OR 28/2010

INTARESE

Revised integrated monitoring

Hai-Ying Liu, Alena Bartonova and Maria Dusinska (eds)

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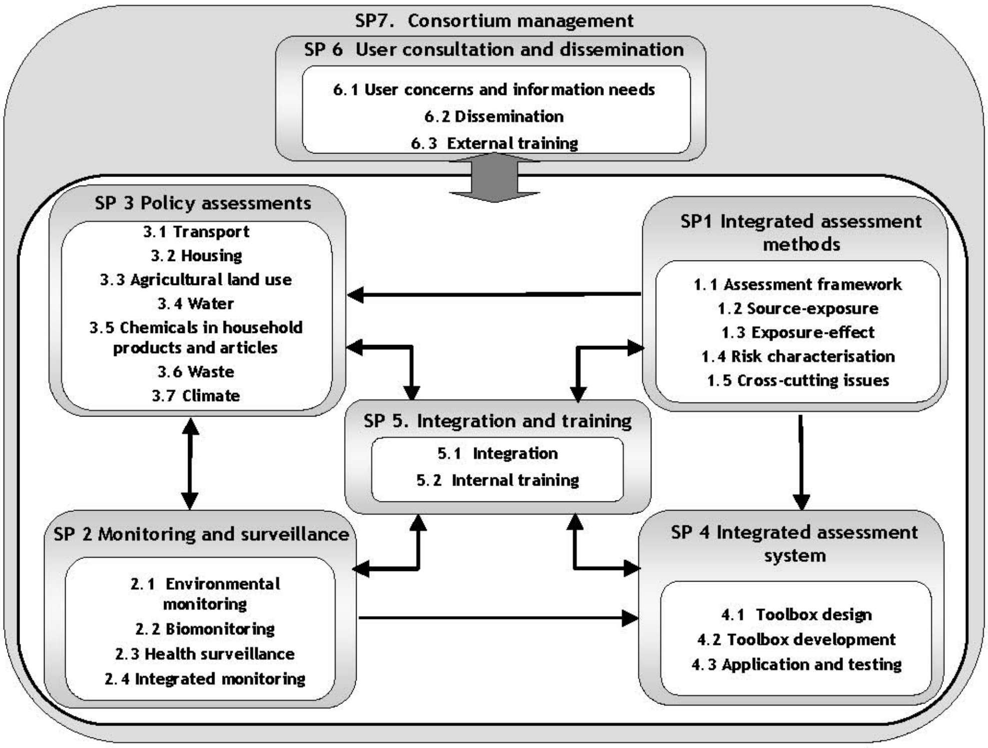
Preface

This report is a deliverable of a project INTARESE (Integrated assessment of health risks of environmental stressors in Europe). INTARESE is funded under the EU 6th Framework Programme Priority 6.3 Global Change and Ecosystems, Contract No. 018385. The purpose of INTARESE is to support implementation of the European Environment and Health Action plan, by providing the methods and tools needed for integrated assessment of health risks from environmental stressors (e.g. air and water pollution, climate change, etc.).

The project INTARESE involves leading scientists and practitioners from 32 institutions in Europe, as listed below.

	Institution	**Acronym**	**Country**
1	Imperial College London	IC	UK
2	London School of Hygiene and Tropical Medicine	LSHTM	UK
3	National Institute for Public Health and the Environment	RIVM	Netherlands
4	Utrecht University	UU	Netherlands
5	Agence Francaise de Securite Sanitaire Environnmentale	AFSSE	France
6	Kansanterveyslaitos (National Public Health Institute)	KTL	Finland
7	Norsk Institutt for Luftforskning	NILU	Norway
8	ASL Rome	ASL	Italy
9	National and Kapodistrian University of Athens	NKUA	Greece
10	Forschungszentrum fur Umwelt und Gesundheit GmbH	GSF	Germany
11	Netherlands Organisation for Applied Scientific Research	TNO	Netherlands
12	Karolinska Institutet	KI	Sweden
13	Consejo Superior de Investigaciones Cientificas	CSIC	Spain
14	World Health Organisation, Rome	WHO	Italy
15	Université Catholique Louvain	UCL	Belgium
16	Fundació IMIM (Municipal Institute of Medical Research)	FIMIM	Spain
17	University of Maastricht	UM-ICIS	Netherlands
18	Health Protection Agency, UK	HPA	UK
19	Institute of Experimental Medicine AS CR	IEM	Czech Republic
20	Vlaamse Instelling voor technologisch onderzoek NV	VITO	Belgium
21	Czech National Institute of Public Health	CNIPH	Czech Republic
22	Vinca Institute of Nuclear Sciences, Serbia and Montenegro	IV	Serbia
23	Slovak Medical University-Institute of Preventive and Clinical Medicine	RB-SMU	Slovakia
24	University of Stuttgart	USTUTT	Germany
25	Institut de Veille Sanitaire	INVS	France
26	Institut National de l’Environnement Industriel et des Risques	INERIS	France
27	Department of Civil Protection-Italy	DCP	Italy
28	Centre for Research and Technology Hellas	CERTH	Greece
29	European Chemical Industry Council	CEFIC	Belgium
30	CSTB	CSTB	France
31	Barcelona Science Park (Parc Científic de Barcelona)	BSP	Spain
32	IC Consultants Ltd	ICON	UK

The project INTARESE has been arranged within six technical 'sub-projects', supported through a seventh dealing with project coordination, as structured below.



This report is one of Work package 2.4 (WP2.4) tasks under Subproject 2 (SP2). SP2-Monitoring and surveillance is included to review and develop the monitoring tools and data sources in the way to support implementation of integrated environment and health assessment methodology. WP2.4-Integrated monitoring is to explore the ways of linking and enhance various sources and technologies in order to provide a more integrated (e.g. EU-wide, multi-agent, multi-pathway, multi-media/receptor, etc.) approach to monitoring in the EU.

The key contents within this report are:

- review of existing and planned integrated environment and health (E & H) monitoring programs
- assessment of frameworks currently used in existing and planned integrated E & H monitoring programs
- analysis of results of SP 1, SP 2 and SP 3 to date
- identification of development needs
- development of methods
- case studies (based on WP 2.1-2.3)

For more information, please visit INTARESE website at http://www.intarese.org or contact Dr. Hai-Ying Liu, E-mail: hyl@nilu.no and/or Dr. Alena Bartonova, E-mail: aba@nilu.no.

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TABLE OF CONTENTS

1 INTRODUCTION

1.1 About this deliverable

The project INTARESE (Integrated assessment of health risks of environmental stressors in Europe) is designed to support implementation of the European Environment and Health Action Plan (EHAP), by providing the methods and tools that are essential to enable integrated assessment of environment and health risks. Based upon this goal, first we defined the integrated environment and health monitoring (IEHM) as ‘an ongoing and systematic process to determine, analyze and interpret environmental quality and environment-related health status’ (D51) (http://www.intarese.org). In this report, instead of focusing on ‘IEHM’, a realistic and reasonable topic would be the ‘integrated usage of information from multiple monitoring systems’ in the view of providing the methodologies and tools on integrated usage of information from multiple monitoring systems in E&H (environment and health) fields. In order to avoid adverse reactions from the ‘owners’ of existing monitoring systems, we have first summarized the relevant existing integrated monitoring systems in the E&H fields (section 2.1, detail in D51). Based upon the review of frameworks which are currently used in the integrated monitoring programs (section 2.2, detail in D51), and the results of SP 1, SP 2 and SP 3 to date within INTARESE project (section 2.3, detail in D51), we identified the development needs for IEHM and integrated usage of data/information from multiple sources (section 3); proposed a conceptual framework of IEHM (section 4); developed a work process of integrated information from multiple monitoring programs (section 5), and summarized the relevant tools and methodologies for the integrated usage of information from multiple monitoring systems (section 6).

1.2 Reader’s guide for this document

This document is a revised version of D51. This chapter gives a general introduction. Chapter 2 provides the background information on relevant integrated monitoring programs, relevant integrated frameworks and results of SPs1-3. Chapter 3 identifies the development needs on integrated monitoring and data integration from multiple sources. Chapter 4 describes a conceptual framework of IEHM. Chapter 5 describes the general work process of the integrated usage of information from multiple monitoring programs. Chapter 6 provides information on tools and relevant methodologies like GIS, statistical or deterministic modelling techniques. Chapter 7 summarise the main results of this report.

2 REVIEW OF RELAVANT MONITORING PROGRAMS, FRAMEWORKS AND RESULTS OF SP_S 1-3

2.1 Review of relevant integrated monitoring programs

There are a large number of existing and planned environment and health monitoring programs in Europe. Some major monitoring programs dealing with health risks of environmental stressors at national level are listed below and some of their features are summarized in Table 1. By concentrating on their use of integrated methodology, we want to focus on (i) the data information, (ii) integrated methodology and (iii) the potential that the integration of existing activity could have for supporting informed policy decision-making. Here, we have identified three types of programs that followed the same main scheme:

- International, objectives of documenting trends and comparison across countries include a wide range of indicators, e.g. AMAP-Arctic Monitoring and Assessment Programme, and ENHIS-European Environment and Health Information System.
- National, objectives of documenting general health trends focus on some health based indicators. e.g. GerES-German Environmental Survey, EHMS-the Environmental Health Monitoring System in the Czech Republic, PCBs in Slovenia- PCB Monitoring and Assessment Projects in Slovakia, and KiGGS-The German Health Interview and Examination Survey for Children and Adolescents.
- National, objectives of following on a specific risk, including both observation and forecasting, e.g. HWWS-Heat Wave Warning System in France, and ONERC-National Observatory of Climate Change Impact in France.

2.2 Review of relevant integrated monitoring frameworks

There have been a number of approaches in order to form more holistic models to address interlinked environment and health challenges. Key issues have been to focus on interdisciplinary approaches and identify causal societal relationships. In this study, the following frameworks were reviewed (Table 2).

- DPSIR (Driving Force-Pressure-State-Impact-Response) (http://glossary.eea.europa.eu)
- DPSEEA (Driving Force-Pressure-State-Exposure-Effects-Action) (http://www.euro.who.int)
- INTARESE full chain approach (http://www.intarese.org)

2.2.1 DPSIR framework

The DPSIR framework for describing the interactions between society and the environment adopted by the European Environment Agency (EEA) (http://glossary.eea.europa.eu; http://de.wikipedia.org) is an extension of the PSR (Pressure-State-Response) model developed by Organisation for Economic Co-operation and Development (OECD) (http://www.oecd.org), which takes into account human health, ecosystem and social-economic impacts (WHO, 2008) (Figure 1).

Table 1 Overview of eight integrated monitoring programmes in Europe. The abbreviation name is accordance with the name in the text above. The more detail information regarding the review of these eight programs is available in the D51 (http://www.intarese.org).

