SCRUTINISING THE EFFECTS OF ATMOSPHERIC POLLUTION – CHALLENGES FOR SCIENCE AND POLICIES

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INTRODUCTION

In the early 80s the European environmental policies for sustainable development were formulated by taking into account only the effect of emissions on the environment without taking into consideration the transportation of pollutants and the natural background. The relevant European directives are the 85/203/EEC on air-quality standards for nitrogen oxides and 80/779/EEC on limit values and guide values for SO_2 and suspended particles. These were based on models focusing purely on emission logistics, which were then used in carrying out forecasts (with RAINS, GAINS, etc) with the expectation that they meet emission standards and economic objectives.

However, these policies have not achieved the environmental objective of reducing pollutant concentrations in the atmosphere, mainly because they were decoupled from important processes such as the dispersion and chemical transformation of pollutants. These were followed in the 90s by the directives for transport and the environment (directives 1998/69/EC and 1999/96/EC). These accounted for transport and chemical transformation but were based on data from a sparse monitoring network of expensive stations that could not provide a harmonised picture of atmospheric pollution at high spatial resolution. It was realised that ideally, policies should focus on effects (for example, on human health or on the economy) and should cover reasonably long time periods since some of the effects are partially cumulative in nature, and therefore appear only in several consecutive years.

The European Commission has recently introduced a third level of complexity by implementing an action plan (European Commission, 2004) for “reducing the disease burden caused by environmental factors in the EU and for identifying and preventing new health threats caused by environmental factors”. Efforts therefore are being made to set up information systems which link health effects to environmental causes. Although much progress has been made in improving the quality of the environment, it is estimated that one third of the global burden of disease, on a world scale, is attributable to environmental factors (Smith K.R. et al, 2003). Such facts are frequently reported by soft sciences (epidemiologists), which are then incorporated into reports that are adopted by inter-ministerial conferences for legislating atmospheric pollution under the auspices of the UN Economic Commission for Europe (EEA Kiev Report, 2003). Such statements are difficult to support with scientific data and are challenged due to the statistical misuse of scarce data-sets. Modelling is perhaps a vital tool for resolving such challenges. However, the current state of modelling needs to evolve in a new generation of tools which will incorporate health issues in the calculations.

CHALLENGES FOR MODELLING AND POLICIES

The response of the human body or the animals/organisms in the environment is the guide for the development of modelling tools and suitable methodologies to assess exposure and to predict or diagnosing effects. Health statistics, epidemiological studies and other health monitoring activities indicate health effects that can be, or are suspected to be, connected to chemicals, environmental contaminants or other environmental risk factors. The challenge for research is to extend existing models for taking these effects into account.

The elements which need to be incorporated in existing atmospheric pollution models are:

1. Hazard identification: this associates the consequences and the level of harmful effects with pollutant monitoring and characterises the nature and strength of the sources that cause these effects.
2. Dose-response evaluation: where are presented the difficulties in determining the relationship between the amount of exposure to a substance, and the extent of a specific biological response (toxic injury or disease).
3. Exposure assessment: for estimating the magnitude of human exposures, especially for improving the spatial resolution and accounting the effects for the exposed population.
4. Risk characterisation: especially for estimation of the probability, of occurrence of adverse effects if a toxic substance is absorbed by a particular organism or population in a specific dose.

This work outlines how state-of-the-art knowledge on modelling can be utilised in the implementation of the environment and health action plan. In particular it addresses the following topics: Are limit values set in exposure media? Is exposure assessment possible by using compliance data? Is health impact assessment possible, and finally, if tracing exposure back to sources is possible?

Are limit values and standards adequate?

Standards and limit values exist in practically all exposure paths. However, the problems with these standards are that there are many organisations/authorities which are introducing those and frequently their objectives are not always targeting health. Therefore, the main limitations which need to be taken into consideration are: (1) to account for the multidisciplinary of objectives, (2) to consider the frequently introduced changes of the limit values and (3) to bear in mind that there are not, in all cases, “clear cut” thresholds beyond which health effects can observed.

In table 1, are shown four groups of environmentally related stressors that are considered according to the short **(S)** or long **(L)** term consequences on human health and if the stressor is subject to deliberate **(D)** or non-deliberate/accidental **(A)** release into the environment. With bold letters and grey background are highlighted the stressors for which Standards and Limit values already exist.

