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Inside
Young Scientists' Summer Program

Set-valued Analysis and Differential Inclusions

Alexander B. Kurzhanski and Vladimir M. Veliov, Editors

A distillation of some of the most important new work in the field, based on papers from a workshop held in Pamporovo, Bulgaria.

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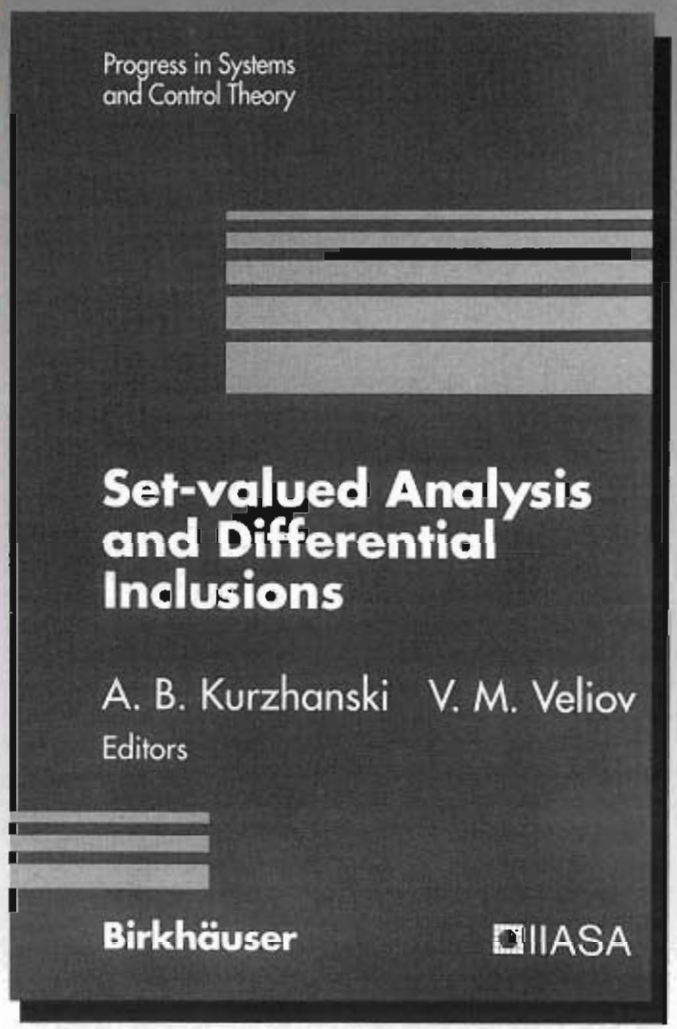
IIASA BOOKS



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E D I T O R I A L

The Young Scientists' Summer Program featured in this issue of *Options* has become one of IIASA's most important and popular activities. Moreover, it is the only one that has been maintained for 15 years with only some, albeit important, changes. The YSSP is the brainchild of IIASA's second director, Dr. Roger Levien, who in 1977 persuaded the Ford Foundation to provide a seed grant to initiate the program. The young scientists in the program are now supported by IIASA's National Member Organizations, but Roger correctly believed that the NMOs at that time would not have provided the funds for an untried and innovative IIASA activity. All of us at IIASA, and the many hundreds of participants in the YSSP from around the world, are in his debt.

The four articles on the YSSP work in 1993 are indicative of the quality and character of the program; space permitting, we could have included many other excellent contributions. We selected these four because they illustrate the program participants' breadth of interest, their willingness to collaborate, and their ability to work in an interdisciplinary fashion without sacrificing disciplinary rigor.

Readers of this issue will also find an article by Professor Nathan Keyfitz on the challenges of interdisciplinary research. The concept of interdisciplinary research is frequently talked about, but rarely is it probed with the sort of clarity Professor Keyfitz brings to the debate.

Finally, we have included a condensation of remarks made in July at an IIASA conference by Anatoly Chubais, Deputy Prime Minister of Russia and the cabinet minister in charge of privatization. Dr. Chubais, a frequent collaborator in IIASA activities, describes the history and the continuing challenges of the Russian government's privatization effort with admirable candor.

Peter E. de Jánosi
Director

C O N T E N T S

Cover: some of the 52 participants in IIASA's 1993 Young Scientists' Summer Program.

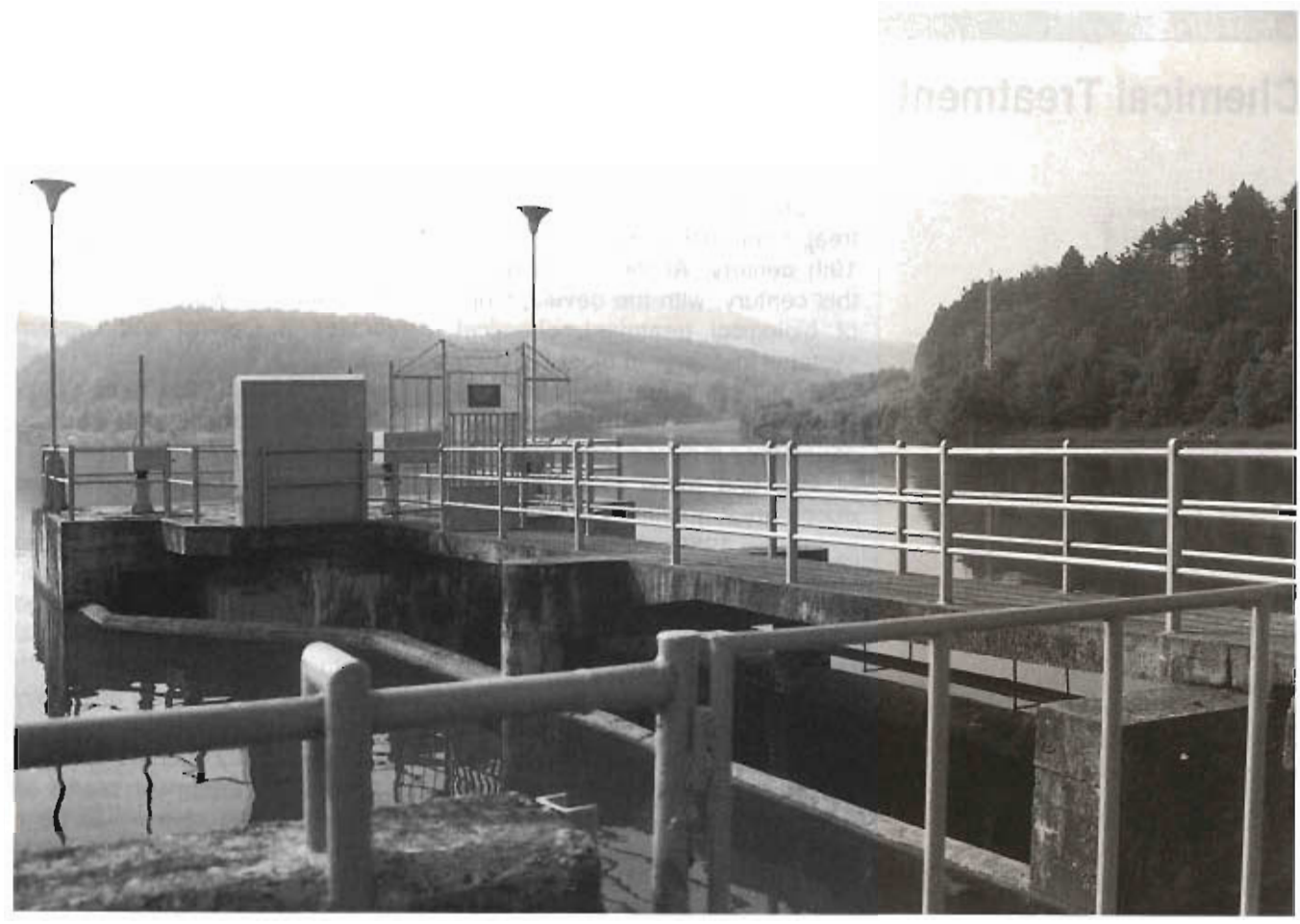
FEATURE

Young Scientists' Summer Program

ONE OF IIASA'S MOST SUCCESSFUL INNOVATIONS HAD ITS START IN 1977, WHEN THE INSTITUTE INVITED 12 talented young scientists to spend the summer working with IIASA scholars. The Young Scientists' Summer Program quickly proved its worth. The YSSP became an annual event, and the modest group of 12 in 1977 grew to more than 50 per year. Through the program IIASA has welcomed more than 650 young scientists from 36 countries. Thirteen scientists currently at the institute, including one project leader, first arrived in Laxenburg with the YSSP. Other participants in the program have gone on to successful careers elsewhere, including at least two appointments as government cabinet ministers. The 1993 YSSP brought together 52 young scientists from all 15 IIASA member countries.

