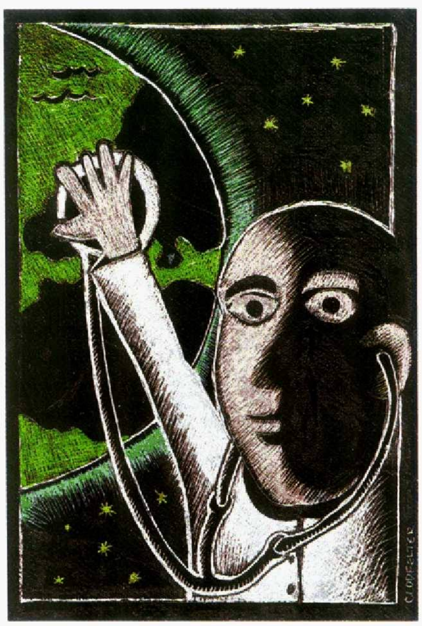
CZECHOSLOVAKIA

EXAMINING A CRITICALLY ILL ENVIRONMENT

Czechoslovakia emerged from a peaceful revolution in November 1989 to face a myriad of environmental problems with few resources. After 42 years of Communist rule, the country is struggling with a transition to a free market economy. It is recognized that recovery of the environment is intrinsically linked to economic improvement.

Czechoslovakia is perhaps the most adversely affected country in Europe. The environmental situation in some of the country can be described as disastrous. The atmosphere, water, and food are polluted; the soil quality is gravely deteriorated; most of the forests are damaged; the landscape as a whole has lost its ecological stability; and several species have become extinct. The Czech Republic in the western half of the country is one of Europe's biggest exporters of pollution to neighboring and distant countries. The worst consequences of the state of the environment are the poor health of the people and the stagnating or even decreasing average life expectancy which is already one of the shortest in all of Europe (3–6 years below average).



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Once one of the most prosperous democratic countries in all of Europe, Czechoslovakia's economic decline is deep, but the ecological decline is possibly even worse.

For years environmental regulations were neither enforced nor considered a high priority, and Czechoslovakia's problems grew. Some of the problems are common to other Central and Eastern European countries, including (1) severe air pollution with sulfur dioxide, nitrogen oxides, particulate matter, and acid rain; (2) water pollution caused by agricultural runoff of soil, nitrates, pesticides, and industrial contamination by toxic organics and metals; (3) discharges of untreated or poorly treated wastewater having high levels of biochemical oxygen demand, nutrients, and total suspended solids; and (4) solid and hazardous wastes at an unknown number of sites containing metals, organics, and radioactive contaminants. The pollution has been associated with human health effects, including polychlorinated biphenyls (PCBs) in breast milk, chronic illness among children during atmospheric inversions, and high lev-

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els of lead in children's blood. The food supply, especially crops, appears to be extensively contaminated with metals, and chlorinated hydrophobic organics have been found in pork, beef, and poultry.

These problems are extensive, but the Czech Ministry of the Environment has begun an assessment and action plan with the publication of three documents. This article is based largely on the first step in that plan, the "Blue Book," entitled *Environment of the Czech Republic* (*1*). It has been followed this year by the Rainbow Program—an outline of where the Czech Republic would like to go with their environmental program—and, most recently, by the Joint Environmental Study for the Czech and Slovak Federal Republic, a joint report of the governments of Czechoslovakia, the Czech and Slovak Republics, the European Community, the United States, and the World Bank (*2*). Czechoslovakia comprises two republics: the Czech Republic in the west and the Slovak Republic in the east. This article is primarily about the Czech Republic, where 60% of the people and 70% of the industry are located.

Air pollution

Although Czechoslovakia has approximately 2% of the land mass of Europe and about 4% of the people (16 million out of 350 million), it emits a significant fraction of Europe's SO_2, NO_x, and toxic metals. The result is severe atmospheric deposition of these contaminants and high gaseous concentrations of SO_2 and particulates in the industrial areas of Prague, Brno, Hradec Králové, Ostrava, Sokolov, Pilsen, Chomutov, and Mělnik (*1, 3*). The Czech economy is based mainly on mining, heavy industry, and building material production. These are extractive and polluting industries.

