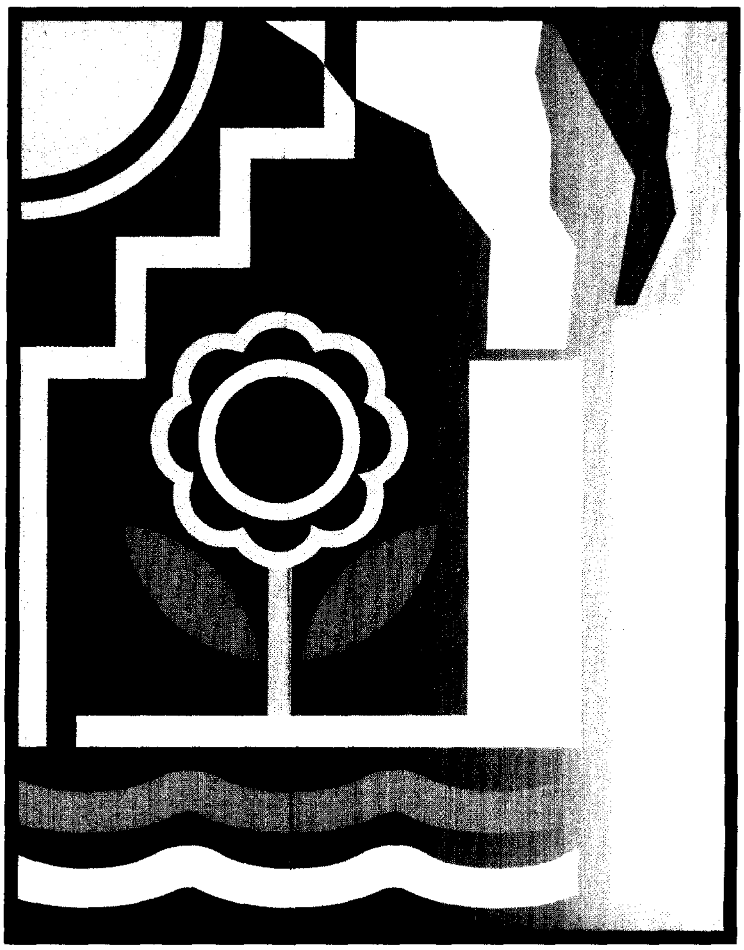
PHASING OUT LEAD FROM GASOLINE IN CENTRAL AND EASTERN EUROPE

HEALTH ISSUES, FEASIBILITY, AND POLICIES



EDITED BY MAGDA LOVEI

IMPLEMENTING THE ENVIRONMENTAL ACTION PROGRAMME FOR CENTRAL AND EASTERN EUROPE

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Phasing Out Lead From Gasoline in Central and Eastern Europe

Health Issues, Feasibility, and Policies

Edited by Madga Lovei

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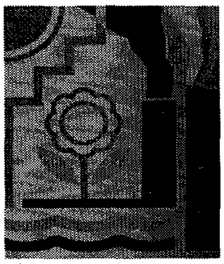

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This report was prepared by Magda Lovei based on case studies:

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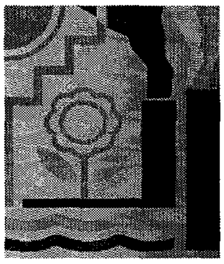


Preface

International Context

As a result of increasing awareness of the dangers of lead to human health and measures to tackle urban air pollution, the use of lead additives in gasoline has been declining rapidly world-wide since the 1970s. The lead content of gasoline has been reduced, and the use of unleaded gasoline has rapidly increased. By the end of 1996, several countries, including Argentina, Austria, Bermuda, Brazil, Canada, Colombia, Costa Rica, Denmark, El Salvador, Finland, Guatemala, Honduras, Japan, Nicaragua, the Slovak Republic, Sweden, Thailand and the USA, have completely eliminated the use of lead additives in gasoline.

An extensive review (Hertzman, 1995) of environmental concerns in Central and Eastern Europe came to the conclusion that lead was one of the most serious and widespread environmental hazards in this region, and one which was relatively inexpensive to remedy. At the *Environment Ministers' Conference* in Lucerne, Switzerland in 1993, 50 countries endorsed the *Environmental Action Programme for Central and Eastern Europe* (World Bank and OECD, 1993) that addressed environmental priority issues such as the exposure to lead.

In order to assist the implementation of the *Environmental Action Programme*, the current study was undertaken as a first step to: (i) determine the major sources and levels of lead exposure in the region; (ii) examine the progress made in reducing lead exposure during the last 5-8 years and identify the corresponding human health improvements; (iii) take a preliminary look at the feasibility and costs of phasing out lead from gasoline; and (iv) draw lessons from the experience of countries in the region in phasing out lead from gasoline. While recognizing the importance of dealing with all significant sources of lead exposure, the major emphasis of this study is on lead exposure from the exhaust of vehicles using leaded gasoline.

Regional Cooperation in CEE

Many countries of Central and Eastern Europe (CEE) and the Former Soviet Union (FSU) face problems and obstacles of lead phase-out which are similar across the region, and a strong interest exists in learning from each other's experience. A regional cooperation among countries in CEE, in partnership with bilateral and multilateral donor organizations could create positive synergies and facilitate the acceleration of lead phase-out. The cooperation would enable CEE countries to (i) carry out joint activities; (ii) share experiences and information; (iii) design programs that address the main obstacles of lead phase-out; and (iv) provide targeted technical assistance to countries which are less advanced in the lead phase-out process. Such cooperation started during the *International Conference on Heavy Metals and Unleaded Gasoline* hosted by the Government of the Slovak Republic in September, 1995. Policy makers and experts from several CEE and Western countries and international organizations gathered in Banska Bystrica to discuss issues related to the hazards of heavy metals, and measures to be taken to phase out leaded gasoline. During the *Environment Ministers' Conference* held in October, 1995 in Sofia, the Government of Bulgaria formally initiated a regional cooperation among CEE countries to support the phase-out of leaded gasoline within the framework of the *Sofia Initiatives* designed to address local air quality problems. Recently, the Committee on Environmental Policy of the UN Economic Commission for Europe (UN-ECE) has started the preparation of a pan-European strategy to phase out leaded gasoline. As a follow-up to the *Sofia Initiatives* and the UN-ECE proposal, the Government of Denmark has initiated the establishment of a *Task Force on the Phase-Out of Lead in Gasoline*. The Task Force would facilitate the preparation of national lead phase-out plans and concrete political commitments to address this issue before the next *Environment Ministers' Conference* in 1998 in Aarhus, Denmark. Several bilateral and multilateral organizations, including the World Bank, support the objectives and the work of this Task Force.

The main objectives of the regional cooperation and partnership program is to develop and strengthen the commitment of key policy makers to support the removal of lead from gasoline; design and implement supporting policies; and build public awareness of the impacts of lead and the proper use of unleaded gasoline. A mechanism is needed to build a consensus among government agencies, industries and public organizations in each country. Such consensus building may be coordinated by appointed National Lead Phase-Out Coordinators (NLPCs). NLPCs would also identify areas where the assistance of a regional or bilateral program is needed.

The type of assistance necessary to facilitate lead phase-out in the region may vary among countries. Based on their achievements in lead phase-out, commitment to pursue such policies, and capabilities to implement them, CEE countries can be placed into two broad groups:

- *Central Europe and the Baltics*. In order to facilitate their accession to the European Union (EU), these countries have been harmonizing their regulations, including those of the lead content in gasoline, with regulations of the EU. The political commitment to accelerate lead phase-out is high. Most of these countries have also created a liberalized market environment in the refining sector allowing its adjustment to changing regulations and demand. The main constraint to the complete phase-out of lead in these countries is represented by the lack of awareness of consumers and policy makers of the feasibility of using unleaded gasoline for the current car fleet.
- *Eastern Europe and the Former Soviet Union (FSU)*. In these countries, political commitment to deal with lead phase-out is relatively weak, overshadowed by serious economic and structural problems in the oil refining sector. Obsolete gasoline specifications allow high concentrations of lead in gasoline, and progress in liberalizing the refining sector and the prices of oil products have been sluggish. Besides constraints of old consumer habits and misconceptions, the main constraint of lead phase-out in these countries is the lack of policy attention to this issue, as well as the slow process of refinery sector adjustment.

A modular structure for the regional cooperation and assistance program, therefore, should address a range of needs. Such modular structure would also (i) facilitate assistance for a large number of countries; (ii) create regional synergies; (iii) achieve economies of scale; and (iv) allow flexibility in donor participation. Program modules could focus, for example, on:

- Carrying out surveys of general public awareness of the impacts of lead, consumer habits, attitudes, price elasticity, and knowledge of the use of different gasoline types in various vehicle models;
- Publication and dissemination of the results and findings of surveys among policy makers across the region;
- Collection, publication and dissemination — to policy makers, gasoline distributors and retailers — of information regarding the feasibility of using unleaded gasoline in various vehicle types, especially those most widely used in the region;
- General public education campaigns on the health impacts of lead in gasoline, and public awareness programs targeted at gasoline consumers based on the results of market survey and car surveys;
- Refinery-specific feasibility studies;
- Twinning arrangements to provide financial and technical assistance to the NLPCs; and

- Regional workshops and forums for policy makers and industry representatives on general and technical issues concerning lead phase-out with the participation of CEE as well as Western experts covering, for example, (i) car technology issues; (ii) refinery technologies (for example, the use of additives); and (iii) policy measures (for example, taxation issues).

The Role of the World Bank Group

Considering that the main obstacles of accelerating the phase-out of lead from gasoline are policy-related, the World Bank should focus on assisting governments in addressing this issue as a priority and adopting supporting policies. Lead phase-out objectives could be discussed and included at various levels of Bank assistance such as Country Assistance Strategies, National Environmental Action Programmes, Sectoral Adjustment Programs, and Transport, Urban, Industrial and Environmental Projects.

Phasing out lead from gasoline typically requires capital investments in refineries. In transition economies, these investments can be part of the ongoing rehabilitation and adjustment of enterprises in the refining sector. Such investments should be economically justified and financially profitable, making them attractive for commercial financing. In countries where financial and capital markets are dysfunctional and under-developed, and foreign investors are deterred by high political risks and unclear government policies, the World Bank Group can facilitate commercial investments by guarantees, equity financing through the International Finance Corporation (IFC), or co-financing with private sources. The use of Bank guarantees, in combination with private financing, may be particularly well suited to cover risks associated with various government policies such as differentiated taxation measures, lead phase-out schedules, gasoline specifications and environmental regulations.

Executive Summary

Sources and Impacts of Lead

Lead is a highly toxic heavy metal. Emerging medical evidence shows that lead affects the neurological development of young children and causes cardiovascular problems in adults even at low levels of exposure previously believed to be safe.

Vehicle emissions represent a significant source of lead in the environment and human exposure in Central and Eastern Europe (CEE). The contribution of vehicular exhaust emissions to airborne lead concentrations is estimated at 84 percent in Hungary, 61 percent in Bulgaria, and 40 percent in Poland. Its role is especially significant in urban areas. In Budapest, for example, 90 percent of airborne lead originates from traffic. The impacts of vehicular emissions could be clearly detected in the significant difference in the exposure levels of children living in downtown areas with heavy traffic and less congested suburbs in Budapest in the 1980s, indicating a potential decrement of 4 IQ points in the more exposed children.

CEE countries that introduced policies to reduce lead use in gasoline experienced significant improvements in environmental and human exposures to lead. Mean ambient lead concentrations declined from 2.5-5.4 micrograms per cubic meter in the 1980s to around 0.5-0.6 micrograms per cubic meter by 1994 in downtown Budapest. While mean blood lead levels (the best indicator of exposure) of sampled children in downtown areas exceeded 20 micrograms per deciliter in the mid-1980s in Budapest, recent measurements of blood lead levels in children rarely exceed 10 micrograms per deciliter. By reducing the likelihood of neuro-behavioral problems and learning disabilities, these measures produced positive life-long effects on the mental health, socio-economic status, and earning abilities of children.

The reduction of lead emissions contributes to a significant decline in the accumulation of lead in various environmental media, especially soil and dust, reducing long-term exposures through ingestion, which is the main route of exposure in children. Additionally, as a recent study in Nizhny Novgorod, Russian Republic has also pointed out, the elimination of lead from gasoline could avoid hundreds of cases of hypertension and several cases of strokes and premature deaths annually due to cardiovascular problems in adults caused by the inhalation of atmospheric lead, the main source of exposure in adults.

Technical Issues, Feasibility and Costs of Lead Phase-Out

Since the 1920s, lead additives in gasoline have been extensively used world-wide as octane enhancers to increase the resistance of gasoline-air mixture in the internal combustion engine to early ignition.

Additionally, lead also provided lubrication to the engine valve seats, allowing car manufacturers to use low-grade soft metals on the engine valves.

Several factors have contributed, however, to a significant reduction in the use of lead in gasoline since the 1970s: (i) catalytic converters introduced in response to growing environmental concern about vehicular emissions of carbon monoxide, hydrocarbons and nitrogen oxides required the use of unleaded gasoline to protect the converters; (ii) new medical evidence, showing that adverse health impacts of lead occur even at low levels of exposure affecting both children and adults, resulted in the growing awareness of the problem, prompting measures to reduce the use of lead additives in gasoline; (iii) the availability of technologies in the refining and chemical industries allowed refineries to introduce substitutes for the octane enhancing and lubricating properties of lead at a relatively modest cost; and (iv) a change in car technology towards the use of high-grade hardened metal parts eliminated the need for special lubrication of the engine valve seats.

As a result, the complete removal of lead from gasoline became technically feasible and relatively simple. In most cases, it can be also carried out at relatively low cost, making it a cost-effective measure to mitigate the public health damage caused by lead. Based on the experience in other countries, calculations show that benefits of the complete removal of lead from gasoline are expected to exceed the costs by a large margin in CEE countries. These benefits include improved health conditions that result in savings in educational and medical costs, reduced mortality, and improved productivity resulting in higher lifetime earning. Additional benefits can be expected from reduced car maintenance costs.

A modeling study was carried out to assess the feasibility and costs of lead phase-out in the Romanian refinery sector, which still uses high amounts of lead additives. The study indicated that, largely due to excess reforming capacities in Romania's large refineries, lead use could be significantly reduced relying on existing process capacities. Initial reductions of the lead content to 0.15 g/l, together with improved refinery optimization measures, could be carried out without reducing refinery margins. The costs of total lead phase-out were estimated at around US$ 0.01-0.02 per liter of gasoline. Another study estimated the costs of lead phase-out in a hydroskimming refinery in Nizhny Novgorod, Russian Republic, in the range of US$ 0.005-0.02 per liter of gasoline (depending on various technical solutions). However, the study also pointed out that the estimated costs assigned to lead phase-out would drop by about 50 percent if the refinery made the necessary adjustments in its production structure to respond to new market conditions. The cost of the successfully implemented complete phase-out of leaded gasoline in the Slovak Republic was also close to these estimates: about US$ 0.02 per liter of gasoline, including annualized investment cost.

Assessing the feasibility and costs of phasing out lead from gasoline in CEE cannot be separated from the restructuring and privatization process of the refining sector. Several CEE countries, particularly the ones that were part of the Former Soviet Union (FSU), face serious technical, economic and financial problems in the refining sector. These problems include (i) low capacity utilization; (ii) undesirable technological and product structure; (iii) poor quality of products; (iv) obsolete technology; (iv) operational inefficiencies; and (v) limited financial resources. From the point of view of phasing out lead, these problems imply that:

- In the short term, low refinery utilization rates, excess conversion capacity; possibilities to improve process optimization; and low octane requirement of the car fleet facilitate the reduction of lead in gasoline;
- In the medium term, market forces will require technical upgrades in viable refineries, also improving the capacity of producing unleaded gasoline;
- Only those costs should be allocated to lead phase-out which are additional to the costs of adjustment to market conditions;
- Sectoral restructuring and modernization offer an opportunity to include lead phase-out objectives into the long-term planning process. What needed most is Government commitment setting lead phase-out schedules and introducing supporting policies; and

• Government policies and requirements focusing on the removal of lead are expected to accelerate the structural adjustment of refineries.

Policies and Implementation

Although considerable progress has been made in CEE in reducing human exposure to lead, much still needs to be done. There are indications that even in countries that took measures to reduce the amount of lead in gasoline, improvements have slowed down or stopped recently. One country, the Slovak Republic, phased out leaded gasoline completely by 1995. Several others, including Bulgaria, the Czech Republic, Hungary and Poland, have significantly reduced the permissible lead content of gasoline (to 0.15 g/l), and introduced and promoted the use of unleaded gasoline during the late 1980s and early 1990s. Elsewhere in the region, for example, in Romania and many of the former Soviet Republics, gasoline is still allowed to contain high amounts of lead (up to 0.6 g/l in Romania, Russia, Ukraine and other Former Soviet Republics), and the market share of unleaded gasoline remains low (for example, below 10 percent in Romania). Therefore, it is necessary to accelerate the lead phase-out process in order to prevent further health damages as traffic grows rapidly, especially in urban areas.

This report concludes that a *technology-based approach* that only relies on the use of catalytic converters to induce lead phase-out is not an effective way of dealing with vehicular lead exposure problems in CEE, where the car fleet is old and its replacement is slow. Lead phase-out objectives, therefore, should be separated from dealing with other vehicular emission control issues, and policies that rely on a combination of *incentives* and *mandatory phase-out* may be more appropriate choices in the region. The availability of unleaded gasoline can, however, facilitate the wider application of catalytic emission control devices that further improve urban air quality by reducing the emission of various pollutants.

The report underlines the role of governments in:

• *Setting and enforcing regulations of the lead content of gasoline.* The first step should be reduction of the high maximum permitted concentrations of lead in gasoline to lower levels, while further steps should include a deadline and schedule for the total elimination of lead. Regulation of the lead content of gasoline may be combined with the revision of other gasoline specifications and regulations of vehicular emissions. CEE countries that applied for membership in the European Union (EU) have started to harmonize their environmental regulations with those of the EU. The acceleration of lead phase-out, therefore, would facilitate the accession process of these countries. In other countries, regulations of lead should be introduced before significant new investments take place in the refining sector.

• *Introducing incentive policies* to influence gasoline demand and the adjustment of gasoline supply. Differentiated taxation of leaded and unleaded gasoline is one of the most effective measures to influence gasoline demand. The ongoing price liberalization and restructuring of the tax systems in many CEE countries offer an opportunity to introduce such taxation. Retail price incentives through the tax system can be introduced by various ways. One of the most simple one would be the imposition of an environmental tax on lead additives. Prices favoring unleaded gasoline also facilitate alternating fueling (buying leaded gasoline only occasionally, relying on the "lead memory" of vehicle engines); and the effective use of catalytic control devices to comply with vehicle emission requirements. Government policies that allow market mechanisms to work can support the adjustment of gasoline supply with consideration of various options including technological upgrade; restructuring of refinery operations based on the purchase of high octane gasoline blendstocks and additives; and the import of unleaded gasoline. Price liberalization, corporatization and privatization of refineries can improve their incentive structure and facilitate their access to commercial financing to undertake necessary investments.

• *Facilitating a broad consensus* and multi-sectoral approach. Lead phase-out requires the cooperation of various government agencies (for example, environmental, health, industrial, energy authorities, trade, fiscal authorities); industrial and business enterprises (for example, oil refineries, distributors, retailers, car manufacturers) and public organizations (for example, non-government organizations) in the development and implementation of lead reduction policies.

- *Raising public awareness* and providing targeted education and training. Lead phase-out can only be implemented successfully if consumers and the public understand and support it. Besides general awareness building programs about the danger of lead, information targeted to motorists, retailers and mechanics about recommended fueling is needed to clarify misconceptions about the use of unleaded gasoline and the proper adjustment and maintenance of vehicles using unleaded gasoline.

Abbreviations

BLL	Blood Lead Level
CDC	Centers for Disease Control
CEE	Central and Eastern Europe
CON	Control Octane Number
CPI	Consumer Price Index
EAP	Environmental Action Programme
EHC	Environmental Health Criteria
EMTC	Environmental Management Training Center
EU	European Union
FCC	Fluid Catalytic Cracking
FSU	Former Soviet Union
GNP	Gross National Product
IEA	International Energy Agency
IFC	International Finance Corporation
LG	Leaded Gasoline
MAC	Maximum Allowable Concentration
MOI	Ministry of Industry
MON	Motor Octane Number
MTBE	Methyl Tertiary Butyl Ether
MT	Metric Ton
NAS	National Academy of Sciences
NLPC	National Lead Phase-Out Coordinator
NRC	National Research Council
OECD	Organization for Economic Co-Operation and Development
PPP	Purchasing Power Parity
PTEI	Provisional Tolerable Weekly Intake
RON	Research Octane Number
SK	Slovak Krone
TEL	Tetra-ethyl Lead
TML	Tetra-methyl Lead
VSR	Valve Seat Recession
ULG	Unleaded Gasoline
U.S.	United States
AID	Agency for International Development
EPA	Environmental Protection Agency
UN-ECE	United Nations Economic Commission for Europe
WHO	World Health Organization

Chapter One

Lead Exposure and Health in Central and Eastern Europe

Lead and Human Health

Lead is one of the best understood and most extensively studied environmental toxins. It adversely affects many organ systems in the body, most notably the nervous system, the blood-forming system, the kidneys, the cardiovascular system, and the reproductive system. Of most concern are the adverse effects on the nervous system of young children, causing damage with reduced intelligence, hyperactivity and attention deficit, learning problems and behavioral abnormalities.

Since lead in children disturbs their coordination, concentration, reaction time, impulsiveness and behavior, standard questionnaires and observations of psychologists and teachers are capable of capturing and quantifying, with IQ gradients, the deviation of performance by children being affected by lead exposure. Most of these effects can be captured and quantified by standardized intelligence test. These standardized tests, for example the Raven test, Wechsler Intelligence Scale for Children or the Stanford-Binet Intelligence Scale, are designed to assess the intellectual capability of children with socio-economic and other factors such as the parents' education, smoking in the family, and children's birthweight taken into account.

Statistically significant relationships have been found between the blood lead levels (BLLs) of children and their IQ gradients by various studies in Western countries. A review of studies concluded that a 10 µg/dl increase in BLLs can be associated with a 2.5 gradient decrease in the IQ of children (CDC, 1991). Similar systematic large scale investigations of a relationship between exposure to lead and health impacts have not been carried out in Central and Eastern Europe (CEE). Less extensive studies, however, have clearly detected a statistical relationship similar to those found in Western countries. A study in Poland, for example, indicated that a 13 point IQ gradient difference existed between children with the highest and lowest BLLs in Katowice, Poland. In Romhany, Hungary, in children with more than 25µg/dl BLLs, IQ measurements showed a 10 IQ point reduction compared to those children with less than 10 µg/dl BLLs (Hertzman, 1995). A study carried out in Bratislava, Slovak Republic, tested the mental and motor abilities of 395 nine-ten years old children, and found that children with higher BLLs tended to have learning and behavioral problems, such as social intolerance and inability to concentrate, and demonstrated lower performance using the Raven test. The performance of children with lower (below 3.5 µg/dl) BLLs was found to be 1.7 IQ points higher than those with higher (more than 3.5 µg/dl) BLLs (**Annex B**). In some cases, however, the existence of potential confounding factors, and the relatively limited samples of data prevented researchers to prove the existence of a clear statistical relationship in CEE.

In recent years, it has been shown that even relatively low levels of exposure to lead, such as BLLs below 10 microgram per deciliter (µg/dl) can cause serious and persistent damage to the nervous system. Although 10 µg/dl is currently considered a limit for concern, no threshold has been identified under which the adverse effects of lead cannot be detected (Rosenstock and Cullen, 1994; Rom, 1992; NRC, 1993). The above mentioned health study carried out in the Slovak Republic confirmed this finding, demonstrating that unfavorable neurological impacts could be detected in Slovak children at blood lead levels as low as 3.5 µg/dl, below the value (10 µg/dl) previously considered as threshold.

Additionally, prenatal exposure of lead was demonstrated to produce toxic effects on the human fetus, including reduced birthweight and skeletal growth, disturbed mental development, spontaneous abortion and premature birth. Studies have also pointed out the effects of lead on male productivity (Silbergeld and Gandley, 1994; WHO, 1995). These effects occur already at relatively low BLLs.

Several studies (Schwartz, 1988; Pocock et al, 1988; Pirkle et al, 1985) also related elevated BLLs with increased blood pressure, hypertension, and other cardiovascular problems in adults without a known threshold of exposure for these effects to occur. Ostro (1994) has estimated that a 1µg/m^3 increase in airborne ambient lead concentrations caused about 70 thousand hypertensions in one million males aged 20 and 70 years, 340 non-fatal heart attacks and about 350 deaths per one million males aged 40-59.

It has been pointed out (NRC, 1993; Walsh and Silbergeld, 1996) that, as a result of the neurological impacts of lead, the exposure to lead in a population shifts the distribution of measured intelligence and blood pressure. The most critical impacts are exerted at the extreme ends of the distribution: lead exposure results in losses of people with superior functions (highest IQ gradients) and increases the number of those with the poorest functions (children close to mental retardation and adults with high existing risks of hypertension and strokes).

The exposure to lead could also have equity implications. Ingested lead may be more effectively absorbed when the stomach is empty, and the diet lacks essential trace elements, such as iron, zinc and calcium (ATECLP and EDF, 1994). Socially deprived children are also subject to higher risk of lead exposure due to unfavorable living conditions, and the lack of proper education and prevention measures.

Main Sources of Lead Exposures in Central and Eastern Europe

Lead is a heavy metal that has many uses in industrial and consumer products. In most Central and Eastern European countries, the main sources of human exposure to lead are (i) the exhaust of vehicles using leaded gasoline; (ii) industrial processes that utilize lead or lead compounds, such as ferrous and non-ferrous metal smelting and processing, and battery manufacturing and dismantling; and (iii) combustion sources, such as power plants, incinerators, and household heating. Water contamination by pipes that contain lead is not known to contribute to significant lead exposure in the region. Lead was removed from indoor paint many years ago in most countries in CEE; therefore, lead-containing paint does not appear to be a factor in exposures.

The exposure of large populations to lead is primarily due to airborne lead, and lead in dust and soil in CEE. Children whose developing nervous system is especially susceptible to disruptions caused by lead, are exposed to lead primarily through ingestion as they put their fingers, contaminated by dirt and soil, into their mouth. The main source of the exposure of adults is the inhalation of lead particles. A relatively smaller group of people is exposed to lead in the workplaces, and by indirect exposure that occurs when workers bring lead dust home on their clothes, hair and skin.

In the late 1980s and early 1990s, the contraction of economic activity resulted in "automatic" improvements in environmental quality, reducing human exposure to harmful industrial pollution. Recent evidence has also shown that serious pollution control measures were implemented in many industrial "hot spots" (Hughes, 1995). As a result, industrial lead emissions often continued to decrease despite the recovery of economic activity in recent years.

Due to falling industrial lead emissions, an immediate decline in human exposures could be detected. For example, in the industrial town of Kurdzhali, Bulgaria, a known "hot spot", mean BLLs of children fell by 31 percent between 1991 and 1995 as a result of control measures at the lead smelter (**Case Study A**). Although comparative tests of the intellectual performance of children were not carried out in Bulgaria, we can infer from internationally established evidence that the approximately US$ 4 million investment in pollution control at the lead smelter in Kurdzhali may have prevented a 1 IQ gradient decrease in exposed children, reducing the likelihood of the impairment of their cognitive development. However, the positive long-term impacts of reduced lead emissions are expected to be larger, due to the reduced accumulation of lead in the ambient environment, especially soil.

Signs of improvements in human exposures could also be detected in the industrial region of Silesia, Poland. In Chorzow in Upper Silesia, for example, a recent study found mean BLLs between 7.2 and 7.5 µg/dl, indicating a 40 percent decrease compared to the results of an earlier, although less extensive, study in the city (**Tables A.10** and **A.11**). Cases of lead poisoning due to occupational exposure have also declined. However, lead concentrations in soil remain high due to the persistent nature of lead in the environment, contaminating crops and food. Additionally, blood lead levels in the vicinity of large industrial sources in Silesia are still generally twice as high as in rural areas.

While industrial lead emission sources were increasingly controlled, vehicles became the largest source of lead exposures in many countries. In the town of Kurdzhali, Bulgaria, for example, the share of industry in total lead emissions decreased from 90 percent to about 17 percent by 1993, while the role of traffic now accounts for over 70 percent. Vehicular lead emissions were responsible for 84 percent of all airborne lead emissions in Hungary, 61 percent in Bulgaria, and 40 percent in Poland in the early 1990s (**Case Study A**). Especially significant is the role of traffic in lead exposures in large urban areas. In Budapest, for example, vehicular lead emissions account for 90 percent of airborne lead.