On the following pages are brief descriptions of work by five members of that group. Each participant addressed a different aspect of the management of river water quality, using Slovakia's Nitra River Basin as an example. Their collaboration is a good example of how IIASA, through the YSSP, enables young scientists to look beyond the barriers that too often separate researchers from different disciplines and countries. The group was interdisciplinary and international. It included students of economics, engineering, public policy, and mathematics; their supervisors were from Hungary, Poland, and the USA. Data and model elements were freely shared. YSSPers and supervisors talked together for many hours, helping each other to understand the perspective of each of their disciplines and what they could bring to the study of the problem. The most tangible result is a set of complementary research papers that constitute a useful addition to ongoing work at IIASA. Less tangible is the lesson that each of the young scientists learned about the possibilities of international, interdisciplinary cooperation: in the long term this is perhaps the most valuable contribution of the YSSP.

IIASA would like to extend thanks to the institute's national member organizations in Austria, France, Germany, the Netherlands, and Sweden, as well as The MacArthur Foundation of Chicago, Illinois, USA, for generous financial contributions that allowed many young scientists from Central and Eastern Europe to take part in the 1992 and 1993 Young Scientists' Summer Programs.



The Nitra River Basin in Slovakia is the subject of a comprehensive, policy-oriented case study by IIASA (Pavel Petrovič photo).

Water Quality Research at IIASA

The articles on the next seven pages all involve work by participants in IIASA's Young Scientists' Summer Program on problems of river water quality management. Much of their research built on, and contributed to, an ongoing study by IIASA's Water Resources project of **Water Quality Management of Degraded River Basins in Central and Eastern Europe**.

Governments and industries in Central and Eastern Europe are under considerable pressure to move immediately to west European water management practices. This is simply unrealistic. They do not have enough money now, and will not have enough money for many years, to adopt the best available treatment technologies. Moreover, they face economic, legislative, and institutional instability unknown in the west.

It makes sense to move to western standards gradually, through a series of intermediate adjustments. The central goal of the IIASA study is to develop innovative strategies and tools that allow managers to improve water quality step by step, as money allows; to phase in successive least-cost policies while gradually tightening water quality standards.

The following articles touch on several areas of ongoing research, including: the investigation of low-cost, innovative wastewater treatment technologies (page 6); the use of economic instruments such as taxes, fees, and tradable discharge permits (page 8); and the development of computer models for cost-effective water quality management (page 9).

Each of the YSSP participants related their work to the Nitra River Basin in Slovakia (page 7). The Nitra is the subject of a comprehensive, policy-oriented case study by IIASA in collaboration with the Slovakian Water Research Institute and the Váh River Basin Authority.

The findings of the degraded river basins study will be broadly applicable to Central and Eastern Europe, and indeed anywhere that water management authorities are willing to consider innovative solutions in order to save money. In highly developed countries water quality managers tend to buy what they perceive as the very best technology; little attention is given to alternative strategies and technologies which could produce comparable results for a fraction of the investment — in some cases, for hundreds of millions of dollars less.

An upcoming issue of *Options* will report further on the study of degraded river basins and other research by IIASA's Water Resources project.

László Somlyódy

FEATURE

Chemical Treatment *A Cost-effective Alternative*

Susan Murcott is currently at the Parsons Laboratory of the Massachusetts Institute of Technology. Her principal research interests are the use of innovative technologies for wastewater treatment, including chemical upgrading and the use of natural polymers in water and wastewater treatment.

In the past decade the development of new polymers and chemical technologies has opened the way to potentially great savings in wastewater treatment. Work in Canada, Germany, and the USA has proved that the addition of low doses of chemicals and special polymers to wastewater can significantly improve the performance and increase the capacity of existing biological treatment plants.

In the summer of 1993 the author began a series of tests which suggest strongly that these emerging technologies offer practical, affordable solutions to some of the water pollution problems of Central and Eastern Europe. The need is clear: many treatment plants in the region are operating at two or three times their design capacity. Overall, less than half of the municipal sewage receives biological treatment. The rest is untreated or given only conventional primary treatment.

Chemicals have been used to treat municipal sewage since the 19th century. At the beginning of this century, with the development of biological treatment, chemical systems lost favor in most Western countries (although they remained in use in Scandinavia), largely because they required large amounts of lime and metal salts and produced great quantities of sludge.

In the 1980s the high costs of biological treatment, a concern with eutrophication of surface waters, and a growing awareness of the problem of metals contamination led to renewed interest in the possibilities of chemical treatment. At the same time, the development of polymers and new chemical technologies raised the prospect of using far lower doses of chemicals than in the past.

The problem is not to choose either chemical treatment *or* biological systems: the two are in fact complementary. It is likely that future sewage treatment will see a combination of mechanical, biological, and chemical techniques to remove solids, organic material, phosphorus, nitrogen, and toxic pollutants.

Conventional biological systems do a better job of removing organic material. Chemical treatment removes more phosphorus, a major cause of eutrophication, and heavy metals. Neither technology effectively removes nitrogen, which can be done only with advanced biological systems. Possible negative impacts of chemical treatment include a lowering of pH and an increase in sludge quantity, depending on the chemical dose.

The cost of chemically upgrading an existing biological system — essentially a few storage tanks and pumps — is negligible compared to the cost of building additional biological treatment capacity. Operating costs are about the same or slightly higher. These low investment costs, coupled with the ability to mix the technologies, raise whole new options for water quality management in Central and Eastern Europe.

First, it would allow rapid extension of the capacity of existing, overloaded biological plants. Chemical pretreatment typically doubles the capacity of a biological system. Metal salts such as $Al_2(SO_4)_3$ and $FeCl_3$ added in the initial, mechanical stage of treatment remove large particles, allowing the biological stage to deal more effectively with small particles. The salts are easily removed in the sludge.

Second, they offer the option of building new treatment plants in stages. The first step would be a low-cost mechanical–chemical treatment facility. When money becomes available, biological treatment could be added as a second stage.

In the summer of 1993 tests of five to ten days each were conducted at three treatment plants in the Nitra Basin of western Slovakia — Nove Zamky, Topolcany, and Nitra — and one in Budapest. The goal was to investigate whether the chemical technologies proven in the West could enhance the performance of existing biological sewage treatment plants in Central Europe, given differences in the type and degree of pollution, the type of technologies in use, and the mix of industrial and domestic sewage.

These tests were without precedent, and it took extensive efforts to arrange them. Local contacts led to local meetings, lots of talk, and more meetings. Cross-border transportation of a portable laboratory in seven trunks, boxes, and cases weighing a total of 100 kilograms, plus chemicals, some of them labeled with a skull and cross-bones, was a logistical miracle.

Considerable effort was made

to obtain and test locally available metal salts. In the long run local sources would be cheaper; their use in the tests also helped to demystify the process for local plant personnel and to convince them that it could in fact work. The chemicals tested were: $FeCl_3$, $Fe(SO_4)_3$, $FeCl(SO_4)$, $Al_2(SO_4)_3$, and $Fe(SO_4)_3$ plus $Al_2(SO_4)_3$. Also tested were polymers imported from Sweden: A302, A305, A392, and N200. Polymers were often omitted from the tests because their relatively high cost makes it unlikely that they could be used in Central and Eastern Europe.

