Five decades of research into the effects of air pollution at the University of Oulu

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1 Introduction

In the early 1960's it was becoming clear that Oulu's forests in urban and industrial environments were suffering from the effects of air pollution. The first initial sign was the disorder of epiphytic lichens, followed by injuries to Scots pines around mixed fertilizer industries in the late 1960's. The Department of Botany (plant ecology) at the University of Oulu was presented with the task of trying to identify the cause into why trees in the Oulu region were dying. In November 1969, the first studies involved a transplant experiment which was designed by Professor Havas for the use of pine saplings (Havas 1971). Pine needle analyses revealed a remarkable accumulation of air-borne phytotoxic fluorides combined with particles rich in sulphur and ammonium-ions. Notable nitrogen oxide emissions were also observed to affect trees in gaseous and nitrogen-rich fertilizer particle form. Furthermore, trees that were growing in the vicinity of industrial sites were observed to be already in decline before forest injuries became visible (Havas and Huttunen 1972). During that time, biological microanalyses were not used in abundance; however the University of Oulu possessed a JEOL JXA – 3 SM microanalyzer by which the presence of an interim accumulation of chlorides and sulphur in pine needle cells was confirmed. This helped to explain the role of air-borne fertilizer particles in forest tree injuries (Huttunen 1973).

2 Research objectives during the 1970's and 1980's

During the first air pollution studies, the main objective was to study the interactions between cold winter climate and air pollutants, especially the role of sulphur compounds and nitrogen oxides (Havas 1971, Huttunen 1979, Huttunen et al. 1981). By 1979, the long range transportation of air pollutants was receiving scientific acceptance through the United Nations Economic Commission for Europe Long-Range Transboundary Air Pollution Convention (UN/ECE LRTAP), which intensified international scientific cooperation. Increasing emissions and air pollution in industrial and urban environments resulted in a collaboration between industries, forest organizations (for example, a meeting in Oulu 1982 by IUFRO specialists on the effects of air pollution), governments, municipalities and university departments. This was followed by a rapid development of field methods both in instruments, bioindication and models (Huttunen et al. 1985).

3 Main results from the late 1980's and early 1990's

Experimental field studies of conifer seedlings treated with acid rain were used to confirm the previously identified interactions between winter climate and air pollution. A connection between frost injury and acid-rain treatment of pine and spruce seedlings was observed (Reinikainen and Huttunen 1989, Bäck and Huttunen 1992). The response of conifers to acid rain treatment during winter revealed a delayed winter hardening while developing malformations and ultrastructural needle injuries. The role of dry deposition and accumulation of toxic pollutant during winter emphasized the role of long-term chronic air pollution effects (Turunen and Huttunen 1991). Diagnostic pathology of needles together with the use of non-destructive analysis tools (Siemens SRS 303 x-ray fluorescence spectrometer and a JEOL JCXA 733 microprobe analyzer equipped with a LINK AN 10/85 Energy Dispersive x-ray Spectrometer (EDS) and digital imaging analysis was performed to determine the extent of injuries caused by different pollutants (Turunen et al. 1995) (Figure 1).

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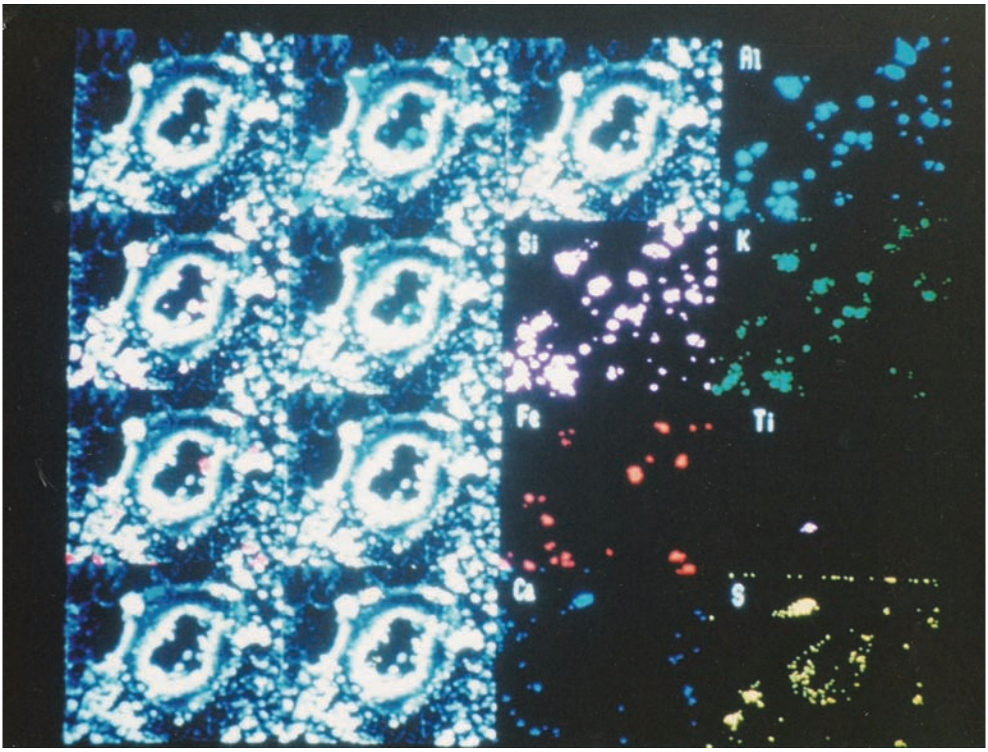