Project acronym	Location	Period	Data information	Integrated methodology
AMAP	The terrestrial and marine areas, north of the Arctic Circle	1991-2012	**Environment** Atmospheric contaminants Marine contaminants Radioactivity Freshwater and terrestrial contaminants **Health** UV radiation and climate change	Guideline and methodology were developed for each monitoring system, quality control and general monitoring issues
EHIS	Europe	2008-	**Environment** Air quality Food safety Chemical safety Water and sanitation Mobility and transport Housing UV and ionizing radiation Occupational hazards **Health** Exposure of population to environmental stressors	Methodology was developed for thirty indicators giving the rationale, definitions, required data elements, calculation methods, data sources, interpretations and policy-relevance.
EHMS	Czech Republic	1994-2006	**Environment** (136 contaminant factors) Air pollution Drinking water pollution Noise Soil contamination **Health** Dietary exposure and human bio-monitoring	Methodology was developed for monitored factors and indicators and their limits, information system and data processing, and QA/QC system

Table 1 (Continued).

Project acronym	Location	Period	Data information	Integrated methodology
GerES	East-, West-Germany	1985-2006	**Environment** Domestic environment: tap water, dust deposit, content of vacuum cleaner bag and indoor air Community: water works sample and dust fall outdoors **Health** Human bio-monitoring, diet and personal air	Methodology was developed for fieldwork, experimental chemical analysis, and data analysis (including checking and revising data, matching different data files, weighting etc.)
KiGSS	East-, West-Germany	1990-1992 2003-2006	**Health (**1990-1992, 4730 participants; 2003 - 2006, 17,641 participants) Measurement: physical and mental health Questionnaire: health status, health behaviour, health care utilization, social and migrant status, living conditions **Environment** Environmental determinants of health	Methodology was developed for the participants interviews, physical examinations, blood and urine samples, and data processing
ONERC	France	2001	**Climate change (15 indicators)** Different sources Several datasets **Population data** Exposure of population to climate risk	Report on specific themes, e.g. human health, relying on the indicators
PCB in Slovakia	Michalovce and Svidnik/Stropkov regions, Eastern Slovakia	2001-	**Pollutants** PCBs and toxic metals. **Health (8 indicators)** Thyroid gland, glucose homeostasis and neurodevelopmental disorders	Report on specific themes, e.g. human health, relying on the indicators
HWWS	France	2003-	**Environmental variables** Temperature and air quality (O_3, PM10) **Health** Mortality	I. Analysis of the temperature data, including the probability of being above threshold II. If the probability are medium to high, analysis of additional risk factors III. During a heat wave or immediately after, analysis of the health data to orientate the actions

The DPSIR provides an overall model for analyzing integrated environmental problems. In practice, this framework is mainly focusing on man-made drivers and pressures, omitting the possible impacts of natural disturbances. Furthermore, it does not illustrate properly the dynamic processes from exposure to effects. This framework has been criticized as being linear and uni-directional (WHO, 2008).

2.2.2 DPSEEA framework

The DPSEEA has been adopted by the World Health Organization (WHO) (http://www.euro.who.int). It provides an overall mechanism for analyzing environmental problems and related health effects. DPSEEA (Corvalan et al., 1996) refers to integrated monitoring and reporting diagrams (Figure 1).

The DPSEEA framework is useful in designing a system of environmental health indicators within a decision-making context (http://heande.pyrkilo.fi). In practice, based on the monitoring program objectives and particular context, the physical, chemical and biological indicators in each of its six components can be selected in order to help identifying and monitoring key DPSEEA relationships. It needs to be adapted and modified according to circumstance. However, this framework addresses more indicators on the man-made environment, less on the natural environment and ecosystem. The complex interactions between natural and human systems are not highlighted.

2.2.3 INTARESE full chain approach

The INTARESE full chain approach comprises all relevant aspects and builds on all relevant methods to provide guidance for a comprehensive and integrated risk/impact assessment (Figure 1). It recognized the concept of the DPSIR, DPSEEA and MEME (The multiple exposures-multiple effects, http://www.who.org) frameworks but provides a more flexible and comprehensive framework (http://www.intarese.org). The key attributes are:

- the full chain approach, including variables and causal relationships linking the different steps in the chain from source to impacts
- the framework also enables a dynamic appraisal of health risks from environmental stressors by taking into account societal changes (e.g. behaviours, policy impacts, etc.) in the different steps of the full chain
- the logical process of assessment (steps involved in the execution of the assessment, tasks and responsibilities of the parties involved)
- information input and models (e.g. data input and processing, applying models, transforming intermediate variables into meaningful indicators and summary indices)
- appraisal of the information from multiple perspectives

The full chain covers all the aspects from the other frameworks and focuses on comprehensiveness and integration (Briggs, 2008). It is limited to human health.

2.3 Summary of results of SP 1, SP 2 and SP 3 to date

2.3.1 Results of SP 1-Integrated assessment methodology

SP 1-Integrated assessment methodology is responsible for developing a framework and methodology for integrated assessment. It comprises five work packages, WP1.1-Assessment framework, WP1.2-Source-exposure, WP1.3-Exposure-health effect, WP1.4-Risk characterization and WP1.5-Crosscutting issues. The results of SP 1 are summarized in Table 3.

Table 2 The comparison of DPSIA, DPSEEA and INTARESE full chain frameworks.

Framework	DPSIR	DPSEEA	INTARESE-Full chain
Driving forces	Areas in public life that exerts pressure on the environment, e.g. economic sectors, households.	The driving forces refer to the factors that motivate and push the environmental processes involved.	
Pressures, e.g. emissions	Resulting environmental burden, e.g. due to waste and built-up areas	The result is the generation of pressures on the environment.	Due to activities and processes (natural and anthropogenic)
State of the environmental media	State of an environmental compartment that is exposed to the burden, e.g. changes in atmosphere and lithosphere	In response to the pressures, the state of the environment is often modified.	After dispersion and transformation, e.g. concentration
Exposure		Deterioration in the state of the environment, however, poses risks to human well-being only when there is interplay between people and the hazards in the environment. Exposure is therefore rarely an automatic consequence of the existence of a hazard: it requires that people are present both at the place and at the time that the hazard occurs. Exposure to environmental hazards, in turn, leads to a wide spectrum of health effects, which may be acute or chronic. The concept of exposure is best developed in relation to pollutants in environmental media. The amount of the pollutant absorbed, i.e. the "dose", depends on the duration and intensity of the exposure.	Depending on population behaviour, e.g. time-activity pattern, product use, diet
Impacts/Effects	Specific impact due to the environmental burden, e.g. greenhouse effect, soil pollution	Some hazards may have a rapid effect following exposure, whereas others may require a long time to produce an adverse health effect.	After inhalation, dermal exposure, ingestion Pathophysiological processes lead from a dose to a health effect
Damages			Taking place of valuation and weighing; risk characterization; e.g. policy deficits, disease burden, societal (external) costs, perceptions
Answers of society/Actions	Social reaction to the burden, e.g. research and laws	In face of the environmental problems and consequent health effects, society attempts to adopt and implement a range of actions. These may take many forms and be targeted at different points within the environment-health continuum. Actions may be taken to reduce or control the hazards concerned, such as by limiting emissions of pollutants or introducing flood control measures. The most effective long-term actions, however, are those that are preventive in approach, aimed at eliminating or reducing the forces that drive the system.	

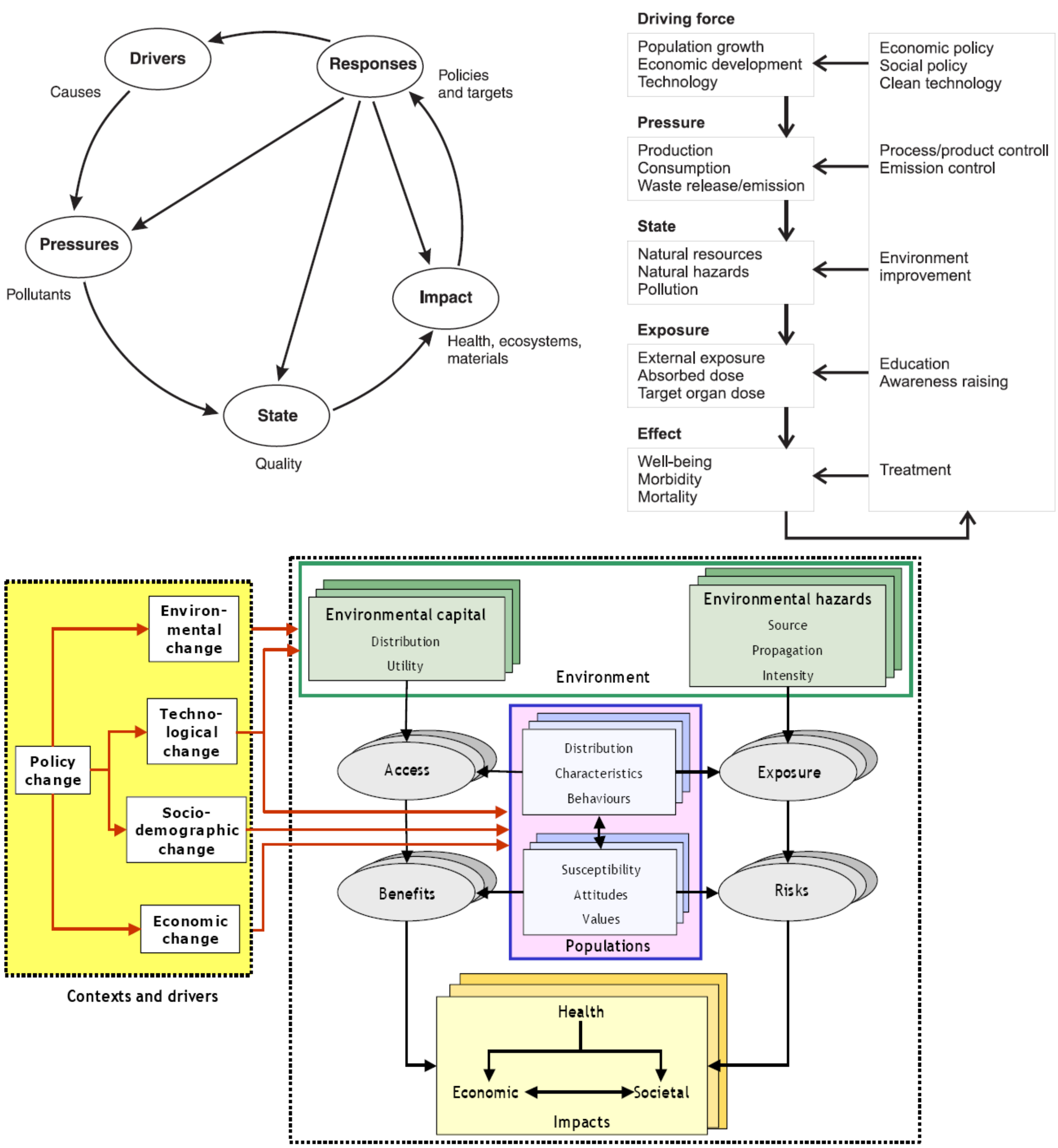

Figure 1 DPSIR, DPSEEA and INTARESE full chain frameworks (Top left: DPSIR framework (Source: EEA, http://www.eea.europe.eu), Top right: DPSEEA framework (Source: WHO, http://www.euro.who.int), Bottom: INTARESE full chain framework (Source: INTARESE, http://www.intarese.org).

