REPORT ON ENVIRONMENTAL CONDITIONS AT AMPELLUM S.A. AND COPPER MINES WITH RELATED HUMAN HEALTH RISK ASSESSMENT IN ZLATNA, ROMANIA

OCTOBER 11 - 15, 1993

WORLD ENVIRONMENT CENTER
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INTRODUCTION

The Romanian government requested the assistance of U.S. AID to improve severe environmental conditions in the town of Zlatna and its vicinity, one of the designated "hot spots" in this country. In response to this request, U.S. AID recommended that the World Environment Center (WEC) initiate steps to develop a program for corrective action under the U.S. AID - WEC Cooperative Agreement (ANE-0004-A-00-0048-00).

On March 23, 1993, WEC's headquarters staff and its in-country coordinator visited the Ampellum S.A., a copper smelter in Zlatna, the main pollutor of this area. As a result of this visit, it was concluded that WEC would organize a team of specialists who would assess the present status of environmental and related conditions at the Ampellum S.A., copper mines and in the town of Zlatna and its vicinity, and develop recommendations for improvements.

On October 11, 1993, WEC's team consisting of Dr. Gail Charnley, Consultant on Toxicology; Mr. Meliton Garcia, Industrial Hygienist with E G & G, Inc. (Managers of Idaho National Engineering Laboratory), Department of Environmental Restoration and Waste Management; Mr. David Swan, retired executive from Kenncott Copper Corp.; Dr. John W. Wilson, Chairman and Professor, Department of Mining Engineering, University of Missouri - Rolla, and Mr. Thomas J. McGrath, Vice President with WEC, arrived at Zlatna to initiate the assessments. During their five day stay, the members of the team undertook the following specific assignments:

Dr. Gail Charnley	-	Perform Human Health Risk Assessment for the town of Zlatna and vicinity;
Mr. Meliton Garcia	-	Perform Workers' Health and Safety Assessment at Ampellum S.A.;
Mr. David Swan	-	Perform Environmental Assessment at Ampellum copper smelter; and
Dr. John W. Wilson	-	Perform Environmental Assessment at the copper mines, including workers' health and safety conditions.

Reports on their findings and recommendations follow this introductory section.

As the reader will note, environmental conditions are severe and are adversely affecting the health of the workers, their families and local residents.

It is not the intent of this introduction to try to summarize the reports of the consultants. Rather, it is to make some general observations and recommendations.

Copper mines have been worked in this region since the time of the Roman Empire and copper has been smelted in Zlatna since 1747.

The severe environmental problems are a direct result of the lack of concern under the Communist regime. The management of Ampellum S.A. anxiously wants to eliminate the causes of its industrial pollution, but lacks the funds. On the second hand, current law prohibits Ampellum S.A. from exporting its electrolytic copper from which it would obtain convertible currency that would be used to update its technology and eventually bring the smelting operation within EC standards.

During the team's visit, it became apparent that closing the smelter would not be a solution to be desired by anyone, especially since such action would idle 2,400 employees at Ampellum S.A. and 35,000 miners which could lead to serious social repercussions. The local EPA, which is very critical of Ampellum S.A., also agrees that the smelter must remain in operation.

Therefore, the experts searched for possible practical solutions which would keep the smelter on stream and, at the same time, would significantly reduce the health hazards caused by the emissions from its operation.

Mr. Swan has recommended a solution currently in practice which could help bring emissions within a country's ambient air standards. He has proposed that a monitoring system based on meteorological data be established to control production which would permit atmospheric dispersion of sulfur oxides within the limits of ambient air standards. This is not a new procedure, but one that has been used and accepted by regulatory officials.

Although this proposal does not correct the causes of the air pollution, it could as a temporary means, allow the smelter to continue operation with an acceptable health risk exposure based on ambient air standards.

We suggest that, in addition to this recommendation, funds also be obtained to introduce Mr. Garcia's health and safety program because the factory workers are the ones most exposed to health hazards.

Since appearances are also important factors, along with the two preceding proposals, we would also recommend that funds be allocated for housekeeping improvements, i.e. such as painting, cleaning, etc. It does not require large sums of money to sweep up and do minor repairs as part of a pollution prevention program Experience has shown that such steps greatly improve worker morale, help the worker to become more environmentally aware and, ultimately, increase manufacturing efficiency.

During final discussions with Ampellum S.A. management, WEC strongly stressed the need for community and regulatory involvement in any recommendations it would make. WEC proposed that, should the necessary funding be obtained, a committee consisting of representatives of Ampellum S.A., the copper mines, local and county officials, and NGOs must be established to oversee the implementation of such recommendations. Ampellum S.A. management agreed to participate and cooperate with all involved.

WEC's specialists estimate that the overall cost involved could be approximately $600,000 - $700,000.

WEC suggests that Zlatna could become a model program for addressing "hot spots" in a cost-effective and environmentally acceptable manner.

ENVIRONMENTAL ASSESSMENT

AMPELLUM S.A.

ZLATNA, ROMANIA

BY: DAVID SWAN

OCTOBER 11 - 15, 1993

World Environment Center
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DECEMBER 1993

This is a report of a visit to the Ampelum Co. Smelter, located in Zlatna, Romania, from 11 October to 15 October 1993. It is intended to provide an assessment of the smelting plant from an environmental point of view, and to recommend changes to allieviate any environmental problems.