The test procedure typically consisted of three stages: rapid mixing of a raw influent sample with the primary coagulant, usually a metal salt; a flocculation stage, which is a slow mix; and a settling stage. If a polymer was added it, like the metal salt, required a rapid mix step and a flocculation step. Metal salts were tested in concentrations from 0 to 200 mg/l, polymers in concentrations from 0 to 1 mg/l. Samples were regularly analyzed for chemical oxygen demand, turbidity, color, pH, and temperature.

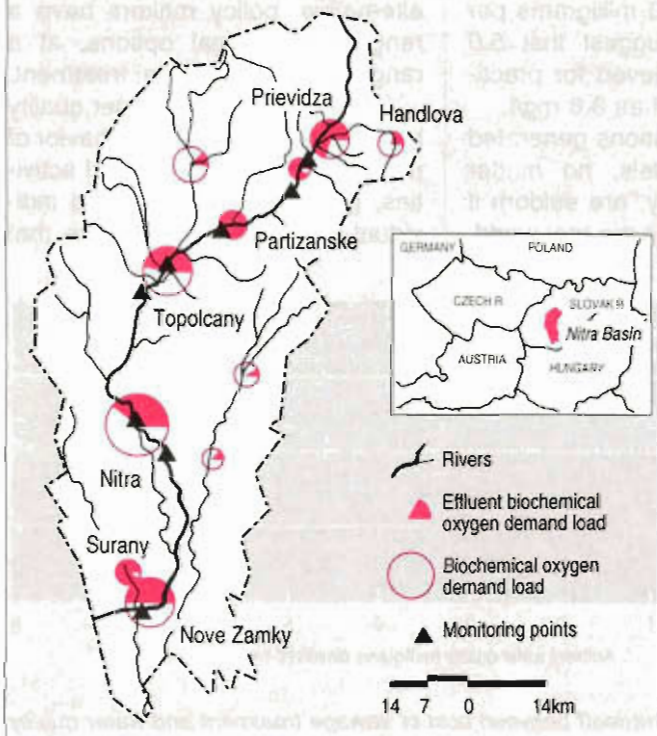
The results of the jar tests at the Topolcany plant were typical. The addition of any of several metal salts, without polymers, doubled removal of biological and chemical oxygen demand, from roughly 30 percent to 50 to 65 percent. The biological stage of the plant is overloaded: only about a third of the flow currently receives biological treatment. It is anticipated that chemical upgrading in the first, conventional stage would double the capacity of the biological stage, with concomitant improvements in overall effluent quality, and at the same time improve the removal of phosphorus.

Tests at the other plants gave similar results. The addition of 20 to 50 mg/l of metal salts in the primary stage of treatment consistently improved the removal of biological oxygen demand, total suspended solids, and phosphorus. The conclusion is that low doses of reasonably priced, locally produced chemicals could significantly improve the performance of existing or new sewage treatment plants in Central and Eastern Europe and could help to solve the problem of overloading.

The next step is full-scale testing. Two such tests were planned, one in October 1993 at the North Budapest wastewater treatment plant, and another in the spring of 1994 at Topolcany. Other work will entail more detailed economic analyses of the capital and operating costs of chemical upgrading in the region. Preliminary analyses indicate that the investment costs are minimal and operating costs per cubic meter of treated water are comparable to conventional biological systems.

This article is based on an IIASA Working Paper currently under preparation.

The Nitra River Basin



The Nitra flows south 171 kilometers through western Slovakia before entering the Váh not far from its confluence with the Danube, east of Bratislava. The Nitra's mean streamflow at its mouth is 24 cubic meters per second; in August it is under 3 m^3/s.

The Nitra Basin is an industrialized area of 5100 km^2. Municipalities contribute about 70 per cent of emissions of traditional pollutants (organic material, phosphorus, and nitrogen). Eleven towns and cities, home to 350,000 of the 600,000 inhabitants, have sewage and wastewater treatment plants. Most of the plants are 15 to 20 years old; several are overloaded by 100 percent or more.

The quality of the Nitra's water is among the poorest in Slovakia – Class IV or V for the oxygen regime and other components in the existing classification system, in which V is the worst. Biological oxygen demand values can exceed 30 mg/l and dissolved oxygen is sometimes below 2 mg/l (good water has at least 6 mg/l; fish begin to die at concentrations of 3 mg/l). Total phosphorus can reach 2 mg/l, while ammonia nitrogen may be 7 mg/l.

FEATURE

Economic Tools and Water Quality

Jeffrey J. Carmichael is currently studying environmental, natural resource, and public policy economics at the University of Colorado, Boulder. His principal research interests are economic modeling of environmental problems and market behavior, and the role of economic instruments as policy tools in environmental quality management.

Western countries often avoid the issue of water quality standards by adopting laws that force all polluters to use the best available treatment technology. They seldom consider the real uses of the river, or the cost implications. The result is very good water – often better than needed – at a very high price. In Central and Eastern Europe, where policy makers must reconcile high levels of pollution with low budgets, a best-available-technology approach is out of the question.

Work is under way at IIASA to develop innovative ways of setting and reaching reasonable water quality goals at the lowest possible cost. As part of this work the author developed a linked water quality–economic model to study least-cost options for municipal sewage treatment along the Nitra River. In particular, the model was designed to look at the potential use of economic instruments to help achieve ambient pollution control at the lowest possible cost.

Ambient water quality standards are a tool to promote the more general goal of maximizing net benefits for users of the river. Uniform standards are seldom cost-effective. A section of a river used as a source of drinking water must be of higher quality than a section used for recreational swimming or as source water for industry.

Different uses also imply different kinds of standards. The upper reaches of a river basin might have a valuable fishery, raising concerns about levels of dissolved oxygen. Downstream, the problem might be excessive growth of algae; here the standards might be based on phosphorus.

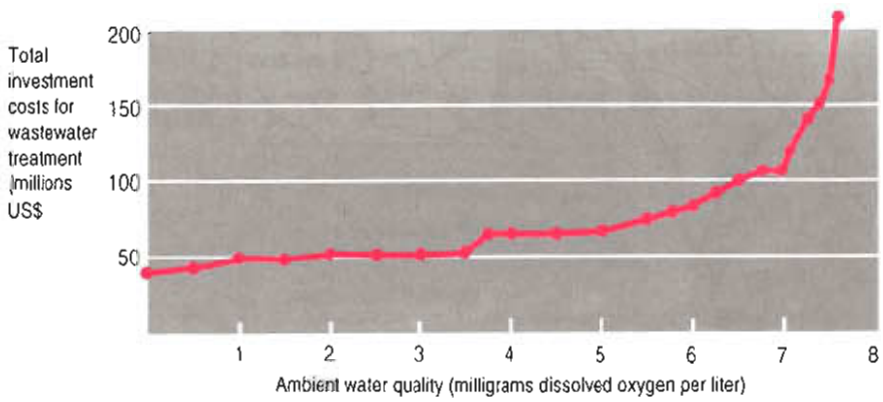
A least-cost approach dictates that standards should vary with use. This has several important implications. Costs rise generally, but not consistently, with higher quality. Model calculations for the Nitra shown on this page, using dissolved oxygen levels as the gauge of quality, illustrate a dramatic rate of increase in costs for a standard above 7.0 milligrams per liter. They also suggest that 5.0 mg/l might be achieved for practically the same cost as 3.8 mg/l.

Least-cost solutions generated by computer models, no matter how good in theory, are seldom if ever implemented in the real world. All or part of a solution may be rejected if it is perceived to be unfair (page 10). People living on one section of a river may not accept water of a lower quality than their neighbors simply because they use the river differently.