Table 3 Summary of results from SP 1.

WP No.	Tasks	Results
WP1.1-Assessment framework	Development of a conceptual framework for integrated assessment of environment and health risks and impacts Specification of the necessary tools, indicators and information requirements	Conceptual model of assessment framework
WP1.2-Source-exposure	Development of methods, tools and indicators for assessing the link between source and exposure	Exposure modelling protocol Exposure-source apportionment and iF-database Source-to-exposure and source attribution modelling methodologies Exposure assessment platform online Exposure intake models
WP1.3-Exposure-health effect	Development of methods, tools and indicators for assessing the link between exposure and health effect	Health effect methodology
WP1.4- Risk characterization	Development of methods, tools and indicators for translating results of assessments to policy-makers	Risk characterization protocol Risk characterization methodology
WP1.5-Crosscutting issues	Development of protocols and procedures • to help focus assessments on susceptible groups (e.g. children, the elderly, etc.) • to deal with multiple exposures and health outcomes • for tracking and reporting uncertainties in the assessment process	Uncertainty concept report First uncertainty training workshop

2.3.2 Results of SP 2-Monitoring and surveillance

SP2-Monitoring and surveillance reviews and develops the monitoring tools and data sources needed to support implementation of this assessment methodology. Table 4 summarized the results from SP 2.

Table 4 Summary of results from SP 2 (---not specified or not described).

WP No.	Tasks	Rationale	Data requirements	Methods	Results
WP 2.1-Environmental monitoring	Environmental monitoring review	Review of environmental monitoring databases and projects	---	Limited thematic scope (e.g. population, soils, climate, land cover, air, water, chemicals, waster, housing traffic and roads, etc.) Limited criteria for selection of data sources (European level) Define assessment criteria	Environmental monitoring review
	Case study on air pollution and noise	Kalman filtering Compare LUR model with dispersion model Interpolation method air pollution Remote sensing study shifted to Greece as a first step	Air pollution Noise Remote sensing	Start: Rotterdam/Rijnmond, Oslo, UK areas Assess exposure to air pollution and noise (and possibly climate) GIS-based land use regression techniques and source dispersion modelling Simple methods and detailed modelling Data assimilation (including remote sensing) Investigation of representativity of monitoring network Apply methods to other parts of Europe	A draft protocol for air pollution and noise in Rijnmond
	PAHs case study in Prague	Modeling PAH concentration based on data from long term stationary monitoring of PM10, PM2.5 and c-PAH	Emission inventory Meteorological information Personal sampling data	In collaboration with WP2.2 Study area: Prague Asses exposure to carcinogenic PAH Modeling PAH concentration based on data from long term stationary monitoring of PM10, PM2.5 and c-PAH Modeling exposure based on personal sampling and biomarkers. 48-hrs personal monitoring is available for two exposed groups (400 subjects)	A draft protocol for PAHs case study
	Lead case study	Report on models predicting lead levels in blood Case study in Belgium European case study (lack of data)	Lead concentration in the environment	In collaboration with WP2.2 Investigate methods to assess exposure to Pb Model past exposure based on data on lead concentrations in the environment. Calculate and compare simple exposure indices Investigate validation methods Integrate biomonitoring	A draft protocol for lead case study
WP 2.2-Biomonitoring	The relevance of human biomarker in integrated health impact assessment	Biomarker review and development strategy		Selected 18 biomarkers	Biomarker review and development strategy
	Lead case study	Study the feasibility to collect humn biomaker data across Europe Assess the comparability of data Link with E&H data	Pb in blood • Gender • Age class • Sampled periods • Number of samples	Collection data methods • Identification of relevant studies • Contacted twice (or more) through mail • Use of official ways to obtain data Data analysis • Assumption: Pb-blood data follow LogNormal distribution • Ranking data points low-high • Excell-module SSWD	Succesfull in gathering raw data across Europe Analysis method works well Difficult to compare

Table 4 (Continued)

WP No.	Tasks	Rationale	Data requirements	Methods	Results
WP 2.2-Biomonitoring	PCBs case study in Slovakia	Environmental exposure to polychlorinated biphenyls (PCBs) in site of their production in Slovakia and use in the Czech Republic	PCBs concentration in components of environment • Ambient air • Soil • Surface water and water sediment • Wildlife • Food contamination	Exposure assessment	There is significant correlation between PCBs and a volume of thyroid gland (ThV) One-compartmental model can make possible to take into account a presently unknown PCB intensity using measured data from the next time period after the end of this initial phase
	PAHs Case study in Prague	Impact of c-PAHs on biomarkers of genetic damage	PAHs in Urine • Policeman, bus driver and children Human exposure data • Adults and children	Exposure assessment	Environmental air pollution by c-PAHs can increase genotoxic risk
	Eco-surveillance	Eco-toxicology-use for investigating interaction of stressors for integrated risk assessment-Spain	Eco-toxicity data • Lab and Field Exposure data • Pollutants in the environment	Transactional approaches • Mesocosms • Lab animals in the wild • Wild animals in the lab Hazard assessment Exposure assessment	Eco-surveillance concept Eco-surveillance framework Use of general eco-toxicity data can help to identify new hazard, to refine exposure calculations
WP 2.3-Health surveillance	Health data review and surveillance strategy	---	Health outcome data (administrative datasets and surveys data)	Questionnaires to gather information on health data sources and availability	Health review and surveillance strategy
	Health outcome projection-lung cancer mortality	Need for a good methodology for projecting health outcomes in the future	Numbers of deaths from lung cancer for males and females: available from 1978 to 2002 (France) Past and future populations (20-95 years old) : estimated for 1978-2012	Mortality rates were o Estimated for 1978-2002, by 5-year periods and ages o Projected in 2003-2012, by 5-year periods and ages The analysis used o Age-period-cohort model o Bayesian approach o Autoregressive constraints	Bayesian APC models are a flexible and robust method to project cancer incidence and mortality Bayesian APC models do not require specific knowledge on aetiological factors
	How to overcome the lack of health data?	Major challenge in health impact assessment is to access to health outcomes baseline at a local scale	Case study applied to total mortality related to exposure on PM10 at local scale in 5 different countries in Europe (France, Italy, Spain, Greece, Finland)	Data gathering is in process	Ongoing
WP 2.4-Integrated monitoring	Integrated monitoring and data integration from multiple monitoring programs	---	---	Integrated monitoring framework Data integration structure Data integration methodologies	Revised review on integrated monitoring Integrated monitoring workshop report Revised integrated monitoring report
	PAHs and its health effect in Czech republic	Integrated monitoring Integrated data from multiple sources	Data/information from drivers, pressure, status, exposure, effects and action	Integrated monitoring framework Data integration structure Data integration methodologies	Ongoing
	PCBs and its health effects in Slovakia	Integrated monitoring Integrated data from multiple sources	Data/information from drivers, pressure, status, exposure, effects and action	Integrated monitoring framework Data integration methodology	Ongoing

2.3.3 Results of SP 3-Policy assessment

SP 3-Policy assessment tests and demonstrates the assessment methodology on a number of different policy issues. It comprises transports, housing, agricultural land use, water, chemicals in household products, wastes and climate. Until now, the first rounds of case studies are completed. The results from case studies are summarized in Table 5.

Table 5-a Summary of results from SP3 case studies-water, chemicals in household's articles and products (source: http://www.intarese.org).

Case study	Stressor	Health outcome	Findings	Limitations and uncertainties	Other comments
Water	THMs	Small for gestational age	Moderate excess risk of low birth weight (ca. 2-2.5%); equivalent to 1600-1700 cases/year	Lifelong effects of low birthweight (e.g. increased risks of cardiovascular illness) not considered.	Large geographic variations in risk, reflecting variations in THM concentrations
		Bladder cancer	Moderate excess risk of cancer (ca. 6-7%) in males, but low in females (ca. 0.3%); equivalent to ca. 580 cases/year (1400+ DALYs)	Data on exposure-response functions derived from pooled analysis across several countries; relevance to study population is unclear; differences in oxidation state (and thus toxicity) or arsenic not alllowed for	Risks in males ca. 20 times those in females; marked geographic variability in THM concentration and risk
Water (cont)	Arsenic		Low levels of arsenic in drinking water imply small excesscancer risks (<0.1% - equivalent to ca. 9 cases/year, or 24 DALYs)	Large uncertainties around risk estimates, due to sparseness of epidemiological data	Risks 2-3 times higher in males than females and mainly in 65 years+
	Nitrates	Methaemoglоninaemia	Extremely low excess risk (ca. 2%), equivalent to 1 case/10 years)	Large uncertainties in data on water consumption by children	
Chemicals in household articles and products	DBP	Reproductive	No exceedances of no observed adverse effect level, so no detectable health risk	Use of effect level extrapolated from animals; uncertainities in data on concentrations in products; exclusion of bystander exposures	Need to apply Monte Carlo methods to model distribution of (and uncertainties in) exposures and risk estimates; need for improved (population-specific) severity rates for DALY calculation
	Toluene	Neurological	Small risks, equivalent to 73 DALYs across Serbia	Exclusion of products with very low concentrations; effect level extrapolated form human volunteers; uncertainties in udage data and concentrations in indoor environment	
	Formaldehyde	Eye irritation; masopharyngal cancer	Moderate excess risk, equivalent to 3470 DALYs across EU	Exclusion of some health endpoints (e.g. sensitisation); uncertainties in reliability of no effect level (based on human volunteers); gaps in data on usage and concentrations; uncertatinties in severity weighting for ocular effects	

Table 5-b Summary of results from SP3 case studies-transport, housing and agriculture (Source: http://www.intarese.org).