Impacts of Vehicular Lead Emissions

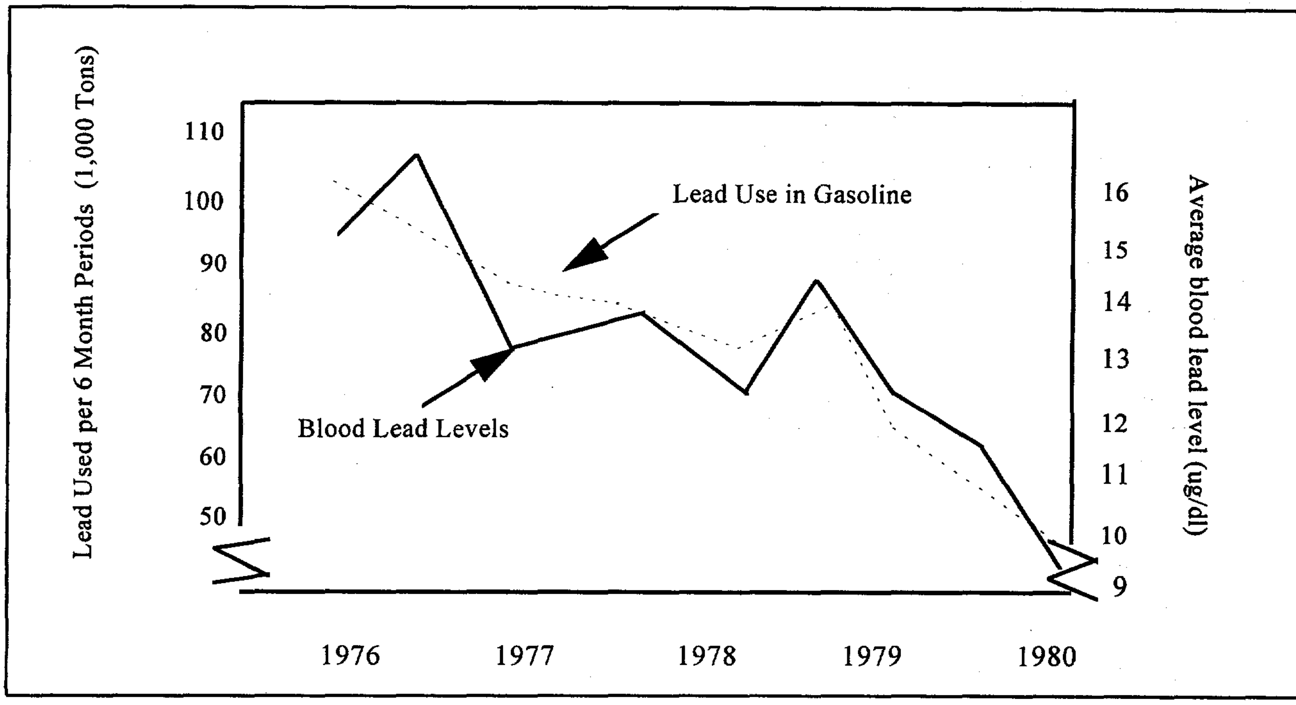
About 85 percent of lead emitted by vehicles consists of highly toxic inorganic lead, much of which is easily absorbed into the body due to the small size of lead particles. Airborne lead from vehicle exhaust is also capable of traveling long distances, although much lead is deposited on the soil near heavily traveled roads, where it can persist for long periods of time.

A strong relationship could also be demonstrated between traffic and the ambient concentration of lead in the atmosphere in CEE. Ambient lead concentrations in congested downtown areas, for example, were 6-11 times higher than in less congested suburbs in the 1980s in Budapest. Mean airborne lead concentrations in inner Budapest, where no other significant lead emission source existed than traffic, actually exceeded those in the industrial town of Katowice, Poland (Hertzman, 1995). Significant reductions in lead concentrations in suspended dust (31 percent) and airborne lead (44 percent) were registered in the downtown area of Budapest after traffic was prohibited in the area in 1989 (Kertesz, 1994).

The impacts of traffic were clearly detected in the soil depositions, as well. In Bulgaria, for example, a relatively small difference was observed between soil samples from a kindergarten in a village close to a lead smelter, and those taken in a town where traffic was the only source of lead emissions (**Table A.13**). In Poland, elevated soil levels were found along roads and in downtown areas of large cities. In Warsaw, for example, lead concentrations found in soil samples from small gardens were 3-7 times higher than in uncontaminated areas, due to the effects of traffic (**Table A.8**)

There has been clear evidence of the effects of traffic on human exposure to lead in CEE. For example, the percentage of children having BLLs above 10 µg/dl declined from 11.5 percent to 8.2 percent in the Hungarian town of Sopron after traffic was re-directed reducing emissions in the city. In 1985, a study found a significant (17.2 µg/dl) difference between the blood lead levels of children living in congested downtown areas and those living in the suburbs with less traffic in Budapest, indicating the impact of traffic-related exposures. This may have caused a more than 4 IQ points difference in the measurable intelligence of the two groups of children (assuming similar socio-economic status and other conditions which also influence IQ measurements). Consequently, children living in downtown areas with high traffic densities were more likely to experience learning problems, short attention span, hyperactivity, and other neuro-behavioral problems than those living in less congested suburbs. Higher lead exposures were also likely to affect the prospects of children throughout their lives.

Figure 1.1 Blood Lead Levels and the Use of Leaded Gasoline in the U.S., 1976-1980.



Source: U.S. EPA, 1985.

A very close relationship was detected between the use of lead in gasoline and the exposure of people, for example, in the U.S., where the most extensive studies of this kind were carried out during the 1970-80s (**Figure 1.1**). The growing recognition of the extreme toxicity of lead even at low levels of exposure and the role of traffic in elevated exposures of urban populations has directed policy makers' attention to measures to limit the use of lead additives in gasoline world-wide since the 1970-80s. Such measures resulted in large reductions of lead in the ambient environment and BLLs (**Box 1.1**).

By the early 1990s, many countries in CEE, including Bulgaria, Hungary, Poland and the Czech and Slovak Republics, introduced unleaded gasoline, and gradually decreased the lead content of leaded gasoline from high levels – often exceeding 0.7 grams per liter (g/l) until the early 1980s – to the current European Union standard (0.15 g/l) (**Figure 1.3**). These measures led to significant reductions in vehicular lead emissions, improvements in ambient air quality, and declining human exposures.

For example, lead emissions nearly halved both in Hungary and Poland in the year when the lead content of gasoline was reduced to its current level. Mean ambient atmospheric lead concentrations in Budapest declined dramatically, from 2.7$\mu g/m^3$ in 1991 to the WHO guide value of 0.5$\mu g/m^3$ in 1994. Based on relationships established between the ambient lead concentrations in the air and blood lead levels in Hungary, as well as internationally established relationships between blood lead levels and measurements of intelligence, the reduction of the lead content of gasoline in 1992 may have prevented a 2 point decrease in the IQ of exposed children in Budapest.

Statistical evidence concerning the linkage between the reduced lead emissions and the impacts on human health may not be available in countries in Central and Eastern Europe. World-wide

[1] Nizhny Novgorod has a population of 1.4 million. Average measured ambient airborne lead concentrations in the city ranged from 0.2 to 1.0 mg/m^3 in 1992, wile maximum measured concentrations were between 0.7 and 7.7 mg/m^3. The mean blood lead level of the population was estimated at 6 mg/dl (Abt, 1996).

Box 1.1 The Impacts of Reducing Lead Use in Gasoline in Switzerland and Italy

Switzerland

In Switzerland, the maximum legal lead concentration of gasoline was reduced from 0.4 to 0.15 g/l in 1982. Unleaded gasoline was introduced on the market in 1985, followed by a rapid increase in the market share of unleaded gasoline reaching 65 percent by 1992. Lead emissions from road traffic were reduced by 29 percent in the 1984-88 period, and by 35 percent in the 1988-92 period.

A study (Wietlisbach, 1995) was carried out to analyze the trend and determinants of blood lead levels (BLLs) in a Swiss region following the introduction of unleaded gasoline. The study found that, for both sexes, the distribution of BLLs had shifted to lower values. Geometric mean BLLs declined from 5.9 μg/dl in 1984/85 to 4.2 μg/dl in 1988/89 and 3.3 μg/dl in 1992/93 in men; and from 4.1 μg/dl to 2.9 μg/dl and 2.5 μg/dl, during the same time period in women.

Comparable changes in BLLs were observed in all age groups and across socio-economic and dietary categories. Wine drinking, smoking and age were also found to be determining factors on BLLs, however, the study concluded that "the decline of BLLs is likely to be caused predominantly by the reduction of the lead emissions from an important and ubiquitous primary source of contamination such as automotive lead exhaust".

Italy

The impacts of legislative and enforcement measures undertaken by the Government of Italy to reduce the concentrations of lead in gasoline from 0.6 to 0.4 g/l in 1982, from 0.4 to 0.3 g/l in 1988, and from 0.3 to 0.15 in 1992, were analysed by Bono et al. (1995).

The study, carried out in Turin, found a progressive decline in the atmospheric lead concentrations from 4.7 μg/m^3 in 1974 to 0.53 μg/m^3 in 1993 (**Figure 1.2**). A statistically significant decline was also found in blood lead levels between 1985/86 and 1993/94. In males, mean BLLs decline from 17.7 μg/dl to 6.5 μg/dl; in females from 12.1 μg/dl to 6.1 μg/dl.

Figure 1.2 Lead Concentrations in Gasoline and Ambient Airborne Lead Levels in Turin, Italy,1974-1992

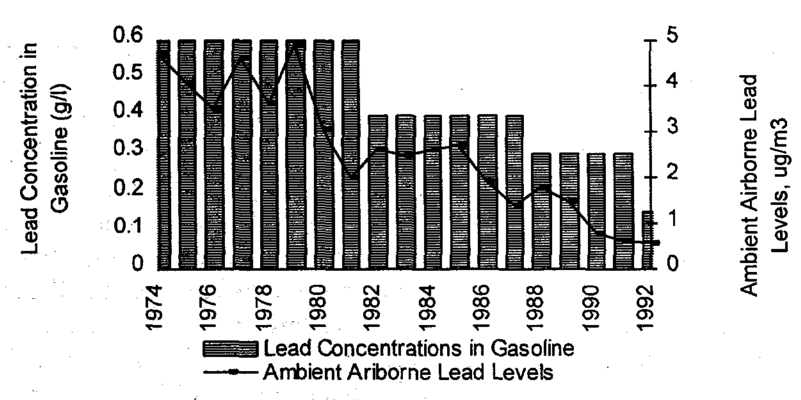
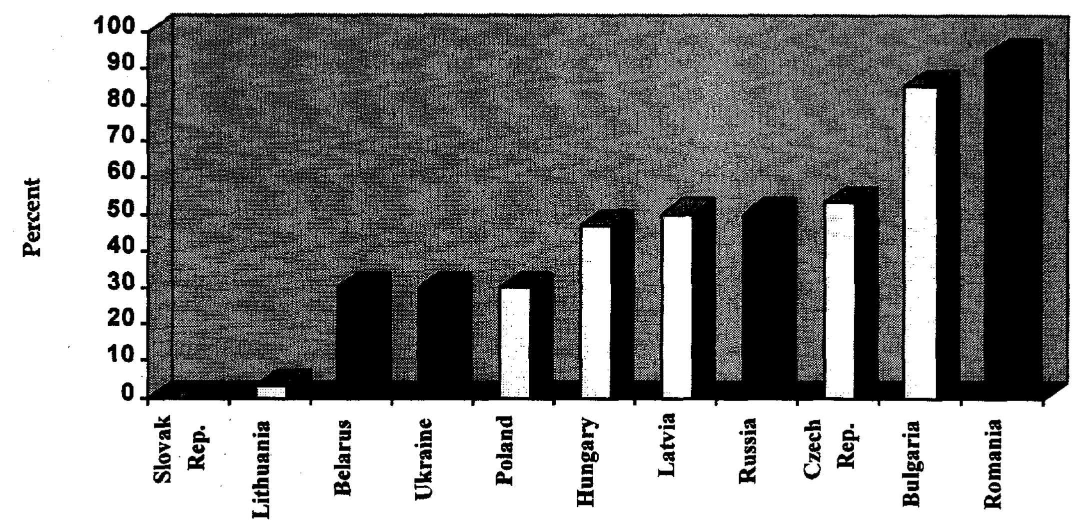


Figure 1.3 Share of Leaded Gasoline in Domestic Gasoline Consumption in Selected CEE Countries



Source: Lovei, 1996; personal communication with Government representatives.
Darker bars indicate higher than 0.15 g/l maximum allowed lead content in leaded gasoline.

experience and well established statistical relationships, as well as the country studies in this report, however, could provide guidance for policy makers throughout the region in assessing the benefits of reducing human exposures to lead, and formulating appropriate environmental and public health policies. A recent study (Abt, 1996), for example, calculated that removing lead from gasoline in Nizhny Novgorod in the Russian Republic[1], would lead to an avoided reduction of a total of 900 IQ points decrement in children, more than 2000 avoided cases of hypertension, and several cases of coronary heart disease, stroke and premature deaths in the adult population. Additionally, several "borderline" cases of children falling into the category of mental retardation (with IQ gradients under 70) could be prevented. Health benefits are expected to Health benefits are expected to be significantly greater in urban cities with larger population.

Although there has been progress in most of the studied countries and elsewhere in the region in reducing the use of lead (**Figure 1.2**) and decreasing human lead exposures, much work needs to be done in addressing lead exposure and related health problems. There are indications that the improvements that followed the measures to reduce the amount of lead in gasoline have slowed down or stopped recently. The case study of Hungary, for example, shows that no further imprvement in air quality has occurred in Budapest since a large decline of ambient atmospheric lead concentrations that took place in 1992 due to the reduction of the lead content in gasoline. In many other countries, no change has taken place in the heavy lead use in gasoline. The acceleration of the lead phase-out process, therefore, is necessary to prevent further health damages in urban areas as motorization increases.

Chapter Two

Feasibility and Costs of Phasing Out Lead from Gasoline

The Economics of Lead Use

For more than fifty years, refiners have added lead to gasoline — in the forms of tetra-ethyl lead (TEL) and tetra-methyl lead (TML) — to increase its octane number[1]. Lead is a relatively inexpensive source of incremental octane (both RON and MON). In most situations, lead addition is the least expensive way of providing incremental octane to meet gasoline specifications. **Figures 2.1** and **2.2** illustrate some key aspects of lead addition:

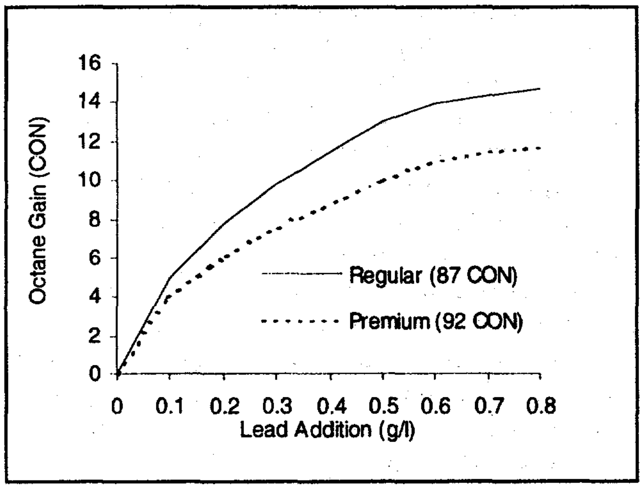
- At sufficiently high levels, lead addition can result in an increase of as much as 12 to 15 octane numbers (the propensity of gasoline to increase its octane with lead addition is called "lead susceptibility");
- In practice, a gasoline's lead susceptibility is a function of the gasoline's composition and blending properties. In general, the higher the octane of the base gasoline (before lead addition), the lower its lead susceptibility; and
- Lead addition is subject to decreasing returns to scale. Each increment of lead added to gasoline provides a smaller octane boost than the previous increment.

The primary obstacle to lead phase-out at the refinery level is economic: in most situations, lead is cheaper than any other source of incremental octane. Furthermore, as **Figure 2.2** indicates, the marginal economics of lead work against phase-out. As one removes lead from the gasoline pool, each increment of lead removed has a lower marginal cost of octane than the previous increment removed. Therefore, each increment of lead removed is cheaper (relative to the alternative sources of octane available to the refinery) than the preceding increment. The last increment to be removed has the biggest cost advantage over the alternatives.

The economics of lead use in gasoline production, however, do not take into consideration the negative effects of lead on the health of populations exposed to vehicular exhaust emission. For reasons of health and environmental protection, lead blending is no longer permitted or practiced in a growing number of countries. During the next few years, lead is likely to be completely phased out of gasoline throughout the European Union and several other countries.

[1]A gasoline's octane number is a measure of its propensity to knock in a standard test engine. The higher a gasoline's octane number, the better is its anti-knock performance. Gasolines are typically characterized by two octane ratings: (i) *Research Octane Number (RON)* measures anti-knock performance at *low* engine speeds; and (ii) *Motor Octane Number (MON)* measures anti-knock performance at *high* engine speeds. For any gasoline, RON is higher than MON, usually by 8 to 12 octane numbers. The difference between the two is referred to as "octane sensitivity". Most countries, including the EU member states, set specifications (minimum levels) for both RON and MON. The U.S., by contrast, sets specifications for *Control Octane Number* (CON), defined as the arithmetic average of RON and MON: *Control Octane Number* (CON) = (RON + MON)/2.

Figure 2.1 The Impact of Lead Addition on Gasoline Octane



Refinery Processes and Types

An oil refinery transforms crude oils into numerous co-products from heavy ("black") to light ("white") products according to increasing boiling range. In virtually all situations, light products, such as gasoline and distillate, are the most valuable, while heavy products, such as residual oil, are the least valuable co-products. Gasoline manufacturing is a complex operation that involves producing and blending various gasoline components (refinery streams in the gasoline boiling range), called *blendstocks*, in order to produce finished gasolines that meet all quality specifications (for example, for octane and vapor pressure).

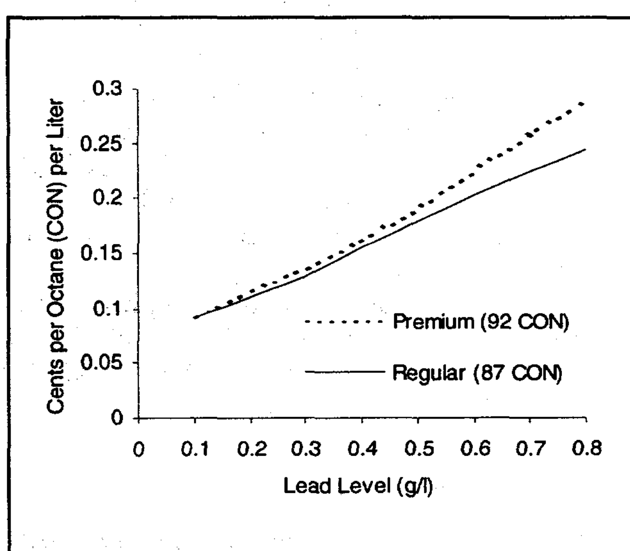
In any given refinery, various refining processes produce gasoline blendstocks (the most important refining processes involved in gasoline production are described in (**Box 2.1**). Some processes are dedicated to gasoline manufacture, others produce blendstocks for a number of refined products. Each process that contributes to gasoline manufacture produces a characteristic class of blendstocks, with a unique set of blending properties. No two blendstock classes are alike.

Each refinery is unique, that is, each has its own profile of process capacity and, therefore, produces a unique set of blendstocks. Hence, the composition of finished gasoline differs from refinery to refinery even within a given country or region, in which all refiners are blending to the same quality specifications (**Figures B. 7-9**, for example, show flow diagrams of Slovnaft refinery). Similarly, each refinery has its own cost structure, and faces a unique set of technical requirements when it seeks to improve product quality (for example, by removing lead from its gasoline pool).

Refineries can be grouped into categories based on process capacity and product slate (**Table 2.1**). Refinery complexity, capital intensity, operating flexibility, and value added all increase as one moves from left to right from one refinery type to the next:

- *Skimming* refineries are relatively simple, comprising crude distillation, treating, upgrading (catalytic reforming in hydroskimming refineries only), and blending. In general, most simple skimming (topping) refineries cannot produce finished gasoline without lead addition. Hydroskimmers and conversion refineries can, in general, produce unleaded gasoline, either with their existing capital stock or with revamping.
- *Conversion* refineries shift the product slate toward light products by cracking (converting) heavy crude oil fractions into gasoline blendstocks, distillate blendstocks, and refinery gases. They are

Figure 2.2 Marginal Cost of Octane Increase by Increasing Lead Levels



relatively complex, comprising crude distillation, treating, upgrading (at least catalytic reforming and usually other processes as well), conversion (at least one conversion process and often more than one), and blending. Some deep conversion refineries produce an all-light product slate containing no residual oil products.

Technical Options for Replacing Lead in Gasoline

When lead is removed from a gasoline pool; the octane increment formerly provided by lead must be replaced by a combination of (i) increasing the proportion of high octane blendstocks in the pool; and (ii) increasing the octane of at least some blendstocks. More specifically, the technical options for replacing octane provided by lead include:

- *Increasing the octane of the reformate* by increasing reformer severity (within the limits of sustainable operations). In some instances, achieving the necessary increase in reformer severity will call for revamping and modernizing the reformer.
- *Increasing the production of high octane blendstocks* (reformate, FCC gasoline, alkylate, isomerate or oxygenate) in the refinery by increasing utilization and, if necessary, expanding or revamping existing process units. As discussed previously, alkylate and oxygenate can be produced only in conversion refineries. Increasing their production from existing units calls for increasing the output of the refinery's FCC unit.
- *Blending MTBE* into the gasoline pool.
- *Reducing the volume of light naphtha in the gasoline pool,* by (i) increasing the volume of light naphtha upgraded to isomerate; or (ii) increasing the volume of light naphtha sold to the petrochemical sector.

These technical options may be applied in any combination that is technically feasible in the refinery. Determining the options of choice calls for detailed techno-economic analysis.

Car Technology Issues

In addition to its octane benefit, TEL provides some engine lubrication benefit: lead in gasoline, even in low amounts, prevents the wear of engine valve seats ("valve seat recession") in vehicles manufactured with soft valve technology. Extensive studies of the effects of unleaded gasoline on soft engine valve seats have, however, pointed out that the recession of engine valve seats is typically insignificant under normal driving and occurs only under severe driving conditions such as prolonged high speed driving, towing and hilly terrain (Weaver, 1986). Good maintenance has been found to prevent potential engine wear.

Tests carried out both in the U.S. and Europe have found the amount of lead that sufficiently protects sensitive engine valves as low as 0.02-0.05 grams per liter of gasoline (McArragher et al, 1993). These levels of lead are several times less than currently used in leaded gasoline by many CEE countries, and less then one third of the lead level allowed by EU regulations (0.15 g/l). Therefore, relying on the "lead memory" of vehicle engines, alternating fueling practices (buying leaded gasoline only every third or forth time), or the blending of leaded and unleaded gasoline brands have become commonly accepted practices in many European countries.

As most car manufacturers have increased the hardness of engine valve seats using cast iron and induction-hardened iron or special alloy inserts since the 1970s (McArragher et al, 1993), the need for lead or other lubricants declined. Some Eastern European vehicle manufacturers, however, still have not—or only recently—adopted such technologies and the exact sensitivity of the valve seats and the share of cars with sensitive valves in CEE car fleets are not precisely known. Engine tests carried out by Slovnaft Refinery in the Slovak Republic (Bratsky, 1995) indicated that certain car models (for example older models of *Skoda*) required a lubricating additive in unleaded gasoline to protect the soft engine valve seats. Tests and practical experience with the use of unleaded gasoline in other Eastern European car models (for example, *Lada*) have indicated, however, no damage or need for extra lubrication (Chem Systems, 1996). Systematic collection and dissemination of information on the feasibility of using unleaded gasoline and recommended fueling practices for typical cars in CEE car parks could clarify existing misconceptions and facilitate the phase-out of lead use in gasoline.

Lead is not the only substance that can protect sensitive engine valve seats. Lubricating additives

Box 2.1 Refining Processes of Gasoline Production

- *Crude distillation,* the separation of crude oil into fractions, is the indispensable process in any refinery, the precursor for all other processes. Two fractions are especially important in gasoline blending:
  - ⇒ *Light naphtha* - to be used for (i) direct blending to gasoline in small proportions; (ii) direct blending in larger proportions with addition of lead; or (iii) upgrading by isomerization and then blending; and
  - ⇒ *Heavy naphtha* - the primary feed to catalytic reforming, the workhorse of the upgrading process.

- *Conversion* processes convert heavy crude fractions and intermediate refinery streams into lighter streams. *Fluid catalytic cracking (FCC)* is the most important conversion process. The FCC unit, which converts heavy refinery streams in the residual oil range to a spectrum of lighter, more valuable refinery streams, is the heart of a conversion refinery.

- *Upgrading* increases the octane of crude fractions and intermediate refinery streams already in the gasoline boiling range:
  - ⇒ *Catalytic reforming* is the most important and most universal upgrading process. Reforming upgrades heavy naphtha to a prime gasoline blendstock, called *reformate.* The refinery can vary the octane level of reformate over a wide range (90-102 RON clear) by controlling operating conditions (or operating "severity"). No other refining process allows the refinery comparable control of blendstock octane. The combination of high blendstock octane and operating flexibility usually makes reforming the process of choice for controlling octane level and producing incremental octane-barrels in response to changes in gasoline specifications. However, the reformate has high aromatics and benzene content. The higher the severity is, the higher the aromatics and benzene content becomes. Consequently, reforming may not be the octane source of choice where environmental regulations call for control of the aromatics and benzene content of the gasoline pool.
  - ⇒ *Isomerization* upgrades light naphtha (70-78 RON) to a high quality, moderate octane blendstock (85-90 RON), called *isomerate.*
  - ⇒ *Alkylation* combines light olefins and iso-butane, all produced mainly by the FCC unit, to form a high-quality, high octane blendstock (92-97 RON), called *alkylate.* Because it is tied to the FCC process, alkylation can be employed only in conversion refineries and only to the extent that the FCC unit supports it. Because of its composition, alkylate is an exceptionally desirable blendstock for reformulated gasoline.

- *Oxygenate production* produces oxygenated gasoline blendstocks from FCC by-products, methanol, and ethanol. MTBE (methyl tertiary butyl ether) is the most widely used of the oxygenate blendstocks. It has exceptionally high octane (115 RON) and other desirable blending properties as well. In a refinery, MTBE is produced by an *etherification* process, which combines purchased methanol and iso-butene produced mainly by the FCC unit. Therefore, refinery-based (or captive) etherification can be employed only in conversion refineries and only to the extent that the FCC unit supports it. However, a number of merchant etherification plants produce MTBE, and a world trade exists in merchant MTBE.

Table 2.1 Refinery Classification

	Skimming		*Conversion*		
Category	*Topping*	*Hydro-skimming*	*Coking*	*Catalytic Cracking*	*Deep Conversion*
Crude Distillation	•	•	•	•	•
Treating	•	•	•	•	•
Blending	•	•	•	•	•
Upgrading		•	•	••	••
Conversion			•	••	•••
Oxygenate Production				•	•

are available to be blended to unleaded gasoline to prevent valve seat recession. Many of these additives are sodium based substances which are commercially available. The Slovak Slovnaft Refinery developed its own lubricating additive that helped the transition to a totally unleaded gasoline in the Slovak Republic (**Case Study B**).

Switching from leaded to unleaded gasoline has significant positive impact on engine maintenance. Lead additives cause various problems with vehicle operation including the build-up of deposits in the combustion chamber and on spark plugs. In order to prevent these problems, lead scavengers — substances such as ethylene dibromide and dichloride — are added to gasoline together with lead additives to increase the volatility and emission of lead combustion by-products. Lead scavengers, besides raising health concerns[2], increase corrosion especially in the engine exhaust system. Lead additives and their scavengers, therefore, are known to increase vehicle maintenance costs due to the need for more frequent oil, spark plug and muffler change. Maintenance cost savings associated with the switch to unleaded gasoline were reported in the range of US$ 0.003-0.024 per liter of gasoline in a number of countries (Walsh, 1995). In the U.S., these savings were found to exceed the potential maintenance costs associated with the recession of soft valve seats in the 1980s (U.S. EPA, 1985).

Costs of Phasing Out Lead from Gasoline

Most CEE countries have their own refineries and gasoline production capacity (**Annex A**). A few countries (for example, Armenia, Estonia, Moldova, Tajikistan) import all their gasoline, while some (for example, Croatia) import a large share of their domestic gasoline consumption. For gasoline importer countries, the incremental cost of switching to unleaded gasoline is determined by the price difference of unleaded and leaded gasoline on their main import markets. Large regional markets (for example Mediterranean) have been offering unleaded gasoline at very competitive prices (**Box 2.2**). Frequently, unleaded gasoline prices have been lower for some octane grades (for example, 95 RON) than leaded, due to structural overcapacities in production. The cost of switching from leaded to unleaded gasoline for gasoline importers, therefore, would be very low, mainly determined by the costs of VSR additives and additional transportation costs to access new suppliers if necessary. The cost of importing unleaded gasoline or gasoline blendstocks or additives should always be assessed as an alternative to investment in refinery upgrade.

The costs of lead phase-out at the refinery level are determined by the interplay of (i) principles of refining techno-economics; and (ii) refinery-specific conditions such as processing capabilities, refinery configurations, the existence of excess capacity, crude oil slates and product slates. Due to a large variety of refinery-specific factors, the most cost-effective and technically optimal solutions of reducing the lead content of gasoline may vary across refineries.

World-wide experience and estimates indicate that annualized investment expenditures and added operating costs associated with the removal of lead from gasoline are typically in the range of US$ 0.01-0.02 per liter (Lovei, 1996; Thomas, 1995). Preliminary estimates and experience in CEE confirm similar magnitude of costs.

