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International Institute for Applied Systems Analysis

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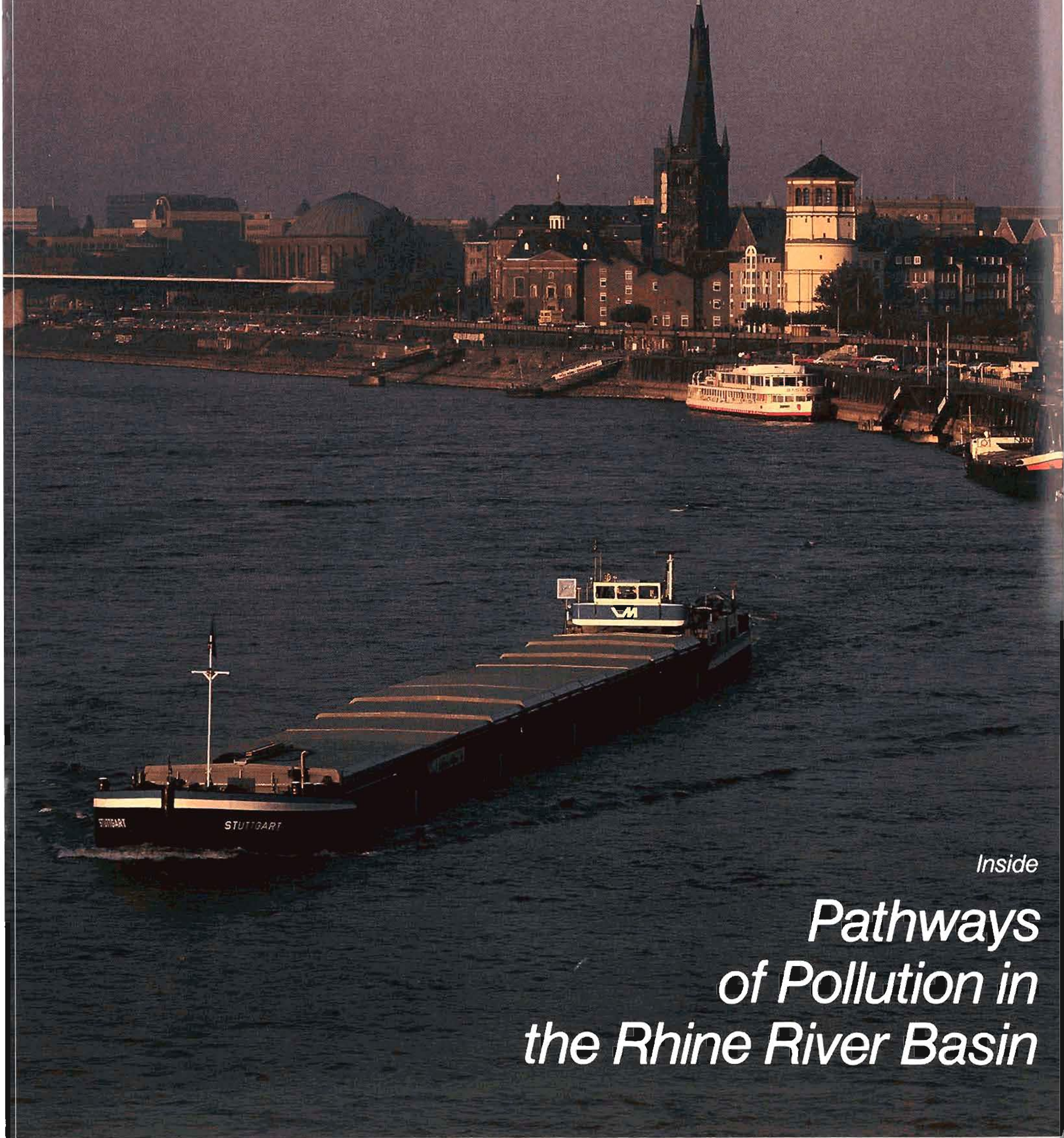

Inside

Pathways of Pollution in the Rhine River Basin

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A-2361 Laxenburg, Austria
Telephone 43 2236 71521 0; Telex 079137; Telefax 43 2236 71313; Electronic Mail postmaster@iiasa.iiasa.ac.at

Managing Editor: Marc Clark
Information: Sebouh Baghdoyan
Design: Martin Schobel, Ewa Delpos
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EDITORIAL

The end of the Cold War has prompted some searching questions about the role of organizations created in whole or in part as a response to it, including IIASA. The Institute had gone two decades without a major review, so the questions were a useful catalyst. In 1990 the IIASA Governing Council ordered a review that would take into account, not just the political changes since IIASA's inception, but the new array of environmental, economic, and developmental issues that have arisen since the Institute was founded in 1972. The result is a new Strategic Plan, a summary of which begins on page 15.

The bulk of this issue of *Options* is devoted to the Rhine Basin Study, which is analyzing the pathways taken by seven major pollutants through the complex economic and ecological system within the Rhine Basin. The study will give policymakers in the region their first comprehensive view of the circulation of these pollutants within their economies and their environment.

While the study is regional, it is of significance for people living well beyond the Rhine Basin. Specific lessons from the study can be applied to any developed economy. For instance, it makes clear that most of the cadmium entering the Rhine Basin does so as a trace impurity in zinc ore, which in years past was extracted by zinc refiners and sold to manufacturers of cadmium-containing products. Banning those products would not block the flow of cadmium into the economy and the environment, but only redirect it. This point is germane for environmental policymakers in any industrial society. More broadly, the study offers methodological insights into the analysis of pollution in a complex industrial economy.

Cadmium, zinc, and other heavy metals make up a group of toxic pollutants that is of growing concern to many policymakers, not only in the Rhine Basin. A story beginning on page 11 notes that atmospheric emissions of heavy metals, like airborne acids, do not respect borders. The lesson learned with acid rain–that the problem cannot be resolved without international cooperation–applies equally to contamination by heavy metals.

Finally, this issue of *Options* returns to the question of economic reform in the Soviet Union. The failure of last August's coup in Moscow has given new life to the process of *perestroika*. We at IIASA hope that research undertaken by our Economic Reform and Integration Project will be of value to the people undertaking this most crucial transformation.

Peter E. de Jánosi
Director

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Cover photo: The Rhine River at Düsseldorf, Germany.

FEATURE

Industrial Metabolism and the Rhine Basin

by W. M. Stigliani and S. Anderberg

The following article is based on a chapter in the forthcoming book Industrial Metabolism — Restructuring for Sustainable Development, *R.U. Ayres and U.E. Simonis, editors.*

In November, 1986, an accident at a pharmaceutical company in Basel, Switzerland, resulted in the inadvertent release of 33 tons of toxic materials into the Rhine River. The results were immediate and dramatic–one-half million fish and eels died, and for a month local residents could not use the river as a source of drinking water. The accident, highly publicized in the world press, raised a major public outcry.

What went virtually unnoticed, however, was that for many years prior to 1986 nearly as much toxic material entered the Rhine *each day*, not in accidents, but through routine, day-to-day activities. In 1980 the river transported about 27 tons of toxic materials every day–about 10,000 tons annually–to the Dutch Delta and the North Sea. This was the equivalent of a major industrial accident occurring daily.

Since then the rates of emissions have declined (page 5), but toxic pollution of the Rhine remains a serious problem. The ecological effects of daily inputs are not as sudden or acute as those from industrial accidents. One reason for this is that most of the chemicals are deposited in sediments of the Dutch Delta or washed out to the North Sea.

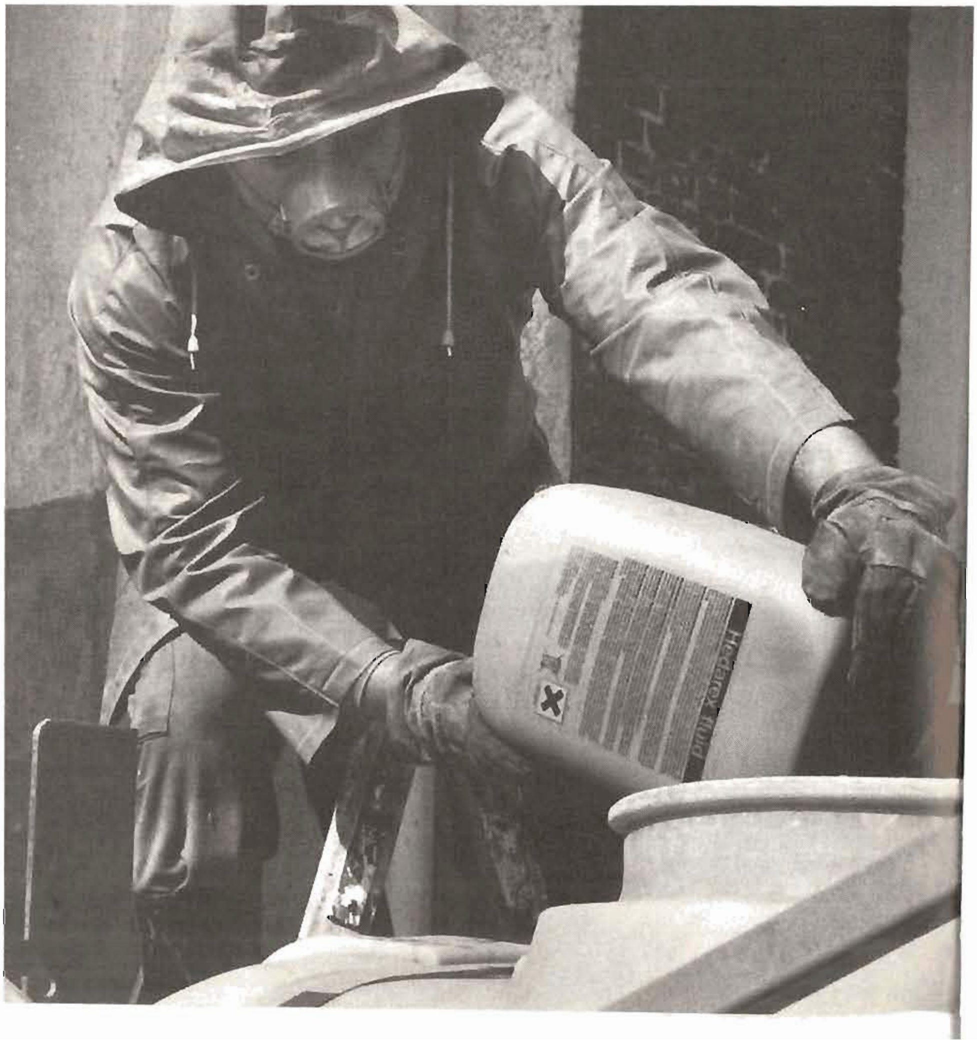
One cannot assume, however, that chemicals stored and accumulated in sediments are out of harm's way. They can be released through resuspension and other physical/chemical processes. In effect, they constitute a potential ecological time bomb (page 9).