Case study	Stressor	Health outcome	Findings	Limitations and uncertainties	Other comments
Transport	PM10, NO2; noise	Respiratory disease; cardio-vascular disease	Large reductions in emissions (10-30%); moderate reductions in concentrations (1-2%); small gains in health (ca 450 years per 100,000 people) from air pollution; ca. 2% reduction in noise annoyance.	Excludes: non-exhaust emissions (e.g. tyre wear); effects of physical exercise; non-residents (outside city); specific effects on susceptible sub-groups	Upstream effects greater than downstream (health) effects - vital importance of analysing full chain; effects vary geographically; time duration of policy crucial.
Housing	Cold and radon	Cardio-vascular disease; cancer	Small reductions in risk due to improvements in indoor temperature, almost offset by increased risks of cancer due to radon exposures, giving overall impact of < 0.4 daysof life gained/person.	Excludes other pathways of effect - e.g. via outdoor air pollution; lack of detailed data on building characteristics and ventilation means thatmodelling of exposures subject to substantial uncertainties	Results depend on 'hazard multiplier' used to weight effects of cardi-vascular disease versus cancer.
Agriculture	Pesticides (herbicides, insecticides, fungicides)	Breast, kidney. Panceratic, prostate cancer; leukaemia; non-Hodgkin's lymphoma; congenital anomalies; stillbirths	Moderate reduction in pesticide usage (<10kg/ha) leads to small reduction in cancer risk (ca. 230 cases/year) and congenital anomalies (130/year); stillbirthd reduced by ca. 30/year.	Data on pesticide usage are highly aggregated and modelling of usage rates has large uncertainties; pesticide usage provides poor proxy for exposure; data on exposure response functions sparse; land use scenario is too generalised to provide sound basis for modelling changes in farming practice; no account taken of impending (independent) policy-induced changes in pesticide usage	Upstream effects (on usage) greater than downstream effects on health; effects vary geographically, depending on land use. Need to take account of impending changes in permitted pesticides, and effects due to climate change.
	Pesticides (active ingredients)	Cancer	Moderate reduction in pesticide usage (<4kg/km2) leads to small reduction in risk of cancers (1/300,000)		

Table 5-c Summary of results from SP3 case studies-waste and climate (source: http://www.intarese.org).

Case study	Stressor	Health outcome	Findings	Limitations and uncertainties	Other comments
Waste	PM, NO2	Respiratory disease	Ca 1-1.25 days of life lost per person in each country, representing a total of 3000-4000 YLL across the 3 countries	Limited number of studies on which to base exposure-response function fro dioxin; uncertainties in effects of changes in technology on emissions from incinerators; exclusion of exposures during transport and storage	Important differences in risk over time due to changes in technology and emission control; long-term risks may be associated with closed landfill sites; need to include other links in the waste management system (collection, transport, storage) for overall impact assessment.
	Dioxin	Cancer	Ca. 3800 additional cases in three countries, mainly in Italy and UK, and mainly (90%) due to past (pre-2001) exposures from old incinerators		
	Unknown	Congenital malformations	Ca 100 additional cases of low birth weight, and 5-6 cases of congenital anomalies across the 3 countries, each year	Use of distance as proxy for exposure; very limited range of epidemiological studies on which to base exposure-response functions; lack of detailed information on landfill characteristics, waste composition, or emissions; exclusion of exposures during transport; exclusion of closed landfill sites.	
Climate	UV radiation	Skin cancer	Number of skin cancer cases in the 2 cities predicted to rise from 10,400 in 2001 to 14-15,000 by 2030, and 15-16,000 by 2050 (largely - 80% - due to BCC; deaths to rise from 270 to 380 aqnd then to 450 (mainly - 90% - due to melanoma); equivalent to ca. 9000 DALYs/year, compared to 7000 in 2001.	Baseline disease rates derived from other regions; incidence-mortality ratios derived from Australian data and assumed to apply in Rome and London; uncertainties in projections of UV radiation	Risks somewhat greater in males than females, and vary over time (peaking in 2030) as effects of past exposures work through the population.
	Heat, cold	Cardio-vascular; respiratory	Not available		

3 IDENTIFICATION OF DEVELOPMENT NEEDS

3.1 Main gaps in existing E & H monitoring programs

In summary, the main gaps in existing E & H monitoring programs are:
- Determined by its aim, often narrow focus
- Short-term
- Different measurement protocols and sampling designs
- Complexity, uncertainty and lack of understanding of the research questions
- Lack of appropriates skills, technical expertise and knowledge
- Some overlap and uncertainty about respective functions and duties
- Ineffective and duplicated monitoring effort
- Lack of methodology and tools for
  - Determining which parameters and/or indicators should be monitored, where and how frequent they should be monitored, and how the results should be analyzed, interpreted and reported
  - Integration of monitoring indicators
  - Control and qualification of uncertainties
  - Issues with exposure estimation

- Data availability/access/quality
  - Not in electronic form/incompatible format/lack of standards
  - Lack of knowledge on where data exist and how to access
  - Spatial/temporal issues
  - Confidentiality and privacy concerns

- Communication and outreach
  - Understanding stakeholder priorities
  - Language berries

3.2 How can gaps be addressed in integrated monitoring?

3.2.1 Integrated monitoring concept and its framework are needed

Currently, health risks of environmental stressors in European countries are monitored and assessed by a number of networks which established by different organizations and institutions. However, many of the monitoring programs have a narrow focus, are of a short-term, and most have different measurement protocols and sampling design. Existing data is not re-usable. The fragmentation and redundancy of the information provided has resulted in a poor basis for the integration of E & H monitoring at an European level, leading to some overlapping of efforts and a lack of harmonized quality data to form policy decisions. Therefore, a systematic approach, to monitor the environmental factors most relevant to health, health outcomes most influenced by the environment and the relationships between this two, is needed, in the view to support a consistent Pan-European long-term integrated monitoring of E & H program (see section 4).

In general, integrated monitoring can help to increase the extent, quality, timeliness and relevance of the information and knowledge base, in turn should lead to more informed decision-making.

In INTARESE, integrated monitoring can:

- Forms the backbone of integrated assessment and provides the framework in which any issue can be framed and assessed
- Integrated monitoring enables the best use of monitoring and surveillance data for integrated environmental health assessment
- Integrated monitoring brings together different sources of existing information and information systems regarding a certain issue. It generates an added value to these separate pieces of information
- Integrated monitoring helps generate synergy between information and data in order to tackle the issue at hand

3.2.2 Data integration methodologies are needed

In recent years, major scientific advances have been made in each of the monitoring technologies available (including ground- and space-based environmental monitoring, bio-monitoring and health surveillance) and in modeling methods (including process models, statistical models and geographical information system techniques-GIS). However, there are still key gaps in existing data integration capabilities, e.g. integration of monitoring indicators, methods for control and qualification of uncertainties, GIS and statistical modeling techniques, etc. Now there is a need to bring these advances together in order to identify and fill key gaps in the existing knowledge and methodologies, and to develop the tools needed to make them operational. Therefore, the databases developed by different monitoring and information networks, the scientific studies and the statistical approaches used need to be harmonized and integrated (section 5). The methods should be further extended to include beyond GIS and state of art statistical models (e.g. Bayesian methods and Monte Carlo simulation, etc.)

4 CONCEPT, FREMAWORK AND STRATEGY OF INTEGRATED MONITORING

4.1 Integrated environment and health monitoring concept

Based upon the goal of the project INTARESE, we define the integrated environment and health monitoring (IEHM) is ‘an ongoing and systematic process to determine, analyze and interpret environmental quality and environment-related health statuses.

IEHM requires the physical, chemical and biological measurements to be taken simultaneously over time of different E & H compartments at the same location.

A good IEHM need to establish mechanism for data sharing, improved data availability, accessibility, comparability, and enhanced exchange of information, between environment and health, across different environmental media, and within health.

IEHM is scale dependent, both temporal and spatial. The scale to be used will depend upon the project aims and objectives.

In INTARESE, IEHM is to explore the ways of linking and enhance various sources and technologies in order to provide a more integrated (e.g. EU-wide, multi-agent, multi-pathway, multi-media/receptor, etc.) approach to monitoring in the EU.

4.2 A conceptual framework for integrated environment and health monitoring

A conceptual framework of IEHM based upon the goal-oriented definition of IEHM developed in INTARESE (detail in D51) is illustrated in Figure 2.

In this framework, we include three type-oriented monitoring systems: the environmental system, the ecosystem and the human system. The environmental system is separated between natural and man-made environments in considering the policy relevance. Natural environment may refer to physical environment. This term includes physical phenomena that lack clear-cut boundaries, such as air, water, and climate, as well as energy, food, radiation, electric charge, and magnetism, not originating from human activity.

The man-made environment comprises the areas and components that are strongly influenced by man. It includes physical structures, public infrastructure, parks, man-made lakes, mines and rock quarries.

The ecosystem refers to the ecological setting, universal resources, ecosystem goods and services. The key components are complete ecological units that function as natural systems without massive human intervention, including all vegetation, animals, microorganisms, rocks, atmosphere and natural phenomena that occur within their boundaries.

Regarding the human system, we divide it into three subsystems, i.e. social-cultural, economic and institutional aspects. Social-cultural aspects include culture, demography, social infrastructure, knowledge, social interactions, social environment, and life style, etc. Economic aspects include economic infrastructure, economic development, and trade, etc.

Institutional aspects include institutional infrastructure, health policy, health-related policy, health services, etc (Huynen et al., 2005).

Exposure means contact between an agent and a target. Mainly used for air pollution. Exposure is usually described as concentration of the argent in the medium around the target during a defined duration (exposure duration) (http://www.intarese.org/glossary/term/90).

Effects include final point human health effects and all the mid-term process effects, e.g. effects on ecosystem, food chains, etc.

Compared with other monitoring frameworks, this IEHM framework includes three important aspects. First, we look at whole systems, not only individual components. It implies a broader approach and includes other elements than the traditional framework, which is restricted to the physical environmental stressors on the human health without considering the exposure on the ecosystem, man-made environment, and social-cultural, economic and institutional aspects. Second, we recommend monitoring processes, not only static elements in order to capture or identify the casual links, and at the end, we assist decision-making. It should cover the main media from pollution (e.g. sources, process and concentration) to exposure (e.g. exposure pathways, exposure routes and exposure factors) to human health effects (e.g. human dose and health effects mechanism). The third element is the spatial and the time dimensions. In summary, this framework can provide better information for the development of more effective environment and health policies dealing with sources and the impact pathway of health stressors.