The Smelting Process (Fig. 1 and 2)

The smelter comprises two separate facilities - a reverberatory furnace-converter plant and a flash furnace-converter plant. Both smelters rely on the same basic technology, commonly called matte smelting. Briefly the process consists of melting copper concentrates, containing about 16% copper together with 32% iron, 6-8% silica, and 33-35% sulfur, in a large furnace at a high temperature (ca. 2700 deg.F). Part of the sulfur reacts with the copper and iron to form cooper matte containing about 35% copper, 20% iron, and 25% sulfur in the case of the reverberatory furnace. The flash furnace produces a higher grade matte, containing 50% copper. The remainder of the sulfur is oxidized to sulfur dioxide gas. Other impurities react with iron and silica to form an iron silicate slag which floats on top of the slag and is periodically skimmed. The molten matte is transferred to converters where air is blown into the molten bath to oxidize the sulfur as a gas, and where silica flux is added to form a slag with the iron and remaining impurities. The copper which remains is called blister copper, which is further refined to cast as anodes for purification by electolysis to cathode copper.

The major difference between the flash smelting process and reverberatory furnace is in the length of time required to produce matte. The flash smelter directly injects dried copper concentrates into a burner, resulting in a very rapid conversion to matte, whereas the reverberatory process depends on external fuel burning to provide the necessary melting energy, a time consuming process, requiring hours to complete compared with minutes for the flash process. Associated with this is excessive dilution of the sulfur containing off gases, which makes a capturing sulfuric acid plant impractical.

While environmental impacts occur at each stage of the process, a principal effect comes from the SO2 gas produced during smelting. Other important environmental effects occur when installed equipment is either bypassed or does not function effectively. Of greatest concern is the possibility of impurities present in the concentrate being released to the atmosphere. Since the concentrates contain significant quantities of lead-reported as of the order of 1-1.5%, a potential for serious health effects are present.

Control Technology

Hot Gas Cleaning

The off-gas stream from the smelting furnace and converters contains sulfur dioxide, some sulfur troxide, entrained dust, volatile metal oxides (typically lead and zinc) and water vapor. If the temperature of the gas drops below the acid dew point (about 400° F), acid mist can condense as sulfuric acid, causing severe corrosion problems. To prevent this, hot gas cleaning is normally carried out above this temperature by means of electrostatic precipitators. In addition, significant amounts of dust are collected in the furnace and converter flues. Waste heat boilers are also often used to permit heat recovery from the hot off gases.

Acid Plants (Fig. 3)

The principal technology used to capture sulfur from copper smelters is the contact sulfuric acid process which produces high strength sulfuric acid by using a catalyst to oxide the SO_2 to SO_3 and absorbing the gas in high strength acid. The sulfur free tail gases are vented to the atmosphere.

The smelter has only limited gas treatment facilities installed. According to the flow sheets furnished by the smelter management, the flash furnace generates 50,000 Nm^3/h and the converters contribute an additional 40,000 Nm^3/h of sulfur bearing hot gases. Of this 90,000 Nm^3/h total, the installed acid plant treats only 47,000 Nm^3/h (52% of the total gas flow, and calculated to contain about 62% of the total sulfur fed to the smelter). Presumably all of the gases are treated to remove particulates, although no data was furnished regarding the efficiency of installed equipment. These calculations also ignore the availability of the acid plant over time. USA practice typically assumes 93-95% availability on an annual basis.

To summarize, the Flash smelter is currently capable of capturing about 60% of the sulfur contained in the concentrates it receives. To increase this would require installing new equipment to increase the sulfur concentration in the gas fed to the acid plant, or alternatively, installation of more acid plant capacity, either of which would require substantial additional investment.

The reverberatory-converter smelter (the old smelter) is currently treating off gases for particulate removal only. At one time, an acid plant was installed to capture sulfur from converter off gases, but apparently did not perform satisfactorily and was abandoned. Reverb off gases are too low strength (0.054% SO_2) to permit recovery in an acid plant. Concentrates are fed directly to the reverberatory furnace (known as green feed charging) without any preliminary roasting or drying. Installing a fluid bed roaster ahead of the reverberatory furnace would permit a high strength (10-13% SO_2) gas to be produced, suitable for sulfur recovery in an acid plant. Up to 50% of the sulfur in the feed can be captured with this technology. By combining this with treating converter off gases up to 90% of the sulfur in the feed could be captured. To employ this strategy would require substantial new investment in roasters and acid plants.

Atmospheric dispersion

Either as a substitute for, or as a primary control technique, atmospheric dispersion of sulfur oxides may be chosen as a sulfur control strategy. To be effective in meeting ambient air standards two conditions must be met: (1) a stack sufficiently tall to permit dispersion and dilution of sulfur containing gases must be built, and (2) a monitoring and control system to permit production curtailment in sufficient time to prevent violating ambient air standards.

The new smelter has a tall stack installed on top of a nearby hill at a 400m elevation above the smelter. Presently, there is no real time SO_2 monitoring available. A single on site monitor is under construction. An effective system would require the construction of a network of monitoring stations tied to a central control station with authority to order production curtailment when required.

Of the options discussed above, the least capital intensive would be atmospheric dispersion, combined with capturing a portion of the sulfur contained in the off gases from the two smelters. This would require diverting all sulfur bearing gases to the tall stack, as well as setting up and testing an ambient air quality monitoring network.

The degree of production curtailment necessary to meet ambient air standards cannot be estimated without adequate monitoring data. A plan to collect and correlate such data with production and atmospheric measurements should be developed as the first step in an overall program. Before the number and locations of specific monitor sites are chosen, a series of measurements by a mobile monitor should be made over a sufficiently long period to encompass normal variation in seasonal weather patterns, perhaps six months to one year. Another important requirement is to improve coordination between the smelter management and the environmental control agencies responsible for compliance. Presumably, existing standards should be reviewed and updated as necessary, with inputs from all interested parties.

Water Pollution (Fig. 4 and 5)

The major water pollution problems at Zlatna are associated with mining operations, including the concentrator, and not with the smelter. A total usage of 1109000 cubic meters of water was reported for 1992, of which 700000 cubic meters was processed in a treatment plant for filtration and clarification. Settled sludge is deposited in a storage pond. We were told that a major upgrading of the Mining Companies waste and water pollution control facilities was underway.