One immediate problem is what to do with the millions of cubic meters of sediments that are annually dredged from navigation channels in the Dutch Delta. In former times the dredge spoils were applied to *polder* lands reclaimed from the sea. Now, because they are considered toxic wastes, this practice is forbidden.

First Systematic Study

Surprisingly, there have been no comprehensive studies identifying the sources of pollution of the river or the ways in which pollutants end up in the river. It is precisely this task that IIASA undertook in 1989, with the support of the Netherlands National Institute for Public Health and Environmental Protection (RIVM) and the Netherlands

The diffuse application of agrochemicals is a major source of pollution, and difficult to control.



The Chemicals Chosen for Analysis

The following is a partial list of problems associated with the seven chemicals analyzed by the Rhine Basin Study.

Cadmium – Elevated levels of cadmium cause kidney problems, anemia, and bone marrow disorders. Inhalation of industrial cadmium fumes may cause a fatal inflammation of the lungs.

The only known case of environmental cadmium poisoning was in Japan's Sasu River Basin. Many residents developed a painful malady called *itai itai* or "ouch ouch" disease, in which their bones became brittle and easily broken. Crops in the area were found to have greatly elevated levels of cadmium caused by irrigation with river waters contaminated by mining and smelting operations.

Lead – Gradual accumulations of lead can poison the entire body, especially the nervous system, the digestive tract, and blood-forming tissues. Low-level accumulations are thought to impair brain development in children. Poisoned individuals usually become moody, irritable, and anemic. High accumulations affect the brain, causing blindness, deafness, convulsions and coma, and possibly death. Some city street dusts are as rich in lead as ores.

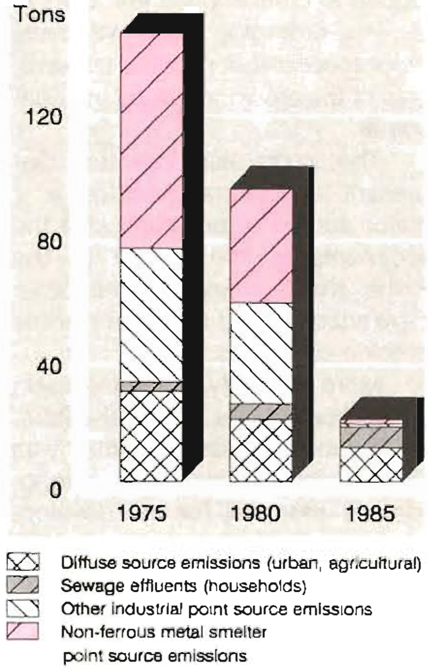
Zinc – Traces of zinc are essential for the proper functioning of the human body, but zinc in high concentrations is poisonous to plants. Directives of the Commission of the European Communities limit zinc concentrations in agricultural soils and in sewage sludge used to fertilize farmland.

Phosphorus – Excessive amounts of phosphorus in waterways cause explosive growth of plankton and algae, depletion of dissolved oxygen, and the death of fish. This process of eutrophication is a major environmental hazard.

Nitrogen – In conjunction with phosphorus, nitrogen causes the eutrophication of lakes and rivers. The use of nitrogen in commercial fertilizers, which are essentially ammonium nitrate, can also lead to nitrate contamination of drinking water. Nitrates can be reduced in the intestines to nitrites, especially by children. In turn, nitrites can react with amines in the digestive tract to produce nitrosamines, which are known carcinogens.

Lindane – This organo-chlorine insecticide is poisonous to fish in concentrations as low as one part per million. In the 1980s about 300 tons were applied per year to farmland in the Rhine Basin. Lindane is long-lived; calculations at IIASA indicate that if it were banned, traces of it would remain in Rhine soils for generations.

Polychlorinated Biphenyls – PCBs in high doses cause skin disorders and damage to organs, especially the liver. In 1968 more than 1,000 Japanese who used PCB-contaminated cooking oil developed *yusho* (rice oil) disease. Symptoms included skin ailments such as chloracne, hyperpigmentation, swelling of the eyelids, and eye discharges, as well as liver damage, digestive disorders, menstrual abnormalities, fatigue, and fever. PCBs are extremely resistant to breakdown by chemical or physical agents.



Tons of cadmium per year in the Rhine River crossing the German-Dutch border.

Ministry of Housing, Physical Planning and Environment.

The Rhine Basin Study is the first major IIASA project based on the concept of industrial metabolism (page 6). It is basin-wide in scale, identifying the sources of pollution and the pathways by which pollutants end up in the river. The time horizon is from 1950 to 2010. The analysis includes three heavy metals—cadmium, lead, and zinc—and four other major pollutants: lindane, a common insecticide that biodegrades slowly; nitrogen and phosphorus, which are introduced to the ecosystem mainly from fertilizer application and sewage wastes; and polychlorinated biphenyls (PCBs), used mainly as an insulating fluid in high-voltage transformers (page 5). The study is expected to conclude in 1992.

Several conclusions are already apparent. The work confirms that since the 1970s industry in the Rhine Basin, as in much of the Western world, has become progressively cleaner. Accompanying this decline in industrial emissions, however, is the increasing importance of diffuse sources of pollution

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related to consumption and disposal. This emerging trend will place more responsibility for the stewardship of the environment on the consumer.

The study also indicates that present agricultural practice is a major source of pollution. Like the sediments at the mouth of the Rhine, the farmlands of the basin have accumulated significant stores of toxic chemicals.

More generally, the Rhine Basin Study shows that comprehensive, systematic analysis, consistent with the principles of industrial metabolism, is essential for the development of effective strategies to limit pollution. In the case of cadmium, for example, the study suggests that banning cadmium-containing products may not effectively reduce cadmium emissions in the basin, unless the bans are accompanied by strict controls at zinc refineries, where cadmium is a major by-product.

This article is intended as an overview of the Rhine Basin Study, using the analysis of cadmium as an example.

The Rhine River drains some 220,000 square kilometers in six European nations, including the western tip of Austria, most of Switzerland, the northeast corner of France, Luxembourg, most of southwestern Germany, and most of the Netherlands. Fifty million people live in the area, giving it a population density about 10 times higher than the United States. About half of the Rhine Basin is farmland, a third is forested, and the rest is cities, towns, and suburbs.

It is perhaps the most heavily industrialized river basin in the world. Although the waters of the Rhine comprise only 0.2 percent of the flow of all rivers in Western industrialized countries, about 20 percent of the West's chemical industry is located in the basin.

Of the six nations in the Rhine Basin, the Netherlands may be the most at risk from toxic pollution. About 75 percent of heavy metals entering the Rhine end up in sediments in the Dutch Delta, which extends from the German-Dutch border to the North Sea. The rest flows into the sea.

International Network

The Rhine Basin Study is divided into three tasks carried out by an international network. IIASA is providing deposition maps of the entire basin for each chemical in 10-year time slices. All emission sources are considered: atmospheric and aquatic emissions from hundreds of point sources, including factories, power plants, and mines; emissions from industrial and municipal landfills; agricultural chemicals; corrosion of materials, such as paints and building materials; and vehicle-related emissions, including engine exhausts and tire wear.

When IIASA's task is completed, it will comprise one of the most extensive and comprehensive European data bases ever assembled on emission sources and the flow of toxic materials through the industrial economy.

A second task is to model the tranport of the chemicals from the land to the river. IIASA is being assisted in this work by VITUKI, the Research Center for Water Resources Development of the Hungarian Academy of Sciences. The last task, modelling of in-stream

On the Concept of Industrial Metabolism

The concept of industrial metabolism, a metaphor borrowed from biology, was proposed in 1989 by R.U. Ayres as a new analytical framework for assessing environmental problems. It recognizes the fact that effective strategies for the reduction of pollution must consider all the processes by which an industrial society, like a living body, takes in substances, uses them, and disposes of them.

Toxic substances are ubiquitous in industrial societies. Recent studies indicate that the main sources of pollution are shifting from industry and production processes to the use and disposal of consumer and commercial goods. Fuels, agrochemicals, solvents and cleaning agents, chemical additives, pharmaceuticals, paints and other surface coatings, construction materials, and many nonferrous metal products all emit toxic materials during normal use. Traditional, end-of-the-pipe control strategies will not work for these diffuse emissions. Rather, the focus must shift from pollution control to pollution prevention, reducing the formation of pollutants at the source.

The concept of industrial metabolism stresses the need for a unified, comprehensive view of production and consumption processes and their effects on the environment. It entails a systematic analysis of all sources of a given material, its pathways through the industrial economy, and the mechanisms by which it is transformed into outputs to be adsorbed and processed by the environment.

Only a handful of industrial metabolism studies have been undertaken thus far. IIASA's Rhine Basin Study, perhaps the most extensive to date, appears to confirm the effectiveness of the approach. Studies of industrial metabolism provide a context within which policies can be assessed. They expose important gaps in information and are useful in setting priorities for a range of policy options. And by presenting the "big picture" they help planners avoid costly mistakes that can arise from policies based on a too narrow assessment of the sources and flows of toxic materials.

