agricultural activities in study area z.” The ultimate goal is to achieve impact statements, with quantified uncertainties, for the EU during the 2nd pass assessment.

Guidance on how to calculate secondary impacts and costs will be derived from WP1.4 deliverables. It may, for example, be possible to calculate DALYs for cancer outcomes, but DALYs may be inappropriate for the morbidity outcomes we selected. To quantify overall morbidity due to agriculture, a qualitative comparative risk (e.g.

high/moderate/low compared to other quantified risks) could potentially be more useful. One such example is to calculate the cost of hospital admissions related to agricultural exposures.

As outlined in Appendix 5, development of a relevant outcome indicator (*Attributable Morbidity - AM*) is also possible through:

- *Average population exposure (APE)* and
- *Attributable body burden (ABB)*

Furthermore, the following indicators for secondary impact and cost can be estimated through *Attributable Morbidity – AM* (Appendix 5b) *:*

- *Severity weighted illness days (SWID)*
- *Attributable health cost (AHC)*

4. ANTICIPATED LIMITATIONS

4.1 Data availability / accessibility

As highlighted in Table 3 the resolution of some data sets will vary somewhat across the EU. Key data sets, however, such as land cover, soils, meteorology, PRELUDE are available and regional agricultural statistics (e.g. from Eurostat) should be available across the study areas. Ongoing work includes collecting the remaining data sets (no costs are anticipated) and determining access to relevant dispersion models.

4.2 Gaps in the assessment

1) Omitted pollutants

Fertilizers

The risk of fertilizers on human health was decided to be excluded from the scope of this assessment, as the effect of nitrates is being evaluated in sub project WP3.4.

Allergens

The study of allergens that are produced from agricultural activities will mainly focus on pollen. The effect of other types of allergens like insect fragments, fungal moulds, and allergens that derive from animals may not be considered due to difficulties in obtaining relevant exposure data and dose-response functions.

Endocrine disruptors

In the case of endocrine disruptors that are spread from livestock waste, the EU has banned the use of hormones oestradiol 17ß, testosterone, progesterone, trenbolone acetate, zeranol and melengestrol acetate as growth factors in animals since 1988. The prohibition covers both the use of these hormones for domestic production, and imports from third countries of meat from animals fed with these hormones for growth promotion purposes. Hormones are only permitted for therapeutic purposes due to the limited duration of the treatments and the limited quantities administered. Therefore, the burden on human health from farm animal hormones is limited only to hormones that are naturally excreted from animals, like estradiol 17β, progesterone, testosterone etc. The most likely exposure pathway for endocrine disruptors is from runoff through contaminated manure to drinking water sources. Although, the adverse effects of endocrine disruptors on ecosystems and animal health are well established, it is still unclear if the intensive livestock rearing can produce concentrations in surface water that are in the biologically active range, posing a threat on human health. For the above reasons, it was decided not to include the risk of natural excreted hormones on human health in this assessment.

2) Omitted exposure pathways

Several potential pathways for exposure will not be considered - at least during the first pass assessment. Food is excluded because modern processing and distribution systems mean that there is almost no geographic limit to this exposure pathway. Additionally, food contamination is the subject of several other ongoing EU projects. Exposures to agrochemicals via drinking water will also be excluded considering that in EU the majority of households is serviced with treated or quality-controlled water. Exposure to zoonoses via surface waters (e.g. via bathing) may, however, be considered.

3) Omitted health effects

Poisoning due to the accidental ingestion of agrochemicals or their misuse and accidents that are caused during agricultural activities were excluded from the scope of the assessment, due to the fact that are restricted mainly to occupationally exposed groups. *Wheeze* was also decided not to be studied due to lack of available data. For the health outcomes that are considered, a comprehensive list was created (Appendix 3), although its is anticipated that it will be eventually shortened due to the lack of available data such as dose-response functions for all the health outcomes of concern.

4.3 Major sources of uncertainty

Source - Exposure

1) A main source of uncertainty regarding the pesticide case study is pesticide usage data as there is no legal requirement in EU for reporting usage. Therefore, there is inadequate information regarding the use of pesticides in almost all Member States. For example, UK has pesticide usage and pesticide residue databases but these kinds of databases are not available for Greece. In the latter case, pesticide sales data will be used from Eurostat and ECPA. Moreover, expert elicitation will be used for estimating the types and quantities of pesticides used for each crop type considered.