Capital and Operating Costs

Acid plants are expensive to build and maintain. Assuming an average gas grade of 4-6% SO_2, U.S. capital cost for new construction acid plants would be of the order of $25,000,000. Annual direct operating costs would be perhaps $2.5 million additional. While direct comparison with Romanian costs would require detailed estimates, the required capital investment for capturing all of the sulfur fed to the smelter would be very high, suggesting that other strategies for meeting environmental standards should be considered.

According to data furnished by the smelter management, the existing acid plant treats 47000 Nm^3/hr of gas containing 4% SO_2 (Fig. 3). By increasing the average SO_2 concentration to 8%, acid capacity could be doubled. This could be achieved my installing additional oxygen plant capacity to enrich the air fed to the flash smelting furnace from its existing 30% 0_2 to 53% 0_2.

Installing a fluid bed roaster to remove sulfur from concentrates fed to the reverberatory furnace would allow the old smelter to produce a gas stream suitable for mixing with other offgases to permit feeding to a sulfuric acid plant. Capital and operating cost estimates would need to be developed to assess the desireability of incorporating this approach to increasing sulfur capture.

The preceding discussion has focused on acid plants as the principal method for capturing sulfur. Such a method is economically feasible as long as a market demand for the acid exists. Absent such demand, other alternatives for sulfur capture and disposal must be considered. A large number of processes capable to capturing sulfur from weak gas streams have been proposed and tested, mostly relying on scrubbing the gases with a reagent such as limestone, and fixing the sulfur as gypsum. The thrust for this development has largely been provided by the desire to burn high sulfur coal in thermal power plants. A few smelters in Japan have employed scrubbers to capture sulfur.

Smelter Closure

Environmental standards could be met by either fully or partially shutting down smelting operations. Such a drastic solution should be carefully examined before being invoked. In addition to the 2,400 smelter employees, the smelter is necessary to the mining operations which provide it with concentrates, as well as being one of the main sources for refined copper for Romanian industry. If shut down, presumably the country's copper needs would have to be imported. Thus, significant upstream and downstream economic and social effects would occur. Most of these would be adverse, and of potential national impact. Because of the remote location of the smelter, and the absence of employment opportunities nearby, the expenses of providing for the welfare of the local population would result in significantly straining government resources.

Air Quality Standards

Air quality standards usually specify limits of concentration permitted in ambient air for specified periods of time, i.e. 3 hours, 24 hours, annual. They are based on averaging measurements taken at specific monitoring locations. Locations are usually determined by such factors as population densities, critical ecosystem locations and the like. In addition, emission limitations for specific types of sources are often specified, particularly for multiple and/or mobile sources. Standards designed to prevent significant deterioration of air quality are often issued to protect scenic areas and the like. The potential for damage at long distances from a pollution source has also received considerable attention, particularly where international boundries are involved.

Because atmospheric conditions are widely variable, the probability of violating a standard at a particular location depends heavily on specific local weather factors. This has led to the widespread use of tall stacks as a device to permit atmospheric dispersion and dilution to permit compliance. The inherent tension between the desire to prohibit all emissions and the economic impractibility of achieving "clean room" conditions on a global basis has led to various compromises. Among those which have been successfully practiced on a broad scale are so-called supplementary control systems, which permit higher emission rates during favorable meteorological conditions, and lower permissible rates during unfavorable atmospheric conditions. The problem of increasing total atmospheric loadings is handled by setting annual emission limitations. To ensure against violation of ambient air standards and to provide the smelter operator of unfavorable atmospheric conditions a monitoring network must be set up to report on local ambient air concentrations so that operations can be curtailed as necessary to avoid violations. Compared with the capital and operating costs of constant control systems with a high degree of control, the cost is almost inconsequential - $250,000 - $500,000 compared with $30-50 million for acid plant technology.

Recommendations

1. Develop a compliance plan for the smelter which

- results in complying with Romanian ambient air standards

- maintains current throughput of concentrates

- relies on periodic production curtailment as necessary to meet standards

2. Undertake a program of monitoring ambient air quality in the vicinity of the smelter

   - set up mobile monitoring equipment to permit optimun siting of permanent stations

   - provide for cooperative interpretation of results with environmental authorities