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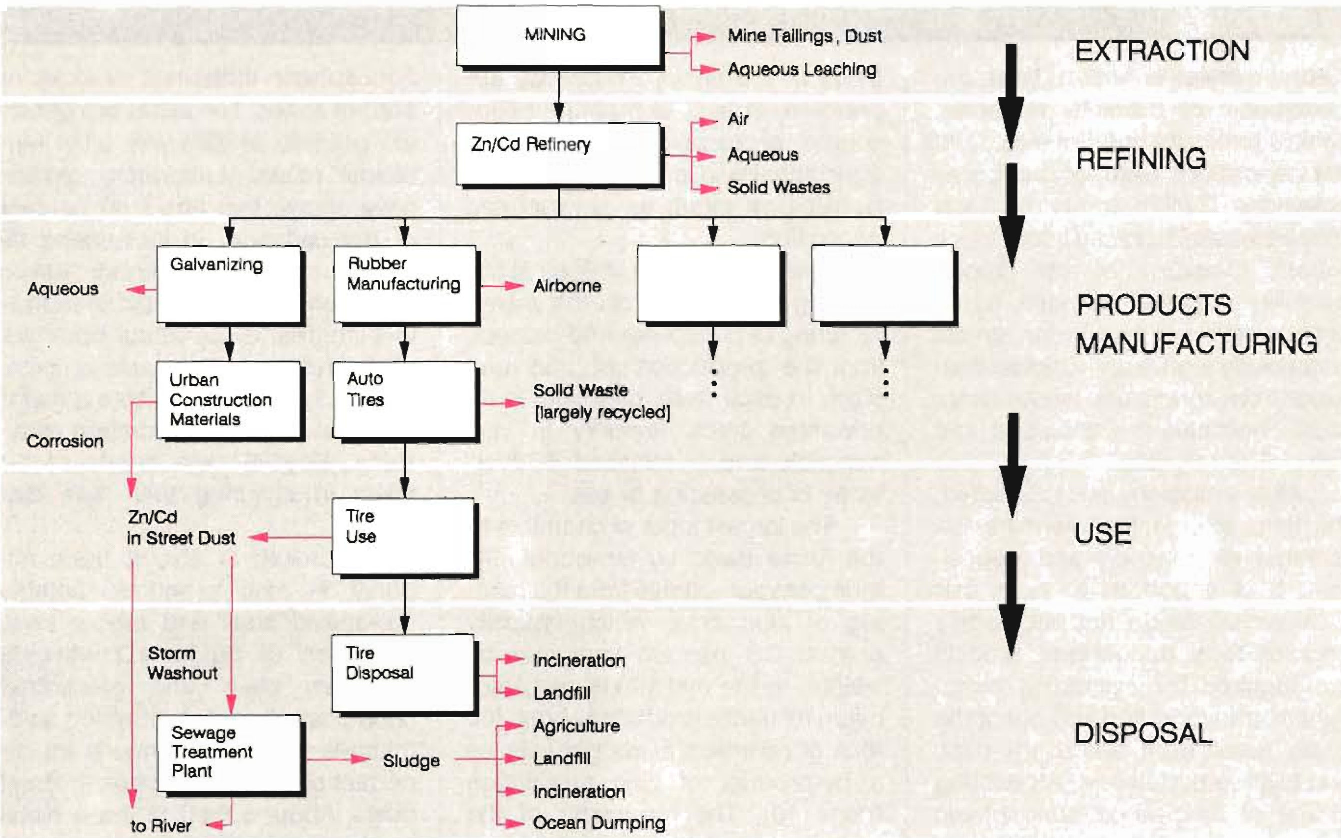

Two examples of the complex pathways taken by zinc and cadmium through the industrial economy of the Rhine Basin. The study analyzed 25 sources of pollution for cadmium alone. Red lines signify emissions, black lines signify the processing, use, and disposal of materials.

transport and downstream ecological effects, is being conducted by Dutch scientists from RIVM and Delft Hydraulics.

The study methodology provides a systems approach for analyzing toxic chemicals. IIASA's task includes three steps:

1. Identification of sources of emissions, including both point and diffuse sources.
2. Estimation of quantities of emissions to air, water, and soil for each source.
3. Tracking of emissions through the industrial economy to their final deposition in soils or surface waters.

An example of the methodology employed is shown in the figure on this page, which depicts the flow of zinc and cadmium through extraction, refining, product manufacture, use, and final deposition. Emissions are estimated at each step in the life cycle. Quantification of emissions and mass flows is guided by mass balance principles, which allow one to make estimates even when there are gaps in available data.

It is important to consider all emissions of a given chemical. These include not only industrial point sources, but also emissions related to routine use and disposal of products containing the chemical. Many toxic chemicals enter the industrial economy inadvertently as trace impurities of high-volume raw materials, such as fuel oils, metal ores, and fertilizers.

Omissions Costly

Failure to consider all emission sources can be costly. US authorities spent billions of dollars to build secondary sewage treatment plants to reduce aqueous pollution by households and industries. The benefits of this investment, however, were largely nullified by discharges of storm waters laden with toxic chemicals into lakes, rivers, and estuaries.

Once the major sources have been identified, the next step is to estimate the emissions from each source. Emissions fall into two broad categories: point source and diffuse. Point source emissions include power and industrial plants, incinerators, sewage treatment plants, and landfills. Emissions are estimated for each point source based on the process and technology involved and the amount and type of material consumed or produced.

The two major sources of diffuse emissions are agricultural lands and urban areas. Agricultural chemicals, the use of which in the Rhine Basin is enormous, are a major source of environmental pollution. Fertilizers, pesticides, and other agrochemicals may stay fixed in the soil (at least until the soil's capacity for adsorbing the chemicals is not exceeded), or they may be mobilized by means of runoff, erosion, and deep seepage to ground waters.

In urban areas, toxic chemicals become concentrated in street dusts. The three main sources of

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heavy metals in urban dust are corrosion of building materials, vehicle exhausts and tire wear, and dry depositions from local airborne emissions. During storms the dusts may be washed directly into surface waters. Because of the impermeability of paved surfaces, runoff of toxic materials from urban streets is generally significantly higher than runoff from agricultural lands, where most chemicals are adsorbed and immobilized in soils.

After emissions are calculated, the third step is to determine the patterns of transport and deposition. It is important to note that local emissions do not necessarily become local depositions. Models are required for estimating atmospheric transport into and out of the basin, runoff from land to the river, and in-stream transport. An existing model of long-range atmospheric deposition developed at IIASA was used to estimate deposition in the Rhine Basin (page 11).

The ultimate purpose of these models is to identify where toxic materials are accumulating. The IIASA study will endeavor to estimate accumulations since the 1950s, and assess the degree to which stored chemicals could be released owing to saturation processes or fundamental changes in the soils' capacities to adsorb chemicals.

Cadmium in the Basin

Minor natural sources of cadmium include sea sprays, windblown dust, and forest fires. The most important natural source in Europe is Mount Etna in Sicily, which discharges between 10 and 40 tons of cadmium per year. Little of this, however, spreads to the Rhine Basin. Mining of zinc, lead, coal, and salt can cause cadmium to leach into surface waters, but such emissions in the basin are also minimal.

About 30 tons of cadmium, present in phosphate fertilizers, are deposited annually on agricultural lands in the basin. Phosphate application, in fact, is now the major source of cadmium pollution on agricultural land, contributing roughly twice as much as atmospheric deposition.

Cadmium is also emitted in the burning of coal and oil, the manufacturing of phosphate and cement, and the production of iron and steel. In each case, cadmium is an unwanted trace impurity in raw materials and is released inadvertently in processing or use.

The largest input of cadmium to the Rhine Basin by far–about 775 tons per year–comes from the refining of zinc ores, which typically contain 0.3 percent cadmium by weight. In the mid-1980s zinc/cadmium refineries produced about 700 tons of cadmium metal per year as a by-product of zinc production (page 10). The remainder of the cadmium ended up as refinery wastes or as a trace impurity in zinc products. Manufacturers' demand for cadmium metal was such that an additional 500 to 600 tons were imported to the basin each year.

The major industrial uses of cadmium were rechargeable nickel-cadmium batteries; pigments, mostly for plastics; stabilizers in polyvinyl chloride plastics; and protective plating for metal in automobiles, machinery, and electronic equipment. Manufacturing of each of these products results in emissions of cadmium to air, water, or soil, but emissions have been greatly reduced in recent years.

Analysis of the use and disposal of these products illustrates the complex paths by which cadmium can pollute the environment. When disposed products are directly landfilled, batteries and plate are susceptible to corrosion, through which cadmium may be mobilized and leached from the landfill. In contrast, cadmium embedded in plastics as pigments and stabilizers exhibits little if any mobilization.

On the other hand, if refuse is incinerated, cadmium in all products will be mobilizable, either through atmospheric emissions or in fly or bottom ashes. The ashes are generally put into landfills with other municipal refuse. Laboratory studies have shown that about 90 percent of the cadmium in incinerated fly ash is mobilizable under acidic conditions typically found in municipal landfills. Since about one-third of the refuse in the basin is incinerated, fly ashes constitute a major potential source of cadmium emissions. Special care needs to be taken in ensuring their safe disposal.

Cadmium is also a trace impurity in zinc products, notably galvanized steel and rubber tires. Corrosion of products containing cadmium plate and galvanized (zinc-coated) steel, in which cadmium is a trace impurity, is an important source of cadmium in street dusts. About a third of these metal products are recycled as steel scrap and are a major source of cadmium pollution in the iron and steel industry.

Changing Patterns

The uses and distribution of cadmium in the Rhine Basin have changed significantly in recent years, and are likely to change further as regulatory agencies consider additional limits. Demand for the metal fell by about one-half as major producers anticipated bans on cadmium-containing products other than batteries. Cadmium plate, once the largest user of cadmium, has been nearly phased out. Imports of cadmium metal, previously hundreds of tons per year, have decreased substantially.

It is important to note that the supply of cadmium to the basin is relatively inelastic because the supply of its major source, zinc ore, would be unaffected by bans on cadmium products. The question, then, is what would happen to the surplus cadmium at the refinery if less of it were required by the cadmium-products manufacturing industry.

CHEMICAL TIME BOMBS

> Future events may trigger the release of toxic chemicals stored in soils and sediments.

Toxic materials have been accumulating in the Rhine Basin at least since the beginning of the Industrial Revolution 200 years ago. While the short-term economic benefits of these chemicals have been clear, their long-term costs are only now becoming apparent.