2) There may be discrepancy between the actual pesticide application rate and the reported/modelled pesticide application rate, as farmer workers very often do not follow the proposed application dose.
3) Pollutants fate depend on topology, meteorology, other local conditions and pollutants special characteristics, such as half-life, water solubility, soil adsorption etc. There is uncertainty as to what extent the above parameters will be studied/included in the estimation of the pollutants fate.

Exposure-health effects

1) *Consideration of exposure through specific pathways*
    a) Inability to take into account occupational exposure, although it may be a major contributor to exposure to the pollutant of concern. In rural areas a significant proportion of the population is anticipated to be involved in agricultural activities.
    b) Not taking into consideration pathways that may contribute to exposure of agricultural families. For example, in the case study of pesticides not considering the take-home pathway, personal hygiene habits of agricultural workers, method for laundering clothes, pesticide storage in houses etc.
    c) Inability to incorporate into the assessment methodology different personal behavioral patterns.
    d) The estimation of exposure will be based on the creation of buffer zones according to the residence of the population under study. However, different exposure may take place to another buffer zone due to various activities of the population (working, attending school etc.).
2) *Retrieving dose response functions for all the health outcomes of concern*
    a) A preliminary review of epidemiological studies has identified serious gaps in the availability of dose-response relationships, especially for the case of pesticides. These gaps as well as significant sources of uncertainty that have been identified stem from lack of good exposure data and proper exposure indicators. Exposure assessment is based usually on :
        i) self-reported data that could lead to exposure misclassification
        ii) to indirect exposure indicators like duration of exposure to pesticides
        iii) occupationally exposed groups

        Thus, there is uncertainty as to whether the dose response functions that will be retrieved could be used for the general population.
    b) The use of toxicological data for pesticide exposure is associated with a series of limitations and uncertainties:
        i) There is extrapolation from animals to humans and from large doses to small doses.
        ii) Slope factors and reference doses are developed for adults and there is uncertainty as to whether they can be used for children, one particular subpopulation of interest.

iii) In toxicological studies, animals are typically exposed to only one active ingredient, while human population can be exposed to several active ingredients (combined exposure). Experimental conditions do not resemble actual conditions that occur during human exposure.

iv) There is also uncertainty regarding availability of slope factors and of reference doses for all the routes of concern; extrapolating from one route to another is an alternative approach.

v) Furthermore, reference concentrations derive from NOAEL values. NOAEL is the highest dose at which there is no biologically significant increase in the frequency of an adverse effect when compared with an appropriate control group. In the WP1.3 report-guidelines it is indicated that the use of the NOAEL has been criticized because of their dependence on study design and their lack of consideration of statistical error or the shape of the dose-response curve. To cope with these problems, a *Benchmark Dose Method* was proposed [WP1.3 guidelines, Crump 1984, Kimmel and Gaylor 1988]. In case the above methodology is followed, additional guidance is expected from WP1.3 in order to cope with the aforementioned problems.

3) *Consideration of long term and reproductive health outcomes*

a) Estimation of the exposure for the whole lifetime for carcinogenic health outcomes. An assumption may be made that the population is exposed to the same concentration of the pollutant for their entire lifetime.

b) Estimation of the exposure during the prenatal development for adverse reproductive health outcomes. For reproductive outcomes, the annual estimated exposure may be regarded as the exposure during the prenatal development.

4.4 Expected problems in the assessment process and how to resolve them

One anticipated problem is the availability of data. It is expected that measured exposure concentrations for most of the pollutants considered will not be available; thus, estimation of pollutants concentration in different media will be based mostly on use of proxies and modelling.

In order to estimate the burden of a health outcome due to pollutants exposure, background health data are needed. If background health data are not inadequate, modelled or estimated values will be used.

Another problem that may be anticipated is data on seasonality pattern of some of the pollutants (pesticides, pollen).

Problems that may arise concerning choice of proper exposure-response relationships are listed above (4.3). If exposure-response relationships will not be available from epidemiological studies, and toxicological data from animal studies cannot yield such relationships, expert opinion will be used.

5. REPORTING AND COMMUNICATION

5.1 Form and dissemination of results

The methods and results derived from WP3.3 will be made available (in accordance with the deliverable deadlines) within the INTARESE project team to facilitate further refinement of the framework, toolbox design and methodologies for integration across policy scenarios. Relevant developments and results from WP3.3 will be published in the scientific literature in a timely manner.