Extensive air pollution began in 1945 with rapid expansion of the use of soft, brown lignite for industry and home heating that contained large amounts of sulfur—typically between 1% and 15%. Figure 1 shows that mining (especially surface mining) of this coal increased from 14 to more than 100 million metric tons between 1945 and 1987 (*1*). Sulfur dioxide emissions increased concomitantly. This coal combustion resulted in extremely high SO_2 concentrations in ambient air (Figure 2), with average concentrations exceeding 100 µg m^{-3} in northwestern Czechoslovakia annually and nearly that in the city of Prague (*1, 2*).

Severe pollution episodes caused by atmospheric inversions are common in the winter. The longest episode in the history of observations occurred in January 1982, when a temperature inversion lasted 19 days without interruption and the average daily SO_2 concentrations surpassed 400 µg m^{-3} for 10 days. The maximum daily average sulfur dioxide concentration in Prague reached 3193 µg m^{-3}, and in the town of Osek below the Erzgebirge Mountains (specifically, *Krušné Hory*, in Czech, or Ore Mountains) it was 2440 µg m^{-3}. The ambient air quality standard in the United States and many countries is 80 µg m^{-3} (*1*).

"In the Czech Republic, 2500 municipalities serving 2.5 million people have no domestic wastewater treatment."

Sulfur dioxide is not the only air pollutant of concern to human health. There are large areas in the Czech Republic that exceed ambient air quality standards for total suspended particulates (TSP) as well. Ambient air quality standards are typically 75 µg m^{-3}. Many urban areas and the industrialized northwest region exceed this standard, with annual average concentrations greater than 100 µg m^{-3} in Prague and northwest Czechoslovakia. Sources of particulate matter in the northwest are power plants and smelters burning lignite coal and, in urban areas, automobiles, home heating units, and cement manufacturing plants.

Figure 3 illustrates that Czechoslovakia, former East Germany, and southern Poland have the highest sulfur deposition in Europe (> 4 g S m^{-2} $year^{-1}$), the result of wet sulfate in precipitation and dry deposition of SO_2 and aerosols on foliage. Sulfur deposition in the Erzgebirge region of extreme northwest Czechoslovakia results in 15 g S m^{-2} $year^{-1}$, which places it among the most polluted locations in the world (*4*).

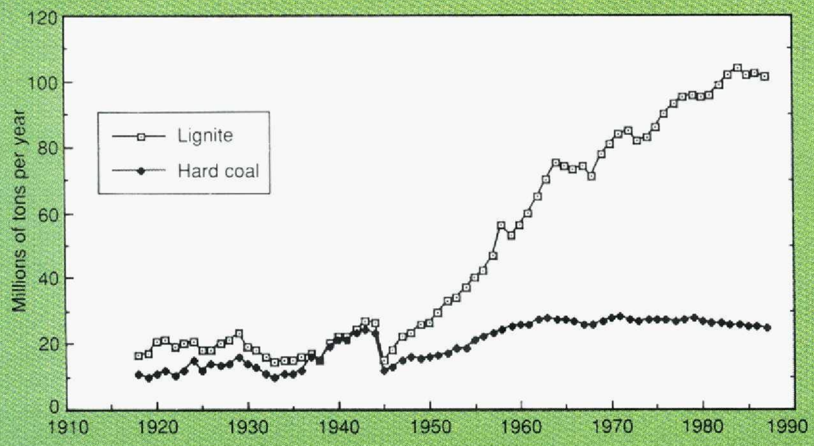
Forest decline

It is always difficult to assess cause and effects when forests show symptoms of decline, but the forest decline in northern and western Czechoslovakia is unmistakable. Since the early 1960s, foresters have noted first the decline and then the collapse of forests in the mountainous Erzgebirge region. One hundred thousand hectares of Norway spruce forests (*Picea abies*) have died, and it is estimated that a total of 54% of the forests in the Czech Republic have suffered irreversible damage (*1*). Dry deposition of SO_2 and sulfate is aided by efficient collection in forest canopies (*5, 6*). The problem is quite severe. Annual average sulfur dioxide gas concentrations in the Erzgebirge (100 µg m^{-3}) are about 10 times greater than those measured in the Bavarian and Black Forests of Germany (*7, 8*). It is not known whether the decline is caused by the direct effects of SO_2 on foliage or by atmospheric deposition and acidification of soils. Other potential causes include magnesium deficiency, aluminum toxicity to roots, drought sensitivity, and toxic metals effects (*9*).

Figure 4 shows the estimated life expectancy of the forests as assessed from visible foliar damage and annual incremental growth (tree rings) by the Czech Research Institute of Forest and Game Management (*1*). Norway spruce forests are generally harvested for lumber anytime between 80 and 130 years of age, so a large percentage of the forests in the northern half of the Czech Republic will not produce fully to harvestable age; a smaller proportion (~5%) have actually died.