A modeling study was undertaken to provide a preliminary assessment of the technical and economic feasibility and costs of lead phase-out in a country, Romania, where no significant measures had been taken previously to reduce the use of lead in gasoline sold on the domestic market (Hirshfeld and Kolb, 1995). Romanian refineries are still allowed to add maximum 0.6 metallic lead per liter to gasoline (g/l) sold domestically. These levels are more than three times higher than the current EU standard for premium leaded gasoline (0.15 g/l). Given the expected growth in economic activity in Romania and the consequent increase in gasoline consumption, phasing out lead is necessary in order to avoid significant increases in lead exposures in the near future. The country's intent to join the EU also makes preparation of a lead phase-out strategy necessary and desirable. Preliminary modeling results indicated that:

- Romania's large inland refineries could reduce the lead content of gasoline relying on

[2]Lead scavengers, most notably ethylene dibromide, have been found to be carcinogenic in animals, and have been identified as potential human carcinogens by the U.S. National Cancer Institute.

Box 2.2 Gasoline Prices and Octane Valuation on European Markets

Benchmark prices for gasoline in Europe are determined by the North West European and Mediterranean markets. Since premium and regular gasoline grades are regularly traded, the market effectively sets the value of octane in the 92 and 95 clear RON range. For high octane values, the market price differences between MTBE and premium gasoline can be used, while low octane values are indicated by the price difference of regular gasoline and naphtha. The market price of intermediate grade gasoline can be determined by using the appropriate octane value.

The price of octane increases with clear RON reflecting an increase in production costs for higher octane components. The clear octane of leaded gasoline can be assumed at three points below its leaded octane grade. Additionally, leaded gasoline prices include the cost of lead additives. As a result, leaded 95 RON gasoline with approximately clear 92 RON is valued higher than unleaded 92 RON gasoline. However, leaded 96 RON gasoline is still valued lower than 95 RON unleaded gasoline reflecting the fact that boosting octane by lead addition is usually cheaper than by incremental reforming or adding MTBE.

Source: Adopted from Chem Systems, 1996.

existing process capacities, mainly due to the presence of excess reformer capacity. The first phase of lowering the lead concentration of gasoline to 0.15 g/l, especially if combined with process optimization measures, could be carried out without reducing refinery operating margins.

- Further reductions, especially below a lead level of 0.15 g/l, would also be feasible without adding to existing processing capabilities, however, only by increasing the cost per unit of lead reduction as the lead level decreases, primary due to the purchase of high-octane blendstocks (such as imported MTBE) and increasing the octane output of the refineries' catalytic reforming units.
- Prelimiary estimates of the cost of removing lead from gasoline in Romania did not exceed the range of US$ 0.01-0.02 per liter of gasoline.

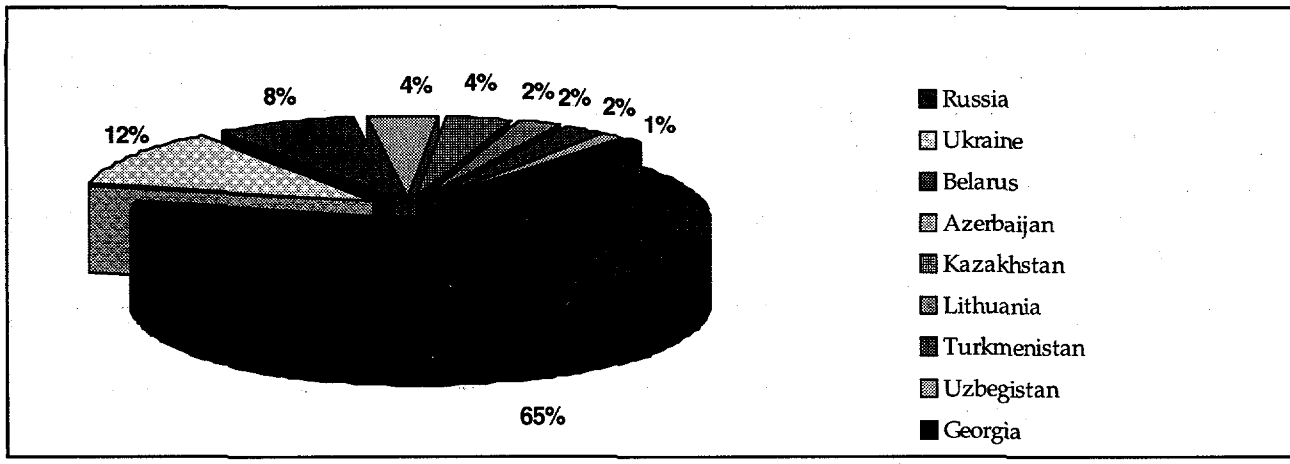
Another modeling study (Abt, 1996) estimated the costs of removing all lead from gasoline produced by a hydroskimming refinery in Nizhny Novgorod, Russian Federation, in the range of US$ 0.005 to 0.02 per liter of gasoline including both operating and capital recovery costs.[3] It was also noted, however, that the refinery was expected to undergo structural changes in order to better respond to market demand, which would not only facilitate the removal of lead, but also reduce the costs to be allocated to lead phase-out by about 50 percent.

A feasibility study of phasing out lead from gasoline in Bulgaria (Chem Systems, 1996) concluded that optimization of operations and a US$ 1.4 million investment to revamp Neftochim refinery's FCC unit could enable the refinery to increase the share of unleaded gasoline in its gasoline production from 24 to 80-90 percent. Additional investment (US$ 61 million) in upgrading the refinery's semi-regenerative reformer to a continuous catalytic regenerative unit was recommended to ensure the total removal of lead from gasoline. Large part of this investment cost, however, was not related to lead phase-out only, since the current reformer had passed its useful life and had to be replaced to ensure continuous gasoline production in the refirnery.

The total phase-out of leaded gasoline was successfully accomplished in the Slovak Republic in three main phases (**Case Study B**). In the first phase, before 1986, the refinery adjusted to government regulations that gradually reduced the allowed concentration of lead in gasoline, largely by increasing the severity of catalytic reforming, adding MTBE to the gasoline pool, and introducing refinery optimization measures. In the second phase, between 1986 and 1988, a new hydrocracking unit was installed that enabled the refinery to start producing unleaded gasoline. In the third phase, after 1992, an isomerization unit was installed that allowed for the increased production of high octane gasoline components without increasing the amount of volatile compounds. The investment costs,

[3] Technical alternatives included (in the order of increasing cost of lead reduction): (i) adding octane-enhancing glycol-based DurAlt; (ii) adding octane-enhancing manganese-based MMT; (iii) investments in FCC and hydrocracking capacity; and (iv) investments in FCC, hydrocracking and reforming capacity.

Figure 2.3 Distribution of Refining Capacity in the Former Soviet Union



Source: Plotnikov et al, 1996

together with the increased operating costs associated with producing unleaded gasoline compared to leaded, amounted to about US$ 0.02 per liter of gasoline at the Slovnaft refinery (**Case Study B**), which confirms the estimated price range of modeling studies.

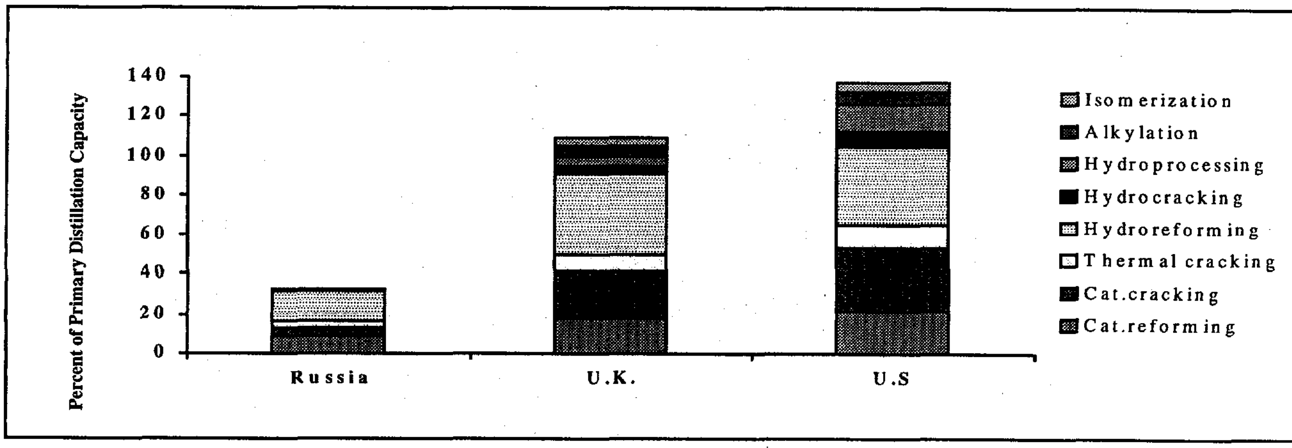
Refining Sector Context

World-wide experience, studies in CEE, and the experience of the Slovak Republic clearly indicate that the removal of lead from gasoline is technically feasible, and the costs are modest. However, the assessment of the extent and costs of necessary technological upgrading cannot be easily generalized for all refineries in the region.

Additionally, the removal of lead from gasoline cannot be separated from the restructuring and privatization of the petroleum refining industry. Progress in this respect varies greatly among countries. Those CEE countries (for example, the Czech Republic, Hungary, Lithuania, Poland, Slovak Republic) which typically have a small number of refineries and more advanced market structure, have liberalized their energy prices, and successfully corporatized their refineries. Several of the Central European refineries have been privatized, and technically upgraded. The Czech Government, for example, approved the sale of a 49 percent stake in two oil refineries to an International Oil Consortium consisting of Royal Dutch Shell, Italy's Agip and the US Conoco with the condition that the products made by these refineries have to be improved. Investments planned to modernize the refineries were reported to reach US$ 480 million during a five year period following the privatization ("Czech Republic: Refineries Deal", 1995). In Hungary, 42 percent of the shares of MOL, the previously fully state owned oil company, had been sold to investors by early 1996, and further sales are planned ("Hungary Pushes Energy Program...", 1996). The Hungarian Petroleum Association has been actively pushing for improvement in gasoline quality, and from July 1996, only one grade (98 RON) leaded gasoline is marketed in the country. Hungary's biggest refinery, Danube, has been upgraded with FCC plant, visbreaking, and hydrocracking capacity, and further modernizations are in the planning stage. In Lithuania, the only refinery was converted to a joint-stock company which does not produce unleaded gasoline any longer. In Poland, significant refinery upgrades are underway in the Plock refinery.

The situation is less encouraging, however, in countries of the Former Soviet Union (FSU), where about 85 percent of refining capacity is concentrated in three countries: Russia, Ukraine and Belarus (Russia itself representing about 66 percent) (**Figure 2.3**). Macroeconomic instability, recession and large structural, operational and economic inefficiencies have been inherited from the system of central planning. These problems cause limitations in the

Figure 2.4 Secondary Processing as the Share of Primary Distillation Capacity in Russia, the U.K., and the U.S.



Source: Plotnikov et al, 1996.

adjustment to market conditions:

- *Refinery utilization rates declined sharply since the late 1980s leaving significant excess capacity* as a result of the contraction of economic activity. Russian oil production output, for example, plunged by more than 40 percent from its peak in 1987, and refinery utilization rates declined to around 60 percent with a variation among refineries from 21 percent (Groznyy) to 75 percent (Moscow and Ukhta) (IEA, 1995). In Belarus, production declined by about 65 percent between 1989 and 1993 (World Bank, 1995a). Ukrainian capacity utilization deteriorated even more drastically: from 99 percent in 1989 to 34 percent in 1994 and 20 percent in the first quarter of 1995. The largest and newest refinery, Lysychansk operated at 10-19 percent capacity utilization rates in 1996 (IEA, 1996).
- The *slow process in market reform* has created obstacles to the market-oriented restructuring and adjustment of the sector. In Russia, product prices were not completely liberalized until 1995 (IEA, 1995). Domestic oil prices rose from 20 percent of world market prices in 1992 to 50-60 percent in 1995 (Pugliaresi and Hensel, 1996). Retail prices of gasoline in 1994, however, were still less than 45 percent of those in the U.S. (IEA, 1995). Additionally, the vertical integration of oil companies into virtual regional monopolies may further restrict, rather than foster, competition and consumer orientation. In Ukraine, five of the six refineries were corporatized, however, this had little positive impact on operations and market orientation (IEA, 1996). Poor process control and refinery management practices often contribute to low energy and labor efficiency.
- *The structure of production capacity is undesirable.* It is characterized by excess crude distillation capacity and shortage of downstream conversion and upgrading capabilities (**Figure 2.4**). For example, only 12 of the 28 refineries in Russia are equipped with catalytic crackers (some of which are more than 40 years old), and the average conversion ratio of Russian refineries is around 10 percent compared to corresponding ratios of 28 and 70 percent in Western Europe and the U.S., respectively. Several big refineries have only hydroskimming but no conversion capacity; alkylation units are rare and only three refineries are capable of producing MTBE (IEA, 1995). In Ukraine, a study (John Brown, 1994) found that the Kremenchuk refinery was the only facility with heavy oil cracking capacity (FCC). In Belarus, high quality domestic crude is becoming wasted due to the technical limitations of the refineries to extract a higher share of light products (World Bank, 1995a).
- *A mismatch exists between refinery output and demand structures.* This is indicated by the excessively large share of heavy products, which is also reinforced by the undesirable production capacity. In Ukraine, for example, gasoline yield in the refining industry averages about 16 percent compared to the 45 to 50 percent yields typical in modern refineries (John Brown, 1994). In Belarus,

Table 2.2 Refinery Projects Under Preparation in the Former Soviet Union

Country/Refineries	*Total Capacity to be Added (bcd)*	*Types of Capacity Additions*
Belarus/PO Naftan	66,000	Refinery, vacuum
Kazakhstan/Atyrau, Kazakhstan	259,400	Catalytic reforming, vacuum distillation, FCC, Hydrotreating, MTBE/TAME, Crude refinery
Russia/Achinsk, Afipsky, Angarsk, Khabarovsk, Kirishinefteorgsintez, Kstovo, Lukoil, Niznikamsk, Novo-Ulfimsk, Orsknefteorgsintez, Ryazan, Saratov, Stavropolnefteorgsintez, Surgut, Tomsk, Tyumen, Yaroslavnefteorgsintez	1,265,000	FCC, hydrocracking, visbraking, isomerization, merox, vacuum, coking, hydrogen, MTBE, CCR
Turkneistan/ Chardzhou, Krasnovodsk	NA	Refinery revamp
Ukraine/ Drogobytch, Kremenchuk, Lysychansk	377,700	Cat. reforming, cat. cracking, hydrotreating, visebraking, isomerization, alkylation, C_5/C_6, vacuum, MTBE
Uzbegistan/Marubeni Corp.	100,00	Refinery

Source: "Worldwide Construction". 1996.

only 40-45 percent of refinery feedstock is produced as high value product (World Bank, 1995a). Additionally, a mismatch between the location of refineries, their supplier and major markets often exasperates weaknesses in the product structure requiring large transportation costs. The export of refined products became unprofitable for many Russian refineries, due to a rise in rail tariffs (Plotnikov et al, 1996). The break-up or the FSU further deepened the problem of geographical mismatch by converting previously domestic business relationships to trade among independent states. There are signs that this may lead to investments in new refinery capacity. Kyrgyzstan, for example, which had frequent difficulties with processing its oil production in the Fergana refinery in Uzbekistan (the refinery was often unavailble to process Kyrgyz crude, and charged a high processing fee) (World Bank, 1995b), installed its first refinery in 1996 ("Kyrgyzstan's First...", 1996) while Uzbekistan is also halfway through the construction of a new refinery at Karaoul Bazar ("Uzbeki Refinery..., 1996). The break-up of the FSU also contributed to disruptions in the crude supply of some refineries. The Mazeikiai refinery in Lithuania, for example, receives its crude supply from Russia by a pipeline that passes through Belarus. Due to trade disputes over exchange rates used in inter-republican trade, crude supply was stopped and operations of the refinery had to be suspended in 1992 (World Bank, 1994).

- *The quality of products especially gasoline is often poor.* The bulk of Russian refined products, for example, are well below Western European quality. Only about 10 percent of AI-93 gasoline meets such criteria (IEA, 1995), while about three forth of gasoline is grade A-76 (Plotnikov et al, 1996). In Ukraine, the majority of gasoline produced was found to be between 78 and 80 Control Octane Number (CON) (John Brown, 1994) compared to 87, 89, and 92 CON ratings of U.S. gasoline brands. Low octane (A-76) gasoline still account for about 75 percent of the total gasoline consumption (IEA, 1996).
- *Much of the refinery technology is obsolete and the equipment performs poorly.* These are consequences of insufficient attention to and investment in maintenance and technology upgrade in the past. According to estimates (IEA, 1995), 80-90 percent of the capital stock in the refining industry in Russia is obsolescent and in poor condition, having surpassed its useful economic life. With the exception of Kremenchuk and Lysychansk refineries, much of the Ukrainian refinery capital stock is also obsolete (John

Brown, 1994). The operation of old equipment also contributes to significant system losses, low feedstock flexibility and energy efficiency, and poor safety. In addition to obsolete refining technology, the equipment and facilities in the distribution and retail networks also need modernization. Traditionally, only a small portion of gasoline was sold retail in the FSU, and enterprises and government agencies purchased wholesale, directly from refineries and direct depots. The number of retail pumps, therefore, is relatively small and a significant share of gasoline sales to private vehicles is made through illegal wholesale deals from tanker trucks (frequently old, with low capacity and efficiency) with minimal quality control.

- *Limited financial resources are available* to undertake larger investments. Due to low domestic prices and difficulties in the collection of receivables, refineries have insufficient internally generated cash, while disrupted financial markets and high inflation rates often limit access to medium and long-term loans. Additionally, due to slow restructuring, continuing government dominance or interference in the sector and frequently changing or unclear regulatory and tax treatment of foreign investors have made refineries unable to attract significant foreign investments.

Demand for oil products is not projected to increase significantly in the medium and long term in the region. Recent projections (IEA, 1996; IEA, 1996, World Bank, 1995a) foresee domestic demand to stabilize well below levels reached at the end of 1980s. Factors such as the slow recovery of economic activity; expected economy-wide improvement in energy efficiency; the restructuring of industry towards less energy-intensive activities; and existing global over-capacity in refined products depress future demand for refinery output. As a result, the vast excess capacity is expected to lead to the partial or full closure of several refineries. As oil markets become fully liberalized, widening profit margins between light and heavy products will shift production towards lighter products. The technologically least advanced topping and hydroskimming refineries will face large difficulties and higher costs to produce lighter products, and upgrading these refineries may not be justified on economic grounds.

The following are the main implications of the above situation on the removal of lead from gasoline:

- In the short term, low utilization rates facilitate the production of unleaded gasoline. In refineries that operate with significant excess conversion capacity, the production of low lead or unleaded gasoline may be less costly than the production of gasoline with high lead content, especially given the current low octane requirements of the car fleet. This has been indicated by the modeling study of the Romanian refining sector, and also confirmed by refinery experts in Belarus.
- In the medium and long term, the exposure of refineries to market forces and competition is expected to lead to the reduction of excess capacities. Investments in rehabilitation and technology upgrade will be needed to increase the production of lighter products (**Table 2.2**). These new investments will increase the capacity of the refineries to produce higher octane gasoline blendstocks and unleaded gasoline.
- Assessments of the feasibility and costs of lead removal have to take into consideration the expected technological changes that would take place even without phasing out lead, "charging" only the additional costs to lead removal.
- Sectoral restructuring, and the rehabilitation and modernization of refineries, offer an opportunity to include lead phase-out objectives into the planning phase. *Clear lead phase-out commitment, schedule and policies are necessary, therefore, to ensure the optimal size and timing of refinery investments.*
- Government policies and requirements focusing on the removal of lead from gasoline are expected to *accelerate* refinery adjustments.

Chapter Three

Policies and Implementation

Cost Effectiveness

The social benefits of reducing human exposure to lead can be grouped into three categories: (i) positive impacts on neurological development and intelligence that affect lifetime productivity and earnings; (ii) avoided costs of the special education needed to deal with children affected by learning disabilities, the extra medical care of prematurely born infants, and the costs of treating adults with cardiovascular diseases; and (iii) avoided cost of prematurely lost lives due to cardiovascular problems caused by lead.

Different methodologies can be applied to estimate the benefits in each of the above categories. Statistical relationships between IQ gradients and wages can indicate the direct effects of intellectual performance on earnings. Adjustments are necessary, however, to calculate the indirect impacts, since IQ can also influence participation in the work force. Avoided educational and medical costs can be estimated relying on medical costs (cost-of-illness approach), and/or information on people's willingness-to-pay (for example based on contingent valuation methods). The most difficult problem is evaluating the benefits of reducing premature death. Applied methods include compensating wage studies and contingent valuation (for detailed discussion see, for example, Schwartz, 1994; Abt, 1996).

All these benefits depend on country-specific factors; for example, on the cost of labor, capital and medical care, people's values of health and life, and their willingness to accept risk. Concrete estimates, therefore, are difficult to make without country-specific data. Studies in western countries, however, may provide some indication of the magnitude of benefits. It was estimated, for example, that a one point IQ reduction could be associated with a 0.9 percent reduction in lifetime earnings in the U.S. The annual benefits of reducing the population's mean blood lead levels by 1 μg/dl were estimated at more than US$ 17 billion (1989 US$), that is, almost US$ 70 per person (Schwartz, 1994). As a result, the benefits of removal of lead from gasoline were estimated to exceed its costs more than ten times in the U.S. (US EPA, 1985).

Although rigorous benefit-cost estimates have not been carried out in CEE, a recent study (Abt, 1996) has linked the costs related to refinery investments to certain health benefits in Nizhny Novgorod, Russian Federation. The study concluded that, depending on the technical solutions applied at the refinery to phase-out lead, a 1 μg/dl reduction in the BLL of exposed population would cost US$ 2.5-8.4 per person annually, assuming that no refinery restructuring and investment would take place without the lead phase-out program. The estimated cost drops to US$ 0.05-4.6 per person, however, if a baseline adjustment in refinery configuration to new market conditions is assumed.

A crude indication of cost effectiveness could be

[1] PPP estimates of 1994 GNP per capita: US$ 25,880 and US$ 4,610 for the U.S. and Russian Federation, respectively (*Source*: World Bank, 1996). The 1989 U.S.$ benefit estimates were converted to 1994 U.S.$ using CPI: 116.6 (*Source:* IMF, 1996)

obtained by assuming that the health benefits of reduced lead exposure are similar to those calculated in the U.S. in proportion to the relevant income levels. Adjusting U.S. benefit estimates based on the relative purchasing power parity (PPP) estimates of gross national products (GNP) per capita[1], the expected annual benefits of a 1 μg/dl BLL increase of exposed population would be about US$ 15 per person in the Russian Federation.

Comparing this benefit estimate with the mid-points of cost range calculations indicates that the benefits of lead removal in Nizhny Novgorod may exceed the costs by 3-6 times depending on assumptions about the refinery's adjustment to changing market conditions and the technical solutions selected to phase-out lead. Even higher benefit/cost ratio may be obtained by considering the benefits of reduced car maintenance costs (see **Chapter 2**). Such back-of-the-envelope calculations, however, cannot replace more rigorous case-by-case analyses.

Lead Phase-Out Approaches

Although the removal of lead is expected to be a highly cost effective measure, it requires a strong commitment and appropriate policy intervention. Four main aspects of public policy intervention should be emphasized: (i) regulations and enforcement; (ii) incentives; (iii) a broad consensus of affected stakeholders; and (iv) public understanding and acceptance.

Based on the world-wide experience of countries with phasing out lead from gasoline, three general policy approaches may be distinguished:

- *Technology-based approach* that relies on the change of gasoline demand due to changing car technology (use of catalytic converters), typically relying on the mandatory use of catalytic control devices on vehicles. This option may be feasible in countries where (i) significant pollution problems exist that can best be tackled by the wide use of catalytic converters; (ii) the penetration of new car technology is high (that is, the turn-over of the vehicle fleet is fast); and (iii) gasoline supply can be easily adjusted to a gradually but rapidly changing demand. The early lead phase-out program in the U.S., for example, was largely relying on this approach.
- *Incentive policy approach* that uses price incentives and other incentive policy measures to promote the use of unleaded gasoline in cars with or without catalytic converters. Such an approach may promote alternating fueling practices (using leaded gasoline only occasionally, relying on the "lead memory" of the engine) or the use of lubricant additives for cars with soft valve seats that require some lubrication previously provided by lead. This approach may be combined with the gradual reduction of the lead content of gasoline and the promotion of catalytic converters. It may be recommended in countries where the slowly changing car park contains a substantial proportion of vehicles with soft valve seats, and domestic gasoline suppliers may need some time to adjust their capacity to unleaded gasoline production. Most Western European countries, for example, Great Britain and France have followed this approach (Lovei, 1996).
- *Rapid phase-out approach* that encourages or bans the use of leaded gasoline even before catalytic converters become universally used for the entire car fleet. The transition period from leaded to exclusively unleaded gasoline market is relatively short under this approach. If the car park includes a significant share of vehicles with soft valve seats, one or two gasoline brands, specifically designed for these cars containing a lubricant additive, may be introduced. This approach has been followed typically in countries that import all or most of their gasoline supply (for example, Bermuda) or those with a relatively homogenous refining capacity capable of producing unleaded gasoline exclusively (for example, Thailand). Besides health benefits, this approach also reduces distributional costs by eliminating the need for a dual system (leaded and unleaded) of storage, transportation, sales and administration; and reducing the risk of contamination and potential misfueling.

In CEE, the *technology-based approach* alone would result in a very slow phase-out of lead from gasoline, as most countries in the region possess car fleets relatively old by Western standards, and the replacement of vehicle fleets proceeds relatively slowly. In the Slovak Republic, for example, the average age of the vehicle fleet has been 14 years, compared to 7-9 years in the European Union.

The *incentive policy* and *rapid phase-out approaches*, therefore, offer a more appropriate way of dealing with the vehicular lead exposure problem in the region. Many countries in CEE, including Bulgaria, Hungary and Poland follow the *incentive approach* combined with regulations reducing the lead content of gasoline, and supporting the use and import of cars with improved pollution characteristics (for example, levying higher duty on the import of older cars or mandating the use of catalytic converters on new and imported cars). As a result, the overall lead use in gasoline and the market share of unleaded gasoline have risen significantly in many cases.

The Slovak Republic is the only country in CEE so far which has chosen the *rapid phase-out approach*. This policy was preceded and combined with an *incentive policy approach* to influence consumer behavior and smooth the transition. In order to overcome the technical obstacle of phasing-out leaded gasoline presented by the existing car fleet (about 70 percent of cars have soft valve seats), Slovnaft refinery developed an additive which provided lubrication for the sensitive soft engine valve seats in the absence of lead. The lubricating additive has played an important role in overcoming the problem of old vehicles and slow fleet turnover.

Some CEE countries, including Romania and many of the former Soviet Republics, however, have not started to implement a lead phase-out program yet. The maximum allowed concentration of lead in gasoline has remained high (in Romania and several countries of the FSU it is still 0.6 g/l[2]) and no significant measures have been taken to facilitate a change in gasoline demand. In these countries, policy intervention to launch a lead phase-out program is urgently needed in order to prevent a growing threat to public health due to human exposure to lead as motorization increases.

Despite the contraction of economic activity in most countries in the region during the late 1980s and early 1990s, traffic continued to grow. While the number of in-use cars showed only moderate growth rate in most Western European countries, double-digit growth rates were registered in several CEE countries (**Figure 3.1**). The number of private cars in Ukraine, for example, increased by 27 percent between 1990 and 1994 despite serious economic hardship (IEA, 1996a). Urban areas have been affected by especially large increases in car fleets. In Moscow, for example, a 10 percent annual increase in the passenger car fleet was observed during 1980-1990, and a more than 17 percent annual increase during 1990-1994 (TME, 1995).

Regulations and Enforcement

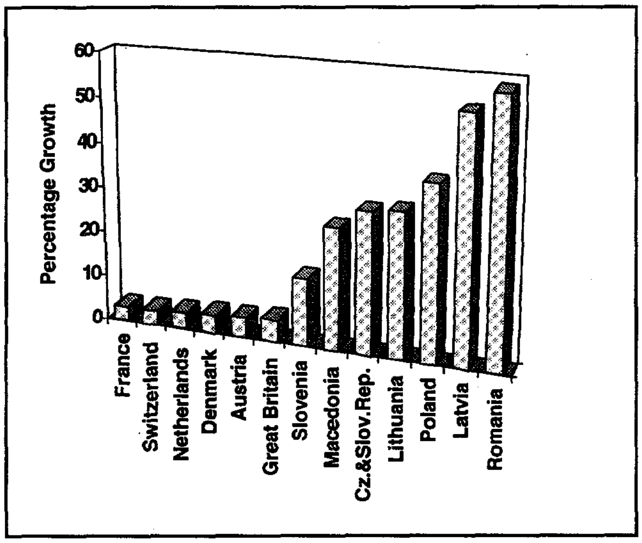
In most countries, it is not the technical capacity of refineries that constrains a significant reduction of lead used in gasoline on the domestic gasoline market, but the lack of regulations and incentives to limit it. Gasoline importing countries (for example, Armenia, Latvia, Moldova, Tajikistan that do not have refineries and Slovenia that imports about 80 percent of its gasoline need) have no serious technical contraints to accelerate the phase-out of lead. Several gasoline producing countries including Bulgaria, Romania and Belarus, export significant amounts of unleaded gasoline, yet do not require its use domestically. Romania, for example, exports half of its gasoline output, all unleaded. The majority of gasoline export of Bulgaria, representing about 15 percent of its total production, is also unleaded. In Belarus, more than 90 percent of gasoline production is unleaded, but only about 70 percent of gasoline used on the domestic market is unleaded.