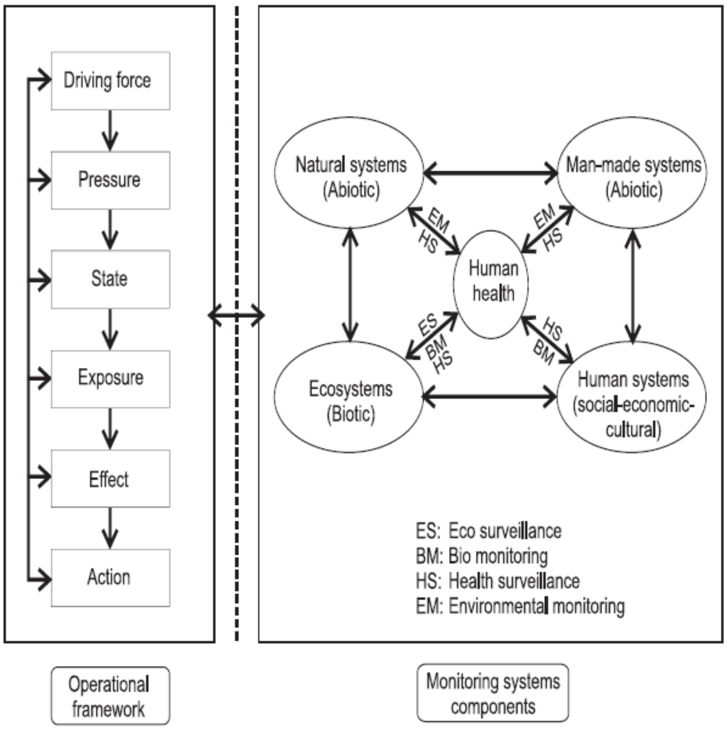

Figure 2 A IEHM framework for integrated environment and health assessment, combined DPSEEA model with environmental monitoring, eco-surveillance, bio-monitoring and health surveillance.

4.3 Integrated monitoring strategy

An important first step in an IEHM is to identify connections, possibly through preparation of a monitoring strategy. Continued monitoring of the situation is necessary. Therefore, we have proposed a general procedure for an IEHM in E & H fields.

· Section A. Plan monitoring diagram

The first step is the creation of a plan. The second step is its introduction. The third step is monitoring the implementation of the plan. The fourth step is to review the data gathered from monitoring the plan implementation. Decisions made through the review step feed into the next iteration of the plan cycle.

· Section B. Background information for integrated monitoring

In this section, except the general background information and database, the most important tasks include an explanation of some basic terms and concepts that are used in describing the project.

· Section C. The IEHM content

The content of IEHM can be presented in a series of tables summarizing sub-programs or work packages dealing with different components in relation to contaminants monitored in the target project.

· Section D. The effects studies of monitoring

This section deals with 'effects' studies according to the sub-programs or work packages for the contaminants monitored in section B, with separate sections concerning effects studies under the target project, such as studies concerning monitoring the effects of contaminants in humans. Ultimately, it will include a sub-section dealing with 'combined effects'.

· Section E. Supporting studies to IEHM

The section complete the activities covered in the two proceeding sections and represents essential additional components to the target project. Integrated supporting studies should provide detailed information required for future assessments to allow, for example, valid interpretation of the results of the IEHM. Together with more routine monitoring components, integrated supporting studies form an integral part of the target project.

· Section F. Outputs of IEHM

This part reports the monitoring results, including the elements necessary for meaningful reporting about monitoring programs to various audiences, including visualization techniques and reporting protocols.

5 INTEGRATED USAGE OF INFORMATION FROM MUTIPLE MONITORING PROGRAMS

This chapter examines the following questions:

- Why integrate multiple data sources?
- What are the challenges and issues of integrating multiple data sources for integrated environmental health impact assessment?
- What is data integration?

The relevant information is derived from journal articles and internet sources. A framework for performing integration of data over multiple data sources is developed. The purpose of this chapter is to take the first steps toward the development of a methodology for integrating multiple data sources (next chapter).

5.1 Integrating data sources across multiple monitoring programs: benefits, barrier and lessons

5.1.1 Why integrate information from multiple monitoring systems?

There are some obvious advantages in integrating information from multiple data sources. Such integration alleviates the burden of duplicating data gathering efforts, and enables the extraction of information that would otherwise be impossible (Subrahmanian, et al., 1996).

Subrahmanian, et al. (1996) gives the following examples of benefits of data integration: "... law enforcement agencies such as Interpol benefit from the ability to access databases of various national police forces, to assist their effort in fighting international terrorism, drug trafficking, and other criminal activities. Insurance companies, using data from external sources, including other insurance company and police records, can identify possible fraudulent claims. Medical researchers and epidemiologists, with access to records across geographical and ethnic boundaries, are in a better position to predict the progression of certain diseases. In each case, the information extracted from the integrated sources is not possible when the data sources are viewed in isolation."

Data integration is intended to add value to the data that are already collected and available in variously scattered places within the same system. Data integration is necessary occur before an environmental health impact assessor can conduct a high-level and high-quality analysis. It is common to see multiple units within a Ministry of Environment or health collect and manage large database and not share them with each other. These various sets of data are collected to describe certain element of the system. In general, these multiple sets of data are often designed in varying database applications, organized in different platforms, and coded with self-developed identification code. As a result, the data cannot readily be integrated or used integrative unless a data integration strategy is implemented. Without coordinated management, there cannot be a monitoring and evaluation system, a planning and policy analysis system, or an environmental health impact system that is effective and policy-relevant. Clearly, we must integrate the data from multiple sources so that we can conduct the right data analysis to answer the right policy questions. Multi-level data from multiple sources and years, once centrally integrated and organized, could have a tremendous value for policy-relevant research and analysis and improvement in environmental health management.

In summary, integrated usage of information from multiple environment and health monitoring programs can bridge the gaps between environment and human health. A common framework for the integration of information from environmental monitoring, biomonitoring and health surveillance can facilitate achieving the goals of greater efficiency and quality and of better-informed decisions, in ways that support specific information management needs. The general benefits from a documented, repeatable data integration process are: (i) easy to define; (ii) easy to query; (iii) easy to use; and (iv) eliminate the redundant data.

5.1.2 What are the challenges and issues by integrating information from multiple monitoring programs?

5.1.2.1 Challenges on data issues

5.1.2.1.1 Data issues in general

5.1.2.1.1.1 Missing data

For missing data, the challenges are:

- Data is not always available
- Missing data may be due to
  - equipment malfunction
  - inconsistent with other recorded data and thus deleted
  - data not entered due to misunderstanding
  - certain data may not be considered important at the time of entry
  - not register history or changes of the data

5.1.2.1.1.2 Noisy data

There is often random error in a measured variable. This leads to a noise data. The incorrect attribute values may be due to

- faulty data collection instruments
- data entry problems
- data transmission problems
- technology limitation
- inconsistency in naming convention

5.1.2.1.1.3 Inconsistent data

When you examine a data plot, you might find that some points appear to dramatically differ from the rest of the data (e.g. inappropriate values, Males being pregnant, or having a negative age). In some cases, it is reasonable to consider such point’s outliers, or data values that do not appear to be consistent with the rest of the data. Such inconsistent data may be due to

- data sample problem
- equipment malfunction
- data entry problem

5.1.2.1.2 Data issues in environment and health fields

Before examining statistical methods for linking various types of data, it is necessary to investigate data sources that are available for tracking and linking hazards, exposure, and health effects (Mather et al., 2004). Fundamental factors that provide confidence in the results of data linkage are data quality, appropriate use of the data, and consideration of data limitations. The quality of hazard, exposure, and HOD (Health Outcome Data) are diverse, and the uses and limitations of data outside of its original purpose are not yet well defined (Table 6).

Table 6 Uses and limitations of environmental monitoring data, bio-monitoring data and health surveillance data.

Data sources	Uses	Limitations
Environmental monitoring	Assessment of exposure • Measure levels of chemicals that people might be exposed to (e.g. in air, food or drinking water) • Support environmental data for evaluating exposure	Difficult to access or not available Not intended for exposure assessment Not representative in time and space Incomparable or unknown quality data
Bio-monitoring	Determine amount of exposure Identify highly exposed individuals or groups Identify hazardous exposures Evaluate trends in exposure over time Evaluate effectiveness of public health actions Identify new or emerging exposures Help set priorities for human health effects research In conjunction with other information: • Understand how people are being exposed • Establish or test easier (non-invasive) ways to estimate exposures • Identify hazardous levels of exposures	Invasive and difficult to obtain samples Results can be difficult to interpret and communicate to participants • Toxic levels (benchmarks) for many chemicals are not known • Lack of "normal" or background levels are unknown for many chemicals • Unclear health impact for chemicals detected at very low levels Integrates exposure from all sources Studies can be very expensive
Health surveillance	Describes health status of populations Describes distribution and frequency of disease	Data completeness • Micro-morbidity (e.g. indoor to outdoor) • Macro-morbidity (e.g. one country to another country) • Non-spatial variability Individual behaviour • Lifestyle factors • Genetic susceptibility Misclassification of disease Generalizability to population Privacy and confidentiality issues
All three types of data	Integrated environmental health impact assessment	Completeness of records Timeliness of reporting Availability of access to data Geographic resolution of the data (scale) Frequency of data collection Lack of data collection standards

Environmental data (hazard-exposure data)

Hazard data tell us about pollutants that may be found in the environment, which can cause potential health problem. In INTARESE, hazard data from environmental monitoring is intended for exposure assessment, which can determine the amount, duration, and pattern of exposure to the pollutant.

Bio-monitoring data (exposure-dose data)

Bio-monitoring is the direct measurements of environmental chemicals, their metabolites or reaction products in people, usually in blood, urine, hair or milk. Exposure is defined as contact between an agent and a target. Dose is defined as the amount of agent that enters a target after crossing an exposure surface. If the exposure surface is an intake dose, the dose is an absorbed dose/intake dose; otherwise, it is an intake dose. In INTARESE, exposure and dose data are intended to estimate how much of the certain pollutant it would take to cause varying degree of health effects that could lead to illnesses.

Health surveillance data (health effect data)

In general, health data includes mortality and morbidity (incidence). In practice, it generally relied on a small number of measures, such as the number of monitoring region deaths, age-adjusted death rates for the monitoring region, and survival. In addition, health surveillance data also include health behaviour and determinants of behaviour (for example, knowledge, attitudes, and beliefs, etc.). In INTARESE, health effect data are intended to be linked to hazard-exposure-dose data in the view to assess the risk for the certain pollutant to cause health problem in the general population.

Other relevant data (covariates)

Other relevant data may include residence, proximity to known health effect-causing sources, socioeconomic status, age, race, and adherence to treatment regimens that may be related to incidence and hazard/exposure.

5.1.2.2 Challenges on data gathering

In general, multiple monitoring programs are implemented by multiple organizations. In practice, using an integrated approach across multiple organizations presents a number of challenges (Zeng, 1999): (i) obtaining data from other agencies is often difficult, and in many cases will be impossible; (ii) legal restrictions often prevent access to a particular data set; (iii) it is also difficult to obtain the cooperation of agency heads, who will often decide whether to participate in data sharing; (iv) data sharing often requires compatibility between different computer systems as well as the availability of information system personnel; (v) data integration also requires the concurrence of system administrators, directors of programs, and services consumers; and (vi) in addition, more cost and time, few data standards, and information overload are also barriers to data integration across multiple organizations.