SCHEMA DE OBTINERE A CUPRULUI ELECTROLITIC

FIG. 1 LA S.C. „Ampelum" SA Zlatna

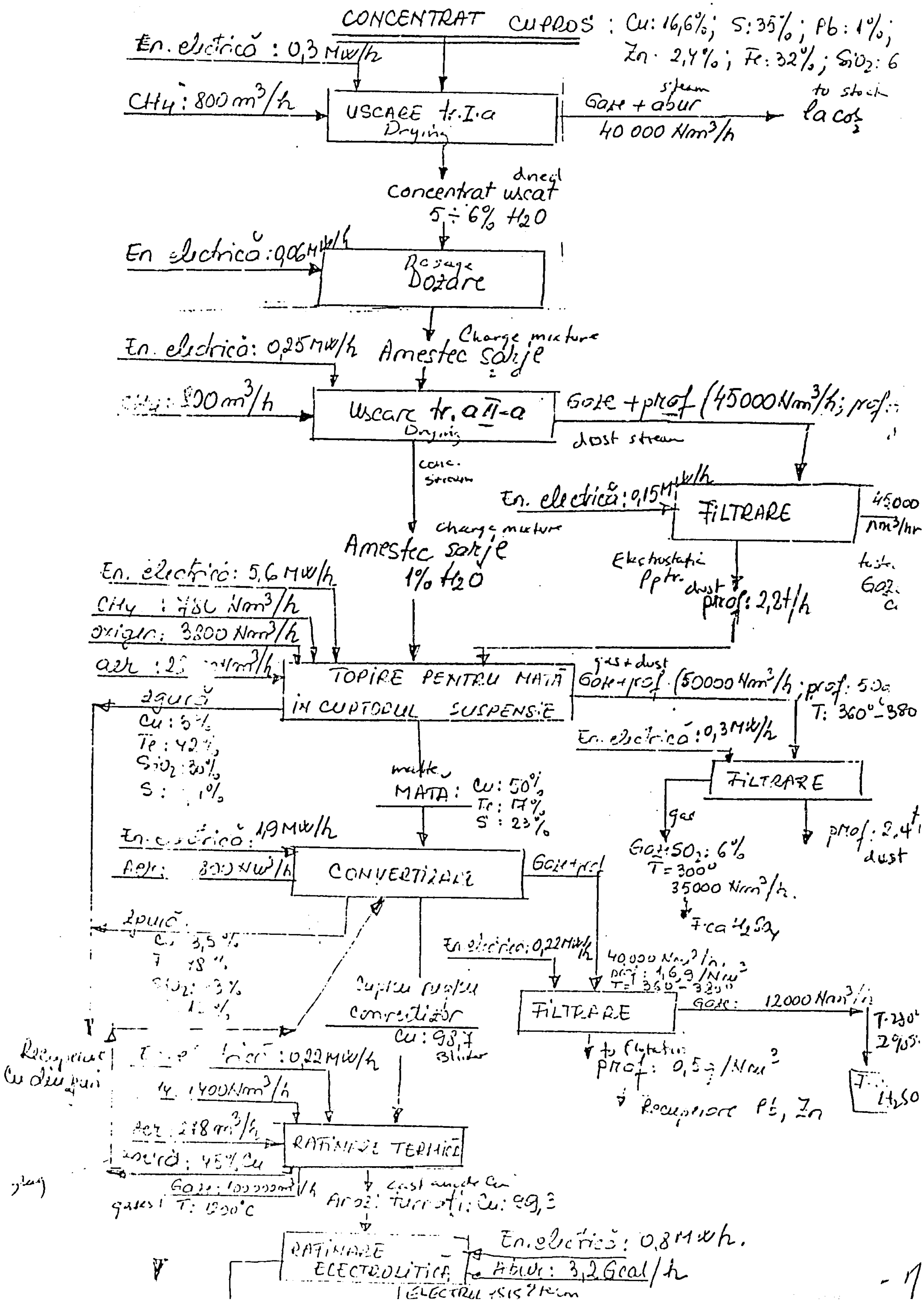


FIG. 2

Old smelter

SCHEMĂ DE OBȚINERE A CUPRULUI DE CONVERTIZOR - UZINA ...