The individual problems associated with exposure routes are:

***(a) Ambient air*;** Limits have been established as part of statistical exercise to reveal few evidences per year. Are not at all representative of health effects and are difficult to find enough data to describe the real exposure to population at large. For the latter it is necessary to access raw measurement of concentrations and a re-analysis of these whenever new limit values are required. Also it is essential to examine what other routes of exposure are effected by violation of exposure above limit values over certain hours (e.g. damage to crops and drinking water etc).

(b) Indoor air; Limits are associated mainly with work-areas and are addressing issues of safety or occupation hazards. Limit value for indoor are well covered in cases of methane releases in cases of dust and for radon.

(c) Problems remain concerning the control and characterisation of the ***interaction between outdoor and indoor air*** as well as the contribution of chemical materials in areas where there are laminar transport conditions with limited exchange between outdoor and indoor air.

(d) Skin exposure will be required because UV protection from the ambient environment is decreasing and secondly, because the toxicity of soil and chemicals is increasing. Hence, this route will require future modelling. The lessons learnt from radiation handling and the complex case of lead in blood are important.

Table 1. Limit values in exposure media; Grey areas mark stressors for which standards and limit values already exist.

Chemical stressors		**Physical stressors:**		**Biological stressors:**		**Genetic ex Stressors**	
Chemicals	D L	**Noise**	A L	E coli	A SL	Inherited Diseases	D L
Pesticides	D SL	EMF	D S	Viruses	A S	Genet. Modified Food	D L
Biocides	D L	**Radon**	D L				
Ambient air pollutants (PM_x, NO_2, O_3, C_6H_6 others)	A SL	**Radiation**	A S L				
Heavy metals	A L	**UV**	D L				
Dioxins, furans and other organics	A SL						

A historical monitoring is required where the reasoning and the targeting of these limit values will be examined and this will reveal the strong and weak points from their application. This is a task which needs to start as soon as possible and is a task that requires coherence in time.

Is exposure assessment possible using compliance data?

The exposure assessment of the actual population to air pollutants across Europe can made on the basis of compliance data for the limit values set in the various exposure routes. The source of these data is either through consistent modelling simulation or through measurements (which are until today is not standardised across member states). Compliance monitoring is not adequate for the Environment and Health action for many reasons. The main reason is that the relation between health effects and environment is not linear neither of the short nor for the long term consequences. In addition, the peak of health effects occurs at specific locations (hot spots) during specific episodes. Hence, large area averaging and the reporting over the whole year (frequently the case in existing monitoring) are not sufficient and give statistics which are doubtful. The options where modelling can be of significance importance are:

(a) Examining the compliance requirements in the exposure route when modifying the exposure limits or
(b) When we take into account routes that more amenable to exposure assessment, and
(c) For identifying zones where a separate data collection measurements will be required for exposure assessment.

There is no need to embark on a new monitoring system for the purposes of health assessments. It will be sufficient to carry out a harmonisation of relevant data and the creation of interfaces with modelling for adaptation of data between the various health stressors. This is a classical area where the internet and the new GRID technologies can provide suitable answers. The areas where existing data are covering adequately the four types of stressors are shown in table 2.

Table 2. Stressors which are not adequately covered by existing data.

Chemical stressors		**Physical stressors:**		**Biological stressors:**		**Genetic ex Stressors**	
Chemicals	D L	**Noise**	A L	E coli	A SL	**Inherited Diseases**	D L
Pesticides	D SL	**EMF**	D S	Viruses	A S	**Genet. Modified Food**	D L
Biocides	D L	Radon	D L				
Ambient air pollutants (PM_x, NO_2, O_3, C_6H_6 others)	A SL	Radiation	A S L				
Heavy metals	A L	UV	D L				
Dioxins, furans and other organics	A SL						

Of immediate value will be the temporal characterisation of human activities between indoor and outdoor and differentiate it according to population groups. Ideally, it is expected that this will change significantly as the use of telematic technologies and the internet increases providing more reliable data about the whereabouts of human congregations.

Is health impact assessment possible?

The main issue for all type of impact assessments is the presence of clear evidence of health consequence and the timing when such evidence will become obvious. For answering the issue of impact assessments the best way is to start by looking into areas where there is clear evidence. Best candidates are: Cardiovascular diseases and the link to certain types of atmospheric pollution (ozone and benzene mainly because for these are long time series of local concentrations) and the use of pesticides and the cases of cancer in the agriculture sector. For the former there is a long bibliography of models which could be used. For the later there is evidence from emissions which are necessary prior to applying standard atmospheric dispersion tools.