Figure 5a shows a stand of 80-year-old Norway spruce in the Erzgebirge that is growing thin from needle loss and will soon die. Stands that have died (Figure 5b) are rapidly harvested, so much of the area is grassy meadow today. Seedlings of a more tolerant species of spruce (*Picea pungens*) have been planted, but growth and survival are low, presumably due to the direct effects of SO_2 gas and possibly the toxic metals in fog and soil wa-

FIGURE 1
Coal production in Czechoslovakia, 1918–87



Source: Reference 3.

ter (Figure 5c). The longest legacy of the last 42 years may be the buildup of toxic constituents in the soil of the region. Foresters have scraped away the top 15 cm of soil with bulldozers into windrows in order to get seedlings to survive (Figure 5d). They amend the soil with limestone and fertilizers, but nonetheless revegetation success is poor. It is not known whether this practice is required scientifically or whether foresters have chosen it as a precautionary measure. At any rate, a decrease in emissions of SO_2 by coal washing, clean-coal technology, fuel switching, fluidized bed combustion, or scrubbers will be needed to improve the situation.

Metals, including beryllium, cadmium, lead, zinc, aluminum, and arsenic (a metalloid), may play a role in the soil toxicity. All of these metals are deposited by dry deposition, but aluminum, zinc, and beryllium are liberated primarily from native soils under extremely acidic conditions, pH 2.6–4.0. Concentrations of these metals in soils and runoff waters are typically as follows: Be, 0.3–3.0 $\mu g\ L^{-1}$; Cd, 0.2–2.0 $\mu g\ L^{-1}$; As, 1–30 $\mu g\ L^{-1}$; and Al, 0.1–2.0 $mg\ L^{-1}$ (*10–12*).

Small-catchment research has flourished in Czechoslovakia, helping to explain the regional pollution problem (*13, 14*). Most of the catchments that lie within areas of severe forest dieback have crystalline bedrock (granitic gneiss) with acid brown soil (spodosols), and they receive heavy loadings of acid deposition, especially dry deposition due to sulfur dioxide. Pačés (*15–17*) has demonstrated that the rates of chemical weathering of calcium and magnesium in these polluted forested catchments (4.3 keq $ha^{-1}\ year^{-1}$) cannot keep pace with the acidic deposition of 6.1 keq $^{-1}\ ha^{-1}\ year^{-1}$ (1.2 wet plus 4.9 dry). The difference is made up by aluminum mobilization and hydrogen ion export.

In addition to aluminum, other metals such as beryllium and zinc are liberated from the soils. Aluminum is toxic to spruce trees (*9*), but the concentrations of Be (3×10^{-7} M) also may be problematical, and they are higher than those reported in other acidified locations around the world. Figure 6 gives the results of a simple beryllium desorption and chemical equilibrium model, demonstrating the high free metal ion concentration (Me^{2+}) that is liberated from the soil as the pH decreases. The source of the beryllium is likely $Be(OH)_2$ from naturally occurring minerals in the soil, but it is possible that fly ash deposition also contributes at some locations.

There is evidence based on intervention analysis and survey results that soils have become significantly more acidic since 1960. Changes in soil pH at more than 200 sites in the Czech Republic were measured by 1:1 exchange acidity in 0.01 N KCl in 1960–62 and then again at identical sites in 1983–85 by the Lesoproject (*18*), Czech Research Institute of Forest and Game Management. Project researchers found a significant decrease in pH during the intervening period from a median of pH 3.8 in 1960–62 to a median of pH 3.3 in 1983–85, and a few soils (4%) became extremely acidic (pH < 2.5). If this survey is correct, it represents one of the few examples of relatively large-scale soil acidification caused by acid deposition reported in the literature.

Water pollution

Seventy percent of all surface waters in Czechoslovakia are considered to be heavily polluted, and 30% are not capable of sustaining fish (*2*). The problems include:

- nitrate in drinking water from agricultural fertilizers,
- metals in surface water from industry,
- organics in surface water from industry,
- erosion of agricultural soils, and
- habitat alteration (dams, channelization, and siltation).