Because of soils' and sediments' capacity to store and immobilize toxic chemicals in "chemical sinks," direct effects of pollution may not be immediately manifested. This positive function of soils and sediments does not guarantee, however, that the chemicals are safely stored forever. Various factors influencing the storage capacity of soils and sediments and the bio-availability of the stored chemicals can change and indirectly cause sudden and often unexpected mobilization of chemicals in the environment. The term *chemical time bomb* was coined by the author in 1988 to describe such phenomena.

Chemical time bombs may be manifested by two processes. The first is direct saturation, by which the capacity of a soil or sediment for adsorbing a toxic material becomes exhausted. At the molecular level, this occurs as charged adsorption sites on the surface of soil particles become increasingly occupied by the toxic substance. As time passes and inputs of the pollutant continue, the fraction of the toxic chemical which binds to the soil at an adsorption site decreases relative to the fraction that is leached from the soils.

One example of this process is phosphate saturation of farmlands in the Netherlands. This is the area of intensive livestock feeding where exceedingly high levels of manure have been applied to sandy soils at local farms. In these areas, extensive phosphorus saturation has already been observed. It is estimated that the groundwater underlying at least 60,000 hectares, or 2 percent of the Netherlands, requires purification for phosphate contamination at an annual cost of $30 million. Even if pollution stopped, these costs would be incurred for the next 200 years or more, during which phosphates in saturated overlaying soils would continue to leach into groundwaters.

The second way to "trigger" a time bomb is through a fundamental change in a chemical property of the soil that shrinks its capacity to adsorb toxic materials. Thus, a soil that in one chemical state may be far from saturation with respect to adsorbed toxic materials may become saturated in another chemical state.

The most important chemical parameters affecting the capacities of soils and sediments to adsorb heavy metals are pH value, reduction-oxidation potential, salinity, and organic matter content. With respect to soil acidification, the implication is that as soils acidify, toxic heavy metals accumulated and stored over long time periods (say, decades to a century) may be mobilized and leached rapidly into ground and surface waters or be taken up by plants.

The ongoing acidification of Europe's soils from acid deposition is clearly a source of real concern with respect to heavy metal leaching. Simulations using IIASA's RAINS model have shown that most of Central Europe's forest areas may be acidified (i.e., pH less than 4.2) in the next 50 years, even if current plans for reducing acidification are adopted.

Another major source of soil acidification may be land-use changes. For example, agricultural soils are usually protected from acidification by the application of lime. It is possible, perhaps even likely, that in the future large tracts of agricultural land in Europe will be abandoned and liming discontinued. There could be a significant and rapid decrease in pH. Because these soils have been the recipient of cumulative doses of heavy metals and pesticides over long periods, the sudden decline in pH could trigger the release of the materials to vulnerable ecosystems.

Central to the analysis of chemical time bomb phenomena is the need for data on the long-term accumulations of persistent toxic chemicals such as heavy metals and organo-chlorine pesticides. Currently, hardly any information of this sort exists in the literature. What have been the historical rates of accumulation in soils for key chemicals? Are the capacities of soils to immobilize these chemicals reaching saturation? How will fundamental changes in the soils' chemical characteristics affect the binding capacities? Are current policies for soil protection environmentally sustainable?

In addressing these questions, the Rhine Basin Study is estimating historical emissions and depositions back to 1950. The cumulative deposition will be mapped using a geographic information system. This deposition map will be overlaid by a series of soil maps. In the case of cadmium, for example, the maps will rank the soils according to their capacity for binding cadmium. Attention will focus on potential "hot spots," meaning areas with high accumulations and a low capacity for binding cadmium.

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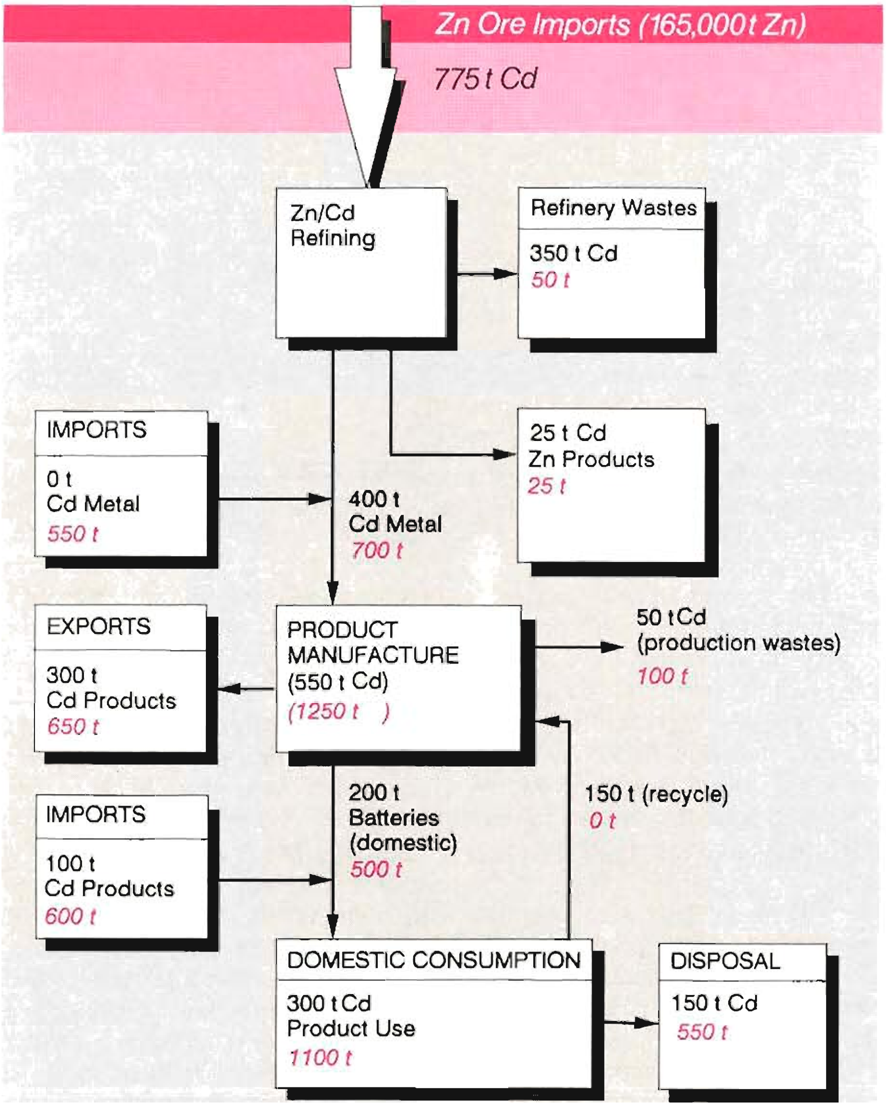

Flow and disposal of cadmium-containing products in the Rhine Basin. Red figures indicate values in tons per year in the mid-1980s. Black figures are based on a late-1990s scenario assuming a ban on all products except nickel-cadmium batteries, half of which are recycled.

The Rhine Basin Study projected a scenario for the late 1990s in which all cadmium products were banned, except batteries (page 10). It was further assumed that half of the batteries were recycled. The results of this scenario illustrate the complexity of pollution pathways and the problems that may arise when regulatory actions are based on incomplete information about those pathways.

Under the scenario, there would be a surplus of cadmium at zinc refineries in the basin of several hundred tons per year. With the reduced market for cadmium metal, only about half of the cadmium would be refined from zinc ores, relative to the mid-1980s. Recycling of nickel-cadmium batteries would increase the surplus further.

The surplus cadmium could end up in refinery wastes in a chemical form that is more easily mobilized than the cadmium in some of the banned products, notably plastics. Alternatively, refiners might allow the trace concentrations of cadmium in zinc products to increase. As described above, the cadmium in high-volume zinc products is a significant source of pollution in urban areas.

Conclusions

This analysis should not be construed to indicate that banning products is not a wise strategy. Rather, it indicates that if such a ban were implemented, special provisions would have to be made for the safe handling of surplus wastes at zinc refineries.

Other policy recommendations are apparent from the study. First, a strategy for reducing cadmium inputs to the environment cannot be narrowly framed in terms of tracing cadmium products from zinc refineries to their final disposal. As noted earlier, the IIASA model estimates that runoff of cadmium from farmlands and urban street dusts washed out during storms are currently the two main sources of waterborne cadmium pollution of the Rhine River. Cadmium occurs in these sources, not as cadmium-containing products, but mostly as trace impurities in high-volume materials such as fertilizer or galvanized building materials.

Second, the study indicates that agricultural lands and urban centers, rather than industry, are now also the major sources of emissions of the other chemicals being analyzed. (PCB use is now highly restricted, so the concern is mostly with the legacy of historical accumulations from industrial and mining activities.) Farmlands are the main sources of emissions of nitrogen, phosphorus, and lindane, whereas urban areas are the principal sources of lead and zinc pollution. Given the increasing importance of these diffuse sources, new strategies will have to be devised for controlling their emissions.

Lastly, the study reveals important gaps in current data and statistics. If researchers are to construct accurate models of the flows of key materials in the industrial economy, from production through consumption to final disposal, they will in many cases require more comprehensive data than are currently being collected. The Rhine Basin Study has already demonstrated that such systematic analyses are powerful tools to aid the formulation of environmental policies.

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Heavy Metals in the Atmosphere

Europeans have known for centuries of the dangers of heavy metal poisoning. In 1568 the Renaissance goldsmith Benvenuto Cellini warned of the perils of gilding, "for the quicksilver [mercury] that has to be used for it is a deadly poison, and so wears out the men that practise in it that they live but a few years."

Only in modern times, however, have scientists begun to appreciate the extent of heavy metal pollution in Europe. Recent studies at IIASA using a model developed at the Institute have yielded the first comprehensive estimates of the long-term atmospheric depositions of heavy metals in Europe. The studies indicate that there is a low but steady deposition of heavy metals into the soils, lakes, and forests of Europe–in some areas 200 or 300 times higher than depositions in remote parts of the world.

The simulation results are preliminary and, in light of the lack of a coordinated heavy metals monitoring program in Europe, not completely verified. But they suggest that heavy metal pollution is potentially a greater and more widespread environmental problem than is generally appreciated.