Over a longer period the success or failure of impact assessments depend on the availability of better monitoring data both on health and environment. At this stage it is critical to point out that more important evidence will emerge. I.e., when health monitoring is carried out into a local targeted area with specific environmental problem, or into population groups with specific risks due to either their life style or due to specific local hazards arising either from food, drinking water, or simply by living in potentially hazardous hot spots (next to waste disposal unit, areas of radon etc). Existing monitoring technologies on telematics and e-health can immediately change the prospects on which health monitoring can be carried out. Table 3 shows the areas where impact assessments can be carried out.

Table 3. Grey indicates areas for which data are available and impact assessments can be carried out already.

Chemical stressors		**Physical stressors:**		**Biological stressors:**		**Genetic ex Stressors**	
Chemicals	D L	**Noise**	A L	E coli	A SL	**Inherited Diseases**	D L
Pesticides	D SL	EMF	D S	Viruses	A S	Genet. Modified Food	D L
Biocides	D L	Radon	D L				
Ambient air pollutants (PM_x, NO_2, O_3, C_6H_6 others)	A SL	Radiation	A S L				
Heavy metals	A L	UV	D L				
Dioxins, furans and other organics	A SL						

Is tracing exposure back to sources possible?

Modelling is also essential in examining if exposure through a given route (whether food, drinking water, ambient air, or indoor air) can be traced back to the responsible emission sources. Also, for identifying what are the problems which need to be addressed and how. This process is also known as "source apportionment". A process which has been successfully used in the AutoOil-II programme for the attribution of expected concentration into the emission categories (Skouloudis A.N., 2000).

Table 4. Grey marks areas where attribution to emission has been carried out.

Chemical stressors		**Physical stressors:**		**Biological Stressors:**		**Genetic ex Stressors**	
Chemicals	D L	**Noise**	A L	E coli	A SL	Inherited Diseases	D L
Pesticides	D SL	EMF	D S	Viruses	A S	Genet. Modified Food	D L
Biocides	D L	Radon	D L				
Ambient air pollutants (PM_x, NO_2, O_3, C_6H_6 others)	A SL	Radiation	A S L				
Heavy metals	A L	UV	D L				
Dioxins, furans and other organics	A SL						

The main problem of tracking back into the source of the emissions is caused by the complexity and the interaction of many phenomena and sciences. However, this can be resolved primarily in two ways: (a) Either by simulation of the exposure processes which could be carried out for emission source; or (b) By linking it to proxies or tracer elements which are part of the exposure process as markers. The second method is good for diffusion and dispersion of chemicals whereas the first is more accurate where mass conservation is more important. The assumptions of linearity which has been used until now for reasons of simplicity has lead into costly solutions which have not really addressed the problem of achieving better air quality.

For food, drinking water, ambient and indoor air it is possible to carry out attribution of exposure into various emission sources. Hence, address indirectly even to health problems. High speed modelling tools and new technologies on monitoring tracer elements have resolved the problem of source apportionment to atmospheric emissions. The situation is bit easier when dealing with transport processes in liquids and the soil. As a rule of thump the smaller the speed of the transport mechanism the easier it is to resolve the attribution process. Hence food and drinking water are easier than in air etc. In table 4 are summarised areas where emission attribution has been already carried out.

CONCLUSIONS

Health statistics and epidemiological studies are not adequate to indicate health effects that can be, or are suspected to be, connected to environmental contaminants. Even worse, they might lead into the introduction of wrong solutions if these are not coupled with suitable modelling simulations which are essential for temporal and spatial generalisation.

The challenge for research is to develop diagnostic tools and methodologies for these effects. Such tools will allow the monitoring of suspected populations with the aim of initiating preventive measures. Research should also focus on establishing the correct characterisation of different exposure situations and on the standardisation of data bases.

Nowadays the approach for diagnosing health effects with modelling tools is feasible, and so is the provision of “early warnings”. “Effect assessment” has also to pay attention to the fact that both the human and environmental populations consist of individuals – every one of us reacts in a unique way to a challenge or stressor.

Last but not least, the next generation of modelling tools should account the extra layer of complexity required by the direct linking of environment with health effects in the calculations. This type of models will allow the realistic assessment of different types of environmental chronic and acute conditions and forecast the true consequences on population health.

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