In the Elbe (Labe) River Basin, nitrate concentrations were measured to be 20–150 $mg\ L^{-1}$ in streamwater and 1–300 $mg\ L^{-1}$ in groundwater in 1989. (The Czech water quality standard for nitrate is 50 $mg\ L^{-1}$ NO_3^-). It is common for pollutants in rivers and streams to exceed drinking water standards in Czechoslovakia. The severest problems were found in the Elbe, Danube, and Odra River Basins.

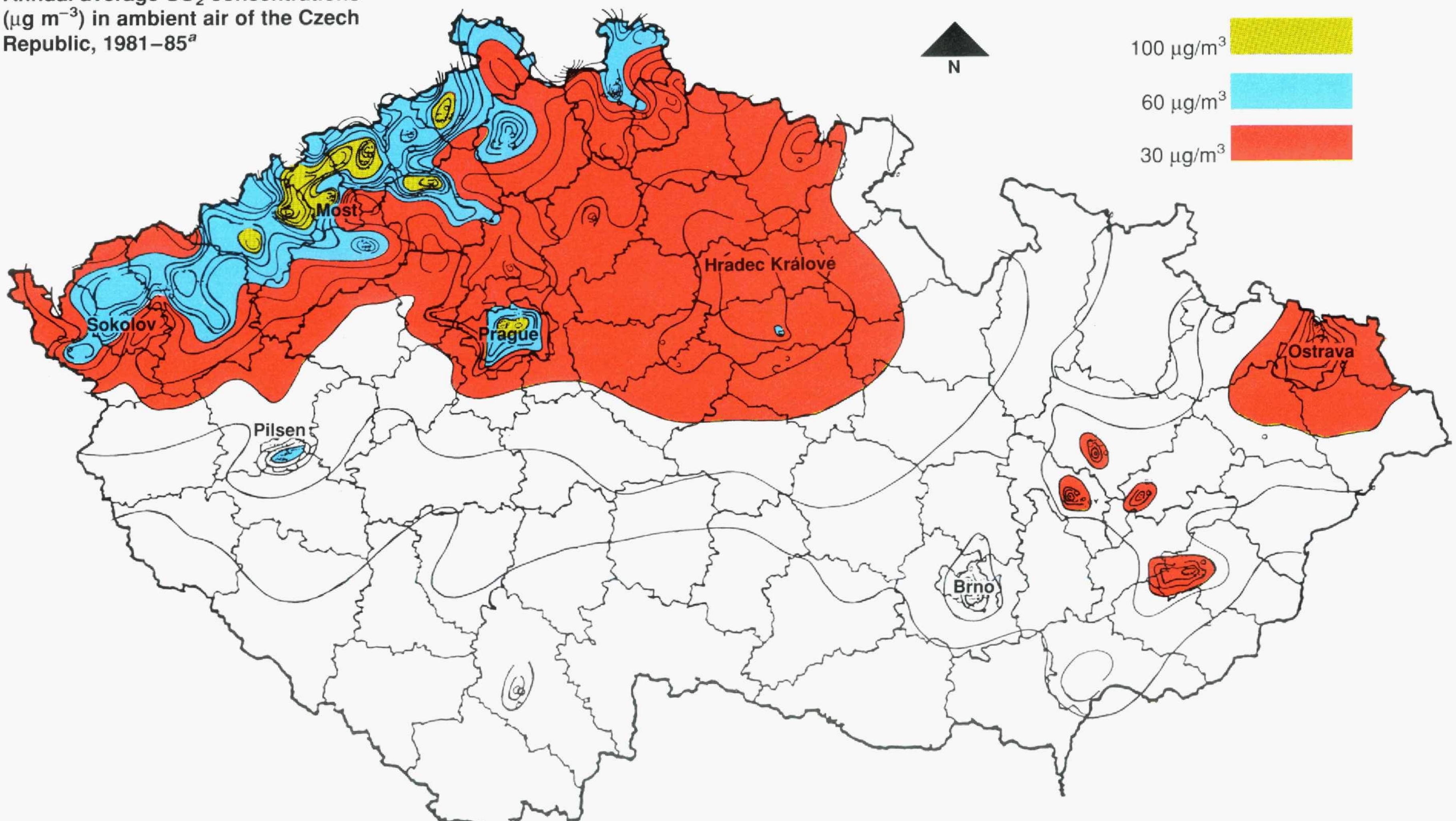
In 123 locations supplying 550,000 inhabitants, heavy metals exceed drinking water standards; oily substances exceed drinking water standards in 169 locations serving one million people; phenols were found to violate standards in 57 locales supplying 230,000 people; and radioactive substances were reported to exceed drinking water standards at 100 locations serving 300,000 people. Heavy metals were measured in streams at the following concentrations: Cu at up to 280 $ng\ L^{-1}$ in the Zlaty Brook, zinc at 1400 $ng\ L^{-1}$ in the Černy Brook, nickel at 280 $ng\ L^{-1}$ and lead at 102 $ng\ L^{-1}$ in the Rakovnický Brook, cadmium at 16 $ng\ L^{-1}$ in the Elbe River, chromium at 71 $ng\ L^{-1}$ in the Dyje River, and mercury at 2.6 $ng\ L^{-1}$ in the Jihlava River (*1*).

