J6.5 A RECONSTRUCTION OF EMISSIONS; PATHWAYS AND DEPOSITIONS OF GASOLINE LEAD IN EUROPE, 1958-1997

Hans von Storch*, Mariza Costa-Cabral, Frauke Feser and Charlotte Hagner
Institute of Coastal Research, GKSS Research Center

1. SUMMARY

After decades of regulating the emission of anthropogenic substances into the environment, a retrospective analysis of their effects is informative, as it allows determining the actual costs and benefits related to the regulations. As a first example we have considered the case of gasoline lead in Europe. With the help of a regional climate model, NCEP re-analyses, spatially disaggregated lead emissions from road traffic and other sources, and various local data, an attempt was made to reconstruct the airborne pathway and deposition of gasoline lead in Europe since 1958. It turns out that this approach is successful in describing the time-variable, spatially disaggregated deposition of gasoline lead.

Additional data from analyses of concentrations in, for instance, leaves, mussels and human blood, allows an assessment about the impact of the phasing-out of lead on the quality of the environment. Demonstrating the success of the lead policy, the concentrations in leaves and human blood has steadily declined since the early 1980s, whereas the concentration in mussels along the North Sea coast is unaffected.

2. EMISSIONS

During the 1960s the emissions of the neurotoxin lead grew steeply until first regulation was introduced in the early 1970s by the German government and in 1978 by the European Community. Since 1985 the European countries gradually phased out lead in gasoline and nearly all European countries have agreed to the exclusive usage of unleaded gas by the years 2005 (1998 Aarhus Treatry).

The history of emissions for Germany is summarized in Figure 1 (Hagner, 2000). The total gasoline sale from 1950 to 1995 in million litres is steadily rising (solid line). After 1985 less and less of the gasoline is sold with lead additives. The volume of leaded gasoline is indicated by the declining curve beginning in 1985 (grey dashed). The dotted curve beginning with an almost exponential increase and the stepwise reduction is describing the emissions of lead added to gasoline. The first two steps in the 1907s were related to abrupt decreases of lead contents in 1971 and 1976, whereas the 1985 introduction of “unleaded” gas took place in a gradual manner through a mix of political measures (like tax reductions).

The emissions related to various sources, like road traffic, industrial production, power plants and waste incineration were assessed and mapped by Pacyna and Pacyna (2000) for the years 1958, 1965, 1975, 1980, 1985, 1990 and 1995.

2. MODELLING

The temporally interpolated emissions were fed into the 2-d transport model TUBES (Costa-Cabral, 1999). The 6-hourly height of the planetary boundary layer (PBL), the wind in the PBL as well as precipitation, needed to run TUBES, were taken from a regional re-analysis of the global NCEP-re-analyses (Feser et al., 2001). As a result a sequence of 6-hourly maps of atmospheric concentrations and depositions of lead became available. That this reconstruction is realistic is demonstrated in the following diagram by a comparison with depositions found in a peat bog in Denmark (peat bog data from Goodsite et al., 2001).

Obviously, the extended simulation allows for a much more detailed analysis than any data set relying entirely on observational data. For instance, time variable emitter-receptor matrices may be built. As an example, the deposition into the Baltic Sea, together with a number of estimates based on observational data are shown in the following diagram. The observations cover only a short interval of time, and are based on many costly observations, so that our retrospective analysis is both economically more efficient and more representatively describing space-time developments. (Which should not be misunderstood as an argument against monitoring programmes.)

A methodological result of the study is that the reconstruction of regional environmental change is doable with dynamical regional environmental models (at least: climate, passive tracers). Past political and economic evolutions may be assessed quantitatively by a retrospective analysis. Scenarios of environmental impact of possible future socio-economic developments can effectively be constructed. Specifically, regional atmospheric modeling allows for dynamical downscaling consistent with large scale forcing.

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*Corresponding author address: Hans von Storch, Institute of Coastal Research, GKSS Research Center, Max-Planck-Str. 1, D-21502 Geesthacht, Germany; e-mail: storch @ gkss.de

4. IMPACTS

It turned out that the regulations were mostly successful in ecological terms while not having exerted an undue load on the economy. For instance, the emissions in Hamburg (Germany) fell by 90% from the mid 1970s until the mid 1990s. The lead concentrations in plants fell by about two thirds, and the lead concentration in human blood by two thirds and likely more. However, in coastal ecosystems (e.g. mussels) the lead concentrations have remained at a relatively high level, due to accumulated sediments acting as a time-delayed lead source (Hagner, 2001).

During the time of maximum emissions, in the late 1960s and early 1970s, little data on the abundance of lead in the environment exists. Using measured data since the 1980s and the modelled aerial concentrations of lead, we estimated the lead concentration in human blood in Germany since 1958. According to this, admittedly crude estimate, the blood concentrations in the early 1970s were on average 150 • g/l, which is considered potentially harmful for unborn children by german standards. In the US the critical level for children is set to be at 100 • g/l.

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More information about the project is provided by the web page http://w3g.gkss.de/staff/blei/index.html.

Figure 1.

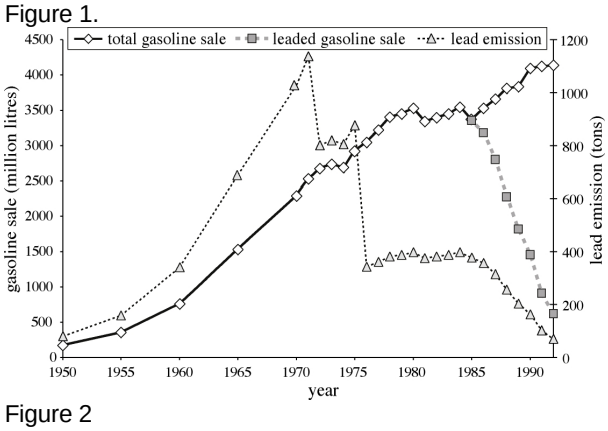

Figure 2

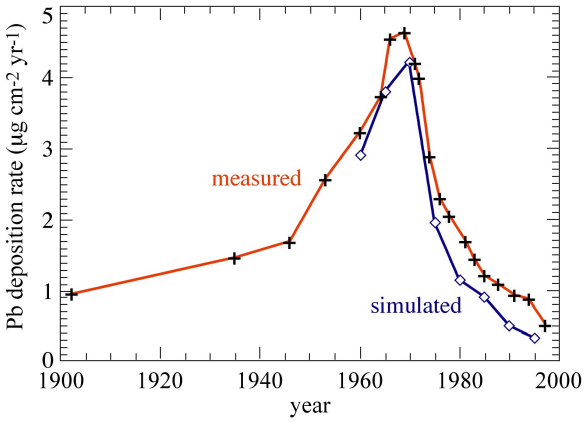

Figure 3