Experience world-wide shows that a strong political commitment is necessary to introduce and enforce regulations aimed at mitigating human exposure to lead (Lovei, 1996). Such regulations fall into two major categories: (i) environmental quality objectives that limit the maximum allowed concentration of lead and other pollutants in the atmosphere; and (ii) regulations necessary to comply with environmental objectives including, for example, the reduction of maximum allowed lead concentration in gasoline; other fuel specifications to ensure that lead in gasoline is not replaced by substances harmful to health; and regulations concerning the pollution characteristics of vehicles.

Strict environmental regulations of lead are present in most countries in CEE. Additonally,

[2] In Russia and Ukraine, for example, the maximum lead content is 0.3 g/l in regular gasoline, and 0.6 g/l in super (AI-93) and premium (AI-98) grades (IEA, 1995; IEA, 1996).

Figure 3.1 Percentage Growth of Number of Cars in Use in Selected European Countries, 1988-1991



Source: Eurostat, 1993.

regulations of the lead content of gasoline are necessary in all lead phase-out policy scenarios. The first step should be the reduction of high maximum permitted concentrations to lower levels such as 0.15 g/l or less. Further steps should include a deadline for the total elimination of lead. Regulation of the maximum allowed lead concentration may also be combined with other gasoline quality specifications such as octane rating, volatility, the content of aromatics, benzene and oxygenates. International reference specifications may provide guidelines. Several CEE countries (Bulgaria, Czech Republic, the Baltic Republics, Hungary, Poland, Romania, Slovak Republic and Slovenia) have applied for membership in the European Union (EU). In these countries, harmonization of regulations with those of the EU is of high priority, and many have already adopted EU gasoline specifications (**Annex C**). Accelerating the phase-out of lead as part of this harmonization process would facilitate the accession process of these countries[3].

Gasoline quality in countries of the FSU is, however, below international levels (IEA, 1995; IEA, 1996a), and the revision of old Soviet standards are under consideration in several countries. It would be essential that the revised quality standards include new limits for the maximum content of lead in gasoline before significant new investments in the refining sector take place.

Regulations are only effective if proper enforcement is available to ensure compliance. When the maximum allowed lead content in gasoline is regulated, it should be ensured that (i) refineries and importers comply with specifications; and (ii) distributors and retailers do not mis-manage the various gasoline brands. While the control and enforcement of gasoline specifications may be relatively simple at the production and wholesale level, it may require a more significant administrative effort at the distribution and retail levels, especially if gasoline taxation is not designed to prevent abuses in the system (see under *Incentive Policies*). The use of colored dyes in the various gasoline brands and differed nozzle sizes at the pump may also help the separation of leaded and unleaded gasolines.

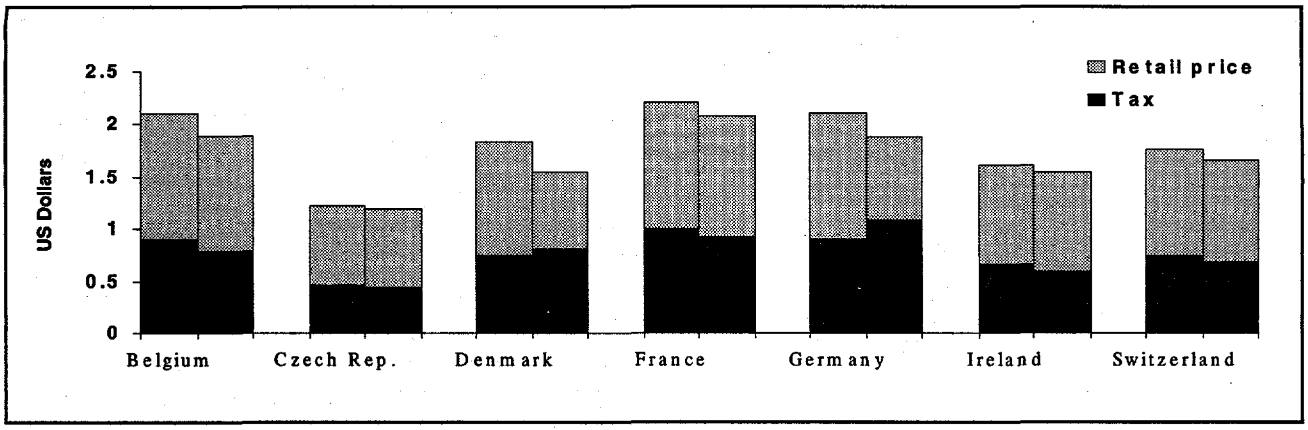
The environmental management effort to mitigate the effects of lead exposures should also include the improvement of environmental monitoring and the evaluation of pollution control measures. On-going surveillance, regular measurement of environmental and biological lead levels, ideally within a national lead monitoring network, are also essential to measure progress and identify priority areas. Targeted testing of biological lead levels should be based on high risk areas and population groups identified by environmental indicators. Targeted testing and intervention can increase the effectiveness of policies.

Incentive Policies

Incentive policies can play a key role in smoothing the transition period of lead phase-out by influencing gasoline demand and the adjustment of gasoline supply. Differentiated taxes can alter the "pump" prices of leaded and unleaded gasoline grades so that, at comparable octane, the price of

[3] The limit of lead content in the EU is 0.15 g/l (however, a Directive in effect since 1985 allows exceptions for adjustment periods during which 0.4 g/l limit is permitted). EU also requires that only one grade of leaded gasoline should be sold, with octane rating of at least 95 RON. A recent European Commission proposal recommended that a Directive should be adopted requiring total lead phase-out by 2000.

Figure 3.2 Premium Leaded and Unleaded Gasoline Prices and Taxes in Selected European Cities, First Quarter of 1996



Source: derived from IEA, 1996b. Data for Denmark and Germany are for the forth quarter of 1995.
Leaded gasoline: left coloums, unleaded gasoline: right coloums.

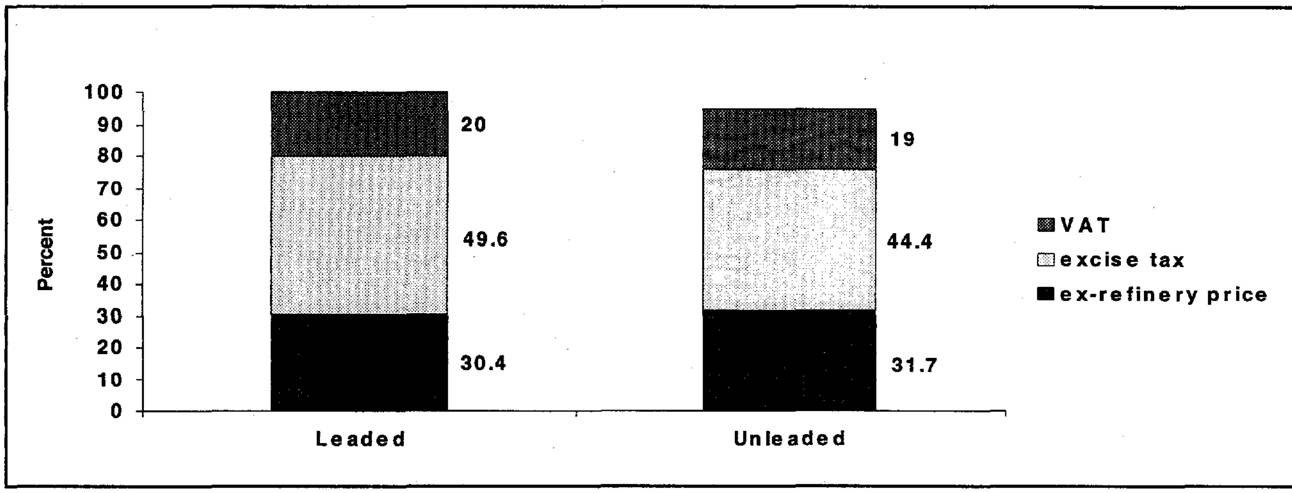
unleaded gasoline becomes less than leaded gasoline (**Figure 3.2**). To facilitate lead removal, such differentiated taxes on leaded and unleaded gasoline brands have been successfully used not only in Western European countries, but also in CEE, for example in Hungary, Poland and Bulgaria. In Hungary, for example, differentiation in excise taxes levied on regular leaded (92 RON) and unleaded (91 RON) gasoline created an approximately 5 percent difference in retail prices of the two gasoline brands (**Figure 3.3**) until July 1, 1996, when the sales of regular leaded gasoline was discontinued. In Poland, the retail price difference between premium (95 RON) leaded and unleaded gasoline has been close to 4 percent due to excise tax differentiation (IEA, 1996b). In the Czech Republic, premium leaded (96 RON) gasoline prices exceeded premium leaded (95 RON) prices by 4.5 percent in 1995, and by 2.5 percent in the first half of 1996 (IEA, 1996b). Differentiated taxation also contributed to the success of leaded gasoline phase-out in the Slovak Republic where, in only eighteen months, a complete and relatively smooth transition to unleaded gasoline has occurred: before the leaded brand was withdrawn from the market, the retail price difference between leaded and unleaded gasoline with similar octane rating (96 RON leaded and 95 RON unleaded) reached 13 percent (**Case Study B**).

Ongoing price liberalization and the restructuring of tax systems in many CEE countries provide an opportunity to introduce tax differentiation between leaded and unleaded gasoline brands. Most previously centrally planned economies in CEE have switched from levying turnover taxes on petroleum products to applying value added and excise taxes. Additionally, other charges and taxes may be levied on gasoline prices. In Russia, for example, a 25 percent road tax is levied on the ex-refinery price. In Bulgaria, a road tax (15 percent) and environmental tax are levied (**Box 3.1**).

Gasoline tax differentiation strategies may be influenced by various considerations. Introduction of tax differentiation may be carried-out in a revenue-neutral way. On the one hand, if revenue stability is the main objective, initial tax differentiation should be greater, gradually declining over time as the market share of unleaded gasoline increases. On the other hand, increasing the difference in gasoline prices over time may be more suited to gain consumer support for the complete phase-out of leaded gasoline.

Retail price incentives may be introduced in various ways. When tax differentiation occurs at the retail level, retailers purchase unleaded gasoline at a higher wholesale price than leaded (due to higher production costs), but sell such gasoline at a lower "pump" price due to lower excise tax included in the unleaded gasoline sales price. As a result, retailers are encouraged to mis-manage the various gasoline brands and abuse the tax system by selling

Figure 3.3 Regular Leaded and Unleaded Gasoline Price Structure in Hungary, Second Quarter of 1996 (Percent, leaded gasoline price = 100 percent)

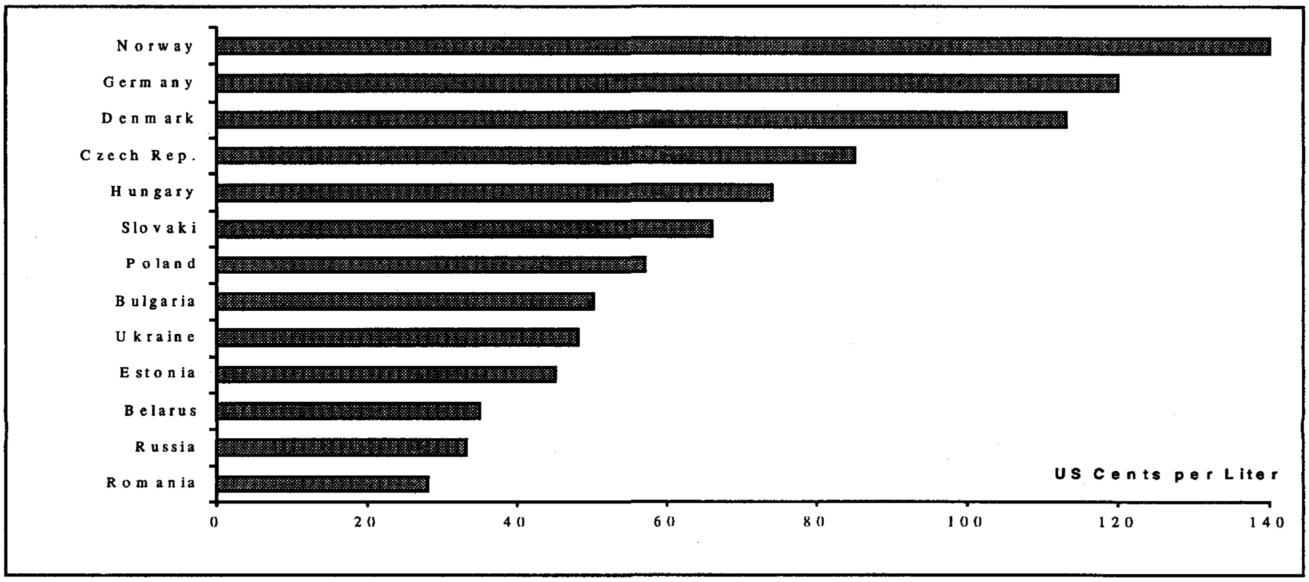


unleaded gasoline as leaded. Such incentives can be significantly reduced and more easily controlled if the tax differentiation occurs at the production level and gets built into the ex-refinery price. Alternatively, an environmental tax could be imposed on the import or sales of lead additives increasing the cost of producing leaded gasoline. Control and enforcement measures at the distribution and retail level, however, will be still necessary.

Retail price differentiation favoring unleaded gasoline not only creates economic incentives to use it, but also helps to avoid misfueling, the use of leaded gasoline in vehicles equipped with catalytic converters. Additionally, in the longer term, the availability and lower prices of unleaded gasoline facilitate the wider use of cars equipped with catalytic control devices. These devices reduce the emissions of carbonmonoxide, hydrocarbons and nitrogen oxides, and prevent the formation of ground-level ozone; thereby they contribute to further improvements in urban environmental quality. CEE countries seeking membership in the EU have started to harmonize their car emission standards with those of the EU (**Annex B**). Currently, these standards can only be complied with by the use of catalytic converters. Many CEE countries, therefore, introduced the requirement that all new and imported cars should be equipped with such devices. In the Slovak Republic, for example, catalytic converters have been required for both imported and domestically produced cars since 1993, and the import of vehicles older than 1985 has been restricted. Similar requirement have been introduced in Bulgaria, Czech Republic, Hungary Poland, Slovenia, and Ukraine. In Russia, on the other hand, where catalytic converters are not required, large vehicle exporters have to modify their vehicles, at an extra cost, to accommodate the use of leaded gasoline due to the unreliable availability of unleaded gasoline in certain parts of the country (Lovei, 1996).

Government policies that allow market mechanisms to work can also facilitate the adjustment of gasoline supply with consideration of various options including technological upgrade; restructuring of refinery operations based on the purchase of high octane gasoline blendstocks and additives (for example, MTBE); and the import of unleaded gasoline. Many small refineries, for example, may not be able to achieve necessary economies of scale to justify investments in capital intensive modern conversion and upgrading technologies. In the short-term, these refineries may phase out lead from gasoline without investments by purchasing (importing) high octane blendstocks or additives for blending. The economic viability of such refineries, however, may be questionable

Figure 3.4 Premium Unleaded Gasoline Prices in Selected European Countries, Second Half of 1996



Source: World Bank data. Data are for 1995 for Hungary, Slovakia and the Czech Republic.

requiring their closing as part of the restructuring of the petroleum refining sector. Lead phase-out requirements, therefore, may accelerate the restructuring process.

If refineries are allowed to recover the costs of their production and investments in gasoline prices; and the import of gasoline, gasoline blendstocks and additives are free of restrictions, refineries have no major disincentives to undertake necessary investments. In some CEE countries, however, gasoline prices have only recently approached world market prices (**Figure 3.4**), and often still remain regulated hindering full market influences to work (**Box 3.1**). Other forms of Government interference may also be present. In Romania, for example, not only the prices of oil supplies and refined products are controlled, but regulated country-wide transportation tariffs also conceal differences in costs; central planning is still in effect in the allocation of crude oil supply and the distribution of refined products; and state-owned enterprises are expected to do business with one another. The elimination of such Government interference is necessary to allow the adjustment of refineries to market requirements.

The corporatization and privatization of refineries are expected to improve their operational and financial performance and, as a result, their access to commercial sources of financing for new investments. Due to dysfunctional domestic financial markets in some countries, however, refineries may need to rely more heavily on internal cash generation or foreign financial sources than domestic bank lending to finance their investments. This requires improvements in the efficiency and profitability of refineries.

Market-based incentive mechanisms, for example, a lead credit trading system, could also be considered in some countries, especially those with a large gasoline market and great number of refineries. A system of lead credit trading can be used to provide flexibility to refiners in meeting lead content specifications. Under this system, refiners that produce gasoline with less lead than the standard obtain lead credits. These credits, in turn, can be sold to other refiners that are unable to meet the standard directly or whose costs of meeting the standard are relatively high. If "banking" is allowed in such a system, lead credits may also be accumulated and used to help meet lower future standards. The U.S. employed this type of system in the latter stages of its lead phase-out program, and it was generally credited for reducing the cost and accelerating the lead phase-out, and moderating

Box 3.1 Setting Gasoline Prices in Bulgaria

Gasoline prices in Bulgaria are regulated by pricing formulas that reflect international world market prices. Ex refinery prices are determined by the following formula:

$$P_{Ref} = \{P_{Med}-C_{Oct}+F)X(1+R_{Ins})\}X(1+R_{Cus})$$

Where P_{ref}: Price (US$/ton) ex-refinery for a specific grade

P_{Med}: Platts Mediterranean FOB gasoline price for gasoline with 0.15 g/l lead content and 98RON/86MON octane rating

C_{oct}: Octane correction assigning a value of US$ 1.5 per RON

F: Freight adjustment (currently at US$ 10/ton)

R_{Ins}: Charge for insurance (0.2 percent)

R_{Cus}: Customs duty (currently at 18.7 percent)

Maximum retail prices are derived by the following formula that includes maximum gross marketing margin:

$$P_{Con}=\{P_{Ref}X(1+M_{Mar}+R_{Ex})\}X(1+R_{VAT}+R_{SC})$$

Where P_{Cos}: Consumer price

P_{Ref}: Ex-Refinery price for certain octane grade

M_{Mar}: Marketers' margin (currently 22 percent)

R_{Ex}: Excise Duty (currently 60 percent on low octane (below 93 RON) and 100 percent on higher grade unleaded; and 70 percent on low octane and 110 percent on higher octane leaded gasoline)

R_{VAT}: Value Added Tax (currently 18 percent)

R_{SC}: Special Charge (currently 10 percent)

Besides the excise tax and VAT, a road tax (currently 14 percent of ex-refinery price) and environmental tax (currently 5 percent of ex-refinery price) are levied on gasoline products.

While price formulas reflect world market prices, they also influence the refineries' incentive structure to phase-out leaded gasoline. It has been noted, for example, that the ex-refinery price formula tends to under-value octane and may create disincentives to increase the production of high octane gasoline blends.

Source: Chem Systems, 1996.

the difficulties faced by small or high-cost refiners in meeting the standards. However, the lead credit program adopted in the United States was implemented in a situation in which: (i) there were established commodity trading markets; (ii) refinery operators were profit-maximizers and had sophisticated tools available to optimize their operations; and (iii) a competent regulatory authority existed for insuring the integrity of the trading system. Whether a lead credit program could be successful in CEE countries as they make the transition from a centrally-planned to a market-based economy is unclear. Making a judgment on the matter would require an in-depth study of the regulatory and legal institutions present in CEE countries together with an assessment of the capabilities of refinery operators to take advantage of a credit trading system.

Consensus-Building Among Affected Stakeholders

Policies aimed at the reduction of human exposure to lead can only be implemented with the support and participation of several government agencies, industries, and public organizations. The cooperation of government agencies responsible for environment protection, public health, and industry is necessary to set targets and determine a feasible schedule of lead phase-out programs.

In order to introduce incentive taxation, support from the financial and tax authorities is also essential. Additionally, coordination with the government agencies responsible for the transport sector provides information about the characteristics of the car fleet and fuel consumption, and allows for the integration of environmental objectives into sector planning and regulation. The consent of domestic vehicle manufacturers to environmental regulations that may require a change in manufacturing technology and increase in costs is also essential. Vehicle manufacturers may facilitate lead phase-out by ensuring that vehicle engines can operate on unleaded gasoline, and providing information and guidelines to vehicle owners and gasoline retailers on appropriate fueling and engine maintenance. Oil companies, distributors and retailers can also contribute, for example, by widely publicizing their willingness to compensate for potential engine valve seat damage due to the use of unleaded gasoline under recommended fueling practice (such guarantees have been provided by gasoline distributors, for example, in Denmark).

Furthermore, the regulation of foreign trade, especially the regulation and taxation of vehicle imports should take into account overall environmental objectives to improve air quality and phase out leaded gasoline. In order to facilitate the dialogue and cooperation among various stakeholders, an inter-governmental coordinating committee was established in Bulgaria, for example, with the participation of a large number of government agencies, industries, and other affected parties. In Romania, an inter-agency board was set-up that is preparing an Action Plan for Lead Phase-Out (The preparation of such Action Plan is a covenant of the World Bank's Road Project).

Cooperation among gasoline producers, distributors and retailers is essential to ensure the supply and distribution of unleaded gasoline. In the Slovak Republic, for example, the transition to an exclusively unleaded gasoline market was supported by close coordination between the Slovnaft refinery and Benzinol, the largest gasoline distributor in the country. The transition was implemented smoothly, without additional investment in the distribution infrastructure. Extensive coordination among producers, distributors and retailers may be necessary before significant changes take place in the structure of gasoline brands in countries where a large number of companies are involved in these areas.

Public Information and Education

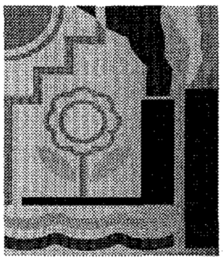
A lead phase-out program can be more effectively implemented if consumers and the public understand and support the objectives of the program. Public understanding is part of a broad consensus building effort, however, due to its significance, it deserves special attention.

While efforts to raise public awareness about the hazards of lead began many years ago, a recent sociological study in Hungary showed that many people did not know about the severity of health hazards resulting from lead, or believed that they could not do much to mitigate the problem. Additionally, the lack of information, and misconceptions about using unleaded gasoline in older vehicles represents one of the largest obstacles to changing consumer behavior in many countries. Measures to facilitate the lead phase-out process, therefore, should include general public education, and targeted dissemination of information and training.

Using the mass media, an education campaign directed at the general public can better inform people about the health hazards of lead, educate motorists about the feasibility of using unleaded gasoline. Oil companies in several Western European countries, for example, have published information booklets during the late 1980s with detailed information about recommended fueling for a large number of car models and model years (**Annex D**).

Additionally, training car mechanics and gas station attendants is essential to ensure that vehicles are properly adjusted, if necessary, to use unleaded gasoline, and that correct advice is provided to motorists about fueling and maintenance. Consumer interest groups and organizations can be especially helpful in disseminating information. Such organizations also have to be consulted and convinced that lead phase-out does not harm the interest of their members. Therefore, they should be involved in and informed about policy decisions concerning gasoline quality. In Hungary, for example, the Auto Club (a consumer organization of car owners) is a significant player in the lead phase-out process.

Old fueling habits and the lack of consumer knowledge about the dangers of lead and the use of unleaded gasoline were one of the obstacles of lead phase-out in the Slovak Republic. Public information had to be designed to raise awareness about the new unleaded gasoline brands and their recommended use in connection with the phase-out program. Despite the dramatic success in switching to unleaded gasoline, however, knowledge in the community regarding the dangers of lead is still considered inadequate. More efforts must be made, therefore, to inform the public of the risks of lead **(Case Study B).**



Bibliography

Abt. 1996. *Costs and Benefits of Removing Lead From Gasoline in Russia.* Abt Associates, Bethesda, Maryland.

ATELCP and EDF. 1994. *The Global Dimensions of Lead Poisoning.* Alliance to End Childhood Lead Poisoning and Environmental Defense Fund, Washington D.C.

Bono, R. et. al. 1995. "Updating about Reduction of Air and Blood Lead Concentrations in Turin, Italy, Following Reduction in the Lead Content of Gasoline". *Environmental Research.* Vol. 70. pp. 30-34.

Bratsky, D. 1995. "Leaded vs. Unleaded Gasolines in Slovakia". Presentation on the Conference on *Heavy Metals and Unleaded Gasoline.* September 7-8, 1995. Banska Bystrica, Slovak Republic.

CDC. 1991. *Strategic Plan for the Elimination of Childhood Lead Poisoning.* Centers for Disease Control. U.S. Department of Health and Human Services, Washington D.C.

Chem Systems. 1996. *Feasibility Study for Increasing the Supply of Unleaded Gasoline in Bulgaria.* Report for the World Bank. Chem Systems, London, U.K..

"Czech Republic: Refineries Deal". *Oxford Analytica East Europe Daily Brief.* Firday, July 28, 1995.

CEC. 1996a. *Proposal for a European Parliament and Council Directive Relating to Measures to be Taken Against Air Pollution by Emissions from Motor Vehicles and Amending Council Directives 70/156/EEC and 70/220/EEC.* June 18. Commission of the European Communities. Brussels.

CEC. 1996b. *Proposal for a European Parliament and Council Directive Relating to the Quality of Petrol and Diesel Fuels and Amending Council Directive 93/12/EEC.* June 18. Commission of the European Communities. Brussels.

Eurostat. 1993. *Transport. Annual Statistics 1970-1990.* European Union, Brussels.

Hertzman, C. 1995. "Environment and Health in Central and Eastern Europe". *A Report for the Environmental Action Programme for Central and Eastern Europe.* World Bank, Washington D.C.

Hughes, G. 1995. "Is the Environment Getting Better in Central and Eastern Europe?" in the Series of *Implementing the Environmental Action Programme for Central and Eastern Europe.* World Bank, Washington D.C.

"Hungary Pushes Energy Program in Upstream, Downstream Sectors". 1996. *Oil and Gas Journal.* News. May 27. pp. 14-18.

IEA. 1995. *Energy Policies of the Russian Federation. 1995 Survey.* International Energy Agency. Organization for Economic Co-operation and Development, Paris.

IEA. 1996a. *Energy Policies of Ukraine. 1996 Survey.* International Energy Agency. Organization for Economic Co-operation and Development, Paris.

IEA. 1996b. *Energy Prices and Taxes, 2nd Quarter 1996.* International Energy Agency. Organization for Economic Co-operation and Development, Paris.

IMF. 1996. *International Financial Statistics.* International Monetary Fund, Washington D.C.

John Brown. 1994. *Economic and Technical Study for Privatization of Ukraine's Petroleum Sector.* Prepared for the U.S. Agency for International Development. John Brown, Chicago, Illinois.

Kertesz, M. 1994. *Airborne Lead Levels in Hungary.* Paper presented in the workshop on "A Systematic Multi-Sectoral Approach to environmental Health Policy and Program Development: The Lead Poisoning Prevention Project in Hungary". Budapest, Hungary.

"Kyrgyzstan's First Refinery to Start up this Month". *Oil and Gas Journal.* Sept 9, 1996. p. 37.

Lovei, M. 1996. *Phasing Out Lead From Gasoline: World-Wide Experience and Policy Implications.* Environment Department Paper No. 40. Pollution Management Series. World Bank, Washington D.C.

McArragher J. S. et. al. 1993. *Prevention of Valve-Seat Recession in European Markets.* Co-ordinating European Council. Forth International Symposium on the Performance Evaluation of Automotive Fuels and Lubricants. CEC/ 93/EF19. Birmingham, U.K.

NRC. 1993. *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations.* National Research Council, Washington D.C.

Ostro, B. 1991. *Estimating the Health Effects of Air Pollutants.* Policy Research Working Paper No. 1301. World Bank, Washington D.C.

Pirkle, J. L. et al. 1985. "The Relationship Between Blood Lead Levels and Blood Pressure and U.S. Cardiovascular Risk Implications". *American Journal of Epidemiology.* Vol. 121. pp. 246-258.

Plotnikov, V. S. et al. 1996. "Russian Refining Shows Signs of Revival, Needs Investment." *Oil and Gas Journal.* Special Mar. 25. pp. 47-55.

Pocock, S. J. et al. 1988. "The Relationship Between Blood Lead, Blood Pressure, Stroke and Health Attacks in Middle-aged British Men". *Environmental Health Persp.* No. 78.

Pugliaresi, L. and Hensel, A. C. 1996. "Improvements in Progress For Russia's New PSA Law." *Oil and Gas Journal.* Special. Mar. 25. pp. 56-61.

Rom, W. N. (ed). 1992. *Environmental and Occupational Medicine* (2nd ed.). Little, Brown and Company, Boston, U.S.

Rosenstock, L. and Cullen, M. (eds.). 1994. *Textbook of Clinical Occupational and Environmental Medicine.* W.B. Saunders, Philadelphia, U.S.

Schwartz, J. 1988. "Low Level Lead Exposure and Children's IQ: A Meta Analysis and Search for a Threshold". *Environmental Research.* Vol. 65. No. 1. pp. 42-55.

Schwartz, J. 1994. "Societal Benefits of Reducing Lead Exposure". *Environmental Research.* No. 66. pp. 105-124.