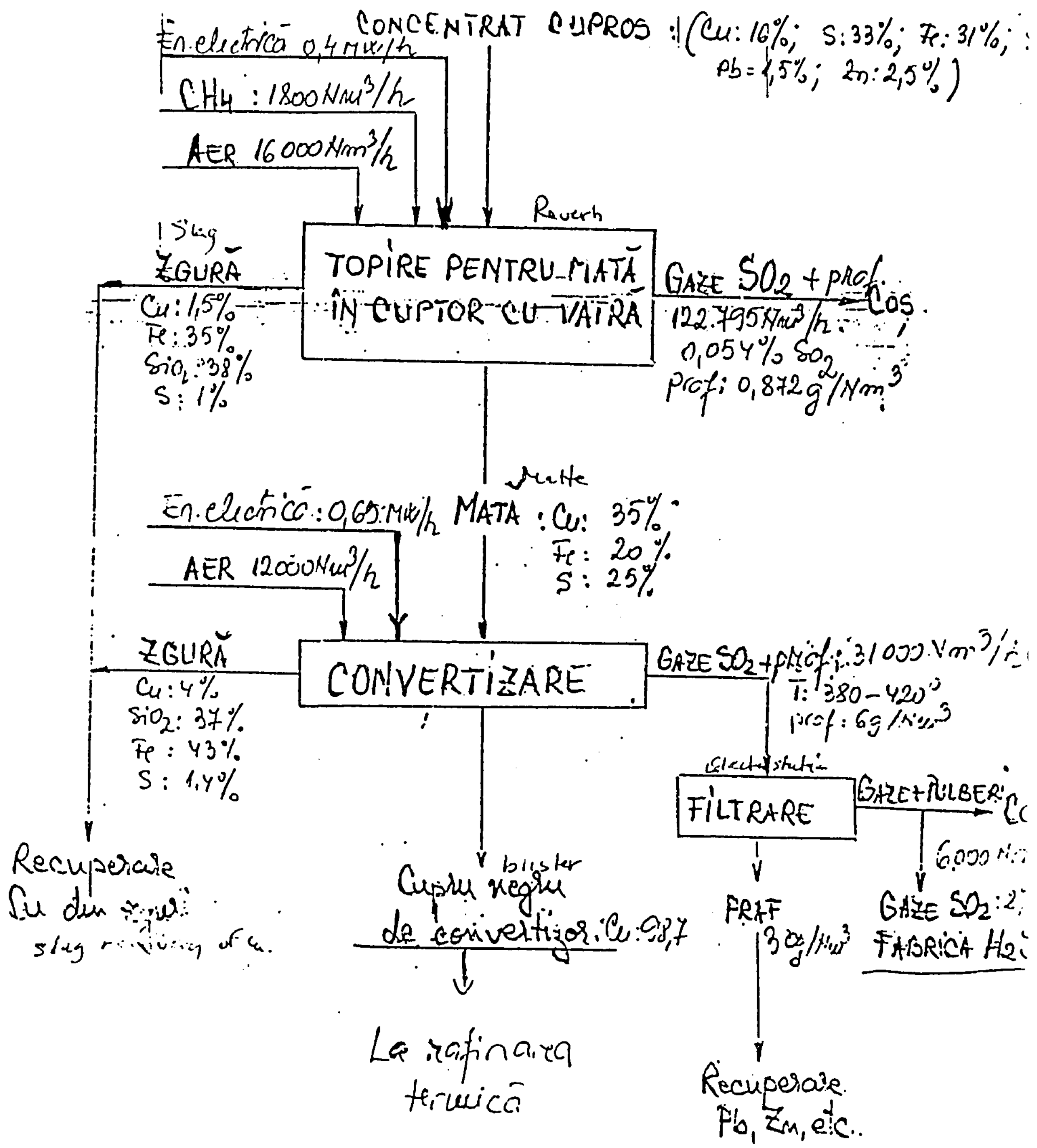


FIG. 3 H_2SO_4

SCHEMA DE OBTINERE A ACIDULUI SULFURIC