Least-cost strategies will almost always entail uneven investment. Sample calculations for the Nitra, based on an ambient standard of 7 mg/l of dissolved oxygen, suggest that the least-cost solution would involve large investments in pollution control equipment – up to US $34 million – along some sections of the river and no investment in others. This skewing of investment is at the other end of the spectrum from equity considerations, especially if local governments must pay for it.

Costs are a consideration everywhere, but especially in Central and Eastern Europe. One feature of the model was cost functions for various water treatment technologies, including low-cost chemical treatments recently tested for the first time in Eastern Europe by IIASA (page 6). It is important to recognize that the best-available-technology approach is not the only alternative: policy makers have a range of technical options, at a range of prices, for water treatment.

Efforts to improve water quality begin with changing the behavior of polluters, including industrial activities, government plants, and individual households. It is there that



An illustration of the tradeoff between cost of sewage treatment and water quality in the Nitra, based on preliminary calculations with the model described above.

pollution originates, and an efficient water quality program must start there to seek ways of reducing waterborne waste loads.

Pollution taxes, fees, and tradable discharge permits for air pollution have all been used extensively in the USA and/or Western Europe, with varying success, to modify user behavior cost-effectively. If it is cheaper for individuals or firms to reduce emissions than to pay fees; or if firms can sell their emission permits for more than it costs them to cut the emissions, they will probably do so. To the extent that firms and individuals behave rationally, they eliminate the emissions that are cheapest to cut; hence the element of cost-effectiveness.

Enforcement of water quality regulations, pollution tax structures, and systems of tradeable discharge permit are issues that follow closely, and must be part of any water quality management system. A simple model of agent behavior in reporting water quality, subject to fines for cheating, was developed to investigate how optimal enforcement might be accomplished.

Understanding the possible effects of economic instruments in the Nitra Basin is one of the goals. Further scenario calculations incorporating fees and taxes will be made with the model to try to get a sense of how such instruments might affect water use.

More generally, the goal of the modeling exercise is to illustrate the potential value of mathematical optimization techniques to help policy makers find the best possible balance between water quality, treatment technologies, and costs. Such tools would be valuable for water quality managers, not just in Central and Eastern Europe, but worldwide.

This article is derived from an IIASA Working Paper prepared jointly with ***Charles W. Howe****, Director of the Program for Environment and Behavior at the University of Colorado.*

FEATURE

A Prototype Model for Water Management

Rainer Berkemer is currently a Ph.D. candidate and research assistant at the Institut für Textil- und Verfahrenstechnik in Denkendorf, Germany. His principal area of research is decision analysis and cooperation theory, with emphasis on object-oriented simulation of decision processes.

David Watkins is working on a doctorate in Civil Engineering of the University of Texas, Austin. His principal research interests are decision support systems for water resources management and for the planning of joint use of surface and ground water systems, as well as water resources in developing nations.

As part of its case study of the Nitra River Basin, IIASA's Water Resources project has encouraged development of a family of models of varying complexity and types, exploring different approaches to the modeling of water quality management problems. A contribution to this family of models was made in the summer of 1993 by the authors, both participants in the Young Scientists' Summer Program, in cooperation with Marek Makowski of IIASA's project on the Methodology of Decision Analysis and with members of the Water Resources project.

A common approach to water quality management is to devise a computerized system that will identify a set of sewage treatment plants and technologies that achieve specified water quality standards at the lowest possible cost. The model described in the story on the opposite page is of this single-criterion (least-cost) optimization type.

Our goal was to develop a decision support system which can augment simulation and single-criterion optimization models. The system is based on a simple but realistic core model that relates costs, water treatment technology, and water quality. It allows examination of this core model by simulation and by generating and solving different optimization problems. A major advantage is multicriteria analysis, which allows users to assess tradeoffs more easily than single-criterion systems and to get insights into the relationships among costs, technology, and water quality.

Core components of the prototype were developed following lengthy discussions with our colleagues in the Water Resources project. Many elements of the system, including the hydrological data base, water quality simulation tools,

and information on treatment alternatives were transferred from their models. All data were directly or indirectly the result of their work.

In addition to creating a simplified core model, we developed a set of software tools for multicriteria optimization. The set comprises the object-oriented programming tool ORVAN, a specialized problem generator, a solver for mixed integer programming problems, and software for the analysis of results.

ORVAN was originally created to assist in the design of systems for materials production planning, but it appears to be extremely flexible. It was programmed at IIASA for this application in just a few weeks. ORVAN proved useful for formal analysis and modification of the data, fast prototyping of the model and its modifications, and scenario analysis using simulations.

The second tool is a problem generator developed specifically for this application. The generator can formulate different types of both single-criterion and multicriteria problems. The generator converts multicriteria problems to an equivalent single-criterion formulation with the help of an achievement scalar function.

MOMIP, a multipurpose modular software tool developed at IIASA, is used to solve the resulting mixed integer programming problem. Simple postprocessing allows illustration of results as plots.

Users of the system can specify variables such as total costs, water standards, or aspiration levels for various criteria. Scenarios can be generated either by a "manual" selection of decision variables (choices of waste treatment technologies) or by solving an optimization problem.

Optimization is not seen as a tool which provides one best solution. Rather, by generating, solving, and analyzing various scenarios it should help decision makers to understand the consequences of different assumptions and decisions. Multicriteria optimization is better suited for this purpose than formulations of different single-criterion problems.

We tested the prototype on scenarios using the same data and assumptions as in the Water Resources project. The key results were broadly in line with the project's, even though the core model on the multicriteria system was much simpler. These preliminary results indicate that the simple model can complement the more complex models by screening out bad alternatives and highlighting workable options that simultaneously satisfy environmental, economic, and other objectives.

This article is derived from an IIASA Working Paper written jointly with ***Marek Makowski****. It contains a detailed description of the model, methodology, data, and examples of analysis.*

Fairness in Water Quality Agreements

Katrina Smith is currently working on a doctorate in Environmental Studies at Duke University, North Carolina, USA. Her principal research interests are the use of science in environmental policy-making, research planning for environmental management, and the selection of appropriate models.

Natural sciences can and do influence most environmental debates, but no more than economics and less tractable "soft" elements. History and tradition, politics and power all play a part. So too do concepts of fairness, no matter how defined. We know that a solution which is considered unfair is unlikely to be accepted, or, if implemented, to survive for long. We also know that the idea of fairness is often appealed to in environmental debates. Beyond these observations, however, fairness is not well understood.

As part of the 1993 Young Scientists' Summer Program, Katrina Smith developed a simple taxonomy of fairness concepts, showed how these concepts are reflected in water quality issues through domestic and international law, and demonstrated how they might be usefully applied to IIASA's case study of the Nitra Basin. This article reviews her application of these fairness concepts to the Nitra and implications for the distribution of the costs and benefits of pollution control.

The application was intended to complement a combined economic and water quality model of the Nitra Basin developed by Jeffrey Carmichael (page 8). The goal of the model is to identify ways to raise water quality to desired levels at the lowest cost. It presumes that a decision has been made about water quality goals, and hence the acceptable level of pollution. Additionally, it offers no guidance as to how to distribute the cost.

The fairness taxonomy was applied to three stages of decision-

making in the Nitra: setting ambient standards, determining emission limits, and distributing abatement costs. The taxonomy was based on three broad principles — parity, proportionality, and priority — proposed by Peyton Young of the University of Maryland, who collaborates extensively with IIASA's Risk Analysis and Policy project.

Setting Standards

Water quality standards are often set uniformly for an entire river. This implies a view of fairness in which water quality is distributed as a good which all people should enjoy equally (**parity**).

But suppose people along a certain part of the river have a need for better quality water: for example, to support a fishery. Uniform quality could be perceived as unfair. Fairness might mean ambient water quality standards which give **priority** to established uses of the river.

Alternatively, people might believe that the river's capacity to assimilate municipal sewage is the main benefit to be distributed. Standards might be made **proportional** to the population on each section of the river.