5.1.2.3 Challenges on data analyzing

Without considering the challenges on obtaining data, there are still a number of technical challenges:

- Increase in data volume
- Increasing need for interdisciplinary use of data
- Integration of data among systems is needed to answer questions that address diverse societal benefits
- Current data from monitoring systems already face challenges, for instance, with regard to spatial information in Europe: (i) fragmentation of data sets and sources (e.g. data is stored in disparate systems); (ii) gaps in data availability; (iii) lack of harmonization between data sets (e.g. data is using inconsistent formats, such as word processing, flat text files, mail messages, scanned images, spatial data files, audio/voice files, video clips, spreadsheet files, databases, graphics and CAD (Computer-Aided Design) files) at different geographical scales make it difficult to access and use available spatial data throughout Europe (Smolders et al., 2008); and (iv) issues around data quality and accuracy.

5.1.3 Points for clarification

Colleting, integrating and analyzing information on environmental exposure, environment-related disease and their trends, must specify the purpose of data integration clearly, identify information needs, and show how they can be integrated. In addition, data integration projects require a significant time commitment. Barriers to participation must be identified and addressed (Zeng, 1999).

5.2 What is data integration?

Data integration is the process of the standardization of data definitions and data structures by using a common conceptual schema across a collection of data sources (Heimbigner and McLeod, 1985; Litwin, et al., 1990). Integrated data will be consistent and logically compatible in different systems or databases, and can use across time and users (Martin, 1986).

Goodhue et al. (1992, p294) defined data integration as "the use of common field definitions and codes across different parts of an organization". According to Goodhue, et al. (1992), data integration will increase along one or both of two dimensions: (1) the number of fields with common definitions and codes, or (2) the number of systems or databases adhering to these standards. Data integration is an example of a highly formalized language for describing the events occurring in an organization's domain. The scope of data integration is the extent to which that formal language is used across multiple organizations or sub-units of the same organization. The objective of data integration is to bring together data from multiple data sources that have relevant information contributing to the achievement of the users' goals (http://www.ctg.albany.edu/publications/reports/multiple_data_sources).

The Advanced Forest Technologies (AFT) in Canada (http://www.ctg.albany.edu/publications/reports/multiple_data_sources) identified the following factors that must be addressed to integrate data properly:

- identification of an optimal subset of the available data sources for integration

- estimation of the levels of noise and distortions due to sensory, processing, and environmental conditions when the data are collected
- the spatial resolution, the spectral resolution, and the accuracy of the data
- the formats of the data, the archive systems, and the data storage and retrieval
- the computational efficiency of the integrated data sets to achieve the goals of the users

5.3 The framework of integrated information from multiple monitoring programs

The huge amount of data has been gathered, organized, and stored by a small number of individuals, working for different organizations on varied problems (Subrahmanian et al., 1996). In light of the multisource and complexity of environmental health problems, the ever-increasing volume of monitoring data, and the expected benefits of integrating the data, a framework for performing integration over multiple data sources is necessary.

5.3.1 Fundamental premise for linking data

Fundamental questions must be asked before linking different types of data (Mather et al., 2004). For example, is there a scientific basis for connecting the data sets? Are the data to be linked adequate and appropriate for addressing the issue? There are several useful frameworks for examining these questions, e.g. DPSIR (EEA), DPSEEA (WHO), INTARESE whole chain approach (Briggs, 2008), and INTARESE IEHM framework (www.intarese.org). In general, integration of information on environment, human bio-monitoring data, and health data should preferably be obtained within an exposure–dose–response triad approach (EDR-Triad), where exposure aims at quantifying the amount of a pollutant present in the environment through different routes or compartments, dose focuses on the internal concentration of this pollutant bio-accumulated over time and through different pathways, and response incorporates the physiological and/or epidemiological consequences of the observed internal dose (Andersen et al., 1992; Committee on Biological Markers of the National Research Council, 1987; Dietert et al., 2000; Smolders and Schoeters, 2007).

Without defining the appropriate rules for data linkage, indiscriminate linking may lead to erroneous conclusions. This highlights the need to understand each data set, articulate the uses and limits of each data set, and standardize methods for using the data (Mather et al., 2004).

The framework for integrated usage of information from multi monitoring programs highlights the necessity for collaboration and partnerships. Data sharing is essential to integrated information and requires overcoming the organizational and functional problems limiting collaboration between health and environmental agencies. Further, multidisciplinary teams with expertise in epidemiology, statistics, toxicology, environmental health, database management, GIS, and other areas will be required to ensure sound science and appropriate analysis of data.

5.3.2 A structural framework of integrated data: step by step plan

The basic structure of the integrated usage of information from multiple monitoring programs contains seven sequential steps (see Figure 3).

5.3.2.1 Step 0: define research questions

In this step, the objective of data integration should be defined clearly from the start. It can help to identify databases that are needed to collect in the next step and the source of data. For example, in the project INTARESE, developing the methodologies on integrated environment and health impact assessment at European level is the main purpose of the data integration from difference sources. In turn, based upon this objective, it is clearly that data from both environmental and health agencies, and other relevant data from other sources are needed.

5.3.2.2 Step 1: collect data

In step 1, the data collection takes place. Data collection is determined by the research questions. In INTARESE, it means that data from multiple sources (e.g. environmental monitoring, eco-surveillance, bio-monitoring, and health surveillance, etc.), multiple years, and multiple levels (e.g. local, regional, national, international, etc.) shall be collected. It is necessarily required both routinely available and specialist data sets, e.g. information on pollution sources, the state of the environment, human population and the individual, etc.

5.3.2.3 Step 2: pre-process data

Before the data integration, it is necessary to do data pre-processing, including define data characteristics, format and process data, assess data usefulness and quality. Why data pre-process? In general, there are three reasons: (i) data in the real world is dirty, e.g. incomplete (e.g. lacking attribute values, lacking certain attributes of interest, or containing only aggregate data, etc.), noisy (i.e. containing errors or outliers), and inconsistent (i.e. containing discrepancies in codes or names); (ii) no quality data, no quality mining results, e.g. quality decisions must be based on quality data, and data warehouse needs consistent integration of quality data; (iii) a multi-dimensional measure of data quality, e.g. a well-accepted multi-dimensional view (e.g. accuracy, completeness, consistency, timeliness, believability, value added, interpretability, accessibility, etc.), and broad categories (e.g. intrinsic, contextual, representational, and accessibility, etc.).

The major task in data pre-processing is data cleaning, which are (i) fill in missing values; (ii) smooth noisy data; (iii) identify or remove outliers; and (iv) resolve inconsistencies.

5.3.2.4 Step 3: integrate and enhance data

Data integration is one of the most important steps. Data integration is a process to integrate multiple databases, data cubes, files, or notes. In INTARESE, integrating and enhancing data mean that data from multiple sources, multiple years, and multiple levels shall be linked, integrated, or merged. These data sets also need to be combined in different ways, according to the issue under consideration (e.g. the exposure of interest, the scale of analysis, or the population group). Often it is difficult to incorporate data on combined environmental pollutant loads or data on biomarkers of exposure or effect, for reasons that include non-representatives, non-availability, non-transferability, or because the effects of combined loads are not well understood and thus impossible to use. GIS and statistical modelling techniques need to be adopted, including Bayesian techniques, to help analyze the information in a coherent and logical (e.g. hierarchical) manner, allowing for their varying quality, completeness and extent. Statistical techniques for combing data sources (e.g. assimilation techniques) will also need to be adopted.

5.3.2.5 Step 4: analyze data

In this step, the data analysis will be done toward the research objective and the methods for the data analysis will be determined by the databases that have been collected. The major steps of data analysis are (i) data transformation, including normalization (scaling to a specific range) and aggregation; and (ii) data reduction, including:

- obtains reduced representation in volume but produces the same or similar analytical results
- data discretization: with particular importance, especially for numerical data
- data aggregation, dimensionality reduction, data compression, generalization

In INTARESE, data analysis will be done in the specific case studies, e.g. PAHs exposures and their relationship to pregnancy outcome and respiratory diseases in children in Czech Republic; PCBs and dioxins and their relation to thyroid gland, glucose homeostasis, neurodevelopment disorders in Slovakia, and exposure to air pollutants and asthma, allergies and respiratory diseases in children in the Czech Republic, etc.

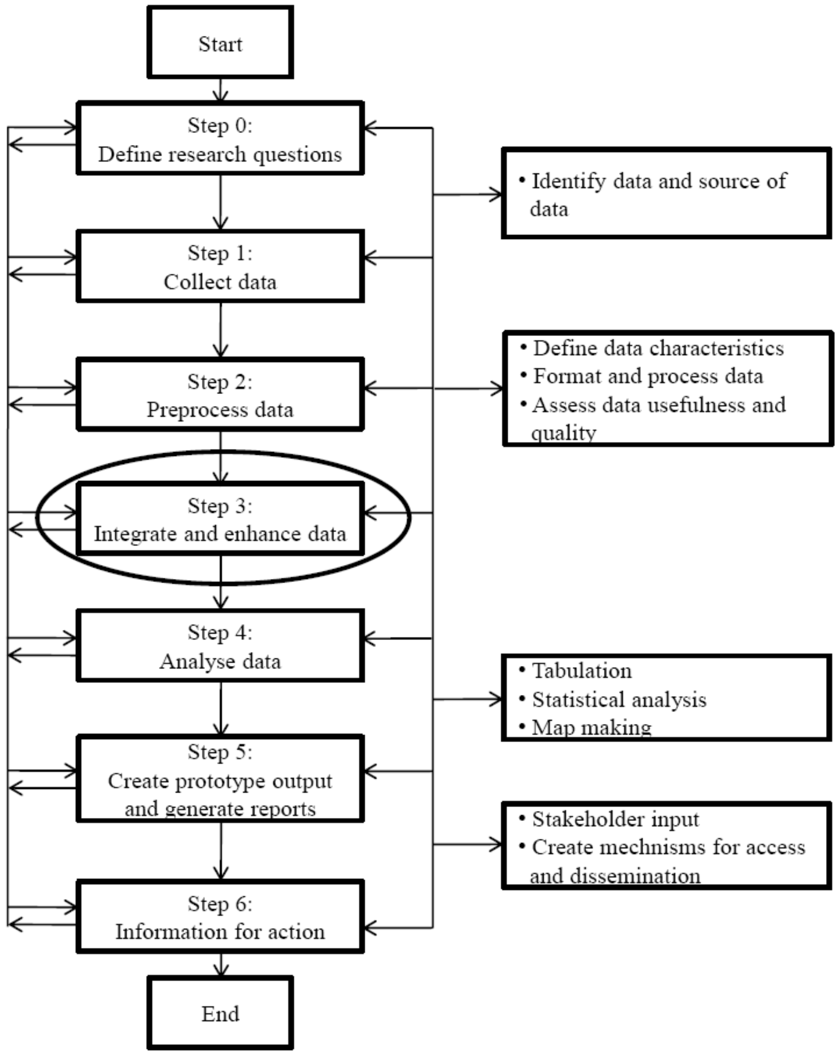

Figure 3 A structural framework of integrated information from multiple monitoring programs.