Chlorinated organics, tetrachloroethylene (TCE), and PCBs occur in streams at concentrations of 10–30 $ng\ L^{-1}$ (200 $ng\ L^{-1}$ in the Bilina River). These are relatively high concentrations and, with bioconcentration factors of up to 100,000, result in large body burdens in fish, humans, and other mammals.

In the Czech Republic, 2500 municipalities serving 2.5 million people have no domestic wastewater treatment. Effluents discharge directly to the streams. The city of Prague has secondary treatment of its domestic sewage, but it has no site to dispose of its stabilized sludge and thus must release it back to the Vltava River. Czechoslovakia

FIGURE 2

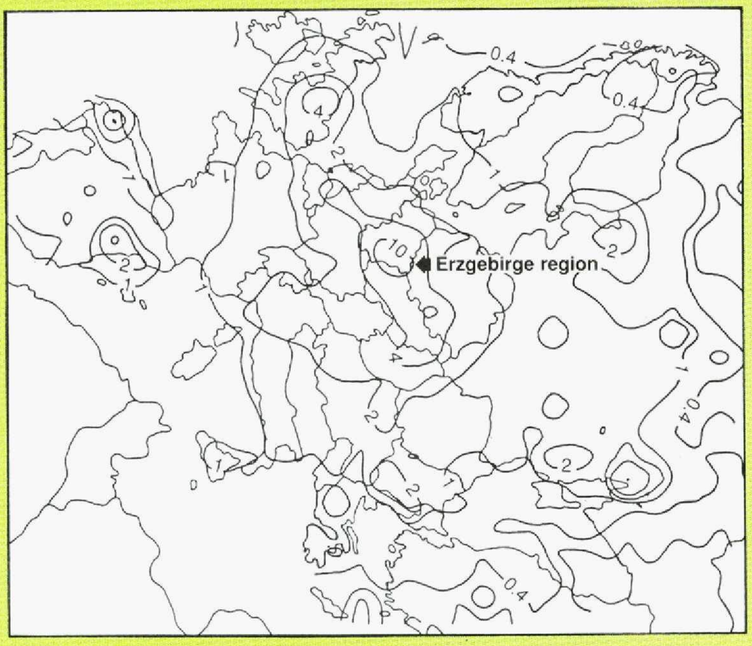
Annual average SO_2 concentrations ($\mu g\ m^{-3}$) in ambient air of the Czech Republic, 1981–85[a]



[a] Arithmetic means of daily values at more than 200 stations.
Source: Reference 1.

FIGURE 3

Computed yearly average sulfur deposition (g m^{-2} $year^{-1}$) in Europe, 1985, from the EMEP model[a]



