USING SCIENCE TO DEVELOP AND ASSESS STRATEGIES TO REDUCE ACID DEPOSITION IN EUROPE

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ABSTRACT

The Regional Acidification Information and Simulation (RAINS) model that has been developed at IIASA can be used to assess the environmental effects of a given pattern of emissions in Europe or, given an environmental target, develop cost-effective international emission reduction strategies. In this paper, the RAINS model has been used to assess the effect of emissions from the United Kingdom at four receptor points in the United Kingdom, southwestern Norway, southern Sweden and the German Democratic Republic. The United Kingdom is, of course, the dominant contributor to sulfur deposition in the UK and is the largest national contributor (outside of the substantial contribution of background sulfur) to deposition in southwestern Norway. It is not important for deposition in southern Sweden or the German Democratic Republic.

1. Introduction

Science helps us to deal with many problems, including environmental ones, by increasing our understanding of cause-effect relationships. The problem of regional acidification from transboundary air pollution can be expressed as a chain of events, each linked by cause-effect relationships, some of which are better known than others. A cause-effect relationship can be used in two ways: in a "forward" sense, one can assess the effects of a certain input action on policy; or, in a "reverse" sense one can, after deciding what the desired effect is, calculate what input, action or policy is needed to achieve it.

This paper will deal with the Regional Acidification Information and Simulation (RAINS) model. This is a tool developed at the International Institute for Applied Systems Analysis (IIASA) that embodies scientific knowledge about cause-effect relationships for acidic deposition in what is termed an "integrated assessment model". The RAINS model can:

(i) Help one to assess the environmental effects (in terms of acidic deposition and acidification of ecosystems) of a given pattern of energy use and emissions in Europe.

(ii) Given an environmental target expressed in terms of maximum concentration or deposition of air pollutants, develop the geographical distribution of emission reductions that will accomplish the target in the most cost-effective manner.

A brief description of the model will be given, followed by examples of its use.

2. Cause-Effect Relationships in the RAINS Model

The chain of events leading to regional acidification may be expressed as follows:

(i) The burning of fossil fuels for energy leads to emissions of sulfur oxides and nitrogen oxides. The sulfur oxides are produced from the sulfur contained in the fuel; the nitrogen oxides mainly from the nitrogen in the combustion air. In addition, agriculture produces emissions of ammonia, mainly from the decomposition of animal wastes.

J. W. S. Longhurst (ed.), *Acid Deposition*

(ii) The above pollutants are diluted by turbulence in the atmosphere, and transported by the winds, usually within a layer whose thickness is no more than 1.5 km above the earth's surface. They are also deposited to the surface by "dry" processes (diffusion, impaction) and by "wet" processes (snow, rain and fog). However, the deposition processes are slow enough that the atmospheric lifetime of these pollutants extends to several days, allowing them to be transported across national boundaries in both Europe and in North America. In addition, during their lifetimes, the sulfur and nitrogen oxides will be transformed into sulfuric and nitric acid. In combination with other pollutants such as volatile organic compounds (VOCs), nitrogen emissions will take part in the formation of photochemical oxidants.

Upon coming into contact with sensitive receptors through impaction or deposition, the pollutants can cause serious damage through acidification of freshwater lakes (thereby harming aquatic life) or acidification of forest soils (causing leaching of nutrients from the soil, mobilization of toxic metals and a general lowering of the resistance of trees to other stresses such as drought or insects). Another effect is the direct damage of forest vegetation by gaseous pollutants such as sulfur dioxide and ozone; these direct effects are exacerbated by the weakening of the trees from soil acidification. Space here does not permit a detailed description of the processes involved, or the extent to which they have been observed but the reader is referred to, for example Nilsson and Duinker (1987) and Rosseland *et al.* (1986).

Following the above three-link chain of events, Figure 1 shows a simplified flow chart for the RAINS model. A complete description of the model, including a more detailed flow chart may be found in Alcamo *et al.* (1987 and 1990).

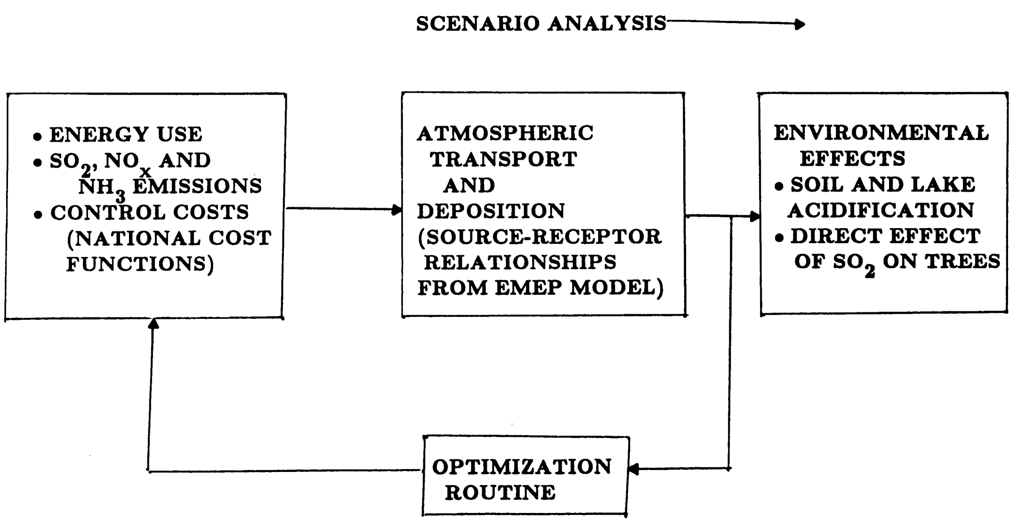

Figure 1: Simplified flow chart for the RAINS model.

(a) Energy, Emissions and Costs of Control

The left-hand box in Figure 1 represents the Energy/Emission/Costs (ENEM) submodel of RAINS (Amann, 1990). In it are data bases for energy use, and sulfur and nitrogen dioxide emissions for the 27 countries of Europe, broken down by economic sector (power plants, industrial emissions, transportation, etc.) and by fuel type (coal, oil, etc.). Sulfur dioxide emissions are calculated on a mass balance basis; nitrogen dioxide emissions on the basis of a regression analysis between fuel use and emissions (Lübkert, 1987). Ammonia emissions are taken from Buijsman *et al.* (1987).

The ENEM submodel also contains various control steps for reducing emissions of sulfur and nitrogen dioxides, and the costs of doing so. Such control steps include flue gas desulfurization and fuel switching for reducing SO_2 emissions, and catalytic converters and low NO_x burners for reducing NO_x emissions. There are as yet no control steps for ammonia emissions. In each country, the control steps can be arranged in order of increasing marginal cost (cost per tonne of pollutant removed) to produce a National Cost Curve (Amann and Kornai, 1987). An example, for SO_2 control in the year 2000 in the United