These alternatives for setting water quality standards are no less arbitrary than a uniform ambient standard for the entire river. Depending on social priorities, any of them might be considered fair.

Allocating Emissions

Members of IIASA's Water Resources project have assessed various approaches to the problem of allocating emissions on the Nitra, including best available technology, uniform percentage reductions, and cost-effective reductions.

Many Western countries require best available technology for pollution control. The best technology gives the best quality water, but at the highest price. Given the economic problems of Central and Eastern Europe, best available technology is not a realistic option.

Uniform percentage reductions are easily understood and often accepted as fair, but they are seldom cost-effective. Additionally, they penalize polluters who have already invested in pollution control. Whether they are seen to be fair depends on society's views of the relative importance of past behavior (grandfathering) and current economic burdens.

A least-cost solution, as determined by the model, might mean installing expensive equipment at some sites and none at others. This presents no problem if pollution control is centrally funded; it simply shifts the question of fairness to the central funder's source of money, to the tax structure. But

Two Peccei scholarships are usually awarded each year. In 1992 they went to **Andrei V. Ganopolskii** (top), from the Computing Center of the Russian Academy of Sciences in Moscow, for his work with IIASA's Climate Change Strategies project on a two-dimensional zonal climate model, and **Wolfgang Schopfhauser**, from the Institute for Forest Ecology of the Agricultural University of Vienna, for his work with IIASA's Forest Resources project on carbon sequestration potential of global afforestation. The 1993 Peccei winners will be announced later this year.

The Peccei Scholarship

Since 1984 IIASA has recognized exceptional participants in the annual Young Scientists' Summer Program by awarding them Peccei Scholarships. The scholarships provide money for them to return to the institute to work on a project of their choosing for a period of three months in the following year.

Aurelio Peccei (1908—1984), perhaps best known as the president of the Club of Rome, enjoyed a distinguished career in industry, conservation, and international affairs. Peccei was a consistent and devoted friend of IIASA, a member of the small group of dedicated individuals who inspired the original concept of the institute and helped to make it a reality.

During his later years Peccei's overwhelming concern was the challenge of finding creative opportunities for young people to influence a shared future. The scholarships that bear his name were established in an effort to meet this charge, and to recognize Peccei's contribution to the promotion of multinational, collaborative research.

FEATURE

with devolution of authority in the Nitra, pollution control measures are not likely in the future to be centrally funded.

Least-cost planning may be a broad societal goal, but it gives no guidance on how to share the burden equitably. At least three economic instruments — emission permits, pollution taxes, and tradable discharge permits — have been used to promote cost-effectiveness. Each has its own distributional implications.

Emission permits could be used effectively only if a planning agency had full knowledge of each plant's marginal costs of pollution reduction — knowledge that is seldom available in Central Europe. The idea is that polluters with the lowest marginal cleanup costs would bear the most cleanup responsibility. Even if it were feasible, this would not likely be seen as fair.

Pollution taxes have been used widely in Western Europe. Each polluter faces the same tax per unit of emissions. Each polluter should reduce emissions until the marginal cost of polluting equals the tax, resulting in a cost-effective reduction of emissions.

Finally, tradable discharge permits have been used extensively in the USA to address problems of air pollution, though they have not yet been applied to water issues. Permits are distributed to polluters. If they pollute less than allowed, they can then sell the remaining allowance. The fairness implications lie in the initial distribution of permits. The distribution is often based on existing emissions, in effect giving priority to historical polluters.

Distributing Costs

One solution would be to charge each user according to the cost of treating its wastes. This would give users an incentive to reduce pollution until the marginal cost of reduction equals the cost of treatment. This polluter-pays approach might be seen as fair, but there are difficulties in metering pollution, especially for residential users.

Concerns about equity complicate the issue. A great deal of research has been done on equitable pricing of regulated industries, such as electric and water utilities. Any such scheme in the Nitra would have to consider, among other things, historic subsidies of treatment plants and the potential shock of a jump to full cost for residential and industrial users.

This discussion about pollution control in the Nitra shows the many levels at which fairness comes into the decision-making process for water quality management. It also underscores the importance of considering the societal concerns about fairness before setting policies regarding ambient water quality, regulation, and pricing.

The study of fairness in environmental decision-making does not promise to make our decisions better, since there is no universal definition of a better decision or standard for fairness. It does, however, have potential for aiding the analysis, organization, and broadening of how fairness concepts are used, and for increasing our understanding of how they influence environmental debates.

This article is based on an IIASA Working Paper currently under preparation.

FEATURE

Genuine Interdisciplinary Study is Possible as Well as Necessary

by Nathan Keyfitz

When scientific disciplines answer different questions that look alike they give the appearance of contradicting one another. If true that would make effective collaboration and interdisciplinary work impossible. We show that there is no contradiction in fact, and its appearance is due to the disciplines asking and answering different questions. Simple examples show the difference between the questions and suggest how their answers complement one another.

Two aspects, the natural and the social, exist for policy questions, and it often seems difficult to express either their methods or their conclusions in terms such that one can be fitted into the other. Yet reconciliation is made necessary by the opposite conclusions at which they arrive on some very practical matters, matters that have to be dealt with urgently. When they contradict one another in their recommendations science as a whole suffers a loss of credibility and usefulness. We will see how the contradictions arise, and how they may be reconciled.

MORTALITY AND POPULATION INCREASE. Infant mortality would seem to reduce the number of children who grow to maturity, and hence the rate of increase of the population. That is what Garret Hardin, a **biologist**, believes (*Living Within Limits*, 1992, New York, Oxford University Press). But, says the **demographer**, that is only when the infant deaths are considered in isolation, and the possibility that couples alter their later childbearing is disregarded. Couples may have a target number of living children in mind and they replace infant deaths to attain their target. If the decline in deaths is part of a development process that includes education, especially the education of women, then the fall in infant mortality goes along with a diminution of population increase, as demonstrated by dozens of concrete instances as development has proceeded in various parts of the world.

EXHAUSTION OF ENERGY RESOURCES. For an **oil engineer** there is only so much oil in the ground, and though we do not know whether it is much or little, whatever we draw out and use reduces the amount, and so brings closer the day when we will be short of energy. But that overlooks the possibility of substitution, says the **economist**; as the end of the supply comes into sight the price will rise, there will be a premium on seeking new sources of energy, and substitution will surely take place. That is why no real energy crisis is ever likely, say those who accept this line of analysis.

EFFICIENT LIGHTING. When we use a new design of light bulb that saves two-thirds of the thermally generated energy required for lighting a room, the **engineer** will be satisfied that only one third as much electricity is drawn and that only one-third as much carbon dioxide is produced, and the householder is pleased with having saved two-thirds of the lighting expense. But the **social scientist**, in this case IIASA's Sture Öberg, asks a further question: what will the householder do with the money saved? Suppose that it is added to a bank account that is later spent on a heavier car. The net energy saving due to the better light bulb would be much smaller.

PREGNANCY TERMINATION. How many births does a miscarriage prevent? Obviously one, answers the **physiologist** or the attending **physician**. Not so obvious, says the **demographer**. If subsequent childbearing is exactly the same as though that miscarriage had been a live birth, then "one" is indeed the answer. But this sequence is improbable; couples are likely to have their next birth sooner after a miscarriage. If the woman proceeds immediately to another conception, the loss of births will be far less than one.

TAX COLLECTIONS. A new expenditure tax is proposed; the purely technical **accountant** or **tax expert** will often calculate the resulting treasury receipts from the previous pattern of taxpayers' expenditure. **Economists** recognize that people alter their expenditures in a direction that lightens the impact of a tax; that is why,

they say, tax collections resulting from a change in legislation often turn out to be less than promised by the specialized expert. Economic theory can give very different results from a multiplication table.

These cases are all different, and yet they have one feature in common: each is answered by a specialist who considers only the particular circumstances in isolation from other concomitant changes; a social scientist considers the question in context. Only very slightly different is the national income.

