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A PARTICLE TRANSPORT STUDY FOCUSSING ON GASOLINE LEAD IN EUROPE AND ITS POLITICAL IMPLICATIONS

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1. INTRODUCTION

During the last decades lead was used as an additive in gasoline and emitted into the atmosphere in sizeable quantities. The amounts increased until concerns rose about negative environmental impacts of the neurotoxin lead in the 1970's. A series of regulations on the allowed gasoline lead content was adopted with the result, that in the 1990's most gasoline contained only small amounts of lead. Demonstrating the success of the lead policies, concentrations in leaves and human blood have steadily declined since the early 1980's.

To evaluate the impact of this environmental pollution during the last decades and the effectiveness of the applied political regulations a model system was set up including atmospheric information on the regional scale, leading to a detailed particle transport study and a subsequent socio-economic assessment.

2. GASOLINE-LEAD REGULATIONS IN EUROPE

In the 1970's, lead, added to gasoline for its anti-knock properties, was perceived as a health threat, given new evidence of its neurotoxical effects of especial severity to children. The German government was the first in Europe to regulate gasoline lead. A maximum content of 0.4 g Pb/l was imposed in Germany in 1972, and lowered further to 0.15 g Pb/l in 1976. The European Union fixed its limit modestly at 0.4 g Pb/l starting only in 1981 (Hagner, 2000).

In the 1980's, the discussion of automobile air pollution in Europe moved to concerns with forest protection from the effects of massive No_x, CO and C_xH_y emissions. In 1985 Germany passed a law to reduce automobile emissions, including the introduction of unleaded gasoline because the largest reductions of No_x, CO, C_xH_y, and other pollutants could be achieved with catalytic converters (already in use in the U.S.A.) that were incompatible with lead. In 1985 the EU mandated all member states to offer unleaded gasoline starting October 1989, and by 2005 the exclusive usage of unleaded gasoline is demanded by the Aarhus Treaty.

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3. RECONSTRUCTING WEATHER ON THE REGIONAL SCALE

To simulate atmospheric transport detailed knowledge of the weather situation is required. The currently available reanalysis for the last decades are of a global resolution of about 2 x 2 degrees, which was considered to be too coarse to simulate the lead transport. Therefore the global reanalysis were dynamically downscaled using a regional climate model (Feser et al., 2001).

The regional model was exposed to the global coarse grid analyses not only via the lateral boundaries (as is conventionally done) but also in the interior of the domain, using the technique of "spectral nudging" (von Storch et al., 2000). This method forces the results of the regional model run towards the global model data on the large scales. Therefore the well-resolved large scale weather phenomena of the global forcing data can not be altered by the regional model while the smaller scales are freely calculated by the regional model.

A resolution of about 50 x 50 km was achieved as well as an hourly output. Precipitation, wind speed, and direction at the 950 hPa level were used to simulate the lead transport and deposition.

4. MODELLING THE ATMOSPHERIC TRANSPORT

The airborne pathways and depositions of gasoline lead in Europe from 1958 to 1997 were reconstructed using regional atmospheric model

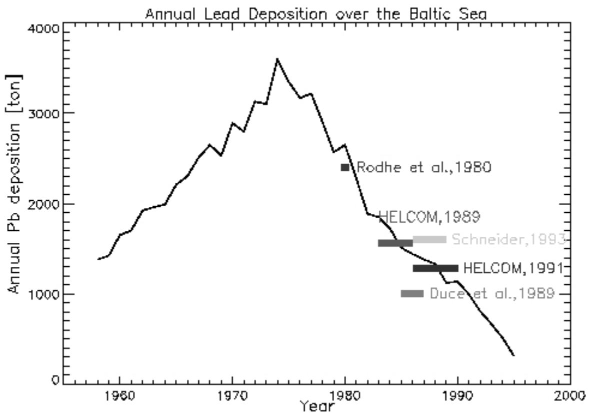

Figure 1: Annual lead deposition over the Baltic Sea, from measurement-based estimates (bars) and our simulations (line)

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data as input for a particle transport model. Additional data from analyses of concentrations in plant leaves, mussels and human blood were examined for environmental quality purposes.

Estimated European atmospheric lead emissions (Pacyna and Pacyna, 1999) were used for the simulation of lead concentration and deposition. All major lead sources were included in these estimates, namely, road transport, non-ferrous metal manufacturing, stationary fuel combustion, iron and steel production, cement production, waste disposal, and miscellaneous sources.

Using these emission estimates and the regionalized atmospheric forcing, lead concentrations and depositions over Europe were calculated by the Langrangian model TUBES (Costa-Cabral, 2001). The model uses flow-tubes of variable width instead of the commonly used linear trajectories. It was assumed, that lead remains within the well-mixed planetary boundary layer, where it is horizontally advected by wind and deposited to the surface by turbulent transport and precipitation scavenging.

Figure 1 shows the simulated total annual lead deposition to the Baltic Sea area throughout the 40-year period. Also indicated in Figure 1 are estimates by different authors based on measurements (see Schneider et al., 2000). An overall agreement is seen between the simulation results and the measurement-based estimates.

