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International Cooperative Programme on Integrated monitoring of air pollution effects on ecosystems

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Encouraging fresh approaches to air pollution

As a novel model for understanding the effects of air pollution continues to make its mark across Europe, **Professors Martin Forsius** and **Lars Lundin** explain the importance of Integrated Monitoring to quantifying and managing human-induced global change in a holistic and standardised manner

To begin, could you please explain the key aims of the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM)?

The ICP IM evaluates the effects of air pollution on ecosystems, focusing particularly on biological impacts. Interactions with climate conditions are also included in the explanation of causes for impacts. Key questions consider the influence of acidification on ecosystems and also the effects and consequences of reactive nitrogen for eutrophication.

In order to provide an explanation of changes in terms of causative environmental factors, the Programme monitors the biological, chemical and physical state of ecosystems over time. These studies take natural changes, air pollution and climate change into consideration, with the aim of providing a scientific basis for emission control.

We also develop and validate models for the simulation of ecosystem responses and use them to estimate responses to actual or predicted changes in pollution stress. We do this in concert with survey data to make regional assessments.

By carrying out bio-monitoring to detect natural changes we can assess the effects of air pollutants and climate change.

The full implementation of the ICP IM will allow the ecological effects of heavy metals, persistent organic substances and tropospheric ozone to be determined. A primary concern is the provision of scientific and statistically reliable data that can be used in modelling and decision making.

Model behaviour

Integrated Monitoring of ecosystems has become increasingly common in recent decades, bringing us closer to understanding the effects of air pollution. The **International Cooperative Programme on Integrated Monitoring** is leading efforts on quantitative analysis which is helping to address knowledge gaps across Europe

RESEARCHERS IN SWEDEN have been at the forefront of international studies into the effects of air pollution on ecosystems for over 30 years. Integrated Monitoring of ecosystems started in 1981 as part of the national Programme for Monitoring of Environmental Quality (PMK) run by the Swedish Environmental Protection Agency. The PMK programme started in 1978 as a consequence of a parliamentary decision the preceding year. Since its inception, researchers in the country have become the pioneers of a new model to efficiently collect, record and share data. This model of Integrated Monitoring was adapted globally by the end of the 1980s.

Jump forward to the present day and the extension of these efforts is spearheaded by Professor Lars Lundin, Chair of the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM), which is set to celebrate its 20th anniversary this year. Together with Professor Martin Forsius, the Finland-based Head of the Programme Centre, Lundin coordinates efforts to further improve the quantification of air pollution effects across the ECE region.

Throughout developments in methodology, the concept of critical loads has been central. Critical loads are deposition limits used to describe the sensitivity of ecosystems to airborne pollution as Lundin elaborates: "For example, the deposition of sulphur or nitrogen compounds may cause adverse biological and ecosystem effects through acidification or eutrophication. The lower the critical load, the more sensitive the ecosystem is considered to be". By establishing a quantitative figure where the effects of air pollution become evident within the environment, ICP IM has been able to explore this necessary and relevant avenue of research. European data and maps of critical loads have been crucial in informing the Programme's work, enabling the development of an efficient and relevant model and testing of concepts.

AN ADAPTABLE RESEARCH MODEL

While ICP IM efforts to date have been highly successful, researchers involved in the Programme are constantly seeking to improve

Can you outline the case studies undertaken by the Programme so far? What knowledge have you derived from them?

Investigations performed as long-term monitoring on well-defined systems based on catchment approaches cover important gradients across geographical, climatical and deposition gradients. Relevant sites are found in locations that furnish the understanding of processes under various conditions.

These studies have provided decision makers with information about threshold values for air pollutants and the long-term ecosystem effects they cause. The links between air pollution and climate change impacts have also been studied.

How has the collected data from the ICP IM informed other studies and provided a link between modelled systems and empirical measurements?