NATIONAL INCOME. The Gross Domestic Product is often used by economists as the measure of welfare, so sociologists as well as the public are puzzled when the GDP is increasing rapidly and at the same time crime, the number of homeless, destruction of forests, smog in cities are also rising. And the biologist mocks the GDP for its failure to recognize the contribution of the living environment. The source of the difficulty is simple: the GDP essentially estimates production in the commercial economy — production for the market. It has no way of evaluating either the quality of life or our effect on the environment. Those who make the compilation of course know this, but they do not protest when the mass media publish the numbers as though they covered every aspect of national wellbeing. They sometimes even encourage misinterpretation by including small adjustments that are supposed to cover non-money transactions.

In fact the contradictory answers given to particular questions are due to the different assumptions in which scientists frame their work. That is common to every one of the cases above. It often takes patient study to find out just what their assumptions are. If the more specialized disciplines are guilty of anything it is their failure to make it easy for outsiders, in particular administrators who use their recommendations, to understand their constraints and limitations. They put their conclusions in large letters and bold face; the assumptions are mentioned, but in finer print.

Impatient readers want things simple, and by taking the questions broadly they overlook the differences in the several disciplines. What is the effect of energy use? No one can answer that as it stands, except by asking "Effect when, and on what?" Economics tells the effect of energy use in the short run, and not its effect on everything but only on productive commercial activities in free markets. Biology tells the effect, also not on everything but on living systems, and over a much longer period of time. Efficiency is paramount in economics while survival is what counts in biology, and these very different criteria orient much of the research in the respective disciplines.

Efficiency and survival of species are both perfectly legitimate ways of regarding the world fishery, where short-run efficiency — i.e. bigger catch per fisherman or per boat — can be perfectly consistent with long-run extinction of commercial species. Once we realize what economic efficiency means, as well as the biological conditions that lead to extinction, the two conditions can coexist in theory as they evidently do in reality.

Where overenthusiastic practitioners of the disciplines are often culpable is in not making clear the restricted scope of the questions they ask and hence of the answers they give. What look superficially like the same questions are different enough in different disciplines that they can have quite opposite answers. The physiologist asks "If nothing else changes, will better nutrition produce more children?" and using much ingenuity to isolate the experiment from all other influences is able to show that it will. The demographer asks "If nutrition improves, along with the spread of education and the freeing of women, will more children be born?" and by examining living societies finds the answer to be that it will not, that fewer children will be born.

A curious situation: in the natural wish to extend to the maximum the scope and usefulness of its science, its field of application and its importance, a discipline makes light of some of the restrictions on its findings, and so does another discipline; making each more general than its data permit causes the two to sound as though they are answering the same question; their different answers contradict one another; the public loses confidence in both.

Mature empirical disciplines, using data drawn from the same reality, cannot contradict one another. The assertions of each have been through a fine sieve of internal testing and criticism. All the institutions of a discipline — its journals, its graduate seminars, its conferences, its peer review — are set up for just this sifting, and they offer innumerable opportunities for uncovering errors of reasoning or inconsistency with data. If two disciplines are both consistent with the real world they cannot be inconsistent with one another. They only seem to contradict because their results are paraded carelessly, expressed in the same words. The first step in interdisciplinary work is more careful discovery and specification of the assumptions in the two disciplines, finding out what really are the questions that they respectively are answering. An incidental benefit of interdisciplinary work is making each discipline more aware of the range of application of its own conclusions.

While that recipe is straightforward, its execution is not always easy. The examples of this article have been chosen for the obviousness of the reasons for their disagreement. On the other hand the different conclusions of biology and economics on growth cannot be so easily traced. In more complex cases such as this nothing less than immersion in the methods and data of the two disciplines will enable one to resolve their apparent mutual contradiction. ■

FEATURE

Privatization in Russia

The transfer of enterprises from public to private hands is a controversial part of the transition from central planning to a market economy. Following is an edited transcript of remarks made in July at IIASA by ***Anatoly Chubais, Deputy Premier of the Russian Federation.***

In preparing for this report I began by trying to make an independent analysis of the privatization situation, but I rapidly realized that it is impossible. I cannot pretend to be independent.

So what would I like to discuss? There are a lot of papers and presentations about the economics of privatization in Russia. And there is a lot of discussion about the political side of privatization. My point is that it's extremely important to emphasize the connection between the politics and the economics. I will try to argue that political factors in Russian economic reform were the number one priority, and economic reasons were number two.

We started in January 1992. At that time there were 37 or 38 private shops and restaurants in Russia. On 1 June 1993 we had 69,000 private enterprises. Most were small firms but there are also about 4,500 large and medium-sized formerly state-owned companies which have became joint stock companies. There are now more than 20 million shareholders in Russia, most of them shareholders in the enterprises where they work. More than 35 percent of employees in Russian industry are now employed in joint stock companies. My guess is that by the end of 1993 more than 50 per cent of employees in Russia will be in non-state businesses.

> ***"If we had not started immediately, we would have lost everything. The discussion about the gradual approach to privatization versus a radical approach has only one right answer."***

Let me return to the links between the politics and the economics of privatization, or, even better to say, the political reasons behind the economic decisions. To find these links I will review the main stages in the process. We can point to five main stages. The starting point was November 1991, when a reform-oriented government was appointed.

At that time we had a privatization law, which had been adopted by the parliament in mid-1991, but we needed a state privatization program. We understood that if we tried to submit such a document to the full parliament it would take months to adopt it. We didn't want to waste this time, so we called the document the *guidelines* of the state privatization program, not the program itself, and submitted it to the presidium of the parliament instead of the full parliament. By the end of December 1991 we had official approval. This was the starting point.

In January 1992 we started two processes. The first was a public discussion about our conception of privatization. Immediately after we got official approval from the presidium, our plan was published: this started the fight. The other thing was to begin implementing our concept. That was the second period, from January till June 1992.

The main practical activity was creation of an institutional framework, the ministry for privatization, GKI. It was responsible not only at the federal level but also at the local level, which is much more important in Russia. On 4 April we had the first sales. By the middle of 1992 we had organized departments of the privatization ministry in each district of Russia.

At the same time there was a strong discussion in the parliament and in the press. I have to say that all the main social groups were against our privatization conception. The workers' collectives said that all the property would be given to the managers, and they could not accept it. The managers said that all property would be distributed to the workers and that's why they could not accept it. The business people said that all the property would be distributed to the managers and workers, and that's why they could not accept it. And the remaining parts of society also said that they would get nothing from privatization, so they could not accept it.

Our goal was to balance these opposing forces, keeping them equally in check. There was a heated discussion in parliament for at least four months, but finally we got a document that was reasonable. The state privatization program which was finally adopted in June 1992, at the end of the second period, reflected the balance of power among the main political forces and main social groups. There were a lot of arguments from the communists, but at that time they could not get more than 35 or 40 percent of the votes in parliament; I could get 55 or 60 percent.

So in June 1992 the revised privatization law was

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approved. At that time we already had real results from small-enterprise privatizations. Much more important, we had two months of holidays for the parliament. We decided that we should make full use of this time.

We immediately started to prepare for mass privatization. On 14 August there was a presidential decree introducing privatization vouchers. This started a big struggle in parliament when it returned in September. But the important point is that during the third period, between mid-1992 and the end of 1992, public attitudes toward privatization started to change.

Before mid-1992 privatization was just something people read about in newspapers. They didn't realize what it meant. From the middle of 1992 more and more people became involved in the process. Privatization started to be a part of everyday life. People shifted from a general discussion about the concept of privatization toward the micro level, toward the competition for a piece of property they might be able to get hold of. This was a very important shift.

At the same time, after the president's decision about privatization vouchers, parliament started to take a much more negative line. They started to think, not about changing the conception, but about stopping the whole process. So by the end of 1992 we had in Russia tens of millions of people involved in the process and a parliament that was against it. By that time I could get in parliament perhaps 10 percent of votes, not more.