Silbergeld, E. K. and Gandley, R. 1994. "Male Mediated Effects on Reproduction and Development: Effects on the Developing Brain". In Mattison D. and Olshan A. eds. *Male Mediated Toxicity to Development.* Liss, New York.

Thomas, V. 1995. "The Elimination of Lead in Gasoline" *Annual Review of Energy Environ.* Vol. 20: 301-24.

U.S. EPA. 1985. *Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis.* EPA-230-05-85-006. Office of Policy Analysis. U.S. Environmental Protection Agency, Washington D.C.

"Uzbeki Refinery is Half Way to Completion" *Oil & Gas Journal*. Aug 26, 1996. p. 57.

Walsh, M. 1995. *Reducing Motor Vehicle Pollution. The Role of Clean Alternative Fuels for Developing Countries*. Draft. Asia Technical Department World Bank, Washington D.C.

WHO. 1995. "Lead". *Environmental Health Criteria Document*. World Health Organization. Geneva.

Wietlisbach, V. et al. 1995. "Time Trend and Determinants of Blood Lead Levels in a Swiss Population over a Transition Period (1984-1993) from Leaded to Unleaded Gasoline Use". *Environmental Research*. Vol. 68. pp. 82-90.

World Bank and OECD. 1993. *Environmental Action Programme for Central and Eastern Europe*. World Bank, Washington D.C. and Organization for Co-operation and Development, Paris.

World Bank. 1994. *Lithuania Energy Sector Review*. Report No. 11867-LT. World Bank, Washington D.C.

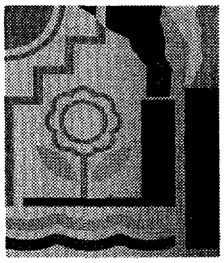
World Bank. 1995a. *Belarus Energy Sector Review*. World Bank, Washington D.C.

World Bank. 1995b. *Kyrgyz Republic Energy Sector Review*. Report No. 14036-KG. World Bank, Washington D.C.

World Bank. 1996. "From Plan to Market". *World Development Report*. World Bank, Washington D.C.

"Worldwide Construction". *Oil and Gas Journal*. Apr. 18, 1996. pp. 53-68.

Case Studies



Contents of Case Studies

Case Study A

Lead Exposure and Health in Central and Eastern Europe: Evidence from Hungary, Poland, and Bulgaria

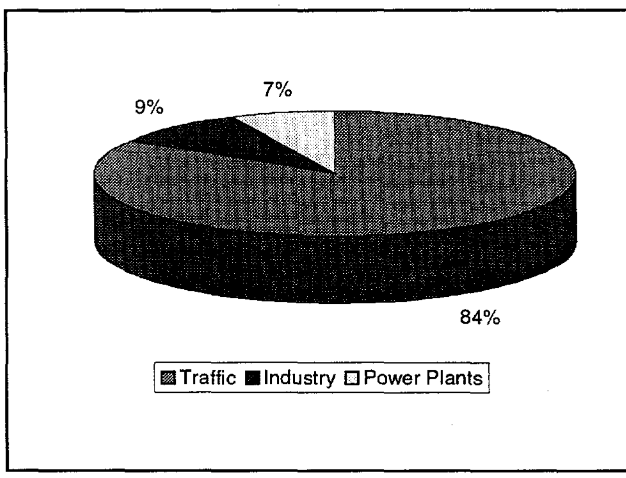
Magda Lovei and Barry S. Levy, Editors

Hungary

Main Sources of Lead Exposure

Traffic is the main source of lead exposure in large cities and in the surrounding areas of busy roads in Hungary. The share of traffic in total atmospheric lead emissions reached 84 percent in 1994, followed by industrial sources and power generation (**Figure A.1**). The total amount of vehicular lead emissions has markedly declined, however, in recent years in Hungary: from 673 to 108 tons between 1980 and 1994 (**Table A.1**). In Budapest alone, which suffers from approximately 25-30 percent of total lead emissions from vehicles in the country, the volume of lead emitted annually declined from 90 tons in 1991, to 43 tons in 1992, and to 31 tons in 1993. The aggressive distribution and promotion of unleaded gasoline resulted in a market share of 48 percent by 1994, and more than 60 percent by 1996. In addition, the reduction of lead in leaded gasoline from 0.7 g/l to 0.4 g/l in 1985, to 0.3 g/l in 1991 and

Figure A.1 Main Sources of Lead Emissions in Hungary



Source: Levy, et al, 1994

Table A.1 Vehicular Lead Emissions in Hungary, 1980-1994 (tons per year)

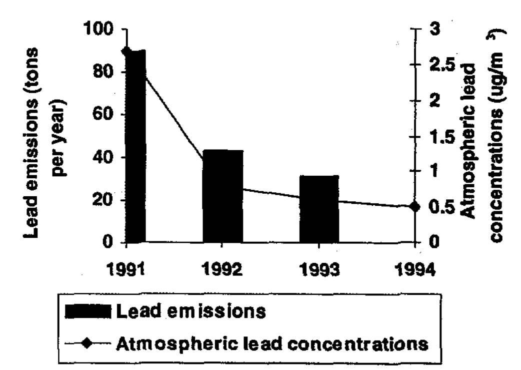
1980	*1985*	*1987*	*1991*	*1992*	*1993*	*1994*
673	452	489	387	199	132	108

Source: Levy et al, 1994; Hungarian Ministry of Environment.

to its current level of 0.15 g/l in 1992 (which corresponds to the European Union standard) also significantly contributed to the reduction of lead emissions. The amount of vehicular lead emissions was halved between 1991 and 1992, when the lead content of gasoline was reduced to its current level.

Localized industrial emissions of lead originate from lead smelters, steelworks, and plants producing metal alloys and lead batteries, as well as those dismantling used car batteries. Less lead originates from the glass, ceramic, chemical, and paint industries. Several studies indicated that lead in food and water are not at hazardous levels in Hungary. In Budapest, the only significant industrial source of lead emissions (a lead processing plant) was permanently closed down in the early 1990s, leaving traffic the only main source of lead exposure (**Box A.1**).

Figure A.2 Lead Emissions and Ambient Atomospheric Lead Concentrations in Budapest, 1991-94



Source: Levy et al, 1994, Rudnai et al, 1995.
(Lead emissions data for 1994 are not available.)

Environmental Measurements

A strong relationship between heavy traffic and high lead concentrations in the ambient air has been repeatedly demonstrated. In Budapest, for example, neighborhoods with heavy traffic had mean airborne lead levels of 2.5-5.4 µg/m^3 in 1985, while airborne lead levels in the suburbs were 0.4-0.5 µg/m^3 (the ambient air quality standard in Hungary is 0.3 µg/m^3). In 1990, all 32 sampling stations in Budapest measured values above the Hungarian limit value, and 27 percent of the samples were above 3 µg/m^3. Other large cities had similarly high concentrations. In the town of Debrecen, for example, lead concentrations varied between 2 and 21 µg/m^3 in 1979-80. Ambient atmospheric lead concentrations were also found to increase parallel with the number of vehicles registered during the day at busy traffic junctions. A 4.3 percent increase of traffic volume, for example, resulted in a 1.2 µg/m^3 increase in atmospheric lead concentrations at one of the locations in Budapest. Vehicular lead emissions were also shown to affect the lead concentrations of indoor air. Mean lead concentrations in peak hours were lower than the values measured near the building on the pavement only by 10-30 percent on the first floor, and 40-50 percent on the second floor in apartments with open windows. Soil smaples were also found to have remarkably high lead concentrations near heavy traffic areas (**Table A.2**).

There is evidence that environmental lead levels have declined in recent years mainly as a result of measures reducing the lead content of gasoline. An analysis of the trend of lead concentrations in ambient air during 1991-1995 showed significant

Box A.1 The Closing of the Last Major Stationary Lead Emission Source in Budapest

The Metallochemia metal-processing plant in Budapest had processed industrial wastes since 1908. Because of suspected lead poisoning among residents of the surrounding neighborhood, an environmental health investigation began in 1977. High lead contents were detected in the dustfall coming from the plant. As a result, lead metallurgy was prohibited in the plant. Within a year, the lead in dustfall decreased by 90 percent. However, from then until 1990, when the plant was closed, used car batteries were still collected and dismantled there. In 1990-1991, airborne lead levels were elevated around the plant, complying with the limit value of 0.3 µg/m^3 only at a distance of 600 meters from the plant. However, airborne lead levels on the heavily traveled roads of Budapest (measured at 1.7-4.8 µg/m^3 in 1990, and 0.24-2.35 µg/m^3 in 1991) were higher than the mean airborne lead levels around Metallochemia during the same period (0.37-0.48 µg/m^3), demonstrating the contribution to airborne lead levels from the exhaust of vehicles using leaded gasoline.

Table A.2 Environmental and Biological Measurements of Lead in Hungary, 1985-1986

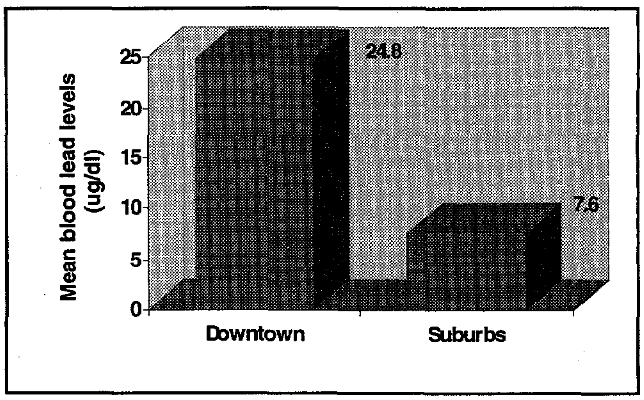
City/Location		*Lead Source*	*Lead in Air*	*Lead in Soil (mg/kg)*	*Mean Blood Lead Level (μg/dl)*
Romhany		Ceramic Industry	-	41	16
Budapest	Medve u.	Traffic	5.3	298	27
	Bern u.	Traffic	2.9	100	23
Szolnok:	Tallin u.	Urb. background		13	17
	Csády u.	Traffic (center)	2.0	35	24
	Abonyl u.	Traffic (main rd.)		12	21
Hygienic Limit Values			0.3	100	-

Source: Rudnai et al, 1989.

decreases in 10 large cities (Rudnai et al, 1995). The lead concentration in ambient air progressively decreased in Budapest from the mean value of 1.7 $\mu g/m^3$ in 1991 to 0.54 $\mu g/m^3$ in 1994 (**Figure A.2**).

A particularly large decrease of the mean ambient concentrations (from 1.7 $\mu g/m^3$ to 0.7 $\mu g/m^3$) was observed in Budapest between 1991 and 1992, when the lead content of gasoline was reduced to its current (0.15 g/l) level. The impacts of reduced lead use in gasoline appear to have leveled off, however, after 1993. Only a small decrease (from 0.6 $\mu g/m^3$ to 0.54 $\mu g/m^3$) was observed in the mean ambient concentrations between 1993 and 1994, and no further improvement occurred in the rate (83 percent) of samples above the Hungarian limit value in 1985.

Figure A.3 The Impact of Traffic on the Lead Exposure of Children in Budapest, 1986



Source: Rudnai et al, 1990

Biological Measurements and Health Effects

Data from Hungarian studies show a strong relationship between the BLLs of children and traffic. A study in the city of Szolnok, for example, showed that children living in the city center with heavy traffic had a mean BLL of 23.7 μg/dl; those living near the main road, 21.0 μg/dl; and those not living near heavy traffic, 16.6 μg/dl. A study of over 180 children aged 9-10 years in Sopron showed that the percentage of children with BLLs over 10 μg/dl declined from 11.5 percent in 1992 to 8.2 percent in 1993, after traffic in the city was re-routed. A significant difference in the mean BLLs of studied children living in downtown areas and suburbs was also demonstrated in Budapest in 1986 (**Figure A.3, Table A.3**).

Only limited attempts were made to confirm the impacts of lead exposure on the intellectual performance of children exposed to different levels of lead in Budapest. Socio-economic status was found to be the most significant factor of the measured IQ of children (Rudnai, 1995). These factors, such as the education of parents and family income, were also likely to confound the relationship was demonstrated between lead exposures and IQ levels. Due to the relatively small sample and the likelihood of confounding factors, no clear statistical relationship was demonstrated between exposure to lead and intellectual performance in Budapest. Based on internationally established epidemiological evidence, however, differences in exposures of children in downtown areas and suburbs may have caused more than 4 IQ points difference in the measurable intelligence of the two groups of children, assuming similar socio-economic and other conditions in the two groups.

Other studies in Hungary did show a significant statistical relationship between BLLs and IQ measures. In the industrial town of Romhany, for example, IQs of children with higher than 20 µg/dl BLLs were 10 points lower, on average, than IQ scores of those with BLLs lower than 10 µg/dl. In Szolnok, an average of 3.5 IQ points difference was found by another study (Hertzman, 1995).

Table A.3 Mean Blood Lead Levels in Budapest, 1986

Group	*Area*	*Number Tested*	*Mean BLL*	*Percent Above*	
				12µg/dl	*20 µg/dl*
Men	Downtown	63	14	59	14
	Suburb	74	13	45	11
Women	Downtown	70	11	39	4
	Suburb	76	9	17	5
Pregnant Women	Downtown	17	9	18	0
	Suburb	38	10	32	0
Children (age 7-9)	Downtown	70	25	89	57
	Suburb	59	8	7	2

Source: Rudnai et al, 1990.

Table A.4 Blood Lead Levels of Children in Budapest, 1990-93

Year	*Age Range*	*Type of Area*	*Number Tested*	*Percent Above*	
				10 µg/dl	*20 µg/dl*
1990	6 - 8	Traffic	193	17	1
1991	3 - 6	Traffic	21	67	0
1991-92	14 -15	?	43	0	0
1992	2 - 12	?	35	0	0
1992	9 - 10	Traffic	98	11	0
1993	6 - 14	Traffic	70	13	0
1993	14 - 18	?	20	5	0

Source: Rudnai et al, 1995.

Table A.5 Blood Lead Levels of Children Outside Budapest, 1990-93

Year	*Age Range*	*Type of Area*	*Number Tested*	*Percent Above*	
				10 µg/dl	*20 µg/dl*
1990	9 - 10	Vác	14	0	0
1990	6 - 10	Vác	14	7	0
1991	9 - 10	Györ	139	1	0
1992	9 - 10	Sopron	182	12	4
1993	9 - 10	Sopron	183	8	0

Source: Rudnai et al, 1995

Table A.6 Mean Blood Lead Levels of Hospitalized Children* of 0-4 Years of Age in Hungary, 1994-95

City/Hospital	*Number tested*	*Mean BLL (μg/dl)*	*Range (μg/dl)*	*Number with BLLs >10μg/dl*
Budapest, Children's Hospital, Buda	4	4.15	2.4-5.6	0
Budapest, Heim Pal Hospital	27	5.38	1.7-9.4	0
Bekescsaba	24	3.92	1.6-11.0	1
Debrecen	73	5.52	1.1-15.4	3
Debrecen	39	4.54	1.9-8.0	0
Kiskunfelegyhaza	22	5.8	1.7-10.4	1
Miskolc	28	5.69	2.5-9.5	0
Pecs	38	4.94	2.3-10.9	1
Salgotarjan	54	5.34	2.0-9.9	0
Szeged	12	5.43	3.1-9.5	0
Szolnok	22	6.08	2.4-12.5	2
Szombathely	16	5.19	3.4-8.1	0
Vác	12	5.63	2.8-9.2	0
Total	371	5.25	1.1-15.4	8

Source: Rudnai et al, 1995.
* Children were hospitalized for reasons other than lead exposure.

Box A.2 Sociological Issues of Lead Exposures in Hungary

In May 1994, the Fact Foundation conducted a sociological survey of some population groups potentially at risk of lead exposure in their communities and workplaces (Fuzesi and Tistyan, 1994). This survey was part of the first phase of a project in Hungary, undertaken by Hungarian scientists and American collaborators for the purpose of facilitating a multi-sectorial approach to prevent lead poisoning. The purpose of the survey was to explore the knowledge, attitudes, and preventive measures in the target groups concerning occupational and environmental health hazard in general, and lead in particular. The target groups included workers, community residents, and parents of children who were exposed to lead. In addition, pediatricians were asked how important they considered lead exposure to be and how they defined their roles concerning the prevention of lead exposure. The most important conclusions of the survey were:

- Workers exposed to lead knew more about the adverse health effects of lead than an average worker did, but this knowledge did not necessarily translate into taking appropriate preventive measures;
- Significant lead exposure occurred infrequently in residential areas, and even when it did occur, residents did not give it high priority among their community health problems. Therefore, community-based preventive measures were usually not implemented;
- People were generally not aware of the adverse health effects of lead and other environmental hazards and they tended to neglect them;
- The surveyed groups generally did not believe that information in the media was accurate, however tended to believe information from the media more than they did from other sources;
- Pediatricians did not know significantly more about the adverse health effects of lead than laymen did; and
- Almost 70 percent of those surveyed thought that they could not do anything to reduce the lead problem.

Recent studies of children in Hungary, mainly those of school age, have repeatedly shown that only a small percentage of children have BLLs above 10 µg/dl, and almost no children have BLLs over 20 µg/dl. There have been relatively few studies, however, of preschool children who are at greatest risk of the adverse health effects due to lead. A study of 21 children aged 3-6 years in 1991 showed that 14 (67 percent) of these children had BLLs above 10 µg/dl, although none had levels above 20 µg/dl. (**Table A.4**). Tests of older children in big cities demonstrated a lower share of elevated exposures (BLLs above 10 µg/dl) (**Tables A.4-A.5**). Another study of 371 children aged 0-4 years who were hospitalized in various locations across the country for reasons other than lead exposure showed that their mean BLL was 5.3 µg/dl, and 2 percent had BLLs over 10 µg/dl (**Table A.6**).

While occasional testing of the general population of children does not show alarming levels of lead exposure, high risk groups including children living in highly congested downtown areas have not been extensively analized recently. According to estimates, about 10 percent of children (approximately 130,000 children) living in urban areas have BLLs higher than 10 µg/dl. Targeted testing and intervention based on environmental indicators of potential lead exposure, therefore, may be necessary.

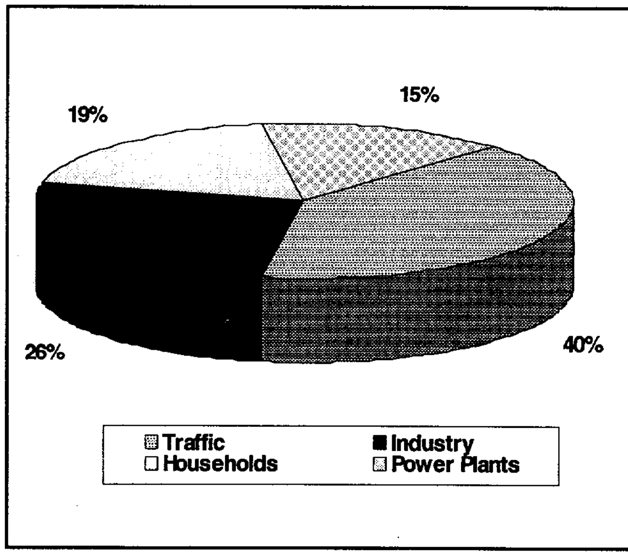
Anecdotal evidence suggests that iron deficiency anemia may be common among children in Hungary. Children with iron deficiency absorb a greater percentage of lead from the gastrointestinal tract. (They also have more pronounced anemia than children without iron deficiency.) As a result, individuals of lower socioeconomic status, including children, may be more adversely affected by lead at a given level of exposure than those of higher socio-economic status.

Poland

Main Sources of Lead Exposure

Traffic is the largest source of lead emissions in Poland. Of 1442 tons of total lead emissions in 1990, 570 tons were from vehicles using leaded gasoline; 382 tons from industrial sources; 280 tons from fuel

Figure A.4 Main Sources of Lead Emissions in Poland



Source: Gorynski, 1995

(mainly coal) combustion in households; and 210 tons from combustion in industry, mainly power plants (**Figure A.4**). Lead emission from industry originated primarily from ferrous and non-ferrous metal smelting, production, and processing, concentrated in the Upper and Lower Silesia regions (Katowice and Legnica districts). These two regions were responsible for 94 percent of the industrial emissions of lead.

Lead production in Poland has declined from 87,300 tons in 1985 to 62,300 tons in 1993. Industrial lead emissions have been also falling during the early 1990s, due to contracting industrial production, and the installation of modern dust filters.

Although there was an approximately 50 percent increase in annual consumption of gasoline (from 2.7 million tons to 4.1 millions tons) during the 1980-92 period, there was a reduction in annual emissions from transportation from 584 tons to 303

Table A.7 Ambient Atmospheric Lead Concentrations in the Administrative Districts of Warsaw (µg/m^3)

Administrative Code	*No. 30.*	*No. 33.*	*No. 34.*	*No. 35.*	*No. 36.*	*No. 37.*
1992	0.192	0.181	1.541	0.161	0.076	0.294
1993	1.264	0.400	0.623	0.248	0.107	0.375

Source: Gorynski, 1995.

Table A.8 Lead in Selected Soil Samples in Poland

Place of sampling	*Main Source of Lead*	*Concentration (mg/kg of dry mass)*
Northern regions	No major source	3-25
Small gardens in Cracow	Industry and traffic	226 (mean)
Small gardens in Warsaw	Traffic	21-185
Lodz	Industry and traffic	6-650
Vicinity of Legnica copper factory	Industry and traffic	30-18,400
Katowice region	Industry and traffic	<10-8,200

Source: Michna, 1991

Table A.9 Mean Blood Lead Levels of Children in Silesia, Poland 1982, 1986

Year of Testing	*Gender*	*Number Tested*	*Mean BLL (µg/dl)*	*Number of BLLs > 20µg/dl*	*Maximum BLL (µg/dl)*
1982	Female	51	15.3	16	36
	Male	42	19.3	18	41
1986	Female	128	14.0	15	54
	Male	54	17.0	14	42

Source: Grabecki, 1993.
BLL: Geometric mean blood lead levels

Table A.10 Mean Blood Lead Levels of Children in Selected Towns in Silesia, Poland, 1988-1990

Town	*Year of Testing*	*Number Tested*	*Mean BLL (µg/dl)*	*Number Tested with BLLs > 20(µg/dl)*	*Maximum BLLs (µg/dl)*
Trzebinia[1]	1988	45 (6-7 years)	13.0	10	36
Trzebinia	1990	50 (6-7 years)	11.7	5	33
Bytom[2]	1989	136 (6-7 years)	15.0	32	36
Bytom	1990	416 (6-7 years)	13.0	77	36
Chorzow	1990	115 (3-4 years)	13.0	24	29

Source: Grabecki, 1993.
BLL: Geometric mean blood lead levels
[1] - Small industrial town
[2] - Large industrial town

tons due to the gradual reduction of the lead content of gasoline (its current level is 0.15 g/l).

The concentration of lead in drinking water does not exceed the Polish standard and is presumed to be an insignificant risk. Lead water pipes are not used, and lead was removed from paint long ago in Poland.

Environmental Measurements

Ambient atmospheric lead concentrations in urban areas are routinely monitored in Poland. They were found to be at moderate levels (rarely exceeding the WHO guidelines of 0.5 µg/m^3), except in Silesia. Even in Silesia, a decline of atmospheric lead concentrations has also been registered during recent years. At some locations in Poland, however, small increases in ambient atmospheric lead levels have been observed. In Warsaw, for example, where the major sources of lead emissions are traffic and power plants, some fluctuation in the ambient atmospheric lead concentrations have been observed. Between 1992 and 1993, concentrations increased in five of the six administrative units, although only in one of them did they exceed 1.0 µg/m^3 (**Table A.7**). (Unfortunately, a monitoring site in central Warsaw that measured levels of 1 µg/m^3 or more in 1992 and 1993 was discontinued in 1994.)

Lead concentrations in soil exceeded Polish standards (50-100 milligram per kilogram) in the industrialized areas of Silesia (more than 100 times in the Katowice region and more than 300 times in the vicinity of the Legnica copper factory) (**Table A.8**). Elevated soil lead levels were also found along some roads, and in downtown areas of large cities, mainly due to the impact of traffic. Elsewhere, however, soil lead levels are considered to be low.

Biological Measurements and Health Effects

Extensive blood lead studies have been carried out in the vicinity of large stationary sources of lead emissions. Mean BLLs measured in the vicinity of a copper factory in Silesia in 1991 indicated that exposures declined with increasing distance from

Box A.3 Biological Monitoring of Lead Exposure in Silesia, Poland

A study was undertaken by the Regional Sanitary and Epidemiological Station in Silesia to assess the results of the biological monitoring of the impacts of lead based on cohort, prospective, and cross-sectional studies of primary school children and their mothers during 1981-1990. The studies indicated that the lead contamination of the environment in the Katowice region is particularly widespread. In general, the region was divided into three categories:

- The vicinity of large industrial lead emission sources, where BLLs were twice as high as in rural areas;
- Large industrial urban agglomerations of the Upper Silesian industrial district, where BLLs of children were 50 percent higher than in rural areas; and
- Rural areas with significantly lower BLLs, but where unacceptable BLLs could still be detected.

Table A.11 Mean Blood Lead Levels Among 2675 Children in Chorzow, Upper Silesia, Poland, 1994 (µg/dl)

Gender	*Age of children (years)*		
	3	*4*	*5*
Female	7.5	6.9	7.2
Male	7.2	7.3	7.5

Source: Gorinski, 1995.

Table A.12 Mean Blood Lead Levels in Studied Populations in Silesia, Poland 1992 (µg/dl)

Location	*Men*		*Women*		*Children*	
	N	*BLL*	*N*	*BLL*	*N*	*BLL*
Legnica	62	6.4	123	3.7	69	5.0
Krakow	59	5.9	96	3.7	99	4.8
Lodz	13	6.4	16	3.5		
Walbrzych	66	7.7	56	4.4	48	4.6

Source: Jakubowski, 1993
BLL: Blood Lead Levels (geometric mean)
N: Number of people studied

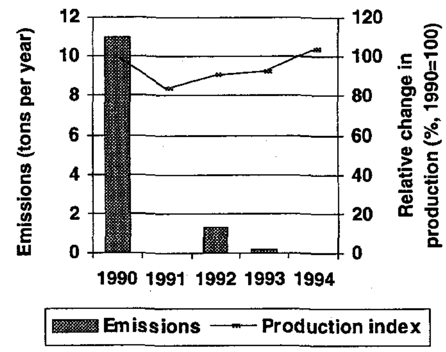
the factory: BLLs were 15.7 µg/dl for men, 11.1 µg/dl for women, and 17.1 µg/dl for children at 500 meters distance; and 11.6 µg/dl for men, 8.0 µg/dl for women, and 9.6 µg/dl for children at 4,000 meters.

Studies in the industrial areas of Silesia indicate some reduction in the exposure of children since 1982. Mean BLLs were 15-19 µg/dl in 1982, 13-16 µg/dl in 1986, and 11-14 µg/dl in 1988-1990 (**Tables A.9-10**). An extensive study of 2675 children conducted recently in the town of Chorzow in Upper Silesia found that the mean BLLs were between 7.2 and 7.5 µg/dl (**Table A.11**), indicating a 40 percent decrease compared to the results of a previous (less extensive) study in the city in 1990 (**Table A.10**). Studies in other industrial cities including Legnica, Lodz, Krakow and Walbrzych also found mean BLLs of studied children in the relatively modest range of 4.6-5.0 µg/dl in 1992 (**Table A.12**).

The number of people exposed to ambient lead above the maximum allowable concentration at work declined from about 6,000 in 1986 to about 5,000 in 1990 (the great majority of these people worked in metallurgy). There has also been a decline (from 202 cases in 1988 to only 117 in 1991) in cases of lead poisoning in recent years (90 percent of these cases occurred in the Katowice district).

With the exception of workers in metallurgy and other lead-emitting industries, mean BLLs in adults did not exceed 9 µg/dl in males and 6 µg/dl in females in Poland. In 1989-1990, mean BLLs in children in non-polluted areas in Poland were around 8 µg/dl, and about 0.5 percent of children had lead levels above 20 µg/dl. A similar mean concentration—about 7 µg/dl— was observed two years later. In Warsaw, the BLLs of 179 children aged 0-14 years were measured in 1994. Among those above 1 year of age, the mean BLL was about 6 µg/dl; and the BLLs of approximately 9 percent of the children exceeded 13 µg/dl. In lead-polluted areas of Upper Silesia, however, mean BLLs were in the range of 10-21 µg/dl, and in some very polluted areas, BLLs reached 40 µg/dl in selected groups of males, and 30 µg/dl in a small group of females.

Figure A.5 Lead Production and Lead Emissions by the Kurdzhali Lead Smelter in Bulgaria, 1990-94



Source: Bainova, 1995
(Data for lead emissions in 1991 and 1994 are not available)

Bulgaria

Main Sources of Lead Exposure

Transport, energy production, and industry are the main sources of lead exposure in Bulgaria. Road transport accounts for 61 percent of atmospheric lead emissions with the remainder coming mainly from industry, especially non-ferrous metal production. industrial "hot spots" have been identified in Bulgaria that pose increased health risks to their workers and the population in the vicinity. The share of lead emissions originating from large stationary sources in some "hot spots" reached 90 percent in the late 1980s.

Total lead emissions have declined recently, primarily due to (i) reduced vehicular lead emissions as a result of the decreasing lead content of gasoline, and the growing use of unleaded gasoline; (ii) declining industrial production; and (iii) emission control measures at industrial sources.