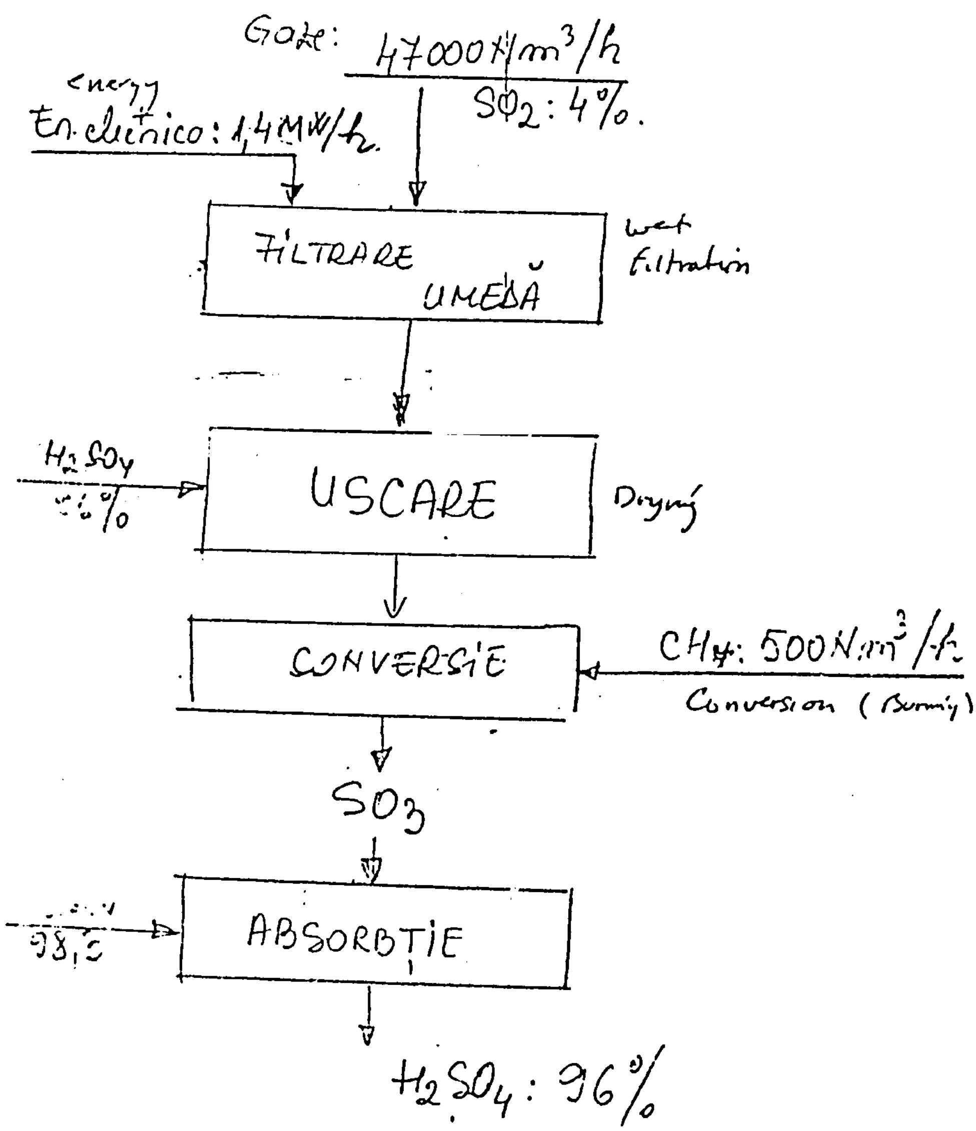
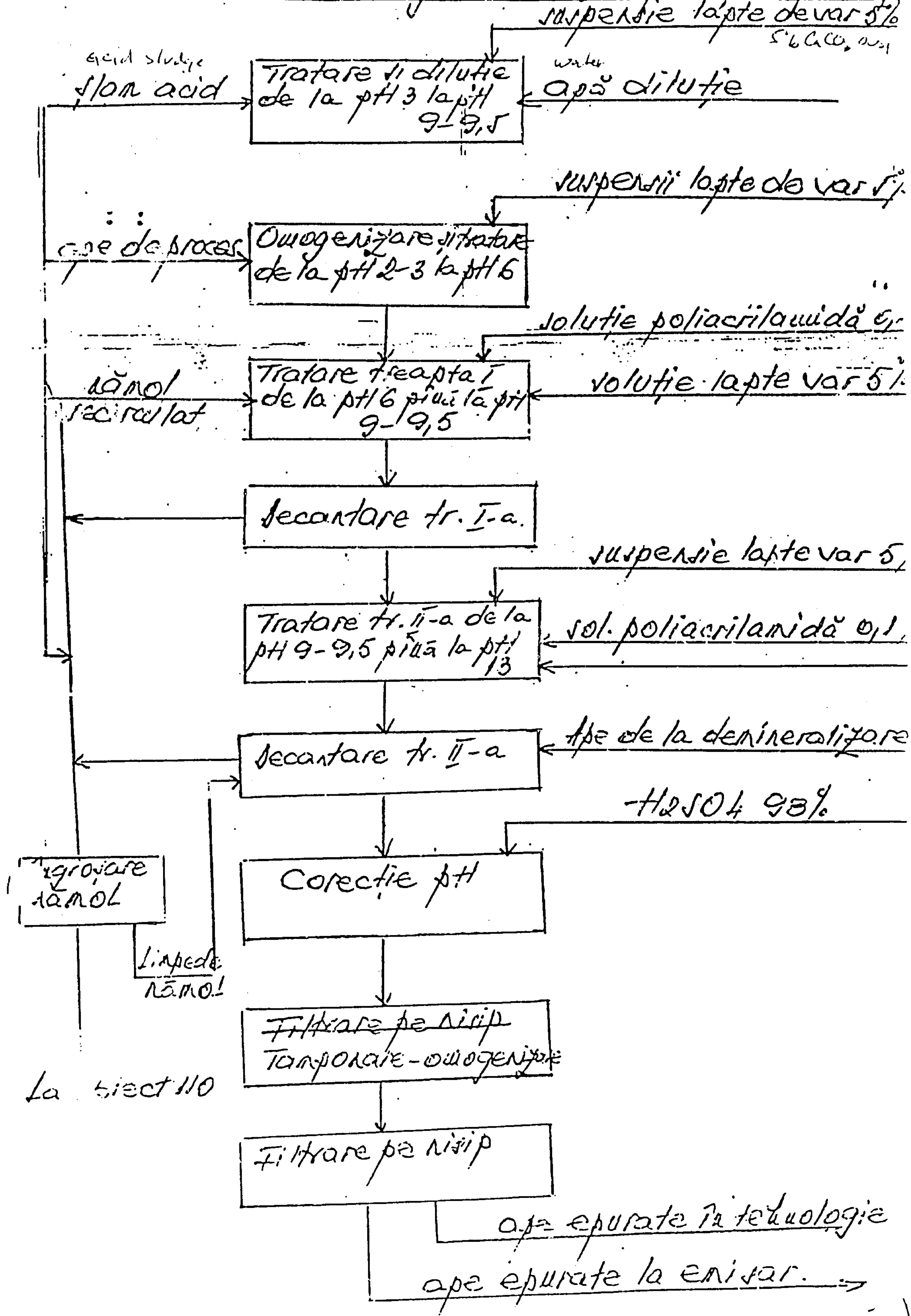
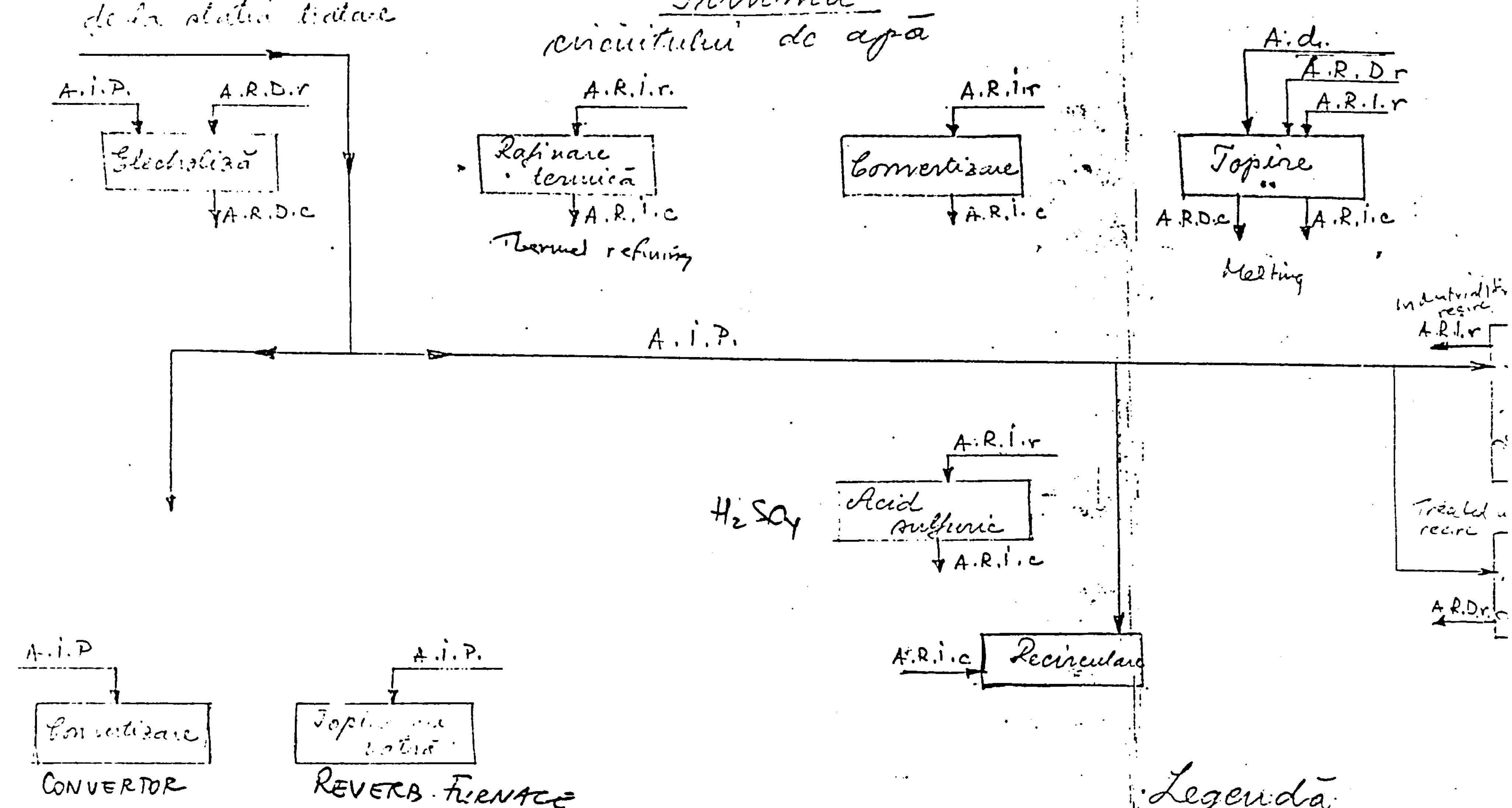