5.2 Procedures for verifying the results

- Formal evaluation process
- External review / evaluation

Validation

Where feasible, indicators will be validated against independent measurements and observational data (as well as expert opinion from local/regional practitioners and scientists). Independent measurements, for example, may be available to validate pesticide exposure in the UK case study using pesticide residue data (POPPIE database). In addition, potential biomarkers of pesticides will be sought (in collaboration with WP2.3).

Where validation is not possible, triangulation techniques will be used to confirm the general ranking of exposures. Sensitivity analyses will also be employed to test the robustness of the estimates to model parameters and assumptions.

6. REFERENCES

Boogaard H, Hoek G, Pekkanen J, Yli-Tuomi T, Pedeli X. Exposure-response assessment protocol. Third draft. *INTARESE internal document*. 19th January 2007.

Crump KS. "A new method for determining allowable daily intakes". Fundam Appl Toxicol 1984;4(5):854-71.

Hoogeveen Y, Volkery A, Henrichs T and Ribeiro T. 2006. "Land use scenarios for Europe – Modelling at the European scale. Background report." European Environment Agency.

Kimmel CA, Gaylor DW. "Issues in qualitative and quantitative risk analysis for developmental toxicology". Risk Anal 1988;8(1):15-20.

Lambin EF, Rounsevell MDA and Geist HJ. 2000, "Are agricultural land-use models able to predict changes in land-use intensity?" Agriculture, Ecosystems and Environment, 82(1-3): 321-331.

U.S. Environmental Protection Agency. "Final guidelines for carcinogen risk assessment" Risk assessment forum. Washington, DC: U.S. Environmental Protection Agency; 2005.

U.S. Environmental Protection Agency. "Guidance on cumulative risk assessment of pesticide chemicals that have a common mechanism of toxicity", Washington, DC Environmental Protection Agency 2002.

7. APPENDICES

Appendix 1. Stakeholders in relation to WP3.3 (agriculture)

Organizations		**Country**	**Type of Stakeholder**[1]
International Organizations			
1	Organisation for Economic Co-operation and Development (OECD)		C and D
2	European and Mediterranean Plant Protection Organization		C and D
3	Food And Agriculture Organization Of The United Nations (FAO)		C and D
4	US Environmental Protection Agency (EPA)		C and D
5	US Food and Drug Administration		C and D
Crop Protection Associations			
6	UK Crop Protection Association (CPA)	UK	C and D
7	Union des Industries de la Protection des Plantes (UIPP)	France	C and D
8	Phytofar - Association Belge de l'Industrie des Produits Phytosanitaires	Belgium	C
9	Industrieverband Agrar eV (IVA)	Germany	C or D
10	Associazione Nazionale Imprese Fitofarmaci (AGROFARMA)	Italy	C or D
11	Asociacion Empresarial para la Proteccion de las Plantas (AEPLA)	Spain	C and D
12	Nederlandse Stichting voor Fytofarmacie (NEFYTO)	The Netherlands	C or D
13	Hellenic Crop Protection Association (HCPA)	Greece	C and D
14	European Crop Protection Association (ECPA)		C and D
15	CropLife International		C
European Union			
16	Directorate – General for Agriculture & Rural Development		C or D
17	Directorate – General for Environment		D
18	Directorate – General for Health & Consumer Protection		C and D
19	European Parliament		C and D
20	The Council of the European Union		C and D
	Farmers Associations		
21	Farmers’ Union of Wales (FUW)	UK	A
22	National Farmers’ Union (NFU)	UK	A and D
23	National Farmers’ Union Scotland (NFUS)	UK	A and D
24	Voluntary Initiative	UK	C or D
25	German Farmers Association (Deutscher Bauernverband-DBV)	Germany	C and D
26	National Federation of Farmers' Unions	France	C or D
27	Panhellenic Confederation of Unions of Agricultural Cooperatives (PASEGES)	Greece	D
Non governmental organizations			
28	PAN Europe (Pesticide Action Network Europe)		C and D
29	The International POPs Elimination Network (IPEN)		C and D
	Farm Animal Welfare Network (FAWN)	UK	C
	The UK Food Group	UK	C
National Agriculture Ministries			
30	Ministry of Rural Development and Food	Greece	C and D
31	Federal Ministry of Food, Agriculture and	Germany	C and D