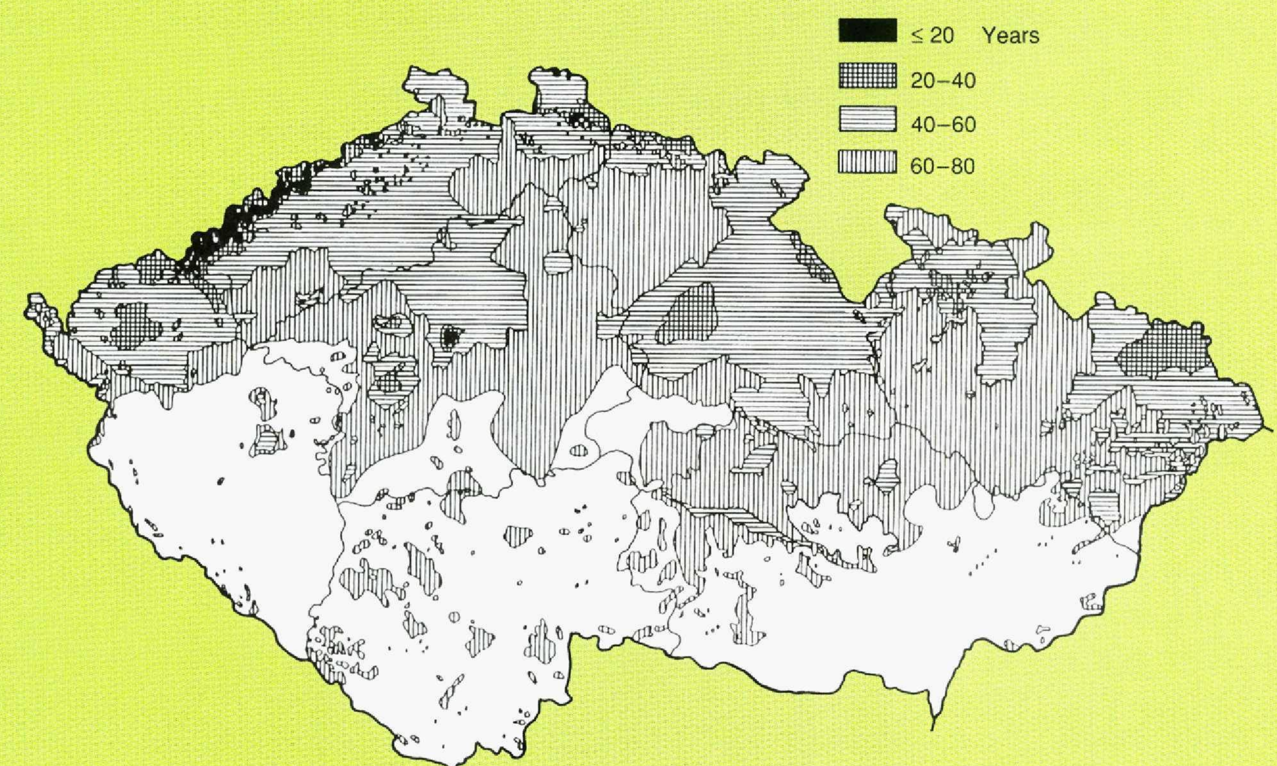
[a] The Erzgebirge region of heaviest pollution is located in extreme northwest Czechoslovakia within the isopleth of 10 g m^{-2} $year^{-1}$.
Source: Reference 4.

does not have a permit discharge elimination system, and there are no estimates of the total amount of municipal contaminants discharged to surface waters or reaching groundwater.

Some studies of hazardous waste sites have been compiled in Czechoslovakia, but no comprehensive list or priority ranking scheme exists. Major problems include metals from mine tailings, organics from industry, and jet fuel spills and solvents from former Soviet military bases. (The Soviet military vacated Czechoslovakia completely on June 24, 1991.) Levels of hazardous wastes in the Czech Republic (in thousands of metric tons per year) include the following: arsenicals and cyanide, 34.7; pesticides, 0.2; chlorinated hydrocarbons, 7.7; aromatic hydrocarbons, 650.9; and heavy metals, 210.2 (*1*). These are quite large amounts for a republic with fewer than 10 million people. No hazardous waste disposal sites are approved in Czechoslovakia today. Prioritization of hazardous waste sites and a risk-based evaluation of human and ecological health

FIGURE 4

Forest longevity, estimated from visual symptoms of foliar damage and annual growth increments



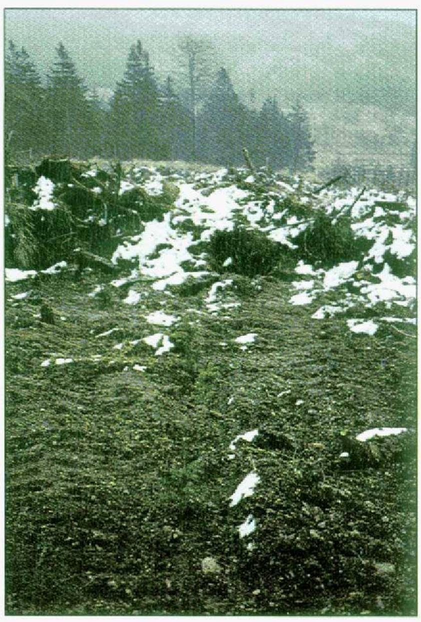
Source: Czech foresters in the Research Institute of Forest and Game Management, 1988.