The state of scientific knowledge of heavy metal air pollution in Europe is roughly comparable to the state of knowledge of acid pollution 10 to 15 years ago. The questions being asked now about heavy metals are much like the ones that were asked then about airborne acids. What are the sources of emissions, and how extensive are they? What are the patterns of deposition? What are the effects on crops and forests? As with earlier discussions of acidification, there is ample scientific evidence to raise concerns about airborne heavy metals, but no consensus on the extent of the threat, if any, to the environment or public health.

The TRACE model–Trace Metal Atmospheric Concentrations in Europe–is a climatological air-pollution model which covers all of Europe, taking into account gridded emission estimates from every country, as well as transport winds and processes of dry and wet deposition.

> *"As with acid pollutants, atmospheric emissions of heavy metals are an international problem, often travelling 1000 or 1500 kilometers before deposition."*

TRACE builds on IIASA's expertise in the field of long-range atmospheric transport in Europe. The Institute's RAINS model–Regional Acidification Information and Simulation–has been selected as the main scientific tool to support renegotiation of conventions to limit acidifying emissions in Europe.

TRACE was developed at IIASA in collaboration with Jerzy Bartnicki of the IBM Scientific Center in Bergen, Norway, Krzystof Olendrzynski of the Institute of Meteorology and Water Management in Warsaw, and Jozef Pacyna of the Institute for Air Research in Oslo. The development team continues to function as a research network. László Bozó of the Institute for Atmospheric Physics in Budapest recently joined the TRACE network.

First used in 1989 to compute nitrogen oxide depositions in Europe, the model has subsequently been developed to analyze emissions, transport, and deposition of arsenic, cadmium, lead, and zinc. These metals were recommended for monitoring by the Paris and/or Helsinki Commissions, which are concerned with pollution of the North and Baltic seas, respectively.

The modified model was used in 1990 to calculate depositions for the Rhine Basin Study (pages 4-10). Subsequent efforts focused on creation of the first comprehensive estimates of long-term heavy metal depositions in Europe. Results compare closely to observations of annual average concentrations and depositions of arsenic and lead. However, model calculations underestimate field measurements of cadmium and zinc.

The discrepancy may stem from underestimation of emissions or from inaccurate observations. Reliable data on heavy metal concentrations are scarce. Most countries are committed to more extensive monitoring, but it will be many years before the information available approaches the quality and quantity now available to support research on acid deposition.

Heavy metals are emitted by metallurgical plants, steel mills, power plants, and other sources as volatile gases or very fine particles. Lead emissions come mainly from the exhaust gases of cars and trucks burning leaded gasoline. Analyses at IIASA indicate that arsenic, cadmium, and zinc typically stay aloft for 27 hours and travel roughly 900 kilometers. Lead particles are, on average, smaller than the other three, and typically stay

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aloft for 64 hours and travel about 1600 kilometers. These figures are only averages; there is considerable variation in atmospheric residence time and travel.

The relatively long distances involved ensure considerable exchange of heavy metals from country to country. For example, preliminary calculations with TRACE indicate that three-quarters of the arsenic deposited in the CSFR is emitted by other Central European countries. And while exports of air pollutants are often associated with Central Europe, calculations indicate that until the late 1980s Western Europe contributed 11 to 46 percent to the atmospheric burden of lead in Central European countries.

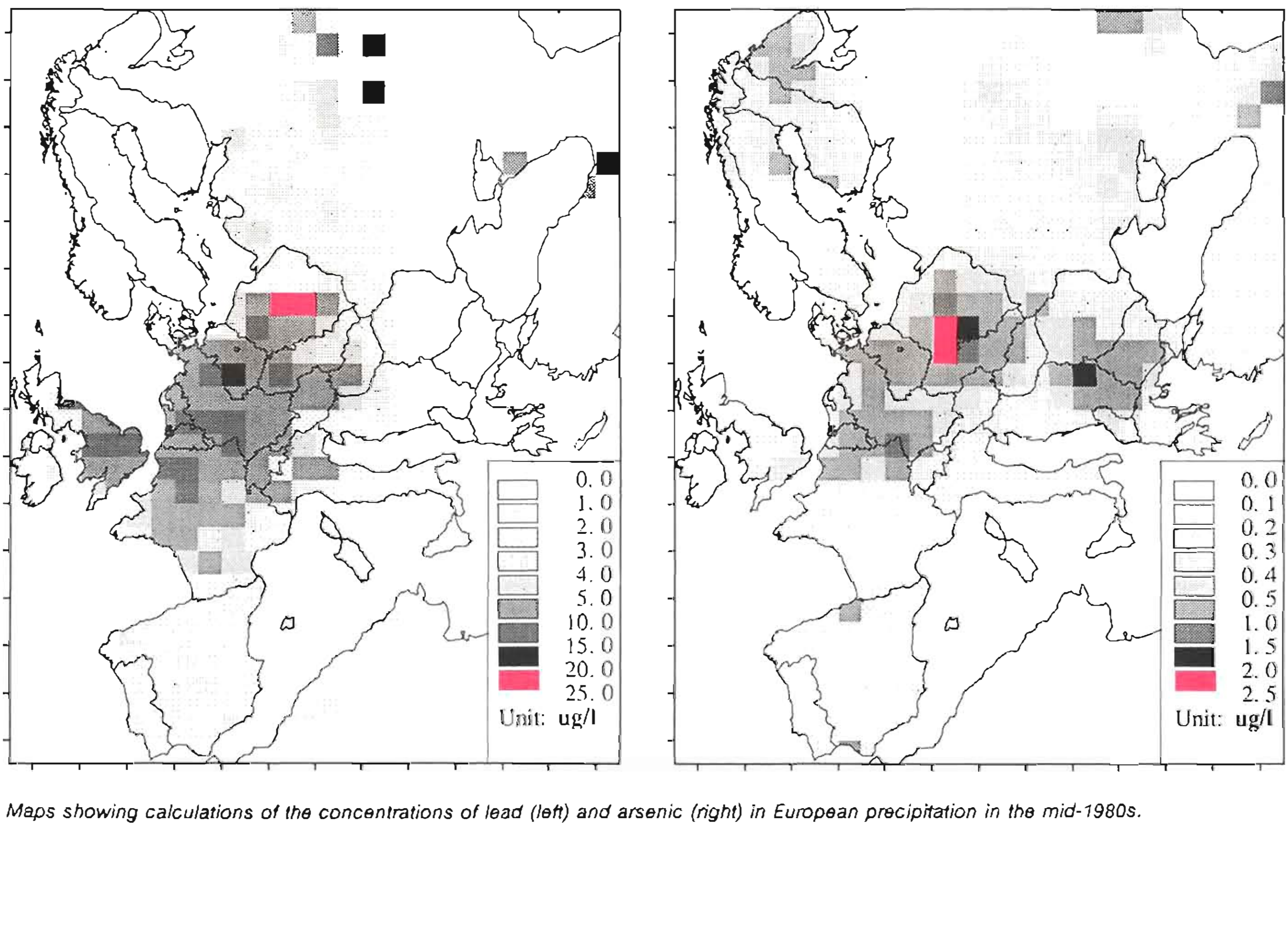
The recent shift to lead-free gasoline has undoubtedly reduced levels of atmospheric lead in Western Europe, but historical emissions are significant. Unlike most acidic depositions, heavy metals are not chemically neutralized, but rather tend to be stored in soils or sediments (page nine).

Patterns of deposition vary considerably from metal to metal. The concentration of arsenic-emitting heavy industry in Central and Eastern Europe, coupled with the relatively short distances traveled by arsenic, meant that in the mid-1980s average concentrations of arsenic in rainwater were up to 2.5 micrograms per liter in Central Europe, some 5 to 25 times higher than in Western Europe and the Nordic countries.

By contrast, depositions of lead were relatively even across all of Northern and Central Europe. In effect, most of the continent was under a lead cloud until the late 1980s. Calculations indicate that in the mid-1980s the level of lead in rainwater even in some rural areas reached 25 micrograms per liter, or half the safe maximum level recommended for drinking water by the World Health Organization. This is noteworthy because the calculated concentrations are annual averages, and short-term concentrations can greatly exceed annual averages. Lead levels remain high in Central Europe, where there has been no shift to unleaded gasoline.

Efforts are underway to calculate deposition maps for 1980 and 1990 and for a scenario in the year 2000. Preliminary results suggest several important conclusions. First, the phenomenon is international; as with acid pollutants, airborne heavy metals in Europe are a transboundary problem that can best be addressed through international cooperation. Second, depositions are not limited to cities and industrial areas, but are a potential problem for vast areas of forest and farmland. Third, high levels of lead and other heavy metals in rainwater in some areas may constitute a health hazard, especially in rural areas where rainwater is directly or indirectly a source of drinking water.

Joseph Alcamo



Maps showing calculations of the concentrations of lead (left) and arsenic (right) in European precipitation in the mid-1980s.

FEATURE

Soviet Economic Reform

What is to be done?

*The recommendations in this article summarize the key findings of IIASA's Economic Reform and Integration Project, led by Merton Peck (*Options*, December '90). The project's conclusions will be reported fully in a book to be published next month by Yale University Press,* **What Is To Be Done? Proposals for the Soviet Transition to the Market,** *edited by Peck and Thomas Richardson of Yale University.*

According to Soviet economist Stanislav Shatalin, the book "offers the best analysis by Western economists of the problems of economic reform in the Soviet Union, and it presents proposals that would create an effective market system for our economy."

The amazing events of this August have given the 15 republics of the Soviet Union a new freedom, but have left untouched its economic problems. The Soviet economy remains in a crisis. Every measure of economic activity shows sharp decline. For instance, gross domestic product has fallen by 20 percent in the first five months of 1991, a drop comparable to that of the early years of the Great Depression.

Boris Yeltsin and the democratic reformers must act on economic reform in the very near future. They can do so with a political mandate that Mikhail Gorbachev never had. Indeed, the experience of economic stabilization and reform plans in the developing world suggests that many policies are politically impossible before a crisis, like the failed coup d'état, but are easy to implement after one. Thus, many of the Western proposals that reform-minded Soviet economists called *nevozmozhno* in the course of several conferences and many meetings over the past 18 months are on the contrary now very possible.