	Consumer Protection		
32	Ministère de l' Agriculture et de la Pêsce	France	C and D
33	Ministero delle Politiche Agricole, Alimentari e Forestali	Italy	C and D
34	Department for Environment Food and Rural Affairs (Defra)	UK	C and D
	Central Science Laboratory	UK	C and D
National Health Ministries			
36	Ministère de l´Emploi et de la Solidarité Haute comité de la santé publique	France	D
37	Federal Ministry of Health	Germany	D
38	Ministry of Health and Social Solidarity	Greece	D
39	Ministry of Health	Italy	D
40	Ministry of Health, Welfare and Sport	The Netherlands	D
41	Department of Health	UK	D
42	Scottish Executive Health Department	Scotland-UK	D
43	National Assembly of Wales	Wales-UK	D
44	Department of Health, Social Services and Public Safety	Northern Ireland-UK	D
Public Health Institutions			
45	Fédération nationale des Observatoires régioneaux de la santé	France	D
46	National Institute of Health	Italy	D
47	National Institute of Public Health& the Environment (RIVM)	The Netherlands	D
48	Public Health Institute of Scotland	Scotland-UK	D
49	Welsh Institute for Health and Social Care University of Glamorgan	Wales-UK	D
50	Institut de Veille Sanitaire (INVS)	France	D
	Small Area Health Statistics Unit (SAHSU), Imperial College	UK	
Agriculture & Chemical Industry[2]			
51	Bayer P.L.C.	UK	A
52	Hockley International Ltd	UK	A
53	DSM Pharma Chemicals Venlo BV	The Netherlands	A
54	Cheminova	Denmark	A
55	Becker Associates	France	A
	Suppliers/manufactures of other agricultural goods (e.g. seed, equipment)		A
	Food distributors		
Other			
	Water supply companies		

1 Types of stakeholders: A: Perpetrators, C: Informants, D: Response Agencies

2 Chemical Industries are considered to belong to category A as their activities contribute to agricultural problems

Appendix 2. PRELUDE Scenarios - A Brief Description

The PRELUDE (PRospective Environmental analysis of Land Use Development in Europe) scenarios provide a set of five coherent scenarios (based on input from key 'stakeholders') that present possible and plausible futures of land use development in Europe. The PRELUDE scenarios combine the assessment of changes in the bio-physical environment with simultaneous changes in the socio-economic environment.

The five PRELUDE scenarios are:

- Great Escape - Europe of contrast
- Evolved Society - Europe of harmony
- Clustered Networks - Europe of structure
- Lettuce Surprise U - Europe of innovation
- Big Crisis - Europe of cohesion

Stakeholders categorised a broad variety of driving forces that influence different land use types and land use change in Europe. The main driving forces are the following:

- Environmental awareness (Environmental Concern, Climate Change, Renewable Energy)
- Technology and Innovation (Technological Growth)
- Agricultural optimization (Food Self Sufficiency, Agricultural Intensity, International Trade)
- Solidarity and Equity (Social Equity, Quality of Life, Human Behaviour, Health concern)
- Governance and Intervention (Subsidiarity, Policy Intervention)
- Demography (Population growth, Settlement Density, Youthfulness, Immigration, Internal Migration, Daily mobility)
- Economic Development (Economic Growth)

1. Great Escape - Europe of contrast

In the Great Escape scenario developments are driven by the **market economy**. The economic development is facilitated by increasing the current transportation possibilities and creating economies of scale in the agricultural sector.

Agriculture is market-oriented and maximises profit. Production intensifies but total agriculture diminishes, affecting almost 75 percent of the total European landscape. Many types of grassland are abandoned or converted into arable. Agricultural intensification and urban sprawl affect the rural environment negatively. Many nature reserves and extensive farmland areas with high nature value are lost. However, in some areas of agriculture cessation, soil and water quality improve and more diverse natural habits may develop.

Key developments in this scenario concern the increased importance of **international trade** (economic globalisation), the decreasing **societal solidarity** and **the strong reduction of policy interventions.**

2. Evolved Society - Europe of harmony

The impacts of **climate changes** play an important role in this scenario.

Heavy floods and exploding energy prices reinforce environmental awareness. Many people come to believe that lifestyles and economy should change. A revival of the countryside takes places as many people move away from densely populated (lowland) areas and settle in more rural and safe areas, especially in Eastern Europe. Local community action is getting new impetus by concerns for social equity. Policies focus on rural development and eco-efficient technologies, at the expense of structural change.

Farming is high-tech and increasingly organic. The agricultural area remains approximately the same while farming intensity decreases. In areas that are prone to repeated flooding, cropland is reduced considerably. Overall land use changes are not dramatic, and extensive farmland with high nature value is relatively well conserved.