Due to emission control measures, industrial lead emissions have decreased in "hot spots" despite the recovery of economic activity. In the town of Kurdzhali, for example, emissions from a large lead smelter decreased dramatically even after the lead production of the smelter started to increase in 1991

Table A.13 Heavy Metal Contamination of the Soil of Kindergartens in Bulgaria

Town	*Source of Lead Exposure*	*Heavy Metal Content of Soil (mg/kg)*
Kurdzhali	Lead smelter and traffic	250
Kurdzhali	Lead smelter and traffic	261
Ostrovitsa	Lead smelter	186
Haskovo	Traffic	167

Source: Bainova, 1995

Table A.14 Mean Blood Lead Levels of Children in the Towns of Kurdzhali, Ostrovitsa, and Haskovo, Bulgaria, 1995

Location	*Age of Children*	*Number tested*	*BLL (µg/dl)*
Kurdzhali *	5-7	16	12.1
Kurdzhali *	7-14	22	10.0
Kurdzhali	10-14	17	9.9
Kurdzhali and Ostrovitsa	5-7	21	12.7
Ostrovitsa	5-7	5	14.4
Ostrovitsa	7-14	21	15.2
Haskovo *	5-7	13	10.1
Haskovo *	7-14	15	11.4

Source: Bainova, 1995.
* Schools near road or motorway

(**Figure A.5**). As a result, the share of industry in total lead emissions decreased from 90 percent in 1990 to about 17 percent in 1993 in Kurdzhali. A comparative analysis of the share of the main sources of airborne lead pollution showed that 73.4 percent of ambient lead originated from traffic; 17.3 percent from the lead smelter; and 9.3 percent from a power plant in the city.

Traffic-related lead emissions are expected to increase in Bulgaria. The gasoline-powered vehicle fleet increased from 1.85 million in 1990 to 1.97 million in 1993. Many 5-to-15- year old cars that use leaded gasoline have been imported from Western Europe recently. A study revealed that 38 percent of drivers have motor vehicles that are 5 to 10 years old. A social survey in Sofia in July 1995 estimated that only 17 percent of the drivers used unleaded gasoline.

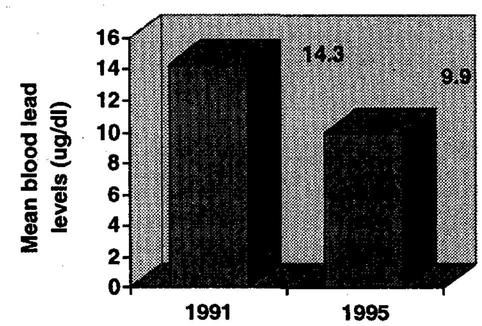
Several measures have been introduced since the late 1980s to reduce the use of lead in gasoline. The lead content of gasoline was reduced from 0.25 g/l in 1987 to 0.20 g/l in 1988, to 0.17 g/l in 1989, to 0.15 g/l (its current level) in 1990. The total consumption of leaded gasoline decreased from 1.4 million tons in 1989 to 0.8 million tons in 1992, while the use of unleaded gasoline increased, accounting for 15 percent of gasoline sales in 1994. As a result, estimated vehicular lead emissions into the ambient air declined from 295 tons in 1987 to 153 tons in 1992.

Environmental Measurements

Environmental measurements of lead have been concentrated in areas of large stationary emission sources. Ambient air concentrations in the town of Kurdzhali, for example, as measured at three locations by the Regional Environmental Inspectorate, show a marked decrease since 1992, due to measures taken by the smelter to reduce the emissions of toxic gases. Recently, lead concentrations in the ambient air have been within the admissible average concentration of 1 $\mu g/m^3$ (the Bulgarian standard). Nevertheless, Kurdzhali had significantly higher ambient atmospheric lead concentrations during 1990-1994 than the control town of Haskovo with similar geography, meteorological, and demographic characteristics (Bainova, 1995).

In 1995, authorities measured the concentration of lead in soil samples taken in kindergartens and schools near heavy traffic in the towns of Kurdzhali and Haskovo, and the village of Ostrovitsa. High contamination was found in the soil of kindergartens in Kurdzhali, where both industrial sources and heavy traffic contribute to the accumulation of lead. Surprisingly, however, the difference in the lead content of the soil between the town of Ostrovitsa, which has an operating lead smelter, and Haskovo, where traffic is the only source of lead emissions, was small, underlining the important role played by traffic-related lead depositions (**Table A.13**).

Figure A.6 Changes in the Lead Exposure of Children Near the Kurdzhali Lead Smelter in Bulgaria, 1991, 1995



Source: Bainova, 1995

Biological Measurements and Health Effects

Measures to control large industrial emissions over time improved the health conditions of exposed populations (**Table A.14**). The reduction of human exposure to lead near the lead smelter in Kurdzhali is reflected in a 31 percent decrease in the BLLs of children observed between 1991 and 1995 (**Figure A.6**).The BLLs of six-year-old children in Kurdzhali are, however, still 20 percent higher than those in the control groups. An analysis in 1995 showed statistically significant differences between the mean BLLs of studied children in the town of Ostrovitsa in the vicinity of lead smelter, and the control group. Thirty percent of the individual BLL values in Ostrovitsa exceeded 15 µg/dl.

Mean BLLs in one of the control groups from the city of Haskovo (with no significant stationary lead emission source) were found unexpectedly high (11.4 µg/dl). This was attributed to the impact of lead emissions from traffic because the control kindergarten was located in a central region of the city with intensive traffic.

Although comparative tests of the intellectual performance of children were not carried out in Bulgaria, internationally established evidence (CDC, 1991) indicates that the approximately U.S. $4 million investment in pollution control at the lead smelter in Kurdzhali may have prevented a 1 IQ gradient decrease in the intellectual performance of exposed children, primarily due to the impacts of lead on their behavior, coordination, attention span, and other areas of neurological development. Moreover, the reduction of emissions is likely to contribute to a significant decline in the accumulation of lead in various environmental media, especially dust and soil, further reducing human exposures over time.

Box A.4 The Impact of Traffic on Health in Stara Zagora, Bulgaria

In the town of Stara Zagora, the only source of lead emission is traffic. A study was conducted here to assess the health impacts of vehicular emissions. The study found that mean annual atmospheric lead concentrations were halved (from 1.6 µg/m^3 to 0.8 µg/m^3) during 1982-84, after traffic restriction measures were introduced in the city. Monitoring sites located near busy highways also indicated significantly higher lead concentration than those in less polluted areas.

Laboratory tests of white mice demonstrated a statistically significant increase of lead in the mice exposed to lead aerosols in the heavy traffic sites. A study of population morbidity in ambulances and hospitals revealed a correlation between lead aerosols and tumorogenic diseases. Hospitalized children 0 - 14 years of age showed correlations between various health problems including inflammation of the upper respiratory systems and skin diseases, and their exposure to dust and lead aerosols.

Source: Bainova, 1995.

Bibliography

Bainova, A. (ed). 1995. *Risk Assessment for the Population of the Town of Kurdzhali Related to Environmental Factors.* Environmental Management Training Center, Sofia, Bulgaria.

Bainova, A. 1995. *Lead Exposure and Human Health in Bulgaria.* Technical Background Paper to "Lead Exposure and Health in Central and Eastern Europe." Sofia, Bulgaria.

Barko, E. et al. 1989. "Studies on Lead Exposure of Children". *Gyermekgyogyaszat.* No. 40. pp. 362-368. (In Hungarian).

Basmadzhieva, K. (ed.). 1991. *Environmental and Health Characteristic of Risk Regions in Bulgaria.* National Institute of Hygiene, Sofia, Bulgaria.

Bozhinova, P. et al. 1992. *A Study on the Pollution of Soils and Agricultural Plants and Development of Agricultural Systems and Structure of Plants, in the Conditions of Pollution in the Region of the D. Blagoev Lead Smelter in Plovdiv.* "N. Pushkarov" Soil Research Institute, Sofia, Bulgaria.

California EPA. 1991. *Chemicals Known to the State to Cause Cancer or Reproductive Toxicity.* State of California Environmental Protection Agency, Office of Environment & Health Assessment, Sacramento, CA, USA.

Dutkiewicz, T. and Kulka, E. 1993. "Reference Levels of Lead in Children Living in Clean Regions of Poland" *Medycyna Pracy.* No. 6. pp. 77-84. (In Polish)

Eikmann, I. and Kloke, A. 1995 – *Ableitungskriterien fur die EIKMANN-KLOKE-Werte. In Beurteilung von Schwermetallen in Boden von Ballungsgebieten: Arsen, Blei und Cadmium.* Dechema, Frankfurt, Germany.

Farkas, I. and Sajgo, K. 1991. "Delta-Aminolevulinic Acid Excretion as a Biological Exposure Index in Children". *International Journal of Environmental Health Research.* No. 1. pp. 174-182.

Fuzesi, Zs. and Tistyan, L. 1994. *Survey on Workers', Inhabitants' and Children's Knowledge - Attitudes Practices Related to Lead Poisoning in Hungary.* Paper presented in the workshop on "A Systematic Multi-Sectoral Approach to Environmental Health Policy and Program Development: The Lead Poisoning Prevention Project in Hungary." Budapest, Hungary.

Gerritze, R. et al. 1993. "Update of Heavy Metals by Crops in Relation to their Concentration in the Soil Solution." *Plant & Soil.* Vol. 75, pp. 393-404.

Gorynski, P. and Wijtyniak, 1995. *Assessment of Lead Exposure and its Impact on Health in Poland.* Technical background paper to "Lead Exposure and Health in Central and Eastern Europe". Warsaw, Poland.

Grabecki, J. 1993. "Monitoring Lead in the Silesian Population, in Particular Among Primary School Children." *Medycyna Pracy.* No. 6. Supplement 1. pp.86-99. (In Polish)

Groszmann, M. et al. 1990. "Examination of Blood Lead and Zinc-Protoporhyrin Levels in People (Children and Adults) Living in the Area of a Lead-Waste Processing Plant". *Egeszsegtudomany.* No. 34. pp. 308-326. (In Hungarian).

GUS. 1994a. *Environmental Protection Yearbook* (Ochrina Srodowiska). Warsaw, Poland.

GUS. 1994b. *Statistical Yearbook* (Roznik Statistyczny). Warsaw, Poland.

Hertzman, C. 1995. *Environment and Health in CEE: A Report for the Environmental Action Programme for Central and Eastern Europe.* World Bank, Washington D.C.

Hlawiczka, S. 1994. *Heavy Metal Emissions in Poland - Evaluation of Emissions in 1980-1992.* Institute of Ecology of Industrial Areas. Prepared for the Ministry of Environment. Warsaw, Poland. (In Polish).

Horvath, A. et al. 1989. *Determination of Environmental Lead Exposure of Children in Hungary*. WHO/EC Workshop on the "Lead Neurotoxicity Study on Children". May 9-12. Dusseldorf, Germany.

Hudak, A. et al. 1992. "Erythrocyte Zinc-Protoporhyrin/Heme Ratio - Screening Test for Detection of Iron Deficiency and Lead Exposure. Experiences with Hematofluorometer." *Orvosi Hetilap*. No. 133. pp. 847-856. (In Hungarian).

Huseman, C. A., Varma, M. M., Angle C. K. 1992. "Neuroendocrine Effects, Toxic and Low Blood Lead Levels in Children". *Pediatrics*. V. 90, pp. 86-89.

ITS. 1993. *Prognosis of the Vehicular Transportation Development and the Environment*. Instytut Transportu Samochodowego. Warsaw, Poland. (In Polish).

Jakubowski, M. 1993. "Biological Levels of Lead Among the Inhabitants of Poland". *Medycyna Pracy*. Suppl. 1. pp.15-34. (In Polish).

Jarosz, W. and Marchwinka, E. 1991. *Impact of Emission from Transportation Corridors on Polution of the Soil and Food Products*. Material presented during the Conference on Nutrition Ecosystems and Food". Warsaw, Poland. (In Polish).

Kertesz, M. 1994. *Airborne Lead Levels in Hungary*. Paper presented in the workshop on "A Systematic Multi-Sectoral Approach to Environmental Health Policy and Program Development: The Lead Poisoning Prevention Project in Hungary". Budapest, Hungary.

Levy, B. S. et al. 1994. *A Systematic Multi-Sectoral Approach to Environmental Health Policy and Program Development: The Lead Poisoning Prevention Project in Hungary*. Paper Presented at the "International Lead Conference, Alliance to End Childhood Poisoning". May 19, Washington D.C.

NAS 1983. *Risk Assessment in the Federal Government Management Process*. National Academy of Sciences, Washington D.C.

Papay, D. and Horvath, A. 1992. "Research and Evaluation of the Activity of Metallochemia Plant, Regarding Environmental Health. *Budapesti Kozegeszsegugy*. No. 24. pp. 87-92. (In Hungarian).

Richardson, M. L. (ed.) 1992. *Risk Management of Chemicals*. The Royal Society of Chemistry, Cambridge, England.

Richardson, M. L. (ed.) 1988. *Risk Assessment of Chemicals in the Environment*. The Royal Society of Chemistry, London, England.

Richardson, M. 1993. *Reproductive Toxicology*. Weinheim, New York, Basel, Cambridge, Tokyo, VCH Verlagsgesellchaft MBH.

Rudnai, P. et al. 1989. *Study on the Lead Neurotoxicity in Children in Hungary*. WHO/EC Workshop on the "Lead Neurotoxocity Study on Children". May 9-12, Dusseldorf, Germany.

Rudnai, P. et al. 1990. "A Survey of Blood Lead Levels in Budapest". *Egesszegtudomany*. No. 34. pp. 273-281 (In Hungarian).

Rudnai, P. et al. 1995. *The Impact of Lead Exposure on Human Health in Hungary*. Technical background paper to "Lead Exposure and Health in Central and Eastern Europe." Budapest, Hungary

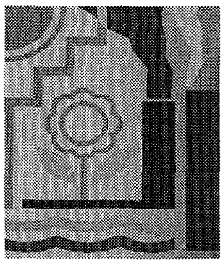
Smith, M. A., Grant, L. D. Sors, A. J. (eds.). 1989. *Lead Exposure and Child Development: An International Assessment*. Kluwer Academic Publications. Dordrecht, Boston, London.

WHO. 1989. "Lead" *Environmental Health Criteria*. No. 85. World Health Organization. Geneva, Switzerland.

Winneke, G. et al. 1990. "Results From the European Multicenter Study on Lead Neurotoxicity in Children: Implications for Risk Assessment". *Neurotoxicology and Teratology.* No. 12. pp. 553-449.

World Bank and OECD. 1995. *Environmental Action Programme for Central and Eastern Europe.* World Bank, Washington, D.C., Orgnization for Economic Development and Co-operation", Paris.

Zespoliwa, P. 1994. *Air Pollution in Poland* . Biblioteka Monitoringu Ochrony Srodiska. Warsaw, Poland. (In Polish).



Case Study B

Complete Phase-Out of Leaded Gasoline: Policies and Implementation in the Slovak Republic

Anna Violová, Daniel Bratský, Eva Šovcíková and Monika Ursínyová

Environmental Lead and Health Impacts

The Main Sources of Lead Exposure in the Slovak Republic

According to a 1992 inventory of heavy metal emissions in the Slovak Republic, stationary sources played a significant role in lead emissions (**Figure B.1**). Steel and iron production (Steel and Iron Works in Košice, and the Iron Works in Podbrezová) emitted the largest amounts of lead to the atmosphere (43 percent). The power sector, which uses mainly coal combustion; and non-ferrous metal production were also significant contributors (17 percent and 7 percent, respectively).

Significant stationary emission sources exist in several towns including Bratislava (chemical industries, and an oil refinery), Dolný Kubín (production of iron alloys), Hliník (aluminum production), Košice (the site of steel and iron production), and Krompachy (copper production). With the exception of Krompachy, however, average ambient lead concentrations in these towns typically did not exceed 0.3 µg/m^3 (**Figure B.2**). (For comparison, the annual average lead concentration

Figure B.1 Main Sources of Lead Emissions in the Slovak Republic, 1992

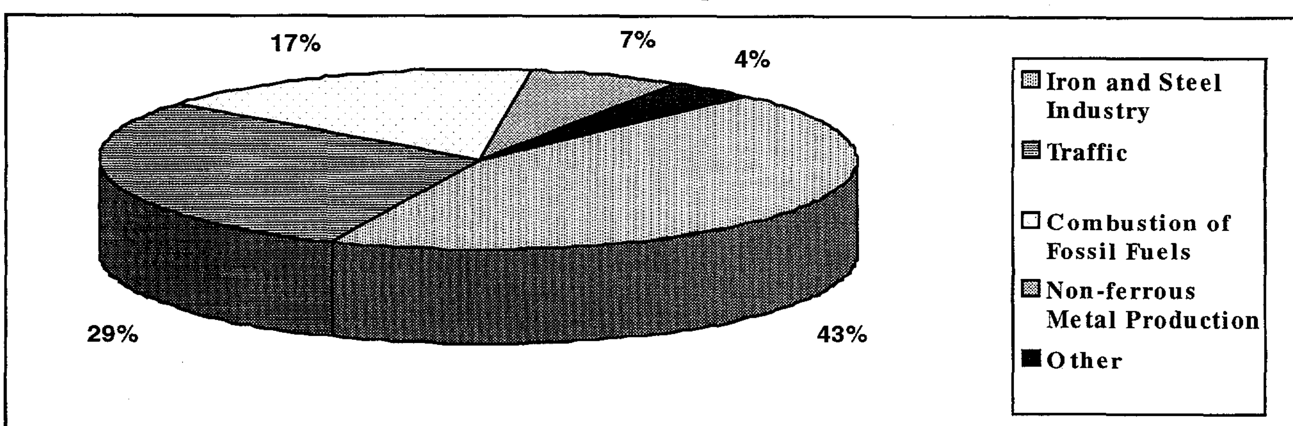
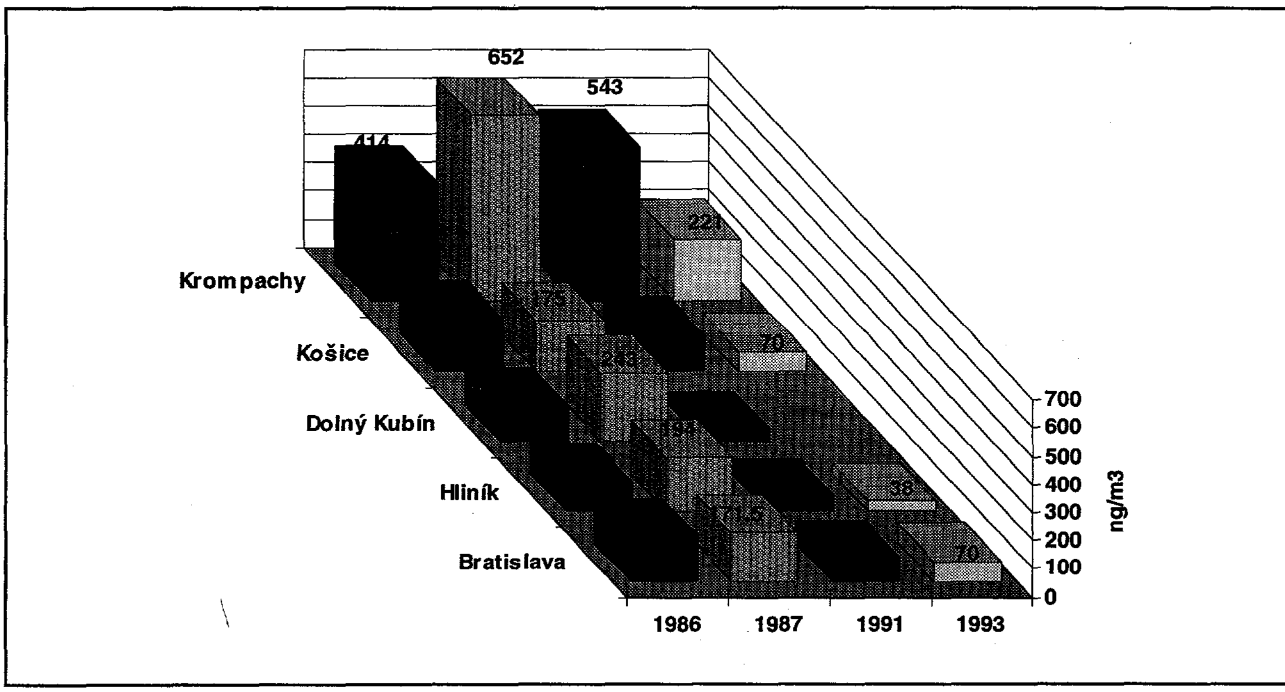


Figure B.2 Concentrations of Lead in the Ambient Air of Industrial Cities in Slovakia, 1986-93



Source: Slovnaft Refinery

in most European cities was generally in the range of 0.5 - 3 μg/m^3 in the late 1980's.)

Traffic was the second largest source of lead emissions in 1992, after iron and steel production, representing about 29 percent of total emissions in Slovakia. Vehicular lead emissions have been declining, however, due to the introduction of unleaded gasoline in 1992 (**Figure B.3**).

Vehicles have been a significant source of lead emissions in many countries. In some industrialized countries, transport has contributed to as much as 70 percent of the total lead emission load. In Austria in 1992, for example, before leaded gasoline was phased out, the share of vehicles was about 74 percent of the total lead emissions (159 tons out of 215 tons). Lead concentrations in urban air have been decreasing throughout Europe, however, in close correlation with the decreasing use of lead in gasoline (WHO, 1987). Cities in Slovakia show a similar relationship between the decreasing use of lead in gasoline and the decline in airborne lead concentrations (**Figure B.4**).

Airborne lead is not the only source of human exposure. For example, lead was used in the past to solder pipes for drinking water. Although it no longer is, many of the pipe systems from that period are still in operation, primarily in older cities like Bratislava. As a result, 33 percent of the drinking water sampled exceeded the admissible standards for lead content in drinking water (50 μg/l, the same standard as in the EU) in the early 1980's. Since then, however, there has been a downward trend: only 7.1 percent of samples exceeded the limit in 1989, (Uhnak and Rippel, 1986-1989), and at present, all samples are within the limit value.

Figure B.3 Lead Emissions from Traffice in the Slovak Republic, 1992-1995

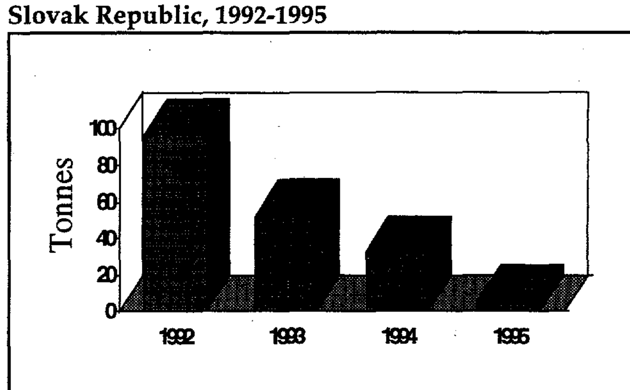
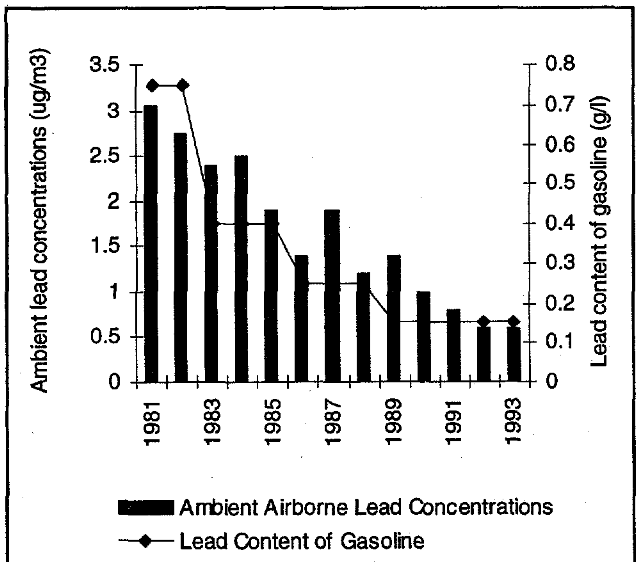


Figure B.4 Lead Content of Gasoline and Ambient Atmospheric Lead Concentrations in Bratislava, 1981-1993



Exposure to Lead and Human Health

There are several pathways by which lead enters the human body. The two primary routes are ingestion and inhalation. Based on the contribution of various pahtways, FAO and WHO have established a provisional tolerable weekly lead intake of 25 µg/kg body weight (PTWI). In a profile of average dietary lead intake of adults in 14 European countries during 1980-1988, only Belgium and the Federal Republic of Germany exceeded the tolerable weekly intake. The former Czechoslovakia had an average weekly intake of 3 µg/kg body weight, far below the tolerable value (WHO, 1995).

Dietary lead intake by Slovakian adolescents and children was monitored from 1990 through 1994. With the exception of vegetarian children, lead intakes were found to be only one third of the PTWI. In vegetarian children, however, lead intakes were higher (up to 43 percent of the PTWI). Cooking ingredients were also analysed during the time of

Table B.1 Estimates of Lead Absorption From Various Media (µg/m³)[1]

Mean Annual Lead Exposure (µg/m³)	*Source*			*Total*	*Contribution of Air to Total (%)*
	Air	*Food*	*Water*		
Adults					
0.3	2.4	10	2	14.4	17
0.5	4	10	2	16	25
1	8	10	2	20	40
2	16	10	2	28	57
3	24	10	2	36	67
Children (1-5 years old)					
0.3	0.6	25	5	30.6	2
0.5	1	25	5	31	3.2
1	2	25	5	32	6.3
2	4	25	5	34	11.8
3	6	25	5	36	16.7

Source: WHO, 1987.

[1]Estimates in Table 1 are based on the following assumptions: air: respiratory volume per day: 20 m³ for adults, 5 m³ for children; food: lead intake per day: 100µg, for adults (absorption 10 percent), 50µg for children (absorption 50 percent); water: daily water intake with a lead concentration of 20µg/liter: 1 liter for adults (absorption 10 percent), 0.5 liter for children (absorption 50 percent).

monitoring children. Root vegetables, oat flakes, soya, and rice were found to contain the highest levels of lead (Ursinyova, 1994).

In Slovakia, adult exposure to airborne lead ranges to around 60 percent of total exposure. For children, the range is up to about 15 percent (**Table B.1**). Airborne lead may be directly inhaled or may accumulate in the soil, move about as dust, and pass into food. Although industry comprises the main source of airborne lead, vehicular emissions are of special concern. Vehicles, through their exhaust, disperse lead particles widely throughout the environment. Most of the lead emitted this way is in the form of submicron-sized particles with high absorption rates. More than 90 percent of the lead coming from gasoline is emitted as more toxic inorganic particles, while the organic lead fraction (mainly lead alkyls) is less than 10 percent. Some 30-50 percent of the inhaled particles are retained in the respiratory system, and virtually all of this retained lead is absorbed into the body. Particles in the size range of 1-3 µm are also efficiently deposited in the lungs. Larger particles are deposited with variable efficiency, mainly in the upper respiratory tract with incomplete absorbtion.

In 1986-1990, a project was carried out, examining the *Environmental Pollution and the Contamination of Biological Materials and Food in Selected Slovakian Localities* (Truska and Balazova, 1990). One of the tasks of the study was to monitor blood lead levels in 345 adults in Bratislava and northern Slovakia. (**Table B.2**) The highest average values (10.2 µg/dl) were found among male smokers.

In the same study, the transfer of heavy metals through the placenta of pregnant women was examined. The study confirmed that lead passes through the placental barrier. This is of particular concern because extended exposure to even low levels of lead may affect the neurological development in children. Several studies indicate that there is no clear threshold, and developmental impacts occur at even low levels of exposure (WHO, 1995).

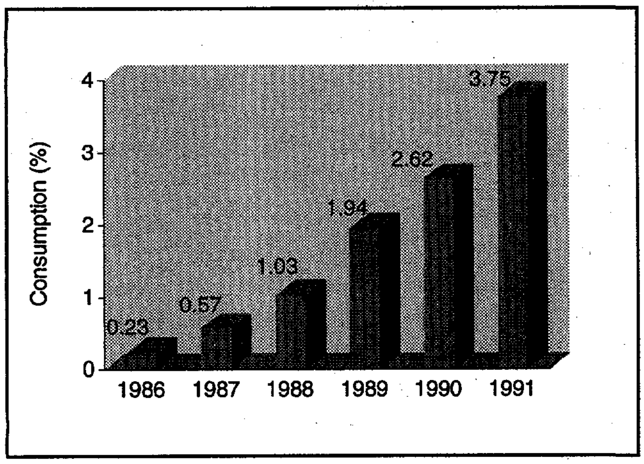
Elevated blood lead levels impair the intellectual performance that can be demonstrated, for example, with the Raven test. This psychological testing method is comprehensive, relating the intellectural performance of children to a number of different factors, particularly concerning the child's social environment. Aside from blood lead levels, the mother's education, smoking in the family, the child's birthweight, and other factors have been found to be significant in influencing test scores. The study focused on determining subtle changes in children's neurological function and behavior in relation to changes in blood lead levels. The study screened the mental and motor abilities of 395, nine and ten year old children living permanently in Bratislava. The following was revealed:

Table B.2 Blood lead levels in Bratislava's population, 1986-90 (µg/dl)

Sex	*Age and Smoking*	*Size of Sample*	*Concentration*	
			Arithmetic Average	*Geometric Average*
Female	18 - 35 smoker	28	7.0	5.8
	18 - 35 non-smoker	28	6.9	5.8
	36 and older smoker	22	4.1	3.1
	36 and older non-smoker	35	3.2	2.3
Male	18 - 35 smoker	40	10.2	6.8
	18 - 35 non-smoker	30	8.9	5.8
	36 and older smoker	32	10.0	8.8
	36 and older non-smoker	30	10.3	8.0

Source: Truska and Balázová, 1990.