The measures that must be taken are simple and mutually reinforcing. They do not require foreign aid to be implemented or to be successful, even though such aid would help. They are, moreover, robust to the level of government at which they are carried out. Thus, whether economic reform is implemented by the union government or, as now seems more likely, by the various republican governments, it must entail some variant of the following five sets of measures developed by Western economists last year under the auspices of IIASA at the request of the USSR State Commission on Economic Reform.

1. **Deregulate prices.** Firms must be permitted to set prices at profit-maximizing levels. This will bring goods out of the shadows of the second economy; it will mean goods are sold in the front of the store, and not illegally out the back door. Moreover, price deregulation will eliminate the need for most enterprise subsidies, since firms will no longer be able to point to an irrational price system as justification for assistance. This will contribute mightily to eliminating the budget deficit, which in recent years has exploded in an uncontrolled growth of the money supply. The resultant "ruble overhang" has frightened Soviet reformers away from price decontrol, since it seemed to threaten a hyperinflation. But an uncontrolled growth of prices of that sort is only possible with a large and growing budget deficit, something that price decontrol, by eliminating the need for most subsidies at the enterprise level, would make less likely.

2. **Corporatize state enterprises.** Though privatization is the long-run goal, it is hard to imagine how tens of thousands of large- and medium-sized Soviet state enterprises could be sold off in a short period. Even if the shares in such firms were simply given away to the entire population, say, of a republic, these enterprises will need to be managed in the interim by some state body. We recommend republican Property Management Agencies (PMAs) that would act as majority share holders, exercising that control over managers necessary to maximize the long-run profits of the firm. PMAs could be established, and the ownership of state assets transferred to them very quickly, say, in a month.

An apparently persuasive objec-

FEATURE

tion to price deregulation is the fact that the Soviet economy is the most heavily monopolized in the world. Reformers have feared their ability to restrict output and raise prices above competitive levels. Nevertheless, monopoly prices are still market prices, and as such are superior to regulated ones. Thus, we would not regulate them, preferring the strong incentive that monopoly profits provide to potential competitors.

In the interim between now and the ultimate privatization, moreover, existing monopolies must be broken up, for to do so after privatization would only call forth a storm of protest from their new owners. Indeed, given the difficulty of assessing the structure and monopolization of various industries, we recommend a one-plant/one-firm rule. All individual factories or sites would be considered separate legal establishments, owned for the meantime by the PMAs and having the right of merger subject to the usual anti-trust controls.

3. **Stabilize government spending.** Given the monetary overhang, a one-time jump in prices upon deregulation is inevitable. Yet if the budget deficit is eliminated or, at least, reduced, this jump will not transform itself into a hyperinflation. By eliminating many enterprise-level subsidies, price deregulation will do much to facilitate this stabilization. But many other subsidies must be eliminated as well, in order that government expenditures do not exceed revenues. A restrictive monetary policy is important to establish the credibility of the ruble, thereby making it convertible both domestically and on international foreign exchange markets. And, with the exception of those unable to work, income indexation should not be attempted.

4. **Moderate the costs of unemployment.** An effective stabilization plan will mean that many Soviet workers will lose their jobs. The end of enterprise subsidies will mean bankruptcy for many firms, and the workers of these enterprises will be forced to find other employment. An unemployment compensation system, perhaps in the form of the now operational Soviet Law on Employment, is therefore essential. Yet it must not be too generous; it should provide benefits low enough to give workers an incentive to find new jobs, and it should decline the longer an individual has received such assistance. Miserliness is not the goal here, obviously. Rather, the stabilization plan cannot work if government expenditures are not controlled.

5. **Open the economy.** Some have argued that this step can wait for a later stage of the transition period. Ruble convertibility, according to this view, is not essential at the start of the process. We disagree, feeling that trade liberalization and price deregulation support one another. The existence of a large number of monopolies on the Soviet domestic market means that foreign competition will serve as the only brake on price increases for many goods. Further, imports of relatively high-quality foreign commodities should also provide a significant incentive to domestic workers, since rubles, albeit a lot of them, could now purchase these goods.

Until the budget deficit is under control, a flexible exchange rate will be necessary, although in the long run a fixed exchange rate would provide the nation's central bank with a strong incentive not to monetize new governmental deficits, whether at the union or the republican level.

The five sets of measures outlined above are similar to those in other economic reform plans, including last year's 500 Day, or Shatalin, Plan. The world has changed, however, in a way that makes some type of radical reform almost inevitable. We provided these proposals to the union government last fall. And they are the ones we would provide to the central government today as it attempts to build a free-trade zone, with a common currency, on the territory of the old USSR. But they are also the proposals we would give to President Yeltsin or to President Nazarbaev of Kazakhstan, were one of them to go it alone. In this sense, the logic of economic reform is robust to the way internal Soviet borders are redrawn.

The emergence of independent republics raises the issue of whether the present territory of the Soviet Union will be one market economy or 15. Will it be like interwar Central Europe, when the newly independent components of the Austro-Hungarian Empire built tariff walls against one another? Or will it be like the modern European Communities (EC), dedicated to building a single, integrated market?

Much depends on the answer. At present, an average of 29 percent of the net material product of each republic is exported to the others. But for some small republics, the share is as high as 60 percent. The United States, with its constitutional provision against internal tariffs, has long demonstrated the gains in efficiency and economic growth of a vast continental market. Only politics and the reemergence of ethnic hatreds long suppressed can deny these benefits to the Soviet people.

While the EC model is the preferred one for the Soviet Union, meaning coordination in monetary policy as well as free trade, that model entails as well some reduction in a nation's freedom of action in economic policy. For the Soviet republics giving up this freedom would be worth the cost, meaning as it does significant gains in economic efficiency and productivity. Still, we emphasize that the economic policies we recommend make sense both for the union as a whole and for each of its republics individually.

Merton J. Peck
and Thomas J. Richardson

FEATURE

1991 Strategic Plan

Agenda for the Third Decade

In June the IIASA Governing Council adopted a new Strategic Plan that would focus the Institute on three research themes: global environmental change, global economic and technological transitions, and systems methods for the analysis of global issues.

This is a summary of the Strategic Plan.

The International Institute for Applied Systems Analysis is an interdisciplinary, nongovernmental research institution sponsored by a consortium of national member organizations in 15 nations. In its first two decades, IIASA represented a bridge between East and West. The Institute produced scientific research on economic, technological, and environmental issues of interest to all members.

Meanwhile, the world has changed considerably: at the political level, with the end of the East-West confrontation; and more generally, with rising concern about global change and economic transitions. This new setting requires a change in IIASA's strategic direction, with greater emphasis on global change and economic transitions and with reinforced attention to the problems of the developing world.

The Institute's strategic goal will be to conduct international and interdisciplinary scientific studies to provide timely and relevant information and options, addressing critical issues of global environmental, economic, and social change, for the benefit of the public, the scientific community, and national and international institutions. To these ends, IIASA will focus on three central research themes.

(1) *Global Environmental Change*

The primary goal will be to advance understanding and develop the means to assess the implications of the interactions between human development and the environment. The environmental interdependence of nations has brought to the fore a new appreciation of the significance of global environmental change. In general, attention will be given to the state of selected ecosystems of the atmosphere and climate, the ocean, aspects of the soil, and the complex interactions among them and with human activities.

Specific areas of concern will include emission, transformation, and transport of toxic materials and pollutants; changes in water resource availability and quality; degradation of soils, biological resources, and ecosystems; and implications for managed agricultural ecosystems. These will be related to the principal human forces driving global environmental change, which include population growth, land use, development and industrialization, and energy production and utilization. The impacts of environmental change will be assessed on the many dimensions of society and the economy, such as industry, agriculture, land use, and living standards. Technological opportunities, regional strategies, and environmental policies that can potentially arrest environmental deterioration, and the economic and social implications of these strategies, will be examined with the aim of developing feasible options.

(2) *Global Economic and Technological Transitions*

The world socioeconomic system is undergoing massive changes in the 1990s. This is related to the increasing economic interdependence of nations, rapid technological change, and the transitions of economic systems from central control to markets. Such processes are inextricably linked to the broad issues of global change. IIASA researchers will study these changes, transitions, and trends; explore quantitatively their implications; and assess policy options. Special attention will be given to issues arising from the transition from centrally planned economies to market economies, the integration of these economies into world markets, the impact of technological developments on all economies, and the complex relationships between the economy and the environment.

NEWS

(3) *Systems Methods for the Analysis of Global Issues*

Rigorous analysis and projection of these problem areas require a systems approach uniting mathematical modeling and other methods that can deal with complexity, coupling of diverse processes, uncertainty, and nonlinearity. IIASA will maintain a balanced research program in this area, with an emphasis on applying methodological expertise to applied problems in its central areas of concern.

In all its activities, IIASA will focus on issues that are either inherently of global scale or manifested in many countries throughout the globe, emphasizing methods appropriate to specific regions or transferable between regions. IIASA plans to maintain a body of capabilities and resources fully adequate to support its research goals. The international, interdisciplinary resident staff will be recruited on a rotating basis with a view to disciplinary quality, ability in interdisciplinary research, and considerations of balance. In addition to the already extensive network of external linkages and the highly successful Young Scientists' Summer Program, a system of IIASA External Scholars will be developed and relationships with international programs will be enhanced.

Throughout its research the Institute will also stress widespread dissemination of results, and give special attention to strengthening participation from developing countries. IIASA is governed by its national member organizations through the IIASA Council, with the Director as chief executive officer. Expansion of the Institute's membership will be considered only on the basis of substantive and stable participation in its programs. IIASA's program will be subjected to regular external and independent review of its scientific quality, its contribution to the understanding of critical issues, and its relevance to critical policy concerns.