FIGURE 5

(a) Eighty-year-old spruce stand (*Picea abies*) in the Erzgebirge region beginning to show effects of needle loss, thinning, and forest decline

(b) Dead spruce forest near Jezeri catchment in the Erzgebirge region

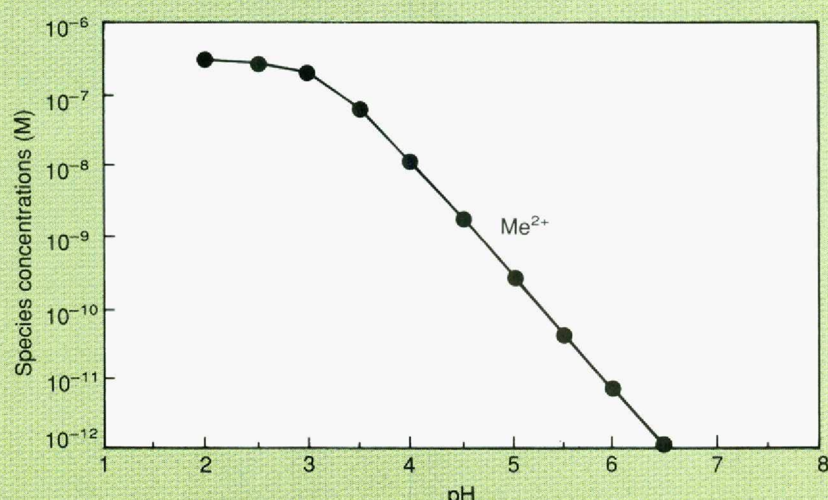
(c) Seedlings of spruce hybrid cultivars (*Picea pungens*) after soil amendment with fertilizer and lime/limestone additions



(d) Replanted spruce (*Picea pungens*) with windrow of scraped-off soil in the background

FIGURE 6

Chemical equilibrium model (pC vs. pH) for desorption of beryllium from soil[a]



[a] Note the increase of free metal ion concentration as the pH decreases from 4.5 to 3.0.

Equations: $MeOH^+ = K' [H^+]^{-1} [Me^{2+}]$ $\quad K' = 10^{-5.7}$

$SOH_2^+ = K_{a1}^{-1} [SOH] [H^+]$ $\quad K_{a1} = 10^{-4}$

$SO^- = K_{a2} [SOH] [H^+]^{-1}$ $\quad K_{a2} = 10^{-9}$

$SOMe^+ = K [SOH] [MeOH^+]$ $\quad KK' = 1.0$

$= KK' [SOH] [H^+]^{-1} [Me2^+]$

Surface charge = $SOH_2 + SO^- + SOMe^+$

are sorely needed before cleanup can begin.

Food contamination, human health

One of the biggest problems facing Czechoslovakia is the contamination of its food supply with toxic organics [benzo(*a*)pyrene, PCBs, hexachlorobenzene] and metals such as Pb, Cd, Hg, and As. For example, the concentration of PCBs in breast milk is 3 mg kg^{-1}, more than three times that in Yugoslavia or Scandinavian countries. Concentrations of lead in the blood of children were 300–450 μg L^{-1} in a recent study, more than three times the level certified as neurotoxic in the United States. People are exposed to high concentrations of toxins in food. The daily intakes for a 60-kg (132-lb) individual (mg day^{-1}) and the percentage of maximum allowable daily intake from food ingestion alone are: 0.46 mg day^{-1} (92%) for lead, 0.55 (91%) for PCBs, 0.56 (93%) for cadmium, and 0.003 (117%) for 3,4 benzo(*a*)pyrene (*1*).

Unlike most western European countries, life expectancy has not increased much in Czechoslovakia since 1964. In 1988, mean life expectancy for both sexes combined was 71.6 years. Average life expectancy for men in the extremely polluted areas of Most and Sokolov in western Czechoslovakia was only 64.2 years. In 1985, a comparison of mean life expectancy in Europe showed that Czechoslovakia was better than only four out of 25 European countries: 71.0 years compared to Hungary (69.4 years), Yugoslavia (68.4 years), Poland (70.6 years), and the U.S.S.R. (67.8 years). The longest life expectancies were in Iceland (77.4 years) and Sweden (76.6 years) (*19*).