Key developments in the scenario concern a far-reaching *energy crisis* which triggers increased support for renewables. A strong increase in *environmental awareness* sets off broader life-style changes and ***ambitious policies by European and national institutions in favour of environmental sustainable regional development.***

3. Clustered Networks - Europe of structure

Action in clustered networks is triggered by two parallel developments: *ageing of the population and increasing environmental problems***.** Ageing affects rural areas the most, causing depopulation and a decline of services.

Globalisation propels economic growth, but environmental and health conditions, especially in the urban centres, get worse. People in the countryside struggle as many local shops and services close down. The needs of an ageing society lead to the development of coherent spatial planning policies. Migration away from polluted urban areas is encouraged. New cities with a service economy are found as economic and social focal points in peripheral regions.

Urbanisation is concentrated and rural development focuses on 'green belts' around urban centres. Agriculture marginalises. As a result of large-scale land abandonment, cropland and grassland strongly decrease. Biodiversity, water, soil and air quality benefits from receding agriculture and creation of green belts. Natural habitats develop in the wider countryside, but at the detriment of high nature value farmland.

Key developments in this scenario concern the impacts of population dynamics **(ageing of society**), the effects of deepened **international trade relations** which lead to a strong marginalisation of agriculture and the occurrence of strong spatial planning interventions to cope with the challenges of the ageing of the society.

4. Lettuce Surprise U - Europe of innovation

In this scenario current trends continue until 2015 when a sharp trend breach occurs. A major **food crisis and lack of trust in central government** lead to a new set of societal values, decentralised decision-making and regional markets. Developments are driven by **technology** with a strong focus on the **environment**. Innovations occur 'bottom-up', boosted by open source knowledge sharing via the internet.

A major food security crisis hits Europe. As crisis management fails, faith in central government and in the safety of Europe's food supply decreases strongly. An alternative food production and control regime and regional self-sufficiency with regard to food and energy are strived for. Political decentralisation becomes prominent. New communication technologies facilitate local participatory decision-making and open-source development of innovative technologies. Migration is limited and urbanisation patterns do not really change.

Environmental awareness grows, leading to widely demands for environmental friendly produced food. Technological innovations offer new opportunities in this regard: New crop varieties are invented that enable higher yields with lower inputs. Agriculture in the core production areas is high-tech, clean and relatively small-scale. Due to increased productivity, cropland decreases strongly. Grassland decreases at a slower rate. The reduction of agricultural area and input leads to an increase of biodiversity and improvements in soil, water and air quality. Land abandonment affects high nature value farmland, but only moderately.

Open-source **technological breakthrough innovations** play a prominent role in this scenario. Other key developments concern a strong increase of environmental awareness and a far reaching decentralisation of political decision-making. **The degree of central policy interventions is reduced, self-regulation becomes more important.**

5. Big Crisis - Europe of cohesion

In the first decade of this scenario (2005-2015) current trends continue and the political focus is on **economic growth** rather than sustainability.

A series of environmental disasters highlights Europe's vulnerability and lacking capacities to effectively adapt. There is widespread support for a strong coordination of policies at the European level and new concerns for solidarity and equity arise. A whole set of new policies for sustainable and regionally balanced development is consolidated at the European level. Efficient public transport systems are strongly promoted as environmental awareness grows.

Agricultural intensification is largely reversed after 2015: Agricultural oversupply is being diminished; the main focus of agriculture is on landscape stewardship. Land use changes are limited. The population in current urban core areas decreases slightly. Cropland and grassland decrease moderately. The initial environmental pressures are relieved. Soil, water and air quality benefit from agricultural extensification and limited land abandonment. The loss of high nature value farm-land remains relatively small.

Key developments in this scenario ***concern a growing environmental awareness and growing social solidarity after an increased rate of environmental disasters. Key changes are mainly triggered by ambitious, top-down policy programs.***

Appendix 3 ICD-10 codes of health outcomes of interest in WP3.3.