NEW PROJECTS

Coastal Water Quality

In collaboration with Delft Hydraulics, Netherlands, IIASA's Advanced Computer Applications Project is implementing with its Applications Interface ToolKit a coastal water quality model, DELPAR, for a case study of Swansea Bay, Wales. The model calculates water quality parameters for waste-outfall systems under various waste-load scenarios and hydrographic regimes, using a two-dimensional horizontal finite difference and particle-tracking scheme with an externally calculated hydrodynamic flow field. The dynamic simulation model features easy interactive scenario definition and animated graphics for the analysis and presentation of design alternatives. (Contact: *Kurt Fedra*, IIASA)

Environmental Uses of Remote Sensing

IIASA's Advanced Computer Applications Project has entered a collaborative agreement with Beckel GEOSPACE, an Austrian remote-sensing and image-processing company in Bad Ischl, for joint research and development of environmental applications of remote-sensing and satellite imagery. The first phase of collaboration will focus on northern Bohemia, and contribute extensive satellite data to IIASA's study on an environmental information and decision support system for air quality management in the region. (Contact: *Kurt Fedra*, IIASA)

High-speed Trains

IIASA and the Joint Research Center of the Commission of the European Communities signed a scientific cooperation contract to study aspects of a proposed hundred-billion-dollar network of high-speed TGV trains in Europe. A phenomenological travel model is used for the assessment. Results from the first progress report indicate that the most profitable configuration would be one of hubs and spokes, with short spokes of less then 100 kilometers, very different from the long-range networks currently proposed. (Contact: *Cesare Marchetti*, IIASA)

CONFERENCES

Recent Conferences

International Energy Workshop, Laxenburg, Austria, 18-20 June.
Attended by 130 participants from 35 countries and several international organizations, the Tenth International Energy Workshop was cosponsored by the Electric Power Research Institute of Palo Alto, California, and the Gas Research Institute of Washington, DC. In addition to presentations and analyses of recent projections of energy consumption globally and regionally, there were discussions of the prospects of the global oil market, global climatic change, and the implications of a single market for Europe's energy system. (Contact: *Leo Schrattenholzer*, IIASA)

Review of Historical Aqueous and Soil Emission Factors of Selected Heavy Metals in the Rhine Basin, Laxenburg, Austria, 20-21 June.
This expert meeting was held to quantify trends in emissions of selected heavy metals in the Rhine Basin from 1950 to 1990 (pages 4-10). (Contact: *William M. Stigliani*, IIASA)

Trade and Environment, Laxenburg, Austria, 21 June.
A draft report summarizing the findings of a five-month study of linkages between international agricultural trade and the environment was presented to 25 Austrian experts in the field. The final report will be submitted in October to the Austrian Federal Ministry of Science, which sponsored the project. The study was conducted jointly with the Austrian Association for Agricultural Research. (Contact: *Muriel Weinreich*, IIASA)

The Common House Alternative on Long-term Energy Strategies under Global Environmental Concern, Laxenburg, Austria, 21 June.
Cosponsored by the Institute of Energy Economics of the University of Stuttgart, Germany, this workshop was held to discuss the idea of establishing an international network on long-term strategies for an environmentally benign energy system. (Contact: *Leo Schrattenholzer*, IIASA)

Social Behavior, Life-styles, and Energy Use, Laxenburg, Austria, 24-26 June.
IIASA's Environmentally Compatible

CONFERENCES

Energy Strategies Project, the Lawrence Berkeley Laboratory of the USA, and Shell International held this workshop to review current research and the present understanding of the role of social behavior and life-styles in determining energy use and its environmental impacts. The aim was to review methods for studying the links between behavioral and life-style variables and energy-use patterns and to explore their possible use in more traditional energy models. (Contact: *Nebojša Nakićenović*, IIASA)

From Data to Model, Laxenburg, Austria, 24-28 June.
The System and Decision Sciences Program organized this meeting jointly with the State University of Groningen and Erasmus University of Rotterdam, Netherlands, to discuss the methodology of building mathematical models for applied problems on the basis of available data (observations), with emphasis on the applications to econometrics. (Contact: *Alexander Kurzhanski*, IIASA)

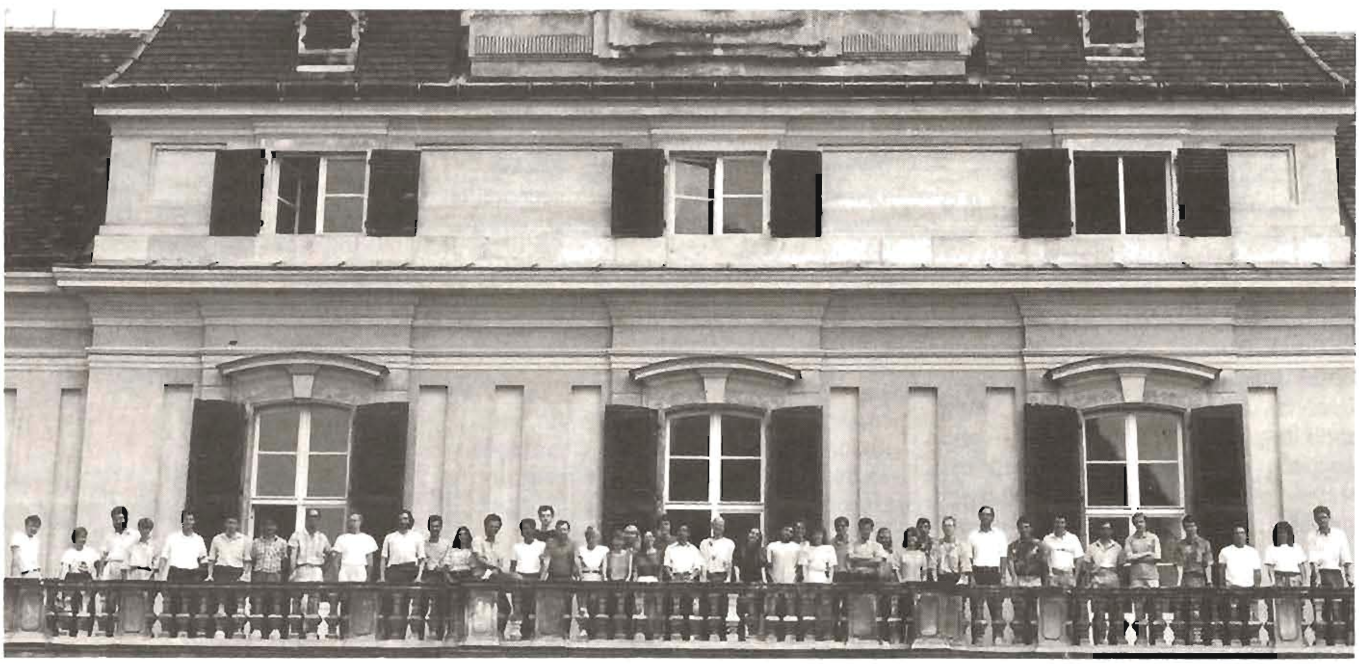
European Sulfur Abatement Strategies; Integrated Assessment Modeling, Laxenburg, Austria, 24-28 June.
IIASA's RAINS model has been selected as the principal scientific tool supporting the renegotiation of the international protocol limiting sulfur emissions in Europe. At the first workshop, held 24-26 June, sponsored by the Dutch Ministry of Housing, Physical Planning, and Environment (VROM), IIASA's Regional Air Pollution Project briefed national delegation leaders and their scientific advisors on the use of RAINS to devise and test emission-reduction strategies.

Requests and comments from the first workshop were considered at a follow-up meeting held 27-28 June, one of a series of regular reviews of models to be used in the negotiations. Topics at the workshop, which was sponsored by VROM and the UN Economic Commission for Europe, included recent model developments and the status of maps of critical and target loads. (Contact: *Markus Amann*, IIASA)

International Multilateral Negotiations, Laxenburg, Austria, 1-2 July.
Negotiation researchers from six countries presented papers for a Processes of International Negotation Project study on international multilateral negotiation. Each paper applied a different analytical paradigm to the Uruguay Round of the GATT and the Single Europe Act of the EC. The six paradigms were game theory, decision analysis, organization theory, small group theory, coalition theory, and leadership theory. The revised papers will be published as a book in 1992. (Contact: *Bertram Spector*, IIASA)

ASCEND-21 Planning Meeting, Laxenburg, Austria, 1-5 July.
Some 70 representatives of industry and the natural, social, and engineering sciences met to prepare for the International Conference on an Agenda of Science for Environment and Development into the 21st Century. ASCEND-21 will be held by the International Council of Scientific Unions in Vienna in November as part of preparations for the 1992 UN Conference on Environment and Development in Brazil. (Contact: *Elisabeth Krippl*, IIASA)

The Concept of Stable Development, Irkutsk, USSR, 2-8 July.
Organized by the Irkutsk Computing Center of the Academy of Sciences of the USSR and UNESCO, and supported by IFAC and IIASA, this international workshop featured discussions of: systems analysis of development globally and regionally; simulation and forecasting of global and regional socioeconomic development; methods of investigation of stability and stabilization of development; and information technology and software for analysis and simulation of stability and for support of stabilizing solutions. (Contact: *Alexander Kurzhanski*, IIASA)



IIASA's 1991 Young Scientists' Summer Program (YSSP) included 50 participants from 14 countries. Each summer the Institute welcomes a group of exceptional young scientists for three months of work with IIASA scholars. Applications for the 1992 YSSP should be sent by January to YSSP Coordinator Margaret Traber. Applicants should be expecting a PhD or equivalent within two years. A good knowledge of English is essential.