The long-term monitoring provides additional information to shorter research studies and contributes to give historical data on acidification and eutrophication conditions. One of the key benefits of the ICP IM approach is that the detailed information collected allows both the application of complicated mathematical models, as well as empirical evidence about the real impacts using the measured data. This data has been most valuable in developing, validating and testing models over the years.

What key findings have emerged from these research activities so far?

Statistical trend analyses of long-term datasets have confirmed the previously observed regional-scale decreasing trends of sulphur compounds in deposition and runoff/soil water. Acid-sensitive ICP IM sites in northern Europe have also indicated recovery from acidification. The situation regarding nitrogen was quite different, however, with few decreasing trends in deposition, and both decreasing and increasing trends in runoff/soil water.

The most evident change as a result of lowered deposition is the improvement in soil base saturation and pH with further positive effects on the acidification of ground and surface waters where higher pH and acid neutralising capacity (ANC) occurs. Sulphur budgets calculations have indicated a net release of sulphur from many ICP IM sites, indicating that the soils are releasing previously accumulated sulphur. The metal contents of the biologically important surface soil layers have been significantly reduced for cadmium and lead but not evident for mercury. The lost metals from upper layers are relocated and retained within the catchments.

What are the next activities required to achieve the aims and objectives of both the ICP on Integrated Monitoring and the larger network of ICPs?

It is crucial to maintain monitoring activities at the sites because real empirical evidence is required to assess the impact of emission reductions and the complex interactions between other environmental problems and changes. Enhanced programmes on sources of greenhouse gas emissions would be desirable in conjunction with the intensive tracking of effects indicators. It is important to provide improved input to the modelling work and improve the modelling outcome. Additionally, increasing efforts are being made to link the data connected by the different ICPs and make joint assessments of this information.

their model in order to gain the most beneficial understanding of the relationship between air pollution and our ecosystems. Within the last couple of decades, the research group has made a number of significant changes. At the centre of this is Lundin's confidence that the strongest and most helpful indicators of air pollution can be found in the soil, by way of observing the water that travels through it and the vegetation that grows from it. Furthermore, this is backed up by stellar research conducted by the Programme Centre along with significant input from the Finnish Environmental Institute (SYKE).

THE FINDINGS

The long-term monitoring carried out by the Programme provides additional information to shorter research studies and contributes historical data on acidification and eutrophication conditions. One of the key benefits of the ICP IM approach is that the detailed information collected allows both the application of complicated mathematical models, as well as empirical evidence about the real impacts using the measured data. Studies using ICP IM data have shown that there are important links between nitrogen deposition and the sequestration of carbon in the ecosystems – and thus direct links to climate change processes.

Researchers studying heavy metals, such as lead (Pb), cadmium (Cd) and mercury (Hg), have observed lower depositions and Pb and Cd show lower concentrations in the soil humus layers (forest floor) but with translocations of the metals to deeper soil layers. Hg still show increased accumulation and the methylation provide one of the most hazardous toxic elements to the environment. Organic material is a key actor in the transport of metals to discharging waters.

Analyses of biodiversity datasets have indicated that long distance transport of nitrogen air pollution is important in determining the occurrence of sensitive lichen species, and constitutes a threat to natural populations that is strongly underestimated so far. Applications of complex mathematical models have shown that the recovery of soil and water quality of the ecosystems is determined by both the amount and the time of implementation of emission

ICP IM

INTERNATIONAL COOPERATIVE PROGRAMME ON INTEGRATED MONITORING OF AIR POLLUTION EFFECTS ON ECOSYSTEMS

OBJECTIVES

Part of the effect-orientated activities under the 1979 Convention on Long-range Transboundary Air Pollution (LRTAP), which covers the region of the United Nations Economic Commission for Europe (UNECE).

PARTNERS

Austria • Belarus • Canada • Czech Republic • Estonia • Finland • Germany • Iceland • Ireland • Italy • Latvia • Lithuania • Norway • Russian Federation • Spain • Sweden • The Netherlands • UK

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LARS LUNDIN is Professor in Soil Science at the Swedish University of Agricultural Sciences (SLU), Uppsala. His research is focused on catchment hydrological balances and chemical budgets, often in relation to land-use, especially forestry. He is also deeply involved in various environmental assessment programs and long-term monitoring.