5.3.2.6 Step 5: create prototype output and generate reports

In this step, you need to create prototype output and generate reports. In general, tabulation, results from statistical analysis and map making are needed.

5.3.2.7 Step 6: information for action

In this step, information for action you need to drive prototype results, to get stakeholder input, and to create mechanisms for access and dissemination, therefore the visualization tools (e.g. maps, interactive computer mapping interface) are necessary. It can help to: (i) enable rich discussion about data needs and uses of monitoring information; and (ii) make statistical issues more accessible to stakeholders.

6 RELEVANT METHODOLOGIES AND TOOLS FOR DATA INTEGRATION

6.1 How to handle redundant data in data integration?

6.1.1 How to handle missing data?

There are several ways to deal with the missing data:

- Ignore the missing data: usually done when class label is missing (assuming the task is classification-not effective in certain cases)
- Fill in the missing value manually
- Fill in the missing value automatically with
  - use a global constant to fill in the missing value
  - use the attribute mean to fill in the missing value
  - use the attribute mean for all samples of the same class to fill in the missing value
  - use the most probable value to fill in the missing value: inference-based such as regression, Bayesian formula, decision tree, etc

6.1.2 How to handle noisy data?

There are several ways to deal with the noisy data:

- Binning method: first sort data and partition into (equi-depth) bins, then one can smooth by bin means, smooth by bin median, smooth by bin boundaries, etc.
- Clustering: detect and remove outliers
- Semi-automated method: combined computer and human inspection, detect suspicious values and check manually
- Regression: smooth by fitting the data into regression functions

6.1.3 How to handle inconsistent data?

In general, the inconsistent data can be dealt by:

- Manual correction using external references
- Semi-automatic using various tools
  - to detect violation of known functional dependencies and data constraints
  - to correct redundant data

6.2 Relevant methods and tools for linking data from environmental monitoring, bio-monitoring and human health surveillance

After handled redundant data in data integration, in addressing connectivity of existing monitoring systems, there is a need to address the tools that are needed to link WP 2.1's environmental monitoring data (hazard and exposure), WP 2.2's bio-monitoring data (exposure and dose) and WP2.3's health data (health effect).

6.2.1 Methods and tools for link exposure and dose data

In general, there are two types of models can be used to link exposure and dose data. First, the Physiologically Based Pharmacokinetic (PBPK) models are powerful computational tools that can be used to link exposure to the internal concentrations of parent compounds and/or active metabolites at the target site(s) of toxicity (http://cfpub.epa.gov). Second, the Biologically Based Pharmacokinetic (BBPK) models are being increasingly used in the risk assessment of environmental chemicals. These models are based on biological, mathematical, statistical and engineering principles. Their potential uses in risk assessment include extrapolation between individuals, species, doses and routes of exposures (http://cfpub.epa.gov). In addition, other tools on hazard identification and exposure assessment can also be used to link exposure and dose data.

6.2.2 Methods and tools for link dose and health effect data

There are many tools to link dose and health effect, e.g. tools on spatial statistics, tools on time-activity patterns, tools on EPHT (Environmental Public Health Tracking, http://www.cdc.gov/eceh/tracking), tools on dose-response assessment (DistGEN, GEN.T, http://www.foodrisk.org/resource_types/tools/dose_response.cfm) and risk characterization, etc.

DCAL (Dose and Risk Calculation software) is a comprehensive software system for the calculation of tissue dose and subsequent health risk from intakes of certain pollutant or exposure to specific pollutant present in environmental media (http://www.wise-uranium.org/rdr.html).

6.2.3 Methods and tools for link hazard, exposure and health effect data

Wakefield and Elliott (1999) and Banerjee et al. (2004) reviewed a variety of statistical methods appropriate for the analysis of environmental and health data as well as the health/environment relationship (Wakefield and Elliott 1999). These methods attempt to realistically represent the hazard-exposure-disease while also considering measurement issues. Mather et al. (2004) separated these methods into three groups generally representing increasing complexity of study design (Table 7).

- Group 1: Tracking and Trend Analysis: It describes spatial and temporal distribution of hazards and outcomes independently and elucidates trends and relationships that can be further explored. These descriptive methods provide basic information to agencies and policymakers and suggestions for further studies, e.g.
- Group 2: Ecologic Analysis: It focuses on ecologic studies that associate hazard with health outcomes using recently developed methods such as GIS spatial analysis, hierarchical models, and Bayesian methods. These methods address environmental and disease measurement issues, and experience with their use will generate hypotheses and a core set of analyses that may become the standard methods for linking health and environmental data.
- Group 3: Etiologic Research Studies: It relates exposure to outcome using traditional epidemiologic study designs to test hypotheses. These are research studies that should build on preceding descriptive and ecologic analyses.

Here, we described each of these methods one by one.

Table 7 Summarization of statistical methods for linking health, exposure and hazards data (Mather et al., 2004).

Groups	Subgroups	Relevant methods
1 Tracking and Trend Analysis	Time trends	Cell-count methods that compare observed with expected counts of events (Knox, 1964; Openshaw et al., 1987, 1988). Adjacency methods that examine whether areas of high rates of disease are likely to be adjacent to other high-rate areas (Moran, 1948). Distance or nearest-neighbour methods that compare physical distances between cases to expected distance (Besag and Newell, 1991; Cuzick and Edwards, 1990; Mantel, 1967). Other statistical methods that can be used to determine interarrival times between rare disease cases or to model seasonal patterns using time series methods, auto-regression methods, and joinpoint regression (Kim et al., 2000).
	Spatial analysis and geographic distribution	GIS that can examine each type of data and compare disparate health and environmental data Tools that can disparate health and environmental data o GeoDa (Anselin et al., 2004) o SaTScan software (SaTScan, 2004) o TerraSeer Space Time Intelligence System (TerraSeer, 2004)
	Disease mapping	Methods to compute and visualize the spatial and temporal-spatial variability in disease/mortality controlling for such covariates as age, race, sex, and deprivation are currently available, as are extensions of the method to smooth the data and model heterogeneity and clustering of the area-specific effects (Banerjee et al., 2004; Wakefield and Elliott, 1999). • Traditional approach • Bayesian framework
2 Ecologic Analysis	Ecologic epidemiologic studies	Analysis of ecologic studies can be conducted visually by • Interpreting the slope of a line plot of the exposure rate by the disease rate for each unit • Using the correlation coefficient *r*, as a measure of association
	Geographic correlation studies	These studies model the interrelationships of hazard, exposure, and health over time and space. • Poisson regression provides the framework for modelling the rates for rare diseases • Binomial or survival analysis is suitable when disease is more common • The models are hierarchical when hazard data are used and are thus subject to ecologic bias. Spatial correlation in the data should be anticipated • The methods for estimating parameters relating hazard to health outcomes in these models are by means of likelihood methods and by Bayesian methods
	Multilevel models	Multilevel models estimating hazard and health outcome effects and controlling for potential confounders and covariates provide hypothesis-generating information • It will likely require more refined hazard and disease data • Statistical methods are available but are not trivial to run and interpret, and the potential for ecologic bias remains
3 Etiologic Research Studies	Epidemiologic studies	It associates exposure in individuals to health outcome by • Case-control studies in rare diseases • Cohort studies in groups such as in occupational settings Statistical analysis of environmental data when appropriate exposure measures are of high quality is handled quite readily by • Multiple logistic regression in case-control studies • Survival analysis methods such as Cox regression

6.2.3.1 Geographical information systems (GIS)

GIS are "automated systems for the capture, storage, retrieval, analysis, and display of spatially referenced data" (Clarke et al., 1996; Higgs and Gould, 2001). GIS can relate otherwise disparate issues on the basis of common geography, revealing hidden patterns, relationships, and trends that are not readily apparent in spreadsheets or statistical packages, and GIS often creating new information from existing data resources. This feature implies, in E & H fields, GIS is a useful instrument to link the indicators from environmental monitoring, bio-monitoring and health monitoring by a visual presentation. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image on a map and a record in an attributed table. Apart from, for example, simply plotting environmental monitoring data or morbidity/mortality information on a map, GIS also offers important opportunities for inter- or extrapolation of data, for a geographical representation of monitoring or modelling data, and for the visualization of overlaps between different layers of information (Smolders et al., 2008).

In general, GIS mapping techniques can be used in two main ways to show the links between environment and health (http://www.who.int/heli/tools/maps/en/index.html): (i) simple overlays (comparisons) of environmental monitoring, bio-monitoring and socioeconomic (health) data can be used to identify patterns, which can then be investigated later for correlations; and (ii) once the causal relationship between environment and health is known, however, spatial models can also be developed to predict changes in health based on environmental changes.

Without doubt, GIS application will be the cornerstone of an integrated monitoring system. Its spatial application techniques will be the best options to provide effective linkage and integration among exposure-dose-response (Smolders et al., 2008). The use of GIS techniques in integrated data from different monitoring programs will be determinately considered and enhanced further in the next step case studies.

In underneath, we summarized several GIS tools that were designed and implemented to help environmental health research in linking environmental and health data.

6.2.3.1.1 GIS-EpiLink: A Spatial Search Tool for Linking Environmental and Health Data

GIS-EpiLink was designed and implemented to help epidemiologists facilitate their research in linking environmental and health data. The tool can be used to search for any pair of environmental sites and cases or controls based on different search criteria when distance is used as a proxy for exposure. For example, the location of an environmental site, the location of the maternal address of a case or control, the environmental hazardous materials (e.g., different chemicals) in question, and a threshold distance between the location of an environmental site and the location of a maternal address of a case or control can be combined into different search criteria. The search results then can be used for subsequent epidemiological analyses (Zhan et al., 2006).

6.2.3.1.2 TOXMAP: A GIS Tool for Exploring Environmental Health Data

TOXMAP (http://toxmap.nlm.nih.gov) is a GIS from the Division of Specialized Information Services (http://sis.nlm.nih.gov) of the US National Library of Medicine (NLM) (http://www.nlm.nih.gov) that uses maps of the United States to help users visually explore data from the US Environmental Protection Agency (EPA)'s Toxics Release Inventory (TRI) and Superfund Program. For more information, see the NLM TOXMAP Fact Sheet (http://www.nlm.nih.gov/pubs/factsheets/toxmap.html).