FIG. 4

Procesul tehnologic – schema operațiilor principale



Schema circuitului de apă



Legendă

AIP – FRESH INDUSTRIAL WATER
ARIR – RECIRCULATED COLD INDUSTRIAL WATER
ARDR – COLD RECIRCULATED DE-HARDENED WATER
ARIC – WARM RECIRCULATED INDUSTRIAL WATER
ARDC – WARM RECIRCULATED DE-HARDENED WATER
AD – DEMINERALIZED WATER

A.i.P. – apă industrială proaspat
A.R.i.r – apă recirculată industrială rece
A.R.D.r – apă recirculată dedurizată rece
A.R.i.c – apă recirculată industrială caldă
A.R.D.c – " – dedurizată caldă
A.d. – apă demineralizată

CURRICULUM VITAE

DAVID SWAN

Mr. Swan received his bachelors degree in metallurgical engineering from Rensselaer Polytechnic Institute in 1940.

A native of Arlington, New Jersey, he joined Crucible Steel Co. in 1940 as a metallurgical observer. In January 1942, he was called to active duty in the US Naval Reserve, serving through World War II on destroyers in the Pacific Ocean. He was discharged as a Lieutenant Commander in 1945.

Following military service, he joined Union Carbide Corporation as a research engineer at the company's Metals Research Laboratories in Niagara Falls, NY, where he ultimately filled the post of Director of Research. In 1957, he came to New York as Director of Research and Development of the Linde Division, being appointed Vice President the following year. In 1959, he was appointed Manager of Planning for Union Carbide Corporation. In 1960, he rejoined the Metals Division as Vice President-Technology. In 1964 he was made General Manager of the Defense and Space Systems Department.

In 1966, Mr. Swan joined Kennecott Copper Corporation as Vice President-Technology. While at Kennecott, he also served as a director of Quebec Iron and Titanium Co. and the Carborundum Co., both subsidiaries of Kennecott. He retired from Kennecott in 1983.

He has been active in a number of professional activities, serving the American Institute of Mining, Metallurgical and Petroleum Engineers as a Director, Vice President and as President of the Metallurgical Society, as well as Chairman of its Institute of Metals Division and its Niagara Frontier Section. He also served as Secretary and President of the Directors of Industrial Research. He has been a member of numeros other professional groups including the American Society for Metals, the Welding Research Council, the American Welding Society, the Iron and Steel Institute, the Engineering Foundation and the National Security Industrial Association. He has been elected a Fellow of both the Metallurgical Society and the American Society for Metals. He was also invited to deliver the Orton Lecture to the American Ceramic Society and was a Krumb Lecturer for the AIME.

In academic affairs he has served on a number of advisory boards, including the Metallurgical advisory councils of the University of Pennsylvania, Carnegie Mellon University and Polytechnic Institute of New York. He was a member of the Engineering Advisory Board of Rensselaer Polytechnic Institute and of the Colorado School of Mines Research Institute. In recognition of his contributions he was awarded the Demers Gold Medal by Rensselaer, and was elected a Fellow of the Polytechnic Institute of New York.

Among his business activities, Mr. Swan has been active in the American Mining Congress, serving as Chairman of its Environmental Matters Committee. He has been Chairman of the Technical Development and Patent Committees of the International Copper Research Association. He also served as President of the Smelter Control Research Association, and was founder and director of the Smelter Environmental Research Association. He served as a director of the William F. Clapp Laboratories of Battelle Memorial Institute. He has also been active on the Environmental Committee of the Business Round Table.

Among his governmental activities, he has served the executive branch as a member of numerous boards and committees, including the National Materials Advisory Board of the NAS-NAE, the Committee on Scope and Conduct of Metallurgical Research, reporting to the President's Science Advisor, the Department of Commerce National Industrial Pollution Control Council and Industrial Advisory Panel on Innovation (as Chairman of its Environmental Panel). For the Interior Department, he served on the General Technical Advisory Committee of the Office of Coal Research, and for the Department of Energy is a member of the Environmental Science Advisory Panel for Oak Ridge National Laboratory.

He has testified on numerous occasions before committees of both the House and Senate on behalf of the American Mining Congress as well as Kennecott, mostly in connection with Environmental activities or on Minerals Availability.

In addition to publications in welding, metallurgy, environmental matters and resource economics, Mr. Swan has been invited to present papers at numerous seminars, both in the United States and abroad, including the OECD, USSR, and as a contributor to International Symposia on Innovation held in New York and the Hague. He has also contributed chapters to several textbooks, including "Economics of the Mineral Industries" and "Modern Uses of Nonferrous Metals" He holds two US patents.

Since his retirement, Mr. Swan has continued as a consultant, and is currently associated with Charles River Associates of Boston, Mass. as a Senior Advisor, as well as with Inspiration Consolidated Copper Co. of Phoenix, AZ and with the Oak Ridge National Laboratory.

HUMAN HEALTH RISK ASSESSMENT

ZLATNA, ROMANIA

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OCTOBER 11 - 15, 1993

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HUMAN HEALTH RISK ASSESSMENT
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EXECUTIVE SUMMARY

This study was undertaken to evaluate the impact of copper smelting in Zlatna, Romania on the health of the surrounding community. Based on meetings held in Romania in October of 1993, on information and data obtained from Romanian doctors and scientists conducting studies in Zlatna, and on the international literature and regulatory standards related to the health effects of copper smelting-associated contaminants, a health risk assessment was performed. This assessment combined quantitative information on levels of contaminant exposure in Zlatna, where available, with information on the known toxicologic properties of those contaminants to obtain estimates of human health risk. Where quantitative analyses were not possible, qualitative evaluations of likely health effects were performed.