Respiratory disease and chronic conditions (asthma, emphysema, and bronchitis) are epidemic among children 0–14 years of age. The 1983–86 average winter concentration of SO_2 in Prague and the city of Most was 150 $\mu g\ m^{-3}$, which correlated with reported respiratory tract diseases in children, resulting in a 320% increase of occurrence relative to spring and summer conditions. Last winter, it was necessary to provide face masks to children in Most so that they could play outside. Based on health criteria exceedance (including SO_2, TSP, and radioactive materials), 6.9% of the land area of the Czech Republic has been classified as "extremely disturbed environments" by the Czech government (*20*). This area includes 2.5 million inhabitants.

Plan for the future

Czechoslovakia's environmental policy is to a great extent shaped by the urgent need to build the economy and create a sustainable way of life. There will be a focus on the cleanup of numerous sources of serious pollution, the legacy of the past communist regime. Coal cleaning, clean coal technology, closing of outdated and inefficient plants, and some flue gas desulfurization will be needed. Adequate treatment of domestic wastes and a secure toxic waste repository are sorely needed. One of the first priorities for future protection of the environment will be an obligatory environmental impact assessment process.

Lasting environmental improvement can be based only on prevention, on modern technologies, on restructuring an obsolete industrial infrastructure, and on reducing Czechoslovakia's extremely high energy consumption. Initially, ecological objectives will be reached by applying a system of fiscal instruments that includes dues, charges, taxes, and penalties. These measures should have both punitive and stimulating characteristics. The "polluter pays" principle is clearly one of the fundamental rules to be followed.

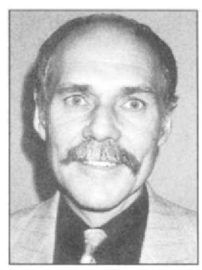
Fiscal measures are probably the most important part of new economic and legal principles. Laws written during the past regime are outmoded. The Czech Ministry of the Environment, charged with rule-making and environmental action, came into existence only on January 1, 1990. There are rudimentary systems of administration and inspection as well as self-reporting by industry of environmental discharges. Usually it is cheaper to pay the fine than to abide by the environmental regulation or permit.

A key factor in further shaping the environment will be the success of the transition to a market economy enabling fast economic growth. However, the future must be sustainable. Economic and societal development must secure human needs without endangering the quality of the next generation's life and without reducing nature's richness. The objective of development is prosperity for all; it must not endanger human well-being, and it must not waste natural resources, but save them for future generations.

Measuring economic performance by using purely market forces tends to underestimate the real value of natural resources, including clean water and air. The market is not able to recognize the true worth of such resources, which is derived from their scarcity and irreplaceability. Market forces are not able to take into consideration long time horizons. Capital that nobody uses but that has intrinsic value, such as wilderness areas, must be appreciated. Prague is still one of the most beautiful cities in all of Europe, rich in history and architecture, especially in the Old Town. Czechoslovakia has some picturesque forested areas remaining, including the Sumava Mountains in the Bohemian Forest in the southwest. The challenge is to preserve the good and relatively unaffected locations and to recover the severely depleted regions and resources. Many of these problems are common to several Central and East European countries. Czechoslovakia is in a good position to affect the recovery of Europe because of its low foreign debt burden, excellent universities, central location, historic beauty, and democratic traditions prior to 1948.

Summary

Environmental degradation has occurred in Czechoslovakia and other central and eastern European countries over the past 40–50 years. The problems are massive—air, water, and soil pollution at the highest levels reported in the world. Initially, the priority for cleanup and enforcement must be reducing the risk of human health effects. The projects that should be funded are those that reduce human health risk the most per dollar invested; however, concerns for ecological risk should not be far behind. For now the government will focus on air pollution and food contamination. Some of the oldest plants may have to be closed, and some of the newer ones should change to clean coal technology, coal washing and, in a few cases, flue gas desulfurization. Fuel taxes will be needed on diesel fuel, leaded gas, energy, and water to decrease the wasteful and inefficient uses of these resources. Czechoslovakia will rely on market forces, where possible, to price more wise-



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ly the use of natural resources. Ultimately, a mixture of "command-and-control" (legislation and regulations) and market instruments will be needed.

New legislation will be needed for requiring environmental impact assessments on new construction projects, a phased permitting of existing discharges, restrictions on the use of fertilizers and pesticides (and removal of subsidies), and the designation of air quality management regions. Existing ambient air quality standards and water quality standards will need to be vigorously enforced or made less stringent, at least temporarily, to fit the realities of the situation.

An essential part of Czechoslovakia's new environmental policy is international cooperation. The experience of scientists from other countries, modern technologies, and financial assistance are badly needed.

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