Figure 1 *Surface with accumulated particles of a Scots pine needle demonstrated by EDS and digital image analysis (photo Dr Stefan Godzik).*

Research looking into forest vitality and their state of health in Lapland stepped up after the mid-1980's (Tikkanen and Niemelä 1995). The role of secondary air pollutants (smog) with increasing tropospheric ozone concentrations became evident in forest injuries in Europe. The role of diagnostic plant pathology in situ was emphasized when the ambient ozone and its phytotoxicity to Scots pine (Bytnerowicz et al. 1989) and other plants was observed (Timonen et al. 2004).

4 A warming climate and the combined effects of enhanced levels of carbon dioxide, nitrogen oxides, sulphur dioxide and tropospheric ozone

The world's most northern open top chambers were built to assist studies with various mixtures of air pollutants, to indicate seasonal plant responses and warming (Hirvijärvi et al. 1993). Interactive effects of ozone and carbon dioxide have been observed to mitigate the positive effects of enhanced carbon dioxide in tree growth while northern tree provenances were less responsible compared to southern ones (Vanhatalo et al. 2003). In Europe, tropospheric ozone levels may still be increasing in the long term. Some recent studies have confirmed an ozone sensitivity in northern plants (Manninen et al. 2009).

5 Subarctic and Arctic responses in a changing climate

In 2002, the Finnish Ultraviolet Research Center (FUVIRC) facility in cooperation with the Finnish Meteorological Institute and the University of Oulu was established in Sodankylä to simulate ozone depletion and future light climates with enhanced UV radiation. Funding from the Academy of Finland was used to focus on the study of subarctic plant responses to past, current and future light climates with early snow melt, low temperatures and excess light. Plant responses to past climates have been reconstructed with the aid of herbarium specimens and environmental specimen bank samples. UV data is obtained from reconstructed models, satellites and long-term data monitoring while present and future responses are studied in situ by enhanced modulated UV-experiments. In addition, evergreens have been used as model plants to observe accumulating radiation effects. The main results indicate that the slow growing evergreens are responsive to large seasonal and interannual variations and that the current ambient UV radiation is harmful to subarctic and arctic plants (Laakso 1999, Lappalainen et al. 2008).

6 The future

In Europe, due to the actions under the UN/ECE LRTAP convention, a reduction in the emission of sulphur into the atmosphere has been seen over the past thirty years. However, over the same period the development in emissions of nitrogen oxides and particulate air pollutants have not been favourable. Levels of ambient carbon dioxide and other greenhouse gases have continued to increase as a result of inadequate emission guidelines. The complexity of climate change is a challenging issue and has been the source of many conflicts such as times scales and available data between policy makers and the scientific world. In my opinion, after spending five decades in international environmental policy related work and research, it is clear that every government and individual is responsible for future development. During the next fifty years we will not be able to call upon the past for help; instead, we must try to work within a time scale of individual decades. This means that current research and policy decisions should be prepared to provide practical solutions.

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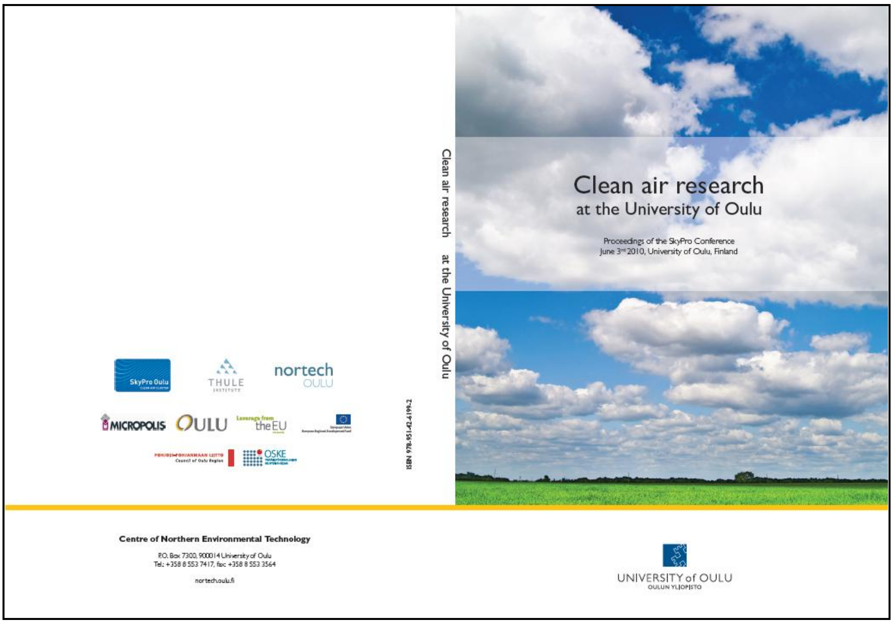

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