6.2.3.2 Hierarchical models

A hierarchical data model is a data model in which the data is organized into a tree-like structure. The structure allows repeating information using parent/child relationships: each parent can have many children but each child only has one parent. All attributes of a specific record are listed under an entity type (http://en.wikipedia.org/wiki/Hierarchical_model).

In a database, an entity type is the equivalent of a table; each individual record is represented as a row and an attribute as a column. Entity types are related to each other using 1: *N* mapping, also known as one-to-many relationships.

6.2.3.3 Bayesian Belief Networks (BBN)

A Bayesian Belief Networks (BBN) is a probabilistic graphical model that represents a set of random variables and their conditional independencies via a directed acyclic graph (DAG). For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases (http://en.wikipedia.org/wiki/Bayesian_network).

BBNs perform just such a function, providing a rational method for the integration of the best possible data from a variety of sources (Wooldridge and Done, 2003). A BBN can also incorporate prior knowledge in order to more accurately model a complex system, which may be difficult when using other techniques (Pollino, 2005).

6.2.3.4 Multiple Lines and Levels of Evidence (MLLE)

Multiple Lines and Levels of Evidence (MLLE) were originally developed for epidemiological studies when it was difficult to assign causality. It was first proposed by Hill (1965) in the medical field and has since been used in human and ecological risk assessments (Culp et al., 2000; Fairbrother, 2003). It is now being adapted by NRM (Natural Resource Management) (Adams 2003; Young et al., 2006). At present, MLLE method is broadly used in research to explore cause-effect relationships (Norris et al., 2005).

6.2.3.5 Advanced statistical models

There are many statistical models used in different monitoring programs. Because of the need to integrate monitoring indicators in integrated monitoring programs, the use of multivariate statistical models (e.g. connecting information from different sources through models) need to be considered and developed.

6.2.3.6 Techniques for assessing uncertainty

There are a large numbers of sources of uncertainties in integrated monitoring in E & H fields, e.g. inaccuracies in observations or insufficient numbers of observations, missing components or errors in the data, random sampling error and biases (non-representativeness) in a sample, etc. All types of uncertainty require to be handled by adequate analytical techniques. A more systematic and structured approach for uncertainty analysis should be recommended.

6.2.3.7 Techniques for quality assurance and quality control

Quality assurance (QA), quality control (QC) and standard operating procedures (SOP) are separate components of an integrated monitoring program that work together to provide data of known quality. QA, QC and SOP together can minimize and quantify the errors that are introduced in sampling, and allow tracking of errors that might occur. One of the most important aspects of quality assurance in a monitoring program is the development of a quality assurance plan, which should identify in a clear way the quality of the data needed and describe in detail the planned actions to provide confidence so that the program will meet its stated objectives (Shampine, 1993). These should be done with all stakeholders and for each objective. Quality control data, which allow for the quality and suitability of the environmental and health data to be evaluated and verified, should be collected and utilized as an integral part of the QA effort associated with a monitoring programs (Shampine, 1993). QA/QC should address the data quality, the data type, quality should be consistent and comparable, and the data should be available and accessible.

6.3 Relevant programs for linking data from environmental monitoring, bio-monitoring and human health surveillance

Except the methods and tools for data integration have been mentioned in last section, there are several networks/programs which are ongoing to develop methodologies for linking data/information from environmental monitoring, bio-monitoring and human health surveillance. The methods and tools from such ongoing programs need to be paid more attention.

6.3.1.1 Environmental Public Health Tracking (EPHT) program

Environmental Public Health Tracking (EPHT) program, developed by the Centers for Disease Control and Prevention (CDC), is the ongoing collection, integration, analysis, interpretation, and dissemination of data on environmental hazards, exposures to those hazards, and related health effects. The goal of tracking is to provide information that can be used to plan, apply, and evaluate actions to prevent and control environmentally related diseases (http://www.cdc.gov/nceh/tracking).

6.3.1.2 Health and Environment Linkages Initiative (HELI)

HELI is a global effort by WHO and UNEP to support action by developing country policymakers on environmental threats to health. HELI encourages countries to address health and environment linkages as integral to economic development. HELI supports valuation of ecosystem 'services' to human health and well-being services ranging from climate regulation to provision/replenishment of air, water, food and energy sources, and generally healthy living and working environments. HELI activities include country-level pilot projects and refinement of assessment tools to support decision-making (http://www.who.int/heli/en).

6.3.1.3 Connectivity between Environment and Health Information Systems (CEHIS)

Connectivity between Environment and Health Information Systems (CEHIS) is a 12 months study on behalf of DG-INFSO (SMART) for supporting the synergy between research and policies. It will provide a state-of-the-art assessment for the integration of environment and health information systems. As Information Systems are considered systems that use information technology to capture, transmit, store, retrieve, manipulate, or display information for environment and/or health, often relying on databases. The aim of CEHIS is to support the synergy between research and policies (http://envihealth.jrc.ec.europa.eu/CEHIS).

6.3.1.4 Action N° 35 of the French NEHAP (National Environment and Health Action Plan)

The aim of action N° 35 of the French NEHAP is to improve the performance and integration of environment and health information systems. It has two sub-actions: (i) inventory of the existing databases in the fields of health and the environment; and (ii) survey of the linkage between environment and health data (http://www.sante-environment-travail.fr).

7 SUMMARIZATION AND RECOMMENDATIONS

7.1 A integrated environmental health monitoring concept is defined

We defined the IEHM is an ongoing and systematic process to determine, analyze and interpret environmental quality and environment-related health status.

7.2 A conceptual framework and a structural framework of an integrated environmental health monitoring project/system/network are developed

The chapters 4 and 5 described the conceptual framework and the structural framework of an IEHM project/system/network. In summary (See Figure 4), it includes:

- Monitoring and surveillance, a systematic, coordinated monitoring and surveillance of hazards, exposures and health outcomes
- Data linkage, to examine potential relationships between environment and health, and to help to develop relevant tools to generate future hypotheses
- Integrating environment and health, to improve understanding of relationships between environmental exposures and public health outcomes to guide action

7.3 The methodologies on data integration are gathered

The linkage of two or more types of data provides a powerful tool, but only if the steps in "hazard-exposure-outcome" model are considered (Thacker et al., 1996). The lack of exposure data is an impediment to more complex linkages. In the descriptive analyses, the lack of exposure data may be acceptable, but studies of more complex linkages will require more and better data (Mather et al., 2004).

Statistical methods are available to link hazards and covariates to health outcomes; however, the appropriate uses and limitations of each data set must be taken into account (Mather et al., 2004).

Newer methods such as GIS spatial analysis, hierarchical models, and Bayesian methods are promising but require experience and repeated use with various types of linkages before they become standard techniques.

7.4 An integrated environmental health monitoring project/system/network is proposed

As we identified, the gaps in existing E & H monitoring programs (Detail in chapter 3) in Europe are:

- Environmental health system is inadequate & fragmented
- Responsibilities are scattered among multiple agencies
- Unable to link environmental and health databases

Because of the lack of basic information linking environment and chronic disease that undermines intervention and prevention, we strongly recommend to establish an ‘integrated environmental health monitoring project/system/network’ at each national wide or even whole European level (See Figure 4).

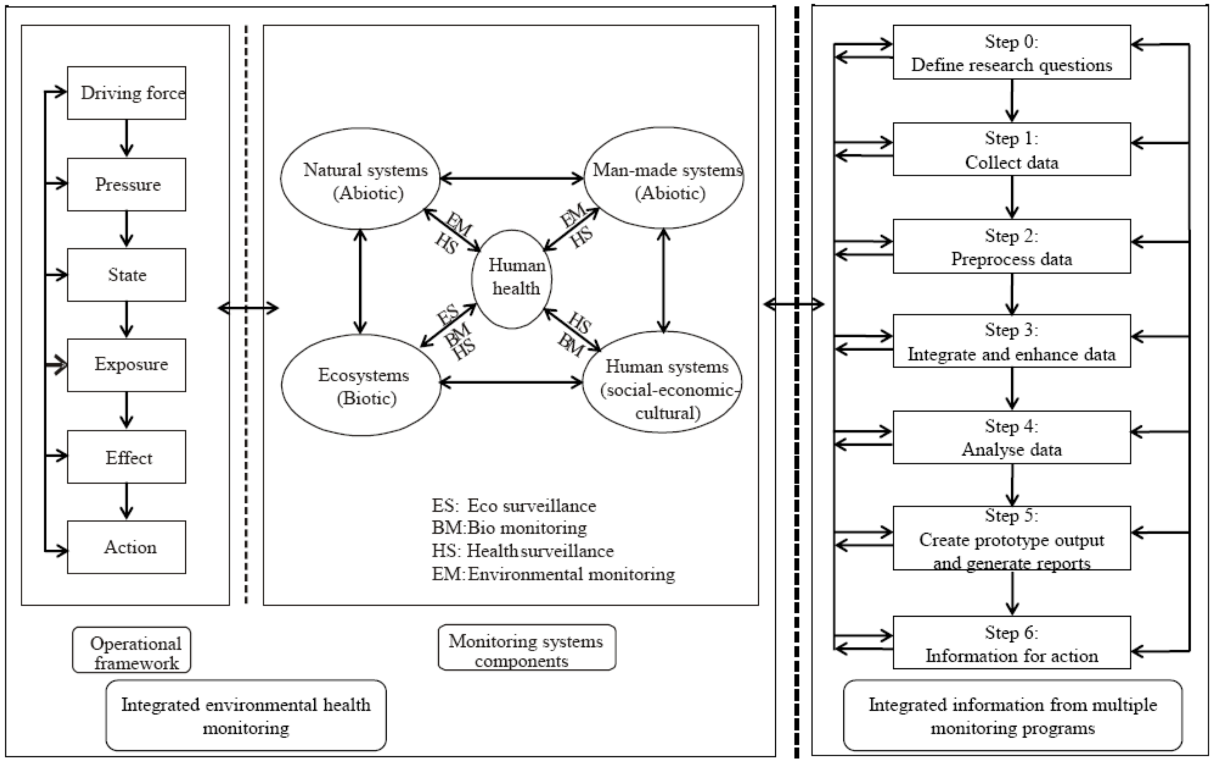

Figure 4 An integrated environmental health monitoring project/system/network and its main ingredients

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ABSTRACT
The aim of this report is to summarize the results from (i) review of existing and planned environment and health monitoring programs (section 2.1); (ii) review of frameworks which are currently used in the integrated monitoring programs (section 2.2); (iii) review of the results of SP 1, SP 2 and SP 3 to date within INTARESE project (section 2.3). Based upon the above results, we identified the development needs for integrated monitoring and integrated usage of data/information from multiple sources (section 3); proposed a conceptual framework of integrated environmental health monitoring (section 4); developed a work process of integrated data/information from multiple monitoring programs (section 5); recommended the relevant tools and methodologies for the integrated usage of information from multiple sources (section 6).

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