In the hazard identification step of the risk assessment, arsenic, lead, cadmium, and sulfur dioxide were identified as the contaminants of concern. In the exposure assessment step of the risk assessment, calculations were made on the basis of monitoring data to estimate dose levels of arsenic and cadmium received through breathing the air and incidentally ingesting the soil in Zlatna. For lead, a pharmacokinetic model was used to relate blood lead levels in children to sources of exposure, namely, air, water, food, soil, and household dust. Sulfur dioxide exposure was considered qualitatively, not quantitatively. In the dose-response step of the risk assessment, the inherent toxicologic properties of the contaminants of concern are described, as well as the adverse health effects that have been documented in Zlatna. Finally, in the risk characterization step, information on the dose level of each contaminant was combined with information on its toxicity to estimate the potential risks to health that may be experienced in Zlatna.

The conclusions of the health risk assessment show that emissions from the copper smelter in Zlatna are increasing the risks of adverse effects on the health of the surrounding community. The contaminants primarily responsible for increasing risks are arsenic, lead, and sulfur dioxide. The presence of arsenic increases respiratory cancer risk; that risk is increased further by the presence of high levels of sulfur dioxide. Sulfur dioxide also impairs respiratory tract function and increases the risk of acute and chronic respiratory disease. Blood lead levels among children have been reported at levels that are likely to be associated with growth, intelligence, and behavioral deficits. In addition, because monitoring data in Zlatna are not extensive, there may be exposures and health effects that this analysis was unable to quantify.

Reducing emissions from the smelter to the air will reduce the risks of respiratory tract diseases, including cancer. The primary sources of blood lead are soil and household dust, not air, however. Controlling exposures to soil and dust is more difficult than reducing air emissions, and may require measures such as restricting childrens' access to soil, promoting personal hygiene practices such as requiring smelter workers to shower and change clothes before returning to their homes, and promoting other dust control measures in homes such as frequent wet-mopping.

Environmental monitoring activities should be conducted on a regular basis and should include air, water, and soil sampling as well as sampling of foods representative of those grown or produced around Zlatna. Food may be an important additional source of heavy metal exposure. Monitoring results should be used to measure the impact of remedial measures such as reducing air emissions and should be made available to interested parties or published regularly. A regular monitoring program is likely to require a financial investment in modern monitoring equipment.

In addition to monitoring contaminant levels in environmental media, blood lead levels should be measured regularly in children, along with indicators of its toxicity such as IQ and growth rates. A concerted effort should be made to reduce lead exposure due to the insidious effects it can have on young children.

INTRODUCTION

This project was undertaken as part of a mission conducted by the World Environment Center (WEC), under a cooperative agreement with the U.S. Agency for International Development, to provide expertise to Eastern European industry and government representatives so that they can more effectively reduce environmental pollution and improve public health. The purpose of this project was to evaluate the conditions associated with copper mining and smelting in Zlatna, a town in Transylvania in western Romania. During the week of 11 October 1993, a WEC team assessed the engineering and industrial practices associated with the mine and smelter, as well as worker health and safety practices, and the impact of these industrial activities on the health of the community. This report focusses on the latter part of the investigation, that of assessing the environmental health impact of the copper smelter on the community of Zlatna.

Copper smelting releases a number of particulate materials, heavy metals, and sulfur oxides to the air, soil, and water. These releases have an impact on environmental quality and provide a source of human exposure to these substances. Many of these substances are known to have adverse impacts on human health. This report considers the toxicologic characteristics of the substances emitted from the copper smelter in Zlatna, the routes and levels of human exposure to these substances, the health effects that have been documented in Zlatna, and characterizes the most critical relationships between environmental exposures and risks to human health. This process is called human health risk assessment.

Human health risk assessment is a methodology used to estimate the likelihood of adverse health outcomes from environmental exposures to chemicals. Health risk assessments are conducted using a four-step process intended to determine whether adverse health effects are likely to occur as a result of a particular chemical exposure, and if so, to what extent. These four steps are described briefly below, and serve as the framework for the organization of this report.

Hazard Identification: Determine the identities and quantities of environmental contaminants present that may pose a hazard to human health.

Exposure Assessment: Determine the conditions under which people could be exposed to the contaminants and the levels of exposure that could occur.

Dose-Response Assessment: Evaluate the relationship between exposure levels and the incidence of adverse effects in humans.

Risk Characterization: Estimate the likelihood of an adverse health outcome in the exposed population.

Because the information available on contaminant levels and health effects in

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Zlatna is not extensive, a full-scale risk assessment is not possible. The information that is available can be used in conjunction with the international literature on copper smelter-related health effects, however, to draw conclusions regarding the nature and likelihood of effects and to make recommendations with regard to health policy that may reduce health risks in Zlatna.

2C

HAZARD IDENTIFICATION

Site Characterization

The information used to characterize the site was obtained during site visits conducted during the week of 11 October 1993 as well as during meetings with the management of the smelter and with the local branch agency of the Ministry of Waters, Forests, and Environmental Protection.

Site Description. The town of Zlatna is located in the county of Alba, in the western part of Romania in the area called Transylvania (Figure 1). It is situated at an altitude of 450 meters, directly upwind from Alba Iulia, the capital city of Alba county, located approximately 25 kilometers to the southeast at an altitude of 300 meters. The population of Zlatna and its surrounding associated villages is 9,800, of which 2,500 are employed in the smelter. The population of Zlatna alone is 5,000.