CONFERENCES

Negotiation Training, Laxenburg, Austria, 3 July.
Diplomatic and negotiation trainers participated in this workshop to identify a role for IIASA's Processes of International Negotiation Project in the training of a new generation of diplomats for Eastern Europe. It was decided that the most effective role for IIASA would be to develop and conduct workshops for trainers of diplomats and negotiators. A manual for trainers would also be produced. A pilot workshop is tentatively scheduled for April 1992. (Contact: *Bertram Spector*, IIASA)

R&D Management in the Transition to a Market Economy, Moscow, 13-15 July.
Cosponsored by the USSR State Committee for Science and Technology, IIASA's Economic Transition and Integration Project organized this meeting to discuss the restructuring of scientific and technological activities in the Soviet Union. Economists, engineers, and R&D managers from the USA, Europe, and Japan discussed papers submitted by Soviet experts on the present Soviet situation and plans regarding R&D management. Further joint workshops are planned in this area. (Contact: *Christoph Schneider*, IIASA)

Advances in DSS Methodology and Software, Laxenburg, Austria, 22-24 July.
IIASA's Methodology of Decision Analysis Project and the Japanese Institute of Systems Research jointly organized this meeting to discuss advances in methodology of design and implementation of decision support systems and to present practical applications. (Contact: *Marek Makowski*, IIASA)

Geometric Methods in Nonlinear Optimal Control, Sopron, Hungary, 22-26 July.
Over 30 experts attended this workshop, organized by IIASA's System and Decision Sciences Program and the Mathematics Department of Rutgers University, New Jersey. Discussions emphasized innovative techniques for the optimization of the performance of nonlinear controlled dynamic systems that could serve to model complex processes of environment, economics, and technology. (Contact: *Alexander Kurzhanski*, IIASA)

Applied General Equilibrium Modeling, Laxenburg, Austria, 27-29 August.
This meeting had four major themes: the environment; transition to a market economy; regional integration; and structural adjustment in developing countries. Papers presented by the 50 participants included five applications of AGEMs to global-warming problems, a set of papers looking at Europe 1992 and the US-Mexican Free Trade Agreement, and 12 papers dealing with the transition from socialism to a market economy. (Contact: *Lars Bergman*, Stockholm School of Economics, P.O. Box 6501, S-113 83 Stockholm)

Forthcoming Conferences

The following conferences will be sponsored or cosponsored by IIASA:

October 21-25: Environmental Training in Engineering Education, Laxenburg, Austria (Contact: ENTREE, UETP-EEE, The Engineering Society in Finland STS, Ratavartijankatu 2, SF-00520 Helsinki).

November 24-29: ASCEND-21 International Conference on an Agenda of Science for Environment and Development in the 21st Century, Vienna (Contact: *Elisabeth Krippl*, IIASA).

December 16-18: Risk Analysis: Underlying Rationales, Paris (Contact: *Philippe Hubert*, CEA/IPSN/DPHD/SEGR, P.O. Box 6, F-92265 Fontenay aux Roses Cedex, France).

January 28-30, 1992: Energy-Ecology-Climate Modeling and Projections, Laxenburg, Austria (Contact: *Yuri Sinyak*, IIASA).

March 2-5, 1992: East-West Migration in Europe, Vienna (Contact: *Sture Öberg*, IIASA).

May 12-13, 1992: IIASA '92: An International Conference on the Challenges to Systems Analysis in the Nineties and Beyond, Laxenburg, Austria (Contact: *Claudia Heilig-Staindl*, IIASA)

June 24-26, 1992: Support Systems for Decision and Negotiation Processes, Warsaw (Contact: *Zbigniew Nahorski*, DNS '92, Systems Research Institute, Polish Academy of Sciences, Newelska 6, PL-01 447 Warsaw).

Position Announcements

The **Population Program** is seeking a **Scientific Researcher** capable of working independently on mathematical models incorporating both social and biological variables. A PhD is neither necessary nor sufficient for the position, but a doctorate in demography or other social science, as well as research experience, would be an asset. The Program is policy oriented and currently concentrates on issues of population and environment.

The selected applicant will be offered a contract for one year, to begin in January 1992 with the possibility of extension. The salary is negotiable. The closing date for applications is 30 November 1991. For further information contact Nathan Keyfitz or Wolfgang Lutz.

The **Environment Program** is seeking a **Research Scholar** to work within a team modifying the Integrated Model to Assess the Greenhouse Effect (IMAGE), developed in the Netherlands. The aim is to incorporate into the model a two-dimensional energy balance model (EBM) that would allow IMAGE to produce geographically varying values of temperature and precipitation, rather than the present global mean values.

The main task will be to work with other model builders to parameterize the evaporation-precipitation cycle and test the EBM results with other models, particularly GCMs. Candidates should have a meteorological background with experience in precipitation physics and use of FORTRAN.

The selected applicant will be offered a 16-month contract with the possibility of extension. The starting date is November 1991. The salary is negotiable. For further information contact Roderick Shaw.

Applications for either position must include a curriculum vitae with the names, addresses, telephone and telefax numbers of at least two reference persons. Applications should be sent to Peter E. de Jánosi, IIASA Director, Schlossplatz 1, A-2361 Laxenburg, Austria.

NEWS

Howard Raiffa, IIASA's first director, speaking with Erna Wodak (left), wife of the late Walter Wodak, one of the founders of IIASA, and Claudia Heilig-Staindl shortly after a ceremony in which Historical Room C of Schloss Laxenburg was renamed the Raiffa Room.

In Memoriam

The death of an IIASA alumnus has recently been announced. Dr. **Eckhard E. Höpfinger**, a researcher with IIASA's Energy Systems Program (1977-78), in Neubiberg, Germany.

Appointments

Meinhard Breiling (Austria) from the Institute for Regional Planning of the Agricultural University of Vienna has joined the Toxic Pollution and the European Environment Project.

Einar Holm (Sweden) of the Department of Geography of Umeå University has joined the Population Program.

Suren Kulshreshtha (Canada), professor of Agricultural Economics at the University of Saskatchewan, Saskatoon, has joined the Water Resources Project.

Assen Novatchkov (Bulgaria), head of the Computer and Information Services Department at the Institute of Information, Communication, and Automated Services Department in Sofia, has been appointed acting Head of Computer Services at IIASA.

László Somlyódy (Hungary), General Director of the Research Center for Water Resources Development (VITUKI) in Budapest, has joined the Water Resources Project.

Kenji Sugimoto (Japan) of Okayama University has joined the System and Decision Sciences Program.

Jacobus (Jaap) Wessels (Netherlands) from the Technical University of Eindhoven, Netherlands, has been appointed Leader of the Methodology of Decision Analysis Project.

IIASA Books

The following books are now available from your regular book supplier or direct from the publisher.

Computer Integrated Manufacturing. Volume 1: Revolution in Progress. R.U. Ayres. Chapman & Hall, London/ New York/Tokyo. ISBN 0-412-39470-7.

East-West Joint Ventures. The New Business Environment. E. Razvigorova, G. Wolf-Laudon. Basil Blackwell, Inc., Cambridge/Oxford. ISBN 0-631-18054-0.

European Forest Decline: The Effects of Air Pollutants and Suggested Remedial Policies. S. Nilsson, editor. The Royal Swedish Academy of Agriculture and Forestry.

PUBLICATIONS

IIASA Reports

The following reports are available from Robert McInnes, IIASA Publications Department, for the amounts indicated.

USSR Energy Efficiency and Prospects. Y. Sinyak. June 1991. Reprinted from *Energy* Vol.16, No.5, pp.791-815, 1991. RR-91-7. US $10.

Evolution of Transport Systems: Past and Future. A. Grübler, N. Nakićenović. June 1991. RR-91-8. US $10.

A Statistical Model of Background Air Pollution Frequency Distributions. M.Y. Antonovsky, V.M. Bukhshtaber, E.A. Zelenuk. June 1991. Reprinted from *Environmental Monitoring and Assessment* 16:203-251, 1991. RR-91-9. US $10.

Germany's Population: Turbulent Past, Uncertain Future. G. Heilig, T. Büttner, W. Lutz. June 1991. Reprinted from *Population Bulletin*, Vol.45, No.4, December 1990. RR-91-10. US $10.

An Exploratory Analysis of Long-Term Trends in Atmospheric CO_2 Concentrations. M.Y. Antonovsky, V.M. Bukhshtaber. July 1991. Reprinted from *Tellus* (1991), 43B(2):171-187. RR-91-11. US $10.

The Greenhouse Effect: Damages, Costs and Abatement. R.U. Ayres, J. Walter. July 1991. RR-91-12. US $10.

A Computer-Based Approach to Environmental Impact Assessment. K. Fedra. July 1991. Reprinted from *Proceedings of the Workshop on Indicators and Indices for Environmental Assessment and Risk Analysis*, A.G. Colombo and G. Premazzi, editors. RR-91-13. US $10.

Population and Development within the Ecosphere: One View of the Literature. N. Keyfitz. August 1991. Reprinted from *Population Index* 57(1):5-22. Spring 1991. RR-91-14. US $10.

◆ Capital Cities of NMO Countries

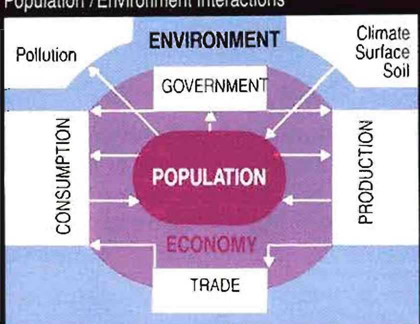
IIASA

International Institute for Applied Systems Analysis

IIASA's ROLE

The International Institute for Applied Systems Analysis is an international, nongovernmental research institution sponsored by scientific organizations from 15 countries. IIASA's objective is to bring together scientists from various countries and disciplines to conduct research in a setting that is non-political and scientifically rigorous. It aims to provide policy-oriented research results that deal with issues transcending national boundaries. Resident scientists at IIASA coordinate research projects, working in collaboration with worldwide networks of researchers, policymakers, and research organizations.

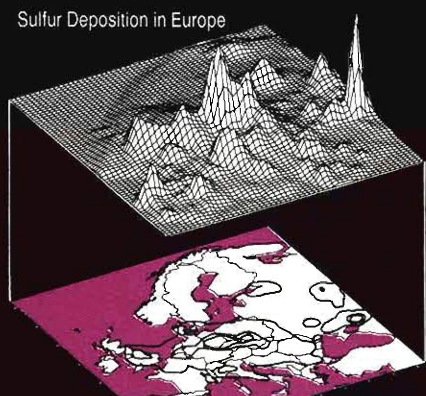
Population /Environment Interactions



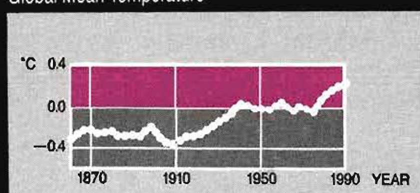
RESEARCH

Recent projects include studies on global climate change, computer modelling of global vegetation, heavy metal pollution, acid rain, forest decline, economic transitions from central planning to open markets, the social and economic implications of population change, processes of international negotiations, and the theory and methods of systems analysis. IIASA applies the tools and techniques of systems analysis to these and other issues of global importance.

Sulfur Deposition in Europe



Global Mean Temperature



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FURTHER INFORMATION

Further information about IIASA and its work is available from: The Office of Communications, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria, Telephone (02236) 715 21-0.