The next stage, the fourth stage, was between January 1993 and April 1993. This was the period when parliament started to understand that it was impossible to block privatization because it was already under way. The leaders of parliament understood that such a decision could only undermine the remaining power of the parliament. They wanted to stop it, but they understood that it was politically impossible.

The latest stage began after the referendum. There was a reorganization of the internal political structure of the parliament and a change in the committee for economic reform. In the last few weeks, they started to attack once again. They demanded that the goverment resubmit the 1992 privatization program to parliament, or they would declare it invalid. Parliament's general attitude toward privatization became even worse than before. So the parliament turned against the government's privatization conception but the people began to understand and support it. Millions of people had become shareholders and they could never accept the idea of giving their shares back.

If I'm right, this means that we had in Russia a very narrow window of political opportunity. After mid-1992 it became impossible to get any kind of positive or even reasonable decision about privatization from parliament. If we hadn't acted when we did, we would never have had privatization in Russia. At the same time, if we had not started the process quickly outside parliament, if we had not involved millions of people, it would have failed. So that's my general conclusion: the only chance to have privatization in Russia appeared in December 1991 and disappeared in mid-1992. It is important to understand this when you consider the economic decisions that we made. I will outline a few of the dilemmas we faced regarding privatization and try to explain some of the choices we made.

The first dilemma was between a case-by-case approach to privatization and a simplified standard procedure. The choice was clear: if we tried the case-by-case approach we would probably have 10 or 15 companies privatized today.

The second privatization dilemma involved the method of property valuation. Western auditors give wonderful advice about how to assess the value of property in each company in Russia, but it would take probably one year and $10 million or $15 million for each assessment. From the purely economic point of view, that's absolutely the right decision. But politically it's absolutely senseless. The only way to evaluate property in Russia is to do it according to extremely simplified rules, to have evaluations based on the book assets, and then sell property through a competitive procedure.

The third dilemma involved the means of payment: should we rely on money or on some artificial means of payment, like vouchers or privatization checks? Again, if we took the first choice, it would have meant that we would have 25 or 50 privatized companies. Vouchers or privatization checks made it possible to get the

results we have now. It was extremely important politically to have this decision, which is probably debatable from the purely economic point of view. Privatization checks made it possible to involve 146 million people in the privatization process and to create political pressure at both the federal and local levels.

Let's say that somewhere you have a 100 percent communist local government and regional council. But they have 1.5 million voucher holders in their region. If they try to stop privatization they immediately have to go to the mass media and explain why they are stopping it, why they don't allow people to use their vouchers and exercise their right to receive property.

The fourth dilemma or probably it's a subdilemma under the privatization voucher discussion - was the question of whether the vouchers should be bearer documents or whether we should set up individual privatization accounts, which was what the law required at that time. I am sure that only our decision to use freely traded vouchers made it possible to have privatization on the scale that ensued.

Individual privatization accounts would have dispersed property. The concept was to prohibit sale for three years from these individual accounts for citizens. What happens now instead is that individual owners buy, say, 15 or 20 percent of stocks through voucher options. This makes it possible to concentrate capital.

The fifth privatization dilemma was the choice between bottom-up and top-down approaches. Again there was only one answer: bottom-up. According to the privatization law, everybody can take the initiative and apply to the local department of GKI for privatization. It could be a company director or it could be the workers; it could be people from the street. There is a very limited list of reasons for refusal of privatization. The same applies to the mass privatizations: it is not the decision of the government, it is the decision of the internal privatization committee in each company. One of our principles is to limit limits: we have no list of companies which were allowed to be privatized; instead we have a list of companies which are not allowed to be privatized. The remaining enterprises can be privatized without a special decision by the government or the GKI.

The sixth dilemma concerned the status of the GKI: should it be a normal ministry or its own master, holding all property rights and able to make any kind of decision, with its own network all over the country. The only right answer is the second answer.

I could add to this list. My point is that if you want to discuss the economic part of privatization, you should keep in mind the political situation. Otherwise the discussion will be just theoretical.

Why we had such a narrow political window of opportunity is another question. Probably it's because the communist party was destroyed after the August 1991 coup. It was in the shop for one year, but after mid-1992 it started to reorganize and to be a real political force. There could be other explanations why we had this short period of time, but I am sure that we had it. And I am sure that if we had not started immediately, we would have lost everything. The general discussion about the gradual approach to privatization versus the radical approach has only one right answer.

We probably will pay a price, an economic price and a political price, for the choices we made. I want to comment on several criticisms of our approach.

One is the question of corruption and crime. There's a lot of criticism that privatization increased the level of crime and made mafia leaders the owners of the big stocks. The level of crime increased, that's sure, but what is the basis for comparison? Let's try to compare radical privatization and gradual privatization: I am not sure that gradual privatization over ten years in our country would create less crime.

Moreover, I could say that radical privatization created the political forces that are now interested in defending property rights in Russia. I think it's impossible to create a social system which would protect property rights without creating those rights first. Radical privatization in the long term is probably the best way to decrease the level of crime.

The second price we paid is that we lost a number

IIASA and Perestroika

IIASA's work on economic transition in Eastern Europe began in 1989 when Stanislav Shatalin, chief economic adviser to then-president Gorbachev, asked IIASA to set up an expert consultative panel. Several Russian members of that project later became leaders of the transition process.

In 1992, at the Russian government's request, IIASA agreed to organize a series of workshops for Russian and Western experts to discuss problems of reform, including:

- *Privatization and the behavior of enterprises,*
- *The impacts of policy on employment and the design of a social safety net,*
- *The Russian taxation system,*
- *Internationalization of the Russian economy.*

Vice-Premier Chubais's remarks were made July 9 at a workshop on privatization. An article in Options, June '93, by ***Christoph Schneider*** *of IIASA and* ***Serguei Glaziev****, then Russia's Minister for Foreign Economic Relations, reviewed a study of the management of research and development during economic transition.*

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of foreign investment projects that did not fit the privatization concept. I know of a case in 1992 when foreigners tried to create a joint venture. They expected an individual decision from the government, but we were against individual decisions because this contradicted the general approach. So we lost this project; probably it is better to say that we just delayed it.

The third argument was that Russian privatization did not create strategic investors. This criticism could be heard every day in the parliament, in the newspapers, but I can't agree with it. Potential investors have a list of possibilities. I could give examples of strategic investment: one company bought 10 percent of the stocks in an auction of 500,000 shares.

The biggest price that we will pay will come tomorrow. The main danger to the whole privatization program is the risk that it will face when some of the privatized enterprises, or probably most of them, become bankrupt. There will again be a big political fight about privatization itself. The communists will say, 'This privatized company became bankrupt, we should take it back to the state and give it additional subsidies, then we shall have a good enterprise'.

Politically that's probably the main risk we took when we chose the radical voucher approach. That's why I was in favor of the creation of a privatization fund, an independent, nongovernmental source for investment. In Russia we now have a systemic negative attitude in government toward any kind of financial support of privatized enterprise. They now have a much more difficult situation than the state enterprises. We have to solve this problem.

So that's some explanation of the decisions we made regarding privatization. My point is that the only way to find the right answers in a discussion about the economics of privatization is to take into account the politics. Thank you. ■

NEW PROJECTS

Climate Change and Bangladeshi Agriculture

Supported by a contract from the UN Food and Agriculture Organization, IIASA will take part in an international effort to upgrade the FAO's land resource data base on Bangladesh and to assess the potential impacts of climate change on the country. Contact: *Günther Fischer*

Maglev in Europe

The CEC Institute for Prospective Technological Studies has awarded IIASA a contract to study the impact of the introduction of maglev subways and trains on the European transportation system and to model a feasible scheme of penetration of maglev systems to 2030. Contact: *Cesare Marchetti*

Analysis of Austrian Negotiating Experiences

The Austrian Ministry of Science and Research has awarded a contract to evaluate a methodology for systematic comparison of international negotiations. The work will involve analysis of an IIASA data set on past Austrian negotiations to see if there are patterns that suggest an Austrian "style" of negotiation. Contact: *Bertram Spector*

NEWS

Appointments

Charles Backman (Canada), from the University of Washington Center for International Trade in Forest Products, **Kai Uwe Blauberg** (Finland), from the Finnish Forest Research Institute, and **Gerhard Raile** (USA), from the North Central Forest Experiment Station of the US Forest Service, have joined the Siberia study of the Forestry project.