Pesticides
C15 Malignant neoplasm of esophagus
C16 Malignant neoplasm of stomach
C25 Malignant neoplasm of pancreas
C34 Malignant neoplasm of bronchus and lung
C50 Malignant neoplasm of breast
C61 Malignant neoplasm of prostate
C64 Malignant neoplasm of kidney
Malignant neoplasms of lymphoid, haematopoietic and related tissue
C81 Hogkin's disease
C82 Follicular non-Hodgkin's lymphoma
C83 Diffuse non-Hodgkin's lymphoma
C84 Peripheral and cutaneous T-cell lymphomas
C85 Other and unspecified types of non-Hodgkin's lymphoma
C88 Malignant immunoproliferative diseases
C90 Multiple myeloma and malignant plasma cell neoplasms
C91 Lympoid leukaemia
C92 Myeloid Leukaemia
C93 Monocytic Leukaemia
C94 Other leukaemias of specified cell type
C95 Leukaemia of unspecified cell type
C96 Other and unspecified malignant neoplasma of lymphoid, haematopoietic and related tissue
G20 Parkinson's disease
G30 Alzheimer's disease
Disorders related to length of gestation and fetal growth
P07.0 Extremely low birth weight
Birth weight 999 g or less
P07.1 Other low birth weight
Birth weight 1000-2499 g
Congenital malformations of genital organs
Q53 Undescended testicle
Q54 Hypospadias
Cleft lip and cleft palate
Q35 Cleft palate
Q36 Cleft lip
Congenital malformations and deformations of the musculoskeletal system
Q69 Polydactyly
Q70 Syndactyly
Q71 Reduction defects of upper limb
Q72 Reduction defects of lower limb
Q73 Reduction defects of unspecified limb
Q76 Spina bifida occulta
Congenital malformations of the nervous system
Q00 Anencephaly and similar malformations
Q01 Encephalocele
Q02 Microcephaly
Q03 Congenital hydrocephalus
Q04 Other congenital malformations of brain
Q05 Spina bifida
Q06 Other congenital malformations of spinal cord
Q07 Other congenital malformations of nervous system
Congenital malformations of the circulatory system
Q20 Congenital malformations of cardiac chambers and connections
Q21 Congenital malformations of cardiac sapta
Q22 Congenital malformations of pulmonary and tricuspid valves
Q23 Congenital malformations of aortic and mitral valves
Q24 Other congenital malformations of heart
Q25 Congenital malformations of great arteries

Q26 Congenital malformations of great veins Q27 Other congenital malformations of peripheral vascular system Congenital malformations of the urinary system Q60 Renal agenesis and other reduction defects of kidney Q61 Cystic kidney disease Q62 Congenital obstructive defects of renal pelvis and congenital malformations of the ureter Q63 Other congenital malformations of kidney Q64 Other congenital malformations of urinary system Congenital malformations of the respiratory system Q30 Congenital malformations of nose Q31 Congenital malformations of larynx Q32 Congenital malformations of trachea and bronchus Q33 Congenital malformations of lung Q34 Other congenital malformations of respiratory system
Aerosols and allergens J00-J06 Acute respiratory infections J10-J18 Influenza and pneumonia J20-J22 Other acute lower respiratory infections J30. Vasomotor and allergic rhinitis J40-47 Chronic lower respiratory disease J66.8 Airway disease due to other specific organic dusts (for organic dust toxic syndrome J67.0 Hypersensitivity pneumonitis due to organic dust / Farmers' lung
Zoonotic agents A04 Other bacterial intensinal infections A04.0 Enteropathogenic *E.coli* infections A04.1 Enterotoxigenic *E.coli* infections A04.2 Enteroinvasive *E.coli* infections A04.3 Enterohaemorragic *E.coli* infections A04.4 Other intenstinal *E.coli* infections A04.5 Campylobacter enteritis A04.6 Enteritis due to *Yersinia enterocolitica* A04.7 Enterocolitis due to *Clostridium difficile* A04.9 Bacterial intestinal infection, unspecified A02.0 Salmonella enteritis A07.1 Giardiasis A07.2 Cryptosporidiosis A03 Shigellosis

Appendix 4. Pesticides : a) Single active ingredient intake estimation, b) Single active ingredient risk estimation based on toxicological data

a) SINGLE ACTIVE INGREDIENT INTAKE ESTIMATION	
Data needs	Daily mean pesticide concentration in water, food, air, soil, foliage etc. Water consumption rate (L/day), Food consumption rate, Inhalation rate (m^3/day), Soil ingestion (mg/day), Dermal absorption rate etc. Adult/children body weight (Kg) Duration of activity, Averaging time of activity, Frequency of activity Skin surface contact area Specification of target groups and pathways of exposure for each group
Data sources	EPA Exposure Factors Handbook : Reported values from EPA for water consumption rate (L/day), food consumption rate, inhalation rate (mg/day), soil ingestion (mg/day), adult/children body weight (Kg)
Availability and quality of data sources	
Variables that are derived	**Intake from inhalation, oral and dermal route** The relative contributions of each exposure route (dermal, ingestion, inhalation)
Units of measurement	μg/kg/day
Calculation of intake	Ingestion Intake= pesticide concentration in ***drinking water*** x water consumption rate/ body weight Intake= pesticide concentration in ***food*** x food consumption rate /body weight Intake = pesticide concentration in ***soil*** x soil consumption rate /body weight Inhalation Intake= pesticide concentration in ***air*** x inhalation rate / body weight Dermal absorption Intake = pesticide concentration in ***air*** x dermal absorption factor x Skin surface contact area / body weight Intake= pesticide concentration in ***foliage*** x dermal absorption Skin surface contact area / body weight