5. EFFECTS ON HUMAN, PLANT and ANIMAL POPULATIONS

Today the harmful health implications of lead on human organisms, animals and plants are scientifically demonstrated in a large number of publications. The effects of lead on children's development and health include the impairment of neurological development even at low exposure levels. Effects on adults can include elevated blood pressure and hypertension, resulting in an increased risk of cardiovascular diseases.

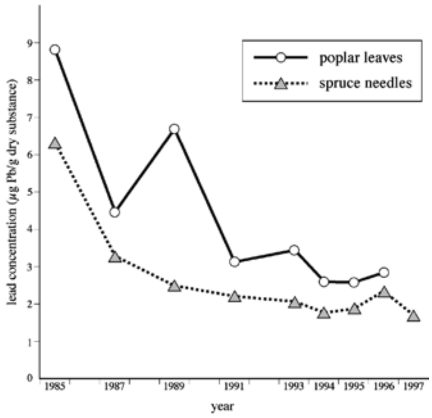
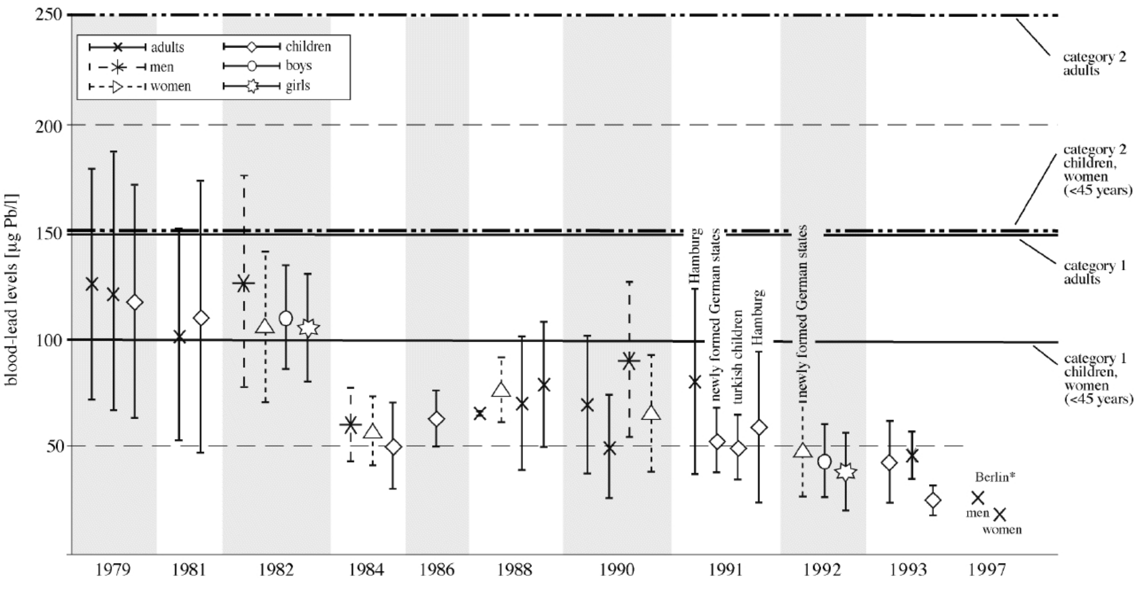


Figure 2: Lead concentration in spruce (Picea abies) sprouts and poplar (Populus nigra) leaves in urban areas in Saarland/Germany.
Data source: Umweltprobenbank 1999.

Figure 2 shows the evolution from 1985 to 1996 of lead concentrations in sprouts of annual spruce (*Picea Abies*) and leaves of poplars (*Populus nigra*) in the German state Saarland (Umweltprobenbank, 1999). This decay is consistent with the modelled drop of atmospheric lead concentrations over that time (not shown).

A significant decline in lead content in human blood was observed in the 1980's and 1990's for all population groups (Figure 3). This decline is due to lowered environmental lead concentrations, including in food such as fish and

Figure 3: Lead concentrations in human blood in Germany, from various studies. Samples were taken within 2 years of the year shown on the plot. Categories 1 and 2 thresholds were redefined by the German Human-Biomonitoring Commission, most recently in 1995. Category 1: normal burden. Category 2: no health dangers expected, but controls recommended. For people with blood lead levels above category 2, health dangers cannot be ruled out and controls are recommended (Data source: Heinzow et al., 1998).



molluscs. Categories 1 and 2 in Figure 3 were defined by the German Human Biomonitoring Commission (1995), which determined that values below category 2 are not expected to cause health dangers. According to this commission, blood lead levels in the general population have not been high enough to cause acute health hazards.

6. CONCLUSIONS

Demonstrating the success of the lead policies, concentrations in leaves and human blood have steadily declined since the early 1980's. The negative economic impacts that had been feared did not emerge. Instead, the affected mineral oil and car manufacturing industries in Germany were able to deal with the regulations without suffering significant extra costs.

We suggest that our model system for reconstruction of particle transports, concentrations and depositions can be applied to other relevant substances as well, such as, for example, Persistent Organic Pollutants, radioactive substances or pollens. A more detailed article on the 'lead study' of the GKSS research center was recently submitted to the Science of the Total Environment (von Storch et al., 2002).

For further information and data download and visualisation please go to

http://w3g.gkss.de/staff/blei

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