MARTIN FORSIUS is a Professor and leader of the 'Ecosystem Change' unit at Finnish Environment Institute (SYKE) in Helsinki (www.environment.fi/syke). His scientific interests are impacts of air pollutants and climate change on biogeochemical processes in catchments and surface waters. He has for many years also been leading the Programme Centre of ICP Integrated Monitoring (www.environment.fi/syke/im).

wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

reductions. Climate change induced processes also have a large impact on future acidification recovery patterns and nutrient nitrogen impacts, and this needs to be addressed if reliable future predictions are sought.

Studies using ICP IM datasets have also demonstrated that there is a clear connection between modelled critical loads for sulphur and nitrogen compounds and observed ecosystem effects: "This increases the confidence in the critical load calculations which are key indicators used in deriving emission reductions," Lundin explains.

The consideration of air pollutants alongside climate change has provided a real possibility for advancing understanding of our changing ecosystems, but this process of developing knowledge has not been simple. As the group aim to establish the combined impacts of air pollutants, climate change and alterations in land use management, its members have found themselves challenged by pinpointing the exact makeup of the combined factors. To combat this difficulty, IM have encouraged their participants to share information, and have formed partnerships outside of the organisation, meaning that researchers can attend knowledge-sharing events with relevant authorities and industry experts, widening the amount of information available to the research community.

SHARING SCIENTIFIC KNOWLEDGE

Through its relationship with ICP IM, the Department of Aquatic Sciences and Assessment at the Swedish University of Agricultural Sciences (SLU) is also part of by the Working Group on the Effects (WGE) of the Convention on Long-Range Transboundary Pollution (CLRTAP): "The six cooperating programmes, Task Force on Health and Joint Expert Group on Dynamic modelling (JEG) that comprise the WGE paint a broad picture of the extent and effects of pollution by cooperating over the total atmosphere, lithosphere, hydrosphere and biosphere that furnish our environment and together covering the vast scope of Earth's inland ecosystems," Lundin outlines. Together, these programmes seek to understand the processes that occur within the environment as a result of air pollution in order to help work to maintain the stability of these ecosystems.

The researchers at ICP IM are fully aware of the need to make the most of the resources available to them. As Lundin highlights, due to the cost of maintaining infrastructures and the consequential importance of making the most of shared knowledge, the ICP IM is a very efficient network with forward-thinking priorities: "Most of the members of ICP IM also work to further other projects, and many catchments that form the ICP core sites are part of the European Long-Term Ecological Research (LTER) network". In a continuation of this aim, the ICP IM benefits from a strong relationship with ICP Forests as well as the other ICPs. This has proved instrumental in understanding hydrological systems and meeting the ICP IM's larger goal of controlling ongoing changes within the forest environment and detecting undesired variation.

WIDENING AWARENESS

To ensure a tangible impact, technical reports and scientific papers are used to communicate their key findings to decision makers. The researchers also tailor summarised documents for fellow members of CLRTAP. The availability of such findings has led to what Lundin describes as a 'success story of the Convention and the IM programme', as decision makers have responded to the groups' findings and helped work towards the positive position in Sweden today, where a very low sulphur deposition is evident.

Lundin articulates that the goal of the ICP IM is ongoing: "The ultimate aim is to provide long-term comprehensive information on ecosystem effects and processes". Indeed, the importance of far-reaching data is evident in his team's studies, as they navigate the complexity of air pollution and climate change and forecast future trends. Despite their successes ICP IM seem reassuringly motivated by the fact there is still unrealised potential in their innovative models and the power of bold collaborations. Process-level monitoring and research will also provide the best potential for answering the questions and problems that may arise in the unforeseen future.

Researchers are constantly seeking to improve their model in order to gain the most beneficial understanding of the relationship between air pollution and our ecosystems