Limitations and uncertainties	Usually a mixture of pesticides is applied and not single pesticides, so subjects are exposed to more than one active ingredient. Pesticides may act in a different way when there is interaction between them Alternatively, a combined exposure could be studied with pesticides that share a common mechanism of toxicity with the assumption that all interactions are additive. In such a case, there should be a determination of the compounds that belong in a common mechanism group and produce the same health outcome Not taking account of individual habits and patterns of behaviour, but assuming a mean exposure for a population group Alternative approach
	Intake = Concentration x Intake rate x Frequency x Duration / Body weight x averaging time Frequency= number of days of exposure Durations= years of exposure Averaging time = 70 years for carcinogens

b) SINGLE ACTIVE INGREDIENT RISK ESTIMATION BASED ON TOXICOLOGICAL DATA

Data needs	**Carcinogenic health outcomes**	Oral, dermal, inhalation ***slope factors***
	Non carcinogenic health outcomes	Oral, dermal, inhalation ***reference doses***
Units of measurement	mg/kg/day	
Data sources	Review databases like: 1. IRIS 2. HEAST tables of EPA	
Availability and quality of data sources	IRIS is available online, while HEAST tables are not. Review data bases usually contain oral slope factors and reference doses but not inhalation and dermal values. Uncertainty about the availability of threshold values for all pesticides of concern	
Terms and concepts	***Slope factor:*** The slope factor is defined as "an upper bound, approximating a 95% confidence limit, on the increased cancer risk from lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg/day ***Reference dose*:** an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects. Reference doses derive from NOAEL/LOAEL values by applying several uncertainty factors ***No-observed-adverse-effect level (NOAEL).*** The NOAEL is the highest dose at which there is no biologically significant increase in the frequency of an adverse effect when compared with an appropriate control group. ***Lowest-observed-adverse-effect level (LOAEL***). The LOAEL is the lowest dose at which there is a biologically significant increase in the frequency of adverse effects when compared with the appropriate control group ***Uncertainty factors (UF).*** A UF is a value applied to a NOAEL to account for variability in response across species and among humans. It usually is a factor of 10 for each area of variability (uncertainty), although each factor might be reduced or enlarged according to the quality and amount of data. Additional factors may be applied to account for uncertainty due to missing or inadequate data	

Limitations and uncertainties	Extrapolation from animals to humans Extrapolation from large doses to small doses Slope factors and reference doses are developed for adults and there is uncertainty as to whether they can be used for children Availability of dermal, inhalation slope factors and references doses. Dermal values can be extrapolated from oral values An assumption is made, that the population is being exposed to a certain concentration of the active ingredient every day for the whole period of study Animals are exposed to only one active ingredient, while human population can be exposed to several active ingredients (combined exposure). Experimental conditions do no resemble actual conditions that occur during human exposure Availability of threshold values for certain health outcomes (for example, for congenital malformations availability of developmental NOAEL values from oral, dermal and inhalation route) Additivity of risks (indicated below) is uncertain.	
Variables that are derived	Carcinogenic health outcomes	**Risk**
	Non carcinogenic health outcomes	**Hazard**
Units of measurement	Dimensionless	
Calculation of risk for carcinogenic and hazard for non-carcinogenic health effects	***Carcinogenic health outcomes***	Risk1 = oral slope factor x intake (food/drinking water/ soil) Risk2 = inhalation slope factor x intake Risk3 = dermal slope factor x intake (air / foliage) (Risk = Risk 1 + Risk2 + Risk 3)
	Non carcinogenic health outcomes	Hazard (inhalation) = inhalation intake / inhalation reference dose Hazard (oral)=oral intake (food/drinking water/soil) / oral reference dose Hazard (dermal)= dermal intake(air/foliage) / dermal reference dose

Appendix 5. Exposure and health outcome indicators

Possible exposure and outcome measures could include:

- Average population exposure (APE)
- Attributable body burden (ABB)
- Intake fraction (IF)
- Attributable morbidity (AM)
- Severity weighted illness days (SWID)
- Attributable health cost (AHC)

These can be approximated in different ways, and the method of approximation is likely to vary by pollutant and pathway. It would also greatly depend on the type of data available (in particular exposure-dose-outcome relationships). Relating to atmospheric pathways, the following give some simple basic algorithms which might be used as a first approximation. Where suitable dispersion models etc exist, these could be improved on.