Péter Dörfner (Hungary), of Hungarian Power Companies Ltd., has joined the Transboundary Air Pollution and Environmentally Compatible Energy Strategies projects.

Mojdeh Keykhah (USA), of Princeton University, has joined the Industrial Metabolism project.

Christopher Heyes (UK), of Warren Spring Laboratory, has joined the Transboundary Air Pollution project.

Matteo Malvani (Italy), from the University of Florence, and **Kenji Okada** (Japan), from the Central Research Institute of the Electric Power Industry of Japan, have joined the Environmentally Compatible Energy Strategies project.

*On 1 September **Ingrid Gürke**, **Eduard Löser** and **Lieselotte Roggenland** joined the ranks of IIASA staff members who have 20 years of service at the institute.*

NEWS

Cynthia Marling, (USA) of Case Western Reserve University, has joined the Advanced Computer Applications project.

Jeffrey Niemann (USA), a participant in the 1993 Young Scientists' Summer Program, and **David Yates** (USA), from the University of Colorado, have joined the Water Resources project.

CONFERENCES

Modeling Environmental Dynamics, 30 Aug–2 Sept, Sopron, Hungary. At this workshop 33 participants from 12 countries discussed methods for modeling, identifying, and forecasting dynamic environmental systems. The main topics were qualitative behavior of population models, ecosystem modeling, parameter estimation and identification, observability, control of uncertain distributed systems, and applications of work in this field. About 10 of the papers presented will be published in the *Journal of Forecasting, Environometrics, and Mathematical Modeling.* Contact: *Arkadii Kryazhimskii*

Advances in Methodology and Software in Decision Support Systems 27–29 Sept, Laxenburg, Austria. This annual workshop, organized jointly with Yoshikazu Sawaragi, chairman of the Japan Institute of Systems Research, is an opportunity for researchers to discuss methodology and to demonstrate new decision support systems. Some 41 participants from 12 countries gave 27 presentations. Abstracts are available on request. Contact: *Marek Makowski*

The Use of Neural Nets for Decision Support, 30 Sept–1 Oct, Laxenburg, Austria. This workshop gave 23 specialists from 9 countries an opportunity to discuss the advantages and disadvantages of neural nets, particularly in comparison with algorithmic and rule-based approaches, and to consider how and when neural nets should be applied in decision support. Participants also discussed what types of neural nets to use, how to construct them, and training and adaptation. Contact: *Marek Makowski* or *Jaap Wessels*

IIASA Gets a Gopher

The millions of users of the Internet computer network can now learn more about IIASA through a new information service. Gopher is an electronic reference service containing documents from institutions worldwide. First set up by universities, it now has documents from literally thousands of academic and research institutions, government organizations, and private firms. Internet users can get free copies of Gopher software for DOS, UNIX, and Macintosh systems from many Internet FTP archive sites. The IIASA Gopher is located at **gopher.iiasa.ac.at**. The information currently available includes:

- A short introduction to IIASA, including history, research work, and membership.
- The research section of IIASA's *1992 Annual Report*, with short descriptions of each project and its accomplishments in 1992.
- *This Week at IIASA*, a weekly timetable of conferences, workshops, seminars, lectures and visitors.
- The IIASA publications catalog which is searchable by keyword, author, publication date, project, subject, and document type (books, working papers, research reports, etc.) and includes a number of abstracts.

More information will soon be available. If you need help accessing the IIASA Gopher server, or if you have any suggestions about the information you would like to see made available, please send e-mail to gopheradmin@iiasa.ac.at.

Forthcoming Meetings

IIASA will sponsor the following scientific meeting in 1993.

Dec 17–21: Evolutionary Game Dynamics in Biology and Economics, Laxenburg, Austria. Contact: *Karl Sigmund*

PUBLICATIONS

Reports

The following reports are available from IIASA's Publications Department for the amounts indicated. For payment by Visa or Mastercard, please send the number of your credit card, the expiry date, and a copy of your signature. A complete publications list is on the Internet Gopher at gopher.iiasa.ac.at.

Industrial Metabolism and River Basin Studies: A New Approach for the Analysis of Chemical Pollution. W.M. Stigliani, P.R. Jaffe. RR-93-006. US $10.

Paving the Road to Prosperity: Management Education in the Czech Republic, Slovakia, Hungary, and Poland. L.E. Grayson. RR-93-012. US $12.

Decision Support and Information Systems for Regional Development Planning. K. Fedra, E. Weigkricht, L. Winkelbauer. Reprinted from *Problems of Economic Transition: Regional Development in Central and Eastern Europe.* RR-93-013. US $10.

Small-Scale Privatization in Eastern Europe and Russia: A Historical and Comparative Perspective. J. Gács, I. Karimov, C.M. Schneider. Reprinted from *Communist Economies and Economic Transformation* (1993)5(1):61-86. RR-93-014. US $10.

A Comparative Assessment of Different Options to Reduce CO_2 Emissions. S. Messner, N. Nakićenović. Reprinted from *Energy Conversion and Management* (1992) 33(5-8):763-771. RR-93-015. US $10.

Are There Ecological Limits to Population? N. Keyfitz. RR-93-016. US $7.

◆ Capital Cities of NMO Countries

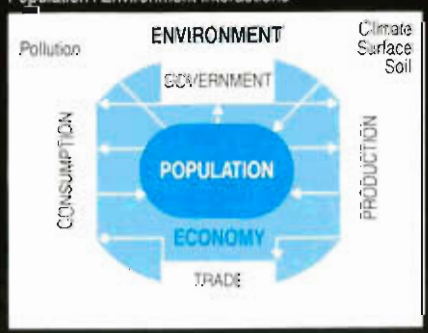
IIASA

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.

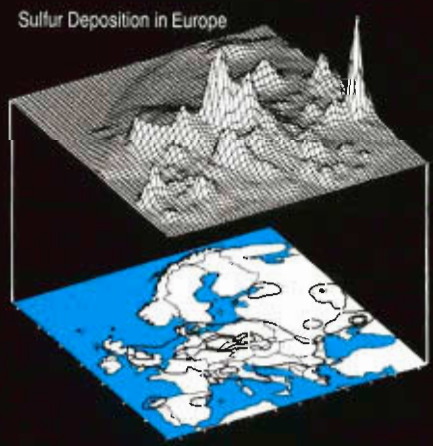
Population /Environment Interactions



RESEARCH

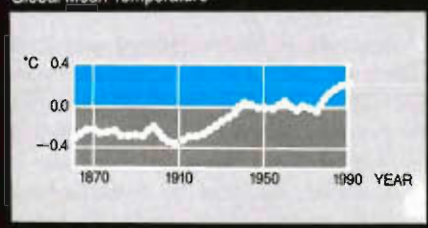
Recent projects include studies on global climate change, computer modelling of global vegetation, heavy metal pollution, acid rain, forest decline, economic transitions from central planning to open markets, the social and economic implications of population change,

Sulfur Deposition in Europe



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.

Global Mean Temperature



MEMBERSHIP

IIASA was founded in 1972 on the initiative of the USA and the USSR, and now also includes eleven European countries, Canada, and Japan. IIASA has member organizations in the following countries: Austria, Bulgaria, Canada, the Czech and Slovak Federal Republic, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Poland, the Russian Federation, Sweden, and the United States of America.

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) 71521-0.