Figure B.5 Consumption of Unleaded Gasoline in Slovakia, 1986 - 1991



- Lead levels in children's blood ranged from 1.1 to 13.5 µg/dl;
- Unfavourable neurological impacts could be detected from 4µg/dl;
- The group of children with higher lead levels in their blood showed lower performance compared with the group of children with lower lead levels. (Those children, however, also came from families including smokers, their mothers' had lower education, and the children's birthweight was also lower.) The children with higher blood lead levels tended to have learning and behavioral problems at school (such as social intolerance and an inability to concentrate), and their parents indicated that they also had behaviour problems at home;
- In intelligence tests, children with lower lead levels (less than 3.5 µg/dl) had an average performance of 30.1 points, while children with higher lead levels (more than 3.5 µg/dl) had an average performance of 28.4 points. The difference (1.7 points) between the groups was statistically significant; and
- In simple motor and concentration tests, a similar relationship with blood lead levels did not appear. In these tasks, factors such as the mother's education and the child's birthweight prevailed.

The study results revealed that children's neurological development was influenced by blood lead levels lower than 10 µg/dl. The effects of lead was further influenced by other factors such as health and social environment (Šovcíková, 1995).

Main Factors and Obstacles Influencing the Phase-Out of Leaded Gasoline

The magnitude of health impacts of lead resulted in a conscious effort of Slovak policy makers to address the problem. The positive experience of industrialized countries in reducing human exposures by the removal or lead from gasoline showed that it was a feasible and effective measure to mitigate human health damage. Three key factors presented obstacles, however, to the rapid phase-out of leaded gasoline in the Slovak Republic:

- Unfavorable technical composition of the vehicle fleet;
- Low availability of unleaded gasoline supply; and
- Old fueling habits and limited knowledge of motorists about the use unleaded gasoline.

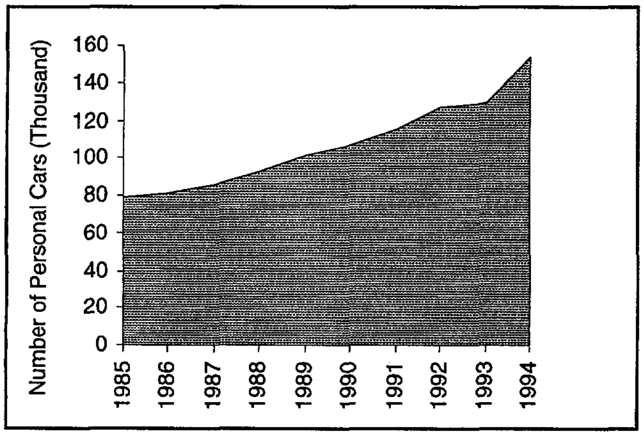
Vehicle Fleet

An analysis of the reasons why unleaded gasoline was consumed at such low levels (**Figure B.5**) at the end of the 1980's in Slovakia indicated that the main limiting factor from a technical point of view was the composition of car fleet in the Republic.

Due to high vehicle prices and low personal income levels, car ownership in Slovakia has not yet reached the levels of Western countries. The situation has been changing, however. In Bratislava, the capital of Slovakia with 451 thousand inhabitants, the number of vehicles has increased significantly since 1991, despite rising vehicle and fuel prices (**Figure B.6**, and **Table B.3**).

Compared to the vehicle fleet characteristics in the European Union, the composition of car fleet in Slovakia is unfavorable (**Table B.4**). According to the mobile source emission inventory, prepared by the Traffic Research Institute in Zilina, the number of vehicles in Slovakia provided with catalytic converters increased from 823 to 3,797 between 1987 and 1993. Of those vehicles, the number with controlled catalytic converters increased from 312 to 2,579. However, from the a total of 985,861 gasoline vehicles in Slovakia, still only 0.4 percent had catalytic converters in 1993. This adverse situation is changing, however. Legislation requires that from October, 1993, only cars with three-way

Figure B.6 Number of Personal Cars in Bratislava 1985-1994



controlled catalytic converters may be imported or manufactured (roughly 20,000 vehicles are being imported annually). As a result, about 4 percent of the fleet is estimated to have catalytic converters in 1995.

Gasoline Supply

Until the 4th quarter of 1992, the following gasoline brands were available on the domestic market:

- Leaded gasoline with the trade name SPECIAL - 91 (0.15 g/l, RON 91);
- Leaded gasoline with the trade name *SUPER - 96* (0.15 g/l, RON 96); and
- Unleaded gasoline with the trade name *NATURAL - 95* (RON 95).

Only a small number of filling stations (approximately 10 percent of all filling stations) carried unleaded gasoline, and more than 70 percent of the car fleet in Slovakia used the 90 - 91 RON leaded gasoline.

The only producer of gasoline in the Slovak Republic is Slovnaft joint-stock company, established by the transformation of the former state-owned company in May 1992. Slovnaft is situated in the south-western outskirts of Bratislava, the capital of the Slovak Republic. In its refining and petrochemical facilities, it process five to six million tons of crude oil annually. The refinery's technical capacity needed to be upgraded in order to switch to completely unleaded gasoline production (see under *Adjustment of Gasoline Supply*).

Consumer Habits and Awareness

Motorists knew very little about the proper use of the various gasoline grades or that it was possible to fuel with unleaded gasoline. According to surveys, ninety percent of the gasoline consumers thought that unleaded gasoline could only be used in cars equipped with catalytic converters.

Government Policies

Regulations and Price Incentives

When the Slovak Republic was established, one of the first tasks of the Government was to work out an environmental policy and legislation to bring the country into accord with requirements of the European Union. Unification with the European Union was strongly supported when the Association Agreement was signed. Since then, all legislative regulations approved by the Government and

Table B.3 Vehicle Ownership in Bratislava, 1990-1994

Year	*Motor vehicles per Thousand Inhabitants*	*Inhabitants Per Vehicle*	*Personal Cars per Thousand Inhabitants*	*Inhabitants per Personal Car*
1990	278	3.59	226	4.42
1991	293	3.42	240	4.27
1992	309	3.23	258	3.87
1993	333	3.00	283	3.54
1994	342	2.93	286	3.50

Parliament must include an analysis of whether they harmonize with EU regulations.

Under the former government, the Federal Ministry of Traffic and Communications was responsible for regulating mobile emission sources. After Czechoslovakia split up, these responsibilities were passed to the new Ministry of Traffic and Communitations of the Slovak Republic. Under the Ministry, legislation was established limiting the maximum permissible lead content in leaded gasoline to 0.15 grams per liter.

The use of fiscal incentives to influence the structure of gasoline demand has been conditioned by the tax and price system in effect in the Slovak Republic. In this regard, there have been two main periods: (i) before 1993, when wholesale and retail prices were fixed by the government; and (ii) after 1993, when the value-added tax system was introduced. During all of the first period and part of the second (until the end of 1993), the state held an exclusive license for purchasing crude oil. Due to these constraints, gasoline producers and distributors had limited opportunity to influence the retail price of gasoline and therefore the market share of unleaded gasoline. Since 1993, the government has set only retail price ceilings.

Although price differentiation was introduced in 1990 and the 2nd quarter of 1992 in favor of

Table B.4 Comparative Vehicle Fleet Characteristics in Slovakia

	Slovakia (%)	*European Union (%)*
Group A: Vehicles with soft valve seats -- can use unleaded gasoline with lubrication	70	20-30
Group B: Vehicles with hard valve seats -- can use unleaded gasoline	25-30	40-60
Group C: Vehicles equipped with catalytic converters -- need to use unleaded gasoline	4	30-50
Average age of vehicles	14	7-9
Annual vehicle fleet renewal rate	5	10-15
Phase-out year of vehicles in Group A	2005	2000

Table B.5 Prices and Taxes of Leaded Gasoline ***SPECIAL - 91, 1990-1992***

Year	*Wholesale Price Annual Average (SK/MT)*	*Retail Price Annual Average (SK/liter)*	*Sales Tax (SK/MT)*
1990	2,986	12.00	7,970
1991	7,953	16.00	12,600
1992	7,221	16.00	12,600

Table B.6 Prices and Taxes of Leaded Gasoline ***SUPER - 96, 1990-1992***

Year	*Wholesale Price Annual Average (SK/MT)*	*Retail Price Annual Average (SK/liter)*	*Sales Tax (SK/MT)*
1990	3,097	13.50	8,980
1991	8,091	18.00	14,600
1992	7,488	18.00	14,600

[2] Gasoline brands marketed in the UNI series contained a special lubricant that provided protection of the soft valve seats of older cars (see **Adjustment of Gasoline Supply**).

Table B.7 Prices and Taxes of Unleaded Gasoline *NATURAL - 95, 1990-1995*

Year	*Wholesale Price Annual Average (SK/MT)*	*Retail Price Annual Average (SK/liter)*	*Sales Tax (SK/MT)*
1990	not available	13.50	7,670
1991	9,050	18.00	13,500
1992	8,365	18.00	13,500

Table B.8 Gasoline Taxation, Third Quarter of 1992 - 1995 (SK/MT)

Trade name of Gasoline	*Type**)	*from 3.Q 1992*	*1993*	*from 1.Q 1994*	*from 3.Q 1994*	*1995*
SPECIAL - 91	LG	14,580**)	10,800	10,800	10,900	N.P.
UNI GASOLINE - 91	ULG	13,380**)	9,390	9,390	9,800	9,800
Differ. (LG - ULG)		1,200**)	1,410	1,410	1,100	
SUPER - 96	LG	16,580**)	10,800	N.P.	N. P.	N.P.
UNI SUPER - 95	ULG	N.P.		9,390	9,800	9,800
NATURAL - 95	ULG	15,380**)	9,390	9,390	9,800	9,800
Differ. (LG - ULG)		1,200**)	1,410			

*) LG - Leaded gasoline, ULG - Unleaded gasoline
**) Sales Tax
N.P. - not produced

Table B.9 Wholesale Prices of Gasoline, Third Quarter of 1992 - Second Quarter of 1995 (SK/MT)

Trade name of gasoline	*Type**)	*3. - 4.Q 1992*	*1993*	*1. - 2.Q 1994*	*3. - 4.Q 1994*	*1. - 2.Q 1995*
SPECIAL - 91	LG	7,060	7,530	7,250	6,450	N.P.
UNI GASOLINE - 91	ULG	7,600	7,930	7,750	7,050	6,340
Differ. (ULG - LG)		540	400	500	600	
SUPER - 96	LG	7,370	8,010	N.P.	N.P.	N.P.
UNI SUPER - 95	ULG	N.P.	9,090	8,680	7,980	7,235
NATURAL - 95	ULG	8,160	8,890	8,300	7,550	6,840
Differ. (ULG - LG)		790	980			

*) LG - Leaded gasoline, ULG - Unleaded gasoline
N.P. - not produced

unleaded gasoline (*NATURAL - 95* versus leaded *SUPER - 96* with the same octane level), the difference merely compensated for the higher manufacturing costs of unleaded gasoline. The retail price of both gasoline brands was equal (**Tables B.5, B.6,** and **B.7**).

The structure of prices and taxes changed radically in the third quarter of 1992. After technological changes took place in gasoline production, increasing the efficiency of Slovnaft Refinery, and a new unleaded gasoline grade—*UNI GASOLINE - 91*[2] — was introduced, there was an effort to raise the consumption of unleaded gasoline by adjusting the prices. This was especially crucial during the 3rd quarter of 1992 through the 4th quarter of 1994, when the leaded gasoline *SPECIAL - 91* and unleaded *UNI GASOLINE - 91* were sold simultaneously; as well as during the 3rd quarter of 1992 through the 2nd quarter of 1993, when leaded gasoline *SUPER - 96* and unleaded gasoline *NATURAL - 95* were marketed simultaneously. Legislation (Act No.213/1992 Code on Consumption Taxes, with later later amendments) assigned unleaded gasolines a lower tax (9,800 SK) than

Table B.10 Slovak Emission Standards for Gasoline Vehicles

Date of Production	*Standard for CO (%)**	*Standard for HC (ppm)*
before 31.12.1972	6.0	2000
1.1.1973 - 31.12.1985	4.5	1200
after 1.1.1986	3.5	800

*measured at idling
All cars being used must pass regular emission inspection. The emission limits for gasoline motor vehicles are given in table 7.3.

leaded gasolines (10,900 SK).

After the complete replacement of leaded gasoline *SUPER - 96* by unleaded *UNI SUPER - 95* throughout Slovakia in the 3rd quarter of 1993, the price advantage of the unleaded gasoline *UNI SUPER - 95* lost its importance. Currently, prices for unleaded gasoline *NATURAL - 95* (without lubricant) is priced advantageously compared to *UNI SUPER - 95* (which contains lubricant) due to the lower manufacturing costs. (A comparison of taxes levied on the various types of motor gasoline brands, and wholesale prices are presented in **Tables B.8** and **B.9**. Retail prices are illustrated in the **Figure B.7**).

Other Policy Measures

Several pieces of legislation have been introduced to set standards for the condition of vehicles on the roads, particularly the technical standards for vehicles produced or imported after October 1, 1993. These regulations regarding exhaust emissions have become increasingly stricter (**Table B.10**). Currently, all gasoline engine vehicles must fulfil the following conditions:

- New vehicles must be capable of running permanently with unleaded gasoline without additives for lubricating the valve seat;
- New vehicles must be provided with functional controled three-way catalytic converters; and
- Imported vehicles must be produced in the 1985 model year or later.

Vehicles that do not fulfill the above conditions, cannot be registered. Owners of those vehicles which fulfill the above conditions, but were produced before 1985, must prove, in authorized pollution testing centers at the owner's cost, that such vehicles meet the standards. In addition, all gasoline vehicles in operation are subject to regular pollution inspections.

There are various additional regulations designed to support the use of three-way catalytic converters in gasoline vehicles:

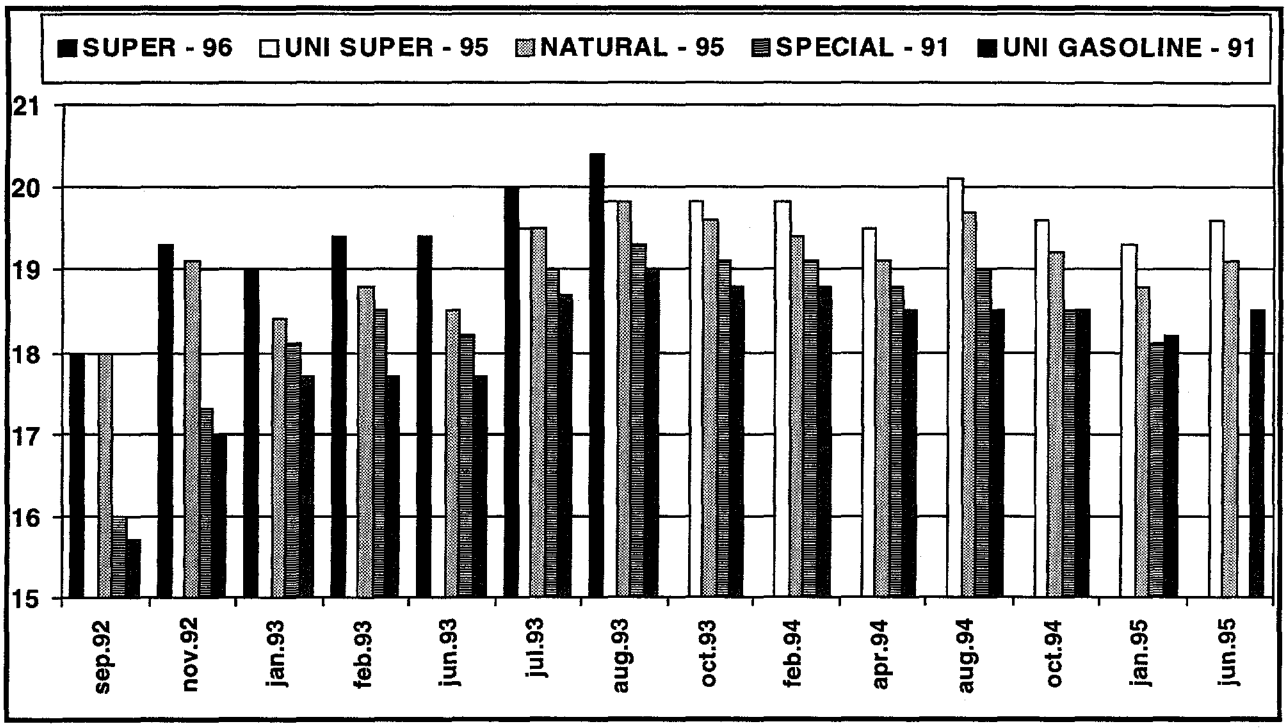
- *Act No.319/1992 on the Road Tax* reduced the road tax by 25 percent for two years on imported gasoline vehicles equipped with catalytic converters or vehicles running on natural gas; and it reduced the tax by 50 percent for two years for vehicles fulfilling the pollution standards with three-way controlled catalytic converters; and
- *Act No.187/1994 on Value Added Tax (VAT)* reduced VAT from 25 percent to 6 percent on catalytic converters.

Public Awareness Building, Education and Information

Before the reform process began in 1989, all information concerning the environment, pollution, and its impact on human health was concealed. After the beginning of the 1990s, information started to be published and the public has become aware of the fact that the average life span of inhabitants in the former Czechoslovakia and the Eastern Block is generally shorter than in the OECD countries. The public has started to keep an eye on environmental quality analysis and its priorities, and to make it more health oriented. The intensified activities in the environment arena have also been due in part to the leading role played by environmentalists in the dissident movements during the previous communist regimes.

In the past, the public was not well-informed about the impacts of lead. In particular, information about lead in children's blood tended to be limited to the parents of children who had been specifically studied. In the future, more attention must be paid

Figure B.7 Gasoline Retail Prices Third Quarter of 1992 - 1995 (SK / liter)



to educating the public systematically. An Environmental Agency has been established next to the Ministry of Environment of the Slovak Republic; its task is to improve public information. The Ministry of Environment has published an informative brochure about heavy metals in Slovakia this year that will provide information on lead levels in children, and the risks they pose to healthy development.

Adjustment of Gasoline Supply

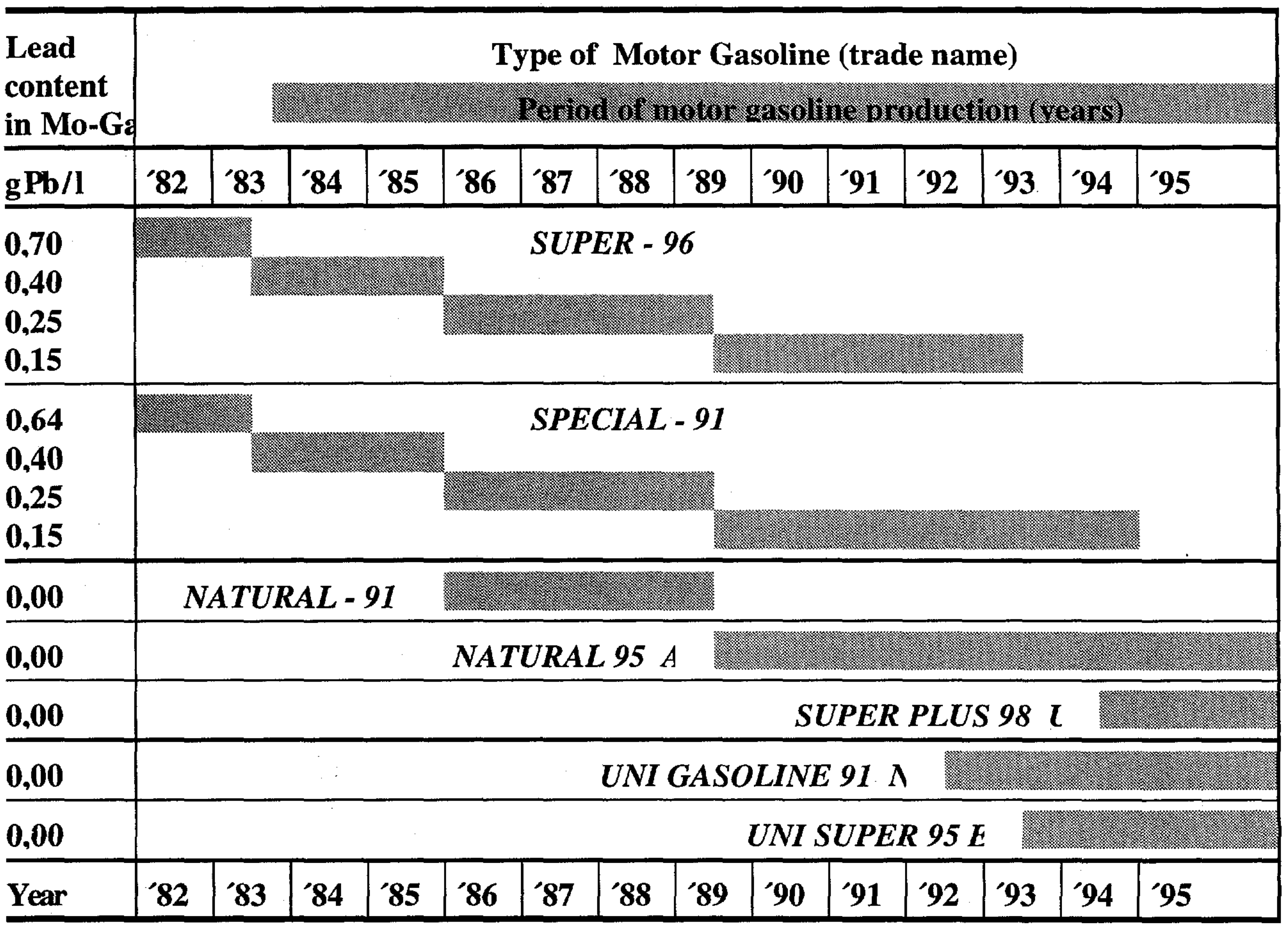
The reduction of lead content in gasoline and introduction of new unleaded gasoline brands took place gradually in the Slovak Republic (**Table B.11**). The technical adjustment of Slovnaft Refinery to produce unleaded gasoline at a large scale progressed in three phases.

Phase 1: Before 1988

In response to changing government regulations, the lead content of gasoline with trade names *SUPER - 96* (RON 96) and *SPECIAL - 91* (RON 91) was decreased from the initial value of approx. 0.7 g/l in the early eighties to 0.40 g/l in 1983. This was achieved by increasing the severity of catalytic reforming of heavy naphtha from the initial RONC of reformate 89 to RONC 91-92 and through the selection of light gasoline fractions. The use of software which simulated optimal gasoline blending, developed in the Research Centre of Slovnaft Refinery, had an important role in this process.

The next step in the reduction of lead content to 0.25 g/l in 1986 was achieved by the optimization of the distillation range of light naphtha, whereby its RONC was increased to 75 by increasing the reformate RONC to 94, and the addition of MTBE

Table B.11 Composition of Gasoline Supply in Slovakia, 1982 - 1995



(10 percent of the volume in *SUPER - 96* gasoline). This solution made it possible to start the production of unleaded gasoline with trade name *NATURAL - 91* (RON 91) at the same time. The technological layout of motor gasoline production from 1986 to 1988 is shown in **Figure B.8**.

Phase 2: Between 1989 and 1991

The next step in development was oriented to more complex crude oil processing, with the goals of maximizing motor fuel production and laying the groundwork for increased production of unleaded gasoline. In 1989, the hydrocracking unit of heavy oil distillates was put into operation. From this unit, light hydrocrackate with RONC 80 and heavy hydrocrackate with high naphtha content (which was converted into reformate with RONC 96 - 98 for motor gasoline by reforming) were obtained. These changes in the technology of gasoline production enabled the refinery to reduce the lead content in leaded gasoline to 0.15 g/l, and at the same time increase the production of unleaded gasoline marketed with the trade name *NATURAL - 95* (RON 95). The technological layout of motor gasoline production in the period 1989 to 1991 is shown in **Figure B.9**.

Phase 3: After 1992

In the interest of setting the stage for the exclusive production of unleaded gasoline, a unit for isomerization of light naphtha (C_5 - C_6 hydrocarbons) started operation in 1992. With the

Figure B.8 Technological Layout of the Motor Gasoline Production at Slovnaft Refinery, 1986 - 1988

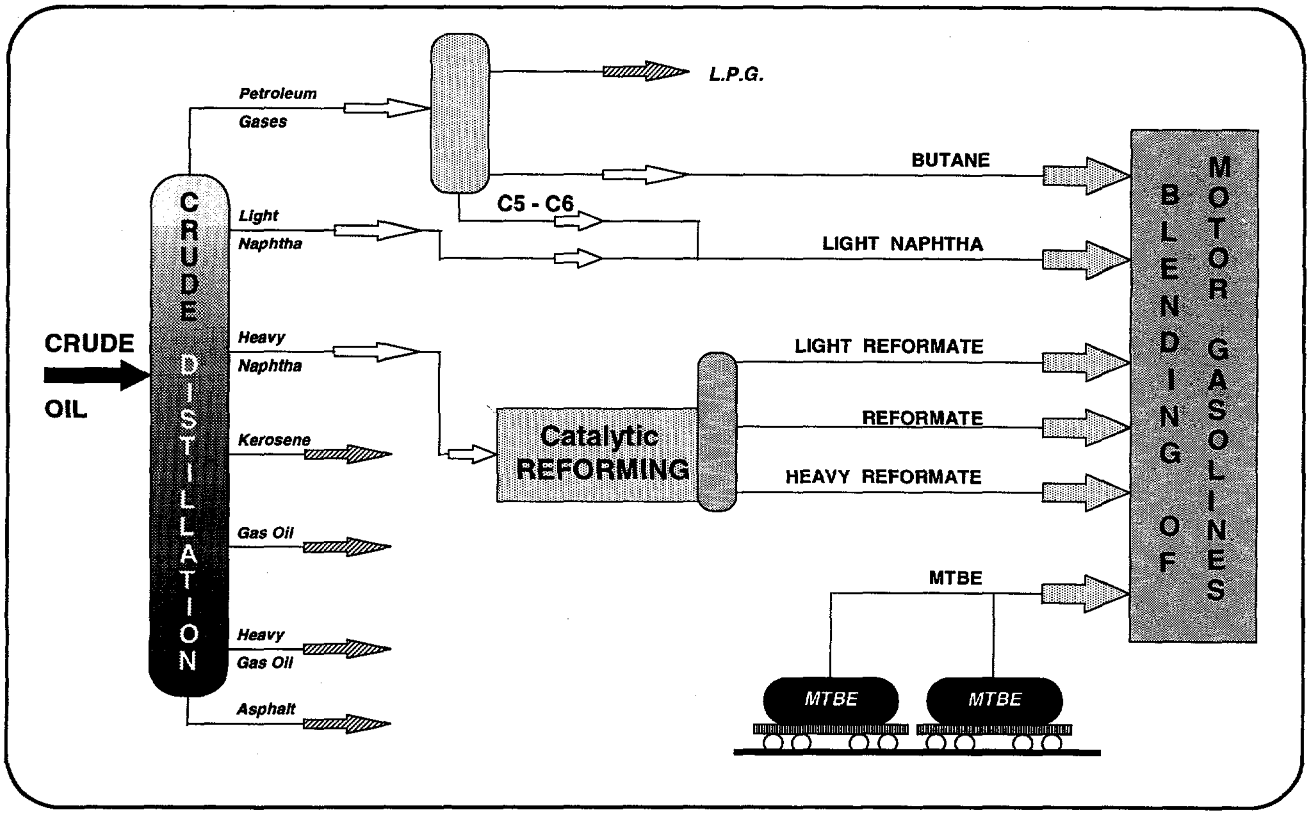
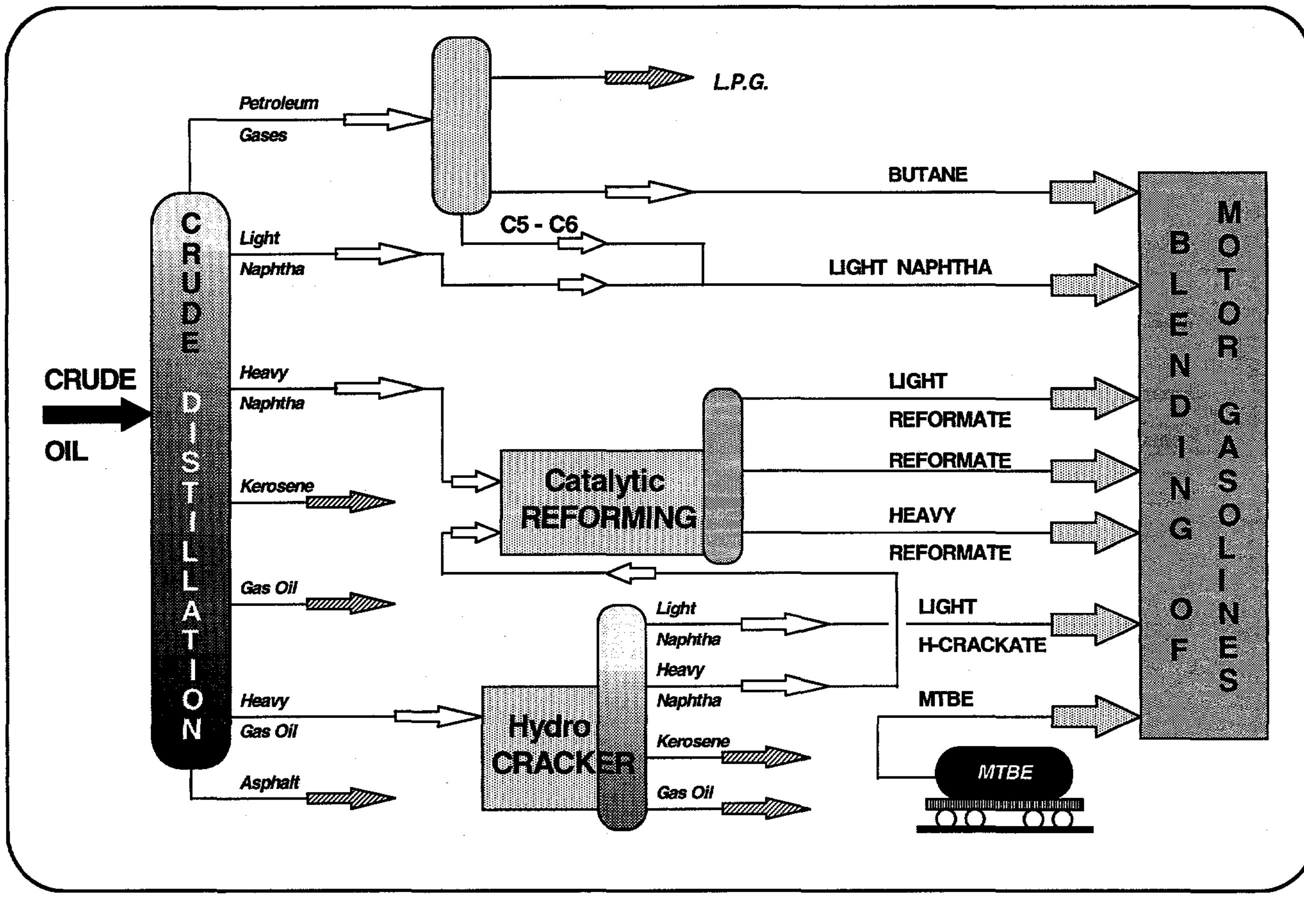


Table B.12 Composition of Gasoline Production Capacity at Slovnaft Refinery

Process	*Charge capacity (b / cd)*
Crude Distillation	120,000
Catalytic Reforming	22,300
Catalytic Hydrocracking	17,000
Isomerization C_5 - C_6	5,800

b / cd: Barrels per calendar day

Figure B.9 Technological Layout of Motor Gasoline Production at Slovnaft Refinery, 1989 - 1991



help of this unit, it was possible to raise the octane number of this component from RONC 70 to RONC 84. In view of the fact that the content of gasoline is almost 30 percent light fractions, the wholesale production of unleaded motor gasoline brands by Slovnaft could be achieved through the use of isomerization without increasing the RONC of reformate and, therefore, without increasing the percentage of aromatics in gasolines. The technological layout of motor gasoline production after 1992 is shown in **Figure B.10**, and the capacities of the main production units are presented in **Table B.12**.

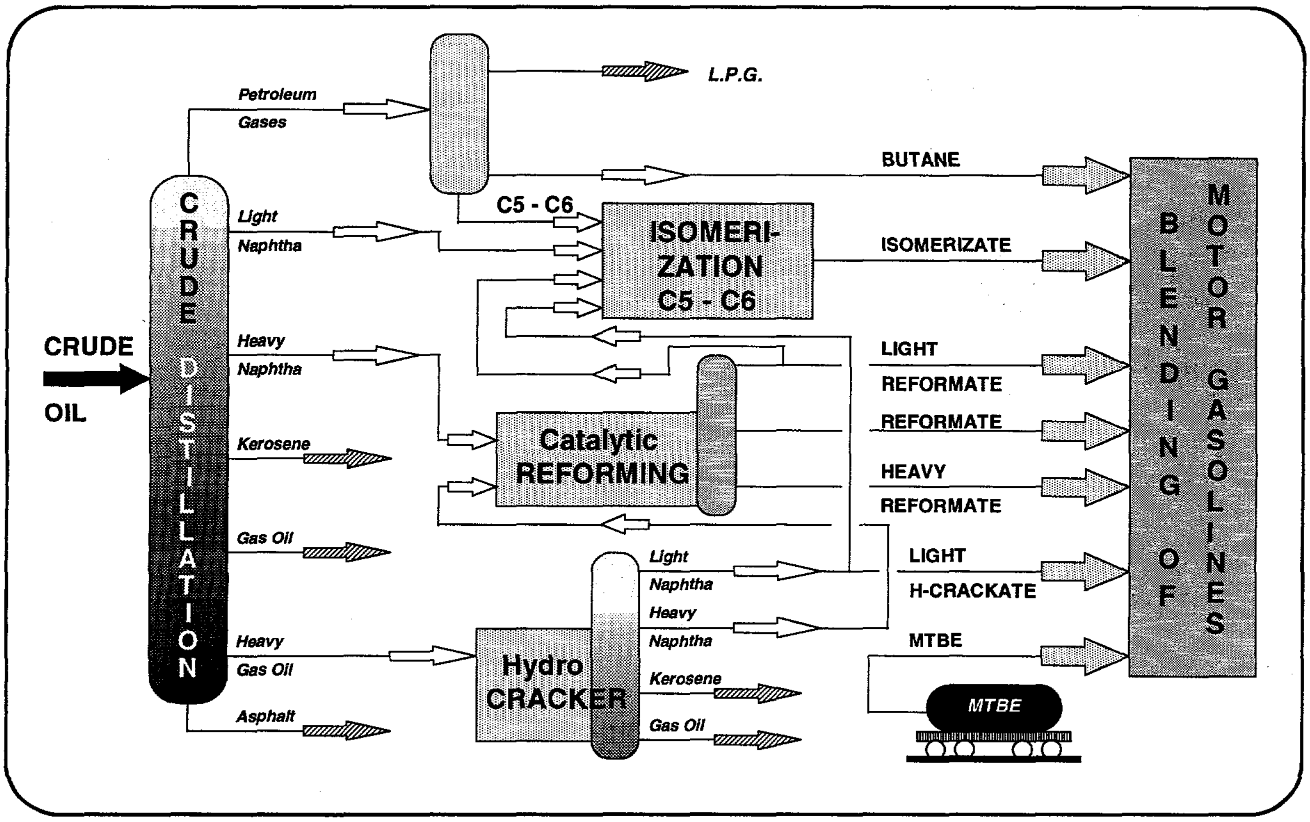
Technical Solution to the Car Fleet Problem

The only practical solution for overcoming the technical obstacle of phasing out leaded gasoline presented by the existing car fleet was the application of an adequate additive that could replace the lubricating property of lead to protect sensitive engine valve seats from excessive wear due to the use of unleaded gasoline. Other desirable requirements of such an additive were that it:

- was health friendly (without toxic, carcinogenic, or mutagenic effects);
- did not compromise the efficiency of catalytic converters;
- was compatible with leaded gasolines; and was compatible with other additives used in gasolines.

All these requirements were fulfilled by the additive which was developed in Slovnaft and marketed with the trade name *ANABEX® - 99*. The existence of this additive has given rise to unleaded gasolines of the UNI series, a universal unleaded gasoline for the entire car fleet in Slovakia. The introduction of UNI - gasoline has significantly

Figure B.10 Technological Layout of Motor Gasoline Production at Slovnaft After 1992



changed the characteristics of the gasoline market in the country (**Figure B.11**).

Since the beginning of 1995, only unleaded gasolines have been distributed in Slovakia. The Republic was one of the first four European countries (after Austria, Finland and Sweden) to use only unleaded gasoline.

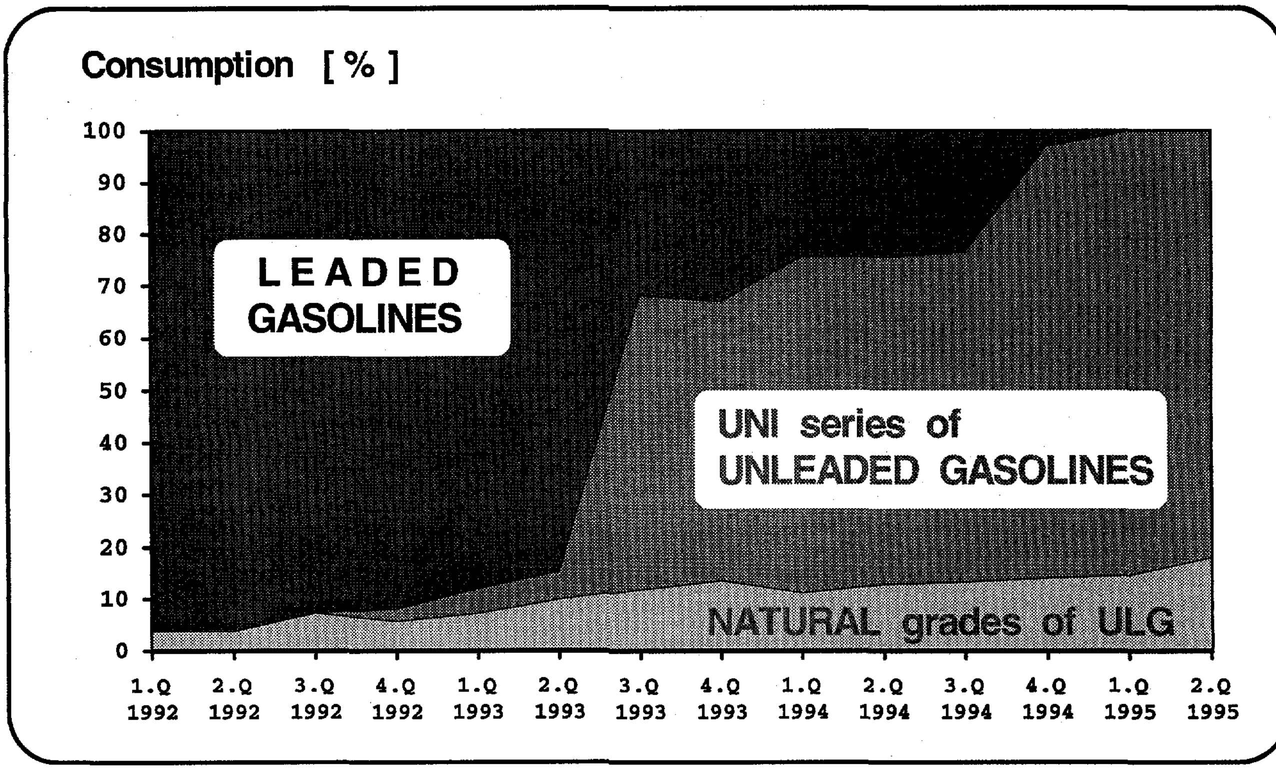
Distribution Issues

The new UNI gasoline — *UNI GASOLINE - 91* — was introduced to the market on August 12, 1992. Mass distribution began in July 1993, when Slovnaft stopped production of leaded gasoline *SUPER - 96,* and the unleaded gasoline *UNI SUPER - 95* was introduced and started to be distributed throughout the Slovak Republic. Simultaneously, the production of *UNI GASOLINE - 91* was expanded and its distribution spread throughout Slovakia. By the end of 1994, the percentage share of leaded gasolines was less than three percent (**Figure B.12**).

The transition was discussed and coordinated with Benzinol joint-stock company, which at that time owned the majority of filling stations in Slovakia (Slovnaft and Benzinol together owned all gasoline distribution terminals). The replacement of the leaded gasoline *SUPER - 96* with unleaded gasoline *UNI SUPER - 95* did not incur any additional investment in construction of new storage tanks for the new type of unleaded gasoline *UNI SUPER - 95.* The total compatibility of these two types of gasolines contributed to the problem-less transition.

The replacement of the leaded gasoline *SPECIAL - 91* by unleaded *UNI GASOLINE - 91* occurred in stages from August 1993 to December 1994, in the distribution terminals of Slovnaft and Benzinol. Similarly to the shift to 95 RON unleaded gasoline brands, there was no need to construct new tanks for storage of the new type of unleaded gasoline.

Figure B.11 Gasoline Market Structure in Slovakia, 1992 - 1995



The transport means (pipeline, rail- and autotankers) previously used for leaded gasolines were utilized after proper cleaning.

Additional Environmental Benefits

In addition to reducing lead emissions, the replacement of leaded gasoline with unleaded has additional positive effects. For example, the emission of halogen compounds (chloroalkanes and bromoalkanes) associated with the use of lead additives (in the form of lead scavengers) has also been reduced (**Figure B.13**).

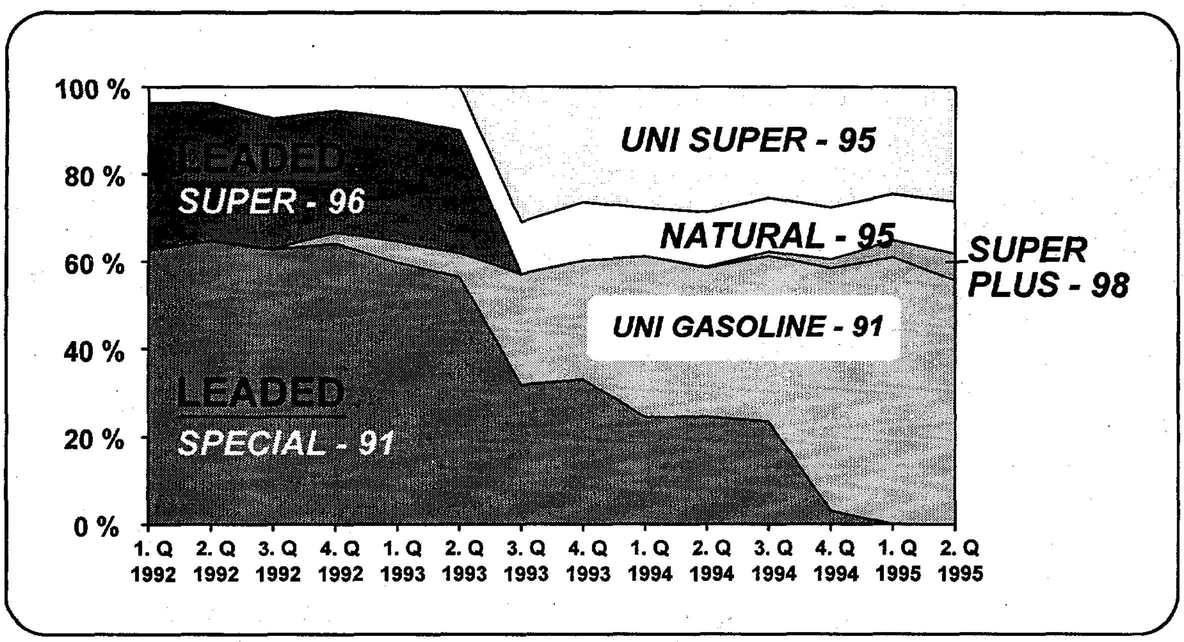
The Economics of Phasing Out Leaded Gasoline Production

In order to complete the transition from the production of leaded to unleaded gasoline, Slovnaft has:

- Invested in a unit for isomerization of light naphtha;
- Developed the lubricating additive with trade name ANABEX® - 99; and
- Invested in a special unit for the production of ANABEX® - 99 additive.

The investment costs of new units (approximately US$ 25 million), together with the increased operating costs associated with producing unleaded gasoline brands compared to leaded ones, amounted to an average of 700 SK / MT (0.53 SK / liter), or about US$ 0.02 per liter. The relatively small increase in production price, together with the lower consumption tax for unleaded gasolines, has resulted in lower retail prices for unleaded gasolines at the filling stations, which facilitated the rapid atancccepe of unleaded gasoline brands.

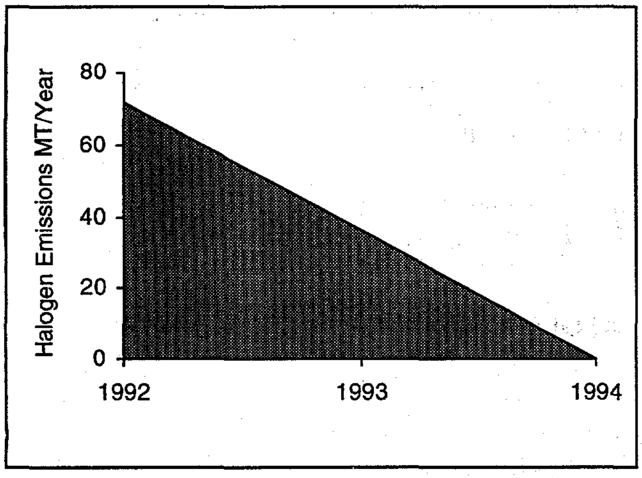
Figure B.12 Development of Gasoline Structure in Slovakia, 1992 - 1995



Box B.1 Key Factors of Success in Eliminating Lead from Gasoline in the Slovak Republic

- The commitment to environmental improvement in Slovakia by all interested parties;
- Tax incentives for the production and consumption of unleaded gasoline;
- General advancement in environmental understanding and changes in consumers' values and mind set;
- A long-term strategy for the modernization of gasoline production technologies;
- Participation of a highly qualified, expert team in the Research Center of Slovnaft Refinery;
- Highly motivated management teams in the Slovnaft and Benzinol companies; and
- Relatively centralized and easily controlled gasoline distribution network.

Figure B.13 Reduction of Halogen Emissions in Slovakia, 1992 - 1994



Bibliography

Truska, P and, Balázová. 1990. Environment Pollution and the Contamination of Food and Biological Materials with Toxic Metals in Selected Slovakian Localities. (In Slovakian). Institute for Preventive and Clinical Medicine, Bratislava

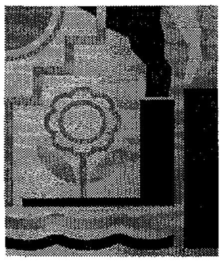
Uhnák, J. and Rippel, A. 1986-1989. Environmental Impacts of Chemicals in Agriculture. (In Slovakian). Institute for Preventive and Clinical Medicine, Bratislava.

Ursínyová, M. 1994. Environmental Pollution and Contamination of Food with Cadmium, Lead and Mercury in Selected Slovakian Localities. (In Slovakian). Ph.D. Disservation.

Šovcíková, E. 1995. Correlation Between Low Blood Lead Levels and the Neuro-psychological Development of Children. (In Slovakian). Institute for Preventive and Clinical Medicine, Bratislava.

WHO. 1987. Air Quality Guidelines for Europe. World Health Organization, Regional Office, Copenhagen.

WHO 1995. Concern for Europe's Tomorrow: Health and Environment in WHO's European Region Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart.



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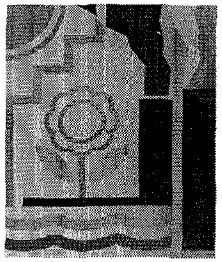


Annex A

Refining Capacity in Central and Eastern Europe and the Former Soviet Union

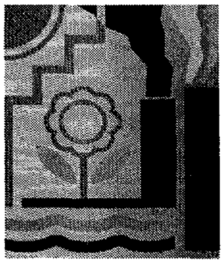
Annex Table A.1 Refining Capacity in Selected Countries in Central and Eastern Europe and the Former Soviet Union

Country	No of Refineries	Capacity b/cd	Charge Capacity (b/cd)							Production Capacity (b/cd)							Gasoline		
			Vacuum Distillation	Thermal Operation	Cat. Cracking	Cat. Reforming	at. Hydro- Cracking	Cat.Hydro- Refining	Cat. Hydro Treating	Alkyl. Polim/Dim	Aromatic/ Isomeriz.	Lubes Exyten	Oxygen	Hydrogen	Coke	Asphalt	Max. Lead Content	Unleaded Prod. as% of Total	Unleaded Market Share (%)
Albania	3	40,000															*na*	na	na
Armenia	0	0															*na*	0	0
Azerbaijan	2	441,808	137,200	38,529	32,986	24,466			25,300	930		27,064			1,400	4,151	na	na	na
Belarus	2	724,967	67,661			98,108			342,107		9,687	7,142				9,630	0.8	90	70
Bulgaria	3	300,000	70,000	30,000	30,000	14,000		30,000	30,000	5,000			1,200				0.15	23	15
Croatia	3	294,275	61,200	17,230	32,000	37,400			51,540		24,507	2,620			170		0.6	40	30
Czech Rep.	4	187,139	52,313			24,798	22,000		82,285		2,700	3,770	2,063	103.4		12,698	0.15	47	55
Estonia	0	0															0.15	0	77
Georgia	1	106,436	24,809			10,276			10,800							3,819	0.37	na	98
Hungary	3	232,000	116,500	14,000	24,000	29,600		38,000	59,000	3,300	9,800	4,200	1,860			10,800	0.15	60	60
Kazakhstan	3	393,611	121,037	55,068	38,356	59,452			207,353	1,003				21.5	1,000	8,550	na	na	na
Kyrgyztan	1*	10,000															na	na	na
Latvia	0	0															0.15	0	~50
Lithuania	1	263,420	83,223	29,525	43,692	25,741			213,363				1,061	24.6		6.333	0.15	100	78
Macedonia	1	51,180				10,780			20,740		3,490						0.6	na	na
Moldova	0	0															0.37	0	0
Poland	7	352,000	144,500		46,000	39,000			110,600	3,000	4,270	4,800	1,600			17,300	0.15	70	70
Romania	10	655,434	219,675	131,072	109,792	97,082	1,534	22,178	295,590	2,300	20,003	11,068	1,310	19.5	3,092	13,735	0.6	76	10
Russia	28	6,720,905	2,123,861	503,067	379,533	843,447	38,356	8,630	2,150,000	11,735	70,898	117,155	2,625	96.8	4,070	167,063	0.6	~50	~50
Serbia	2	168,246	74,850	21,700	20,750	21,033		18,970	28,500	3,400	2,815	1,500		0.5		10,300	na	na	na
Slovakia	1	115,000	59,030			22,270	16,970		67,857	5,200	10,201	3,220		42.8		9,077	0.15	100	100
Slovenia	1	12,000												4.7			0.15	64	50
Tajikistan	0	0															na	0	na
Turkmenistan	2	236,970	71,231	28,568	15,151	32,540			33,300	2,251					1,040	415	na	na	na
Ukraine	6	1,261,539	429,898	39,468	60,545	155,811			412,152		9,643	7,128		21.5	1,155	19,177	0.37	85	70
Uzbegistan	2**	174,715	45,671	27,252		23,487			30,804			9,397			650	4,151	0.37	na	na

Source:Oil and Gas Journal Data Book PennWell Books, PennWell Publishing Co. Tulsa, Oklahoma, 1996; and *OGJ Special Dec. 18, 1995.; 1996; Abt Associates; 1995; Chem Systems, personal communication with local experts.*

* New refinery installed in Oct, 1996. (OGJ, Sep 9, 1996. p. 37)

** An additional 50,000 b/cd new refinery is under construction (OGJ, Aug. 26, 1996. p. 57)



Annex B

Selected Vehicle Emission Requirements[1]

European Union

Annex Table B.1 European Union Emission Standards for Passenger Cars* (g/Km)

Substance	*EC 93*	*EC 96*		*EC 2000*		*EC 2005*	
	Gas=Diesel	*Gas*	*Diesel*	*Gas*	*Diesel*	*Gas*	*Diesel*
HC + NO_x	0.97	0.5	0.7	-	0.56	-	0.3
HC				0.2	-	0.1	-
NO_x				0.15	0.08	0.08	0.25
CO	2.72	2.2	1.0	2.3	0.64	1.0	0.5
PM	0.14	-	0.08	-	0.05	-	0.025

* Vehicles for less than 6 passengers
Test: ECE/EUDC
EC 93: 91/441/EEC Directive defines EC 93 requirements for normal passenger cars. Directive 93/59/EC includes 91/441/EEC plus EC 93 requirements for large passenger cars and light duty trucks.
EC 96: Directive 94/12/EC
EC 2000/2005: EU Commission Proposal of June, 1996, expected publication of final rule: end of 1997.

Economic Commission for Europe (ECE)

Annex Table B.2 ECE R 15/04 and ECE 83 Regulations for Leaded Gasoline (Approval A) (g/test)

Substance	*Referemce volume (kg)*						
	Larger than 1020	*Larger than 1250*	*Larger than 1470*	*Smaller than 1720*	*Smaller than 1930*	*Smaller than 2150*	*Larger than 2150*
HC + NOx	19	20.5	22	23.5	25	26.5	28
CO	58	67	76	84	93	101	110

[1] *Source: Emission Standards Passenger Cars Worldwide.* Delphi Technocal Centre, Luxembourg. October, 1996; CEE, 1996a.

Annex Table B.3 ECE R 83 Unleaded Gasoline (Approval B) (g/test)

Substance	*Engine Displacement**		
	Smaller than 1.4 L	*Between 1.4 and 2 L*	*Larger than 2 L*
HC + NOX	15	8	6.5
CO	45	30	25
NOx	6	-	3.5

* Limits for manual transmission. Automatic transmission limits are multipliead by 1.3 for NO_x and 1.2 for $HC+NO_x$

United States

Annex Table B.4 United States Federal Vehicle* Emission Standards (g/Km)

	1980	*1987*	*1995*	*2001*
HC	0.25	0.25	0.16	0.08
NOx	0.62	0.62	0.25	0.124
CO			2.1	1.06
PM	0.37	0.12	0.05	0.05

* Vehicles for no more than 12 passengers

United States, California State

Annex Table B.5 California Vehicle Emission Standards

Substance	*Conventional Vehicles*	*TLEV*	*LEV*	*ULEV*	*EZEV*	*ZEV*
NMHC	0.39	-	-	-	-	-
Nox	0.4	0.4	0.2	0.2	0.02	0
CO	7.0	3.4	3.4	1.7	0.17	0
PM	0.08					0
NMOG	-	0.125	0.075	0.040	0.004	0
HCHO	0.015	0.015	0.015	0.008		0

HMHC: non-methane hydrocarbon
NMOG: non-methane organic gases
HCHO: Formaldehyde
TLEV: Transitional Lew Emission Vehicle
LEV: Low Emission Vehicle
ULEV: Ultra Low Emission Vehicle
EZEV: Equivalent ZEV
ZEV: Zero Emission Vehicle

Annex C

Reference Gasoline Specifications

Annex Table C.1 Current and Proposed Gasoline Specifications in the EU and the US

	EU	*EU Proposal for 2000*	*US Conventional Gasoline*	*1995 Fed. Phase I*	*2000 Possible Fed. Phase II*	*1995 California CARB 2*
RVP, psi	10-15	8.7	8-9	7-8	6.5-7	7
Aromatics, V%	NA	45	33	25	25	25
Benzene, V%	5.0	2.0	2-3	1.0	1.0	1.0
Oxygen, wt%	2.5-3.7 max	2.3 max	-	2.0 min	2.0 min	2.0 min
Olefins, V%	NA	18[1/]	9.0	~ 9.0	~ 9.0	4.0
Sulfur, pm	500 max	200 max	~ 330	~ 330	~ 200	40
Lead, g/l	0.13 max	0.005 max	0.013	0.013	0.013	0.013

Source: CEC, 1996b; Comitee European de Normalisation; Texaco.

1/ Except for regulat unleaded gasoline for which maximum olefin content should be 21 V%.

Annex D

Recommended Gasoline Use in Selected Car Models

Annex Table D. 1 Gasoline Use Recommended by Shell Corp. for Selected Car Models

Vehicle Model	*Unleaded RON*	*Leaded RON*
Dacia		
1200; 1300; 1400; 1310; 1410 TLE; ARO 10.0; ARO 10.3	95	
Daihatsu, all models	95	
Fiat		
Panda 34; 45/45S; 750; Uno 45 (900) - 45 Sting; Tipo	95	
126	95[1/]	96
Panda 1000; 4x4; Uno 45 S Fire 1000; 55; 60; 65; 70; 127, 1050; 1050 GL/Panorama; 128		
Uno 45 ES; Turbo; 127 Sport 1,11; 1,31	95[2/]	98
Ford		
Fiesta; Escort; Capri; Taurus; Sierra; Granda; Scorpio	98 or 95[3/]	(98)[3/]
Honda		
Accord; Civic; Quintet; Prelude	95[4/]	(96)[4/]
Lada all models	95	
Mazda		
Most models		
Models produced before 1981	95	96
Mercedes-Benz		
124 Series	95	
126 Series	95[5/]	98[5/]
107 Series	98[5/]	(98)[5/]
Mitsubishi, all models	95 or 98	
Nissan, all models	95 or 98	
Opel		
Corsa; Kadett; Ascona; Manta; Vectra; Rekord	98 or 95[6/]	
Polonez, all models	95	
Skoda		
105; 120; 130; 130 LX Rapid	95[7/]	
Rapid 136 L; Favorit 136 L	95	(96)[7/]
Toyota all models	98 or 95	
Trabant	95/92	
Wartburg	95/92	
Yugo 45; 511		98

Source: Benzinbogen. 3. Udgave Nu Kan Mange Flere Kere Blyfri. (Information booklet on the use of unleaded gasoline) A/S Dansk Shell, Denmark. 1989.

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