5 (a) Exposure indicators

Pesticides

APE = Uc * Ac * Pcd * $(1/d^n)$

where Uc = usage rate of pesticide on crop type c

Ac = area of crop type c

Pcd = population living at distance d from crop type c

n = dilution coefficient (a function of windspeed and direction)

Uc can be estimated from the usage data, plus some disaggregation by crop-type etc.

Ac comes from the land use data and/or June agricultural returns

Pcd is estimated by buffering around each source area

n could be approximated as $2x^{-1}$ (where x is windspeed) – This gives an exponent of 2 for low windspeed (<1 m/sec), 1 for a windspeed of 2 m/sec and 0.5 for a windspeed of 4m/sec; thus, it shows how dilution increases with windspeed. Alternatively, one might obtain estimates of how much dilution occurs downwind from the literature (e.g. studies on pesticide drift, or trough a dispersion model (ADMS or AgDrift).

Aerosols

APE = Ac * (Wcs+Rc) * Pcd * $(1/d^n)$

where Wcs = wind entrainment factor for land use/crop type c on soil type s (mainly relating to coarser PM)

Rc = release factor for land use/crop type c (and mainly relates to finer fractions)

Wcs can be modeled as:

$$Wcs = Ac * Fcs * S * W^{m}$$

Where Fcs = the proportion of fallow (bare) area under land use/crop type c on soil type s

S = a function of soil type (dependent on soil texture and structure) and tillage regime

W = windspeed

m = an exponent relating the entrainment rate to windspeed

Ac and Pcd can be calculated as above.

Fcs could be estimated from some basic knowledge, field observation or the literature: it is essentially 1 – the leaf area index. This will change over the season!

S may be estimated as follows:

$$Sb + Sb^{t}$$

where Sb is the background rate of entrainment and t is a tillage factor (some function of the number of times that the soil is tilled – e.g. ploughed, harrowed). Sb is thus a function mainly of the soil texture, structure and organic matter content, plus the tillage regime. The literature will be surveyed to obtain a correlation that would help estimate soil erosion.

m is rather like n in relation to pesticides – again the wind erosion equations might help. There is also a classic relationship developed by Bagnold (ca. 1936) that defines this for different particle sizes.

Rc relates to aerosol production by crops and livestock wastes. This is likely to include two main components: direct releases such as pollen and endotoxins, and indirect production of secondary aerosols via nitrates and sulphates. The literature will be searched for information relating to release rates of these pollutants.

Zoonoses

In principle:

$$APE = [(LUgc * RFg) + RSc] * Ac * Pcd * (1/d^{n})$$

Where LUgc = density of livestock units for livestock group g on land use/crop type c

RFg = the release rate to the atmosphere of zoonoses from livestock faeces for livestock group g

RSc = the release rate to the atmosphere from slurry spreading on land use/crop type c

$1/d^n$ = a wind dilution factor, as for pesticides (though probably with different exponents)

LUgc can be derived from the June agricultural returns (UK) or similar data elsewhere, or could be modelled by disaggregation from regional/national statistics (as in APMoSPHERE).

RFg might be approximated from information on rates of faeces production for different animals (there appears to be a rich literature on this in the agricultural and applied ecology journals). Alternatively, it might just be taken as a function of energy intake. The literature should also be surveyed on zoonoses production rates.

RSc is of the form:

RSc = SSc * ZS * ZR

where SSc = the slurry spreading rate on land use/crop type c

ZS = the zoonoses concentration in slurry

ZR = the zoonoses release rate from slurry

5 (b) Other indicators

If the above can be obtained through modelling, the other indicators are relatively straightforward to determine. In each case:

ABB = APE * P * I

where I is an intake coefficient

IF = ABB / M

where M is emission rate, which may by derived from the left hand side of each of the models above (i.e. the parameters before Pcd)

Health outcome indicator

AM = APE * D

where D is the dose-response function

Secondary impact indicators

$SWID = \Sigma (AM * Vs)_d$

where Vs_d is a severity weighting for disease d

$AHC = \Sigma (AM * Vm)_d$

where Vm_d is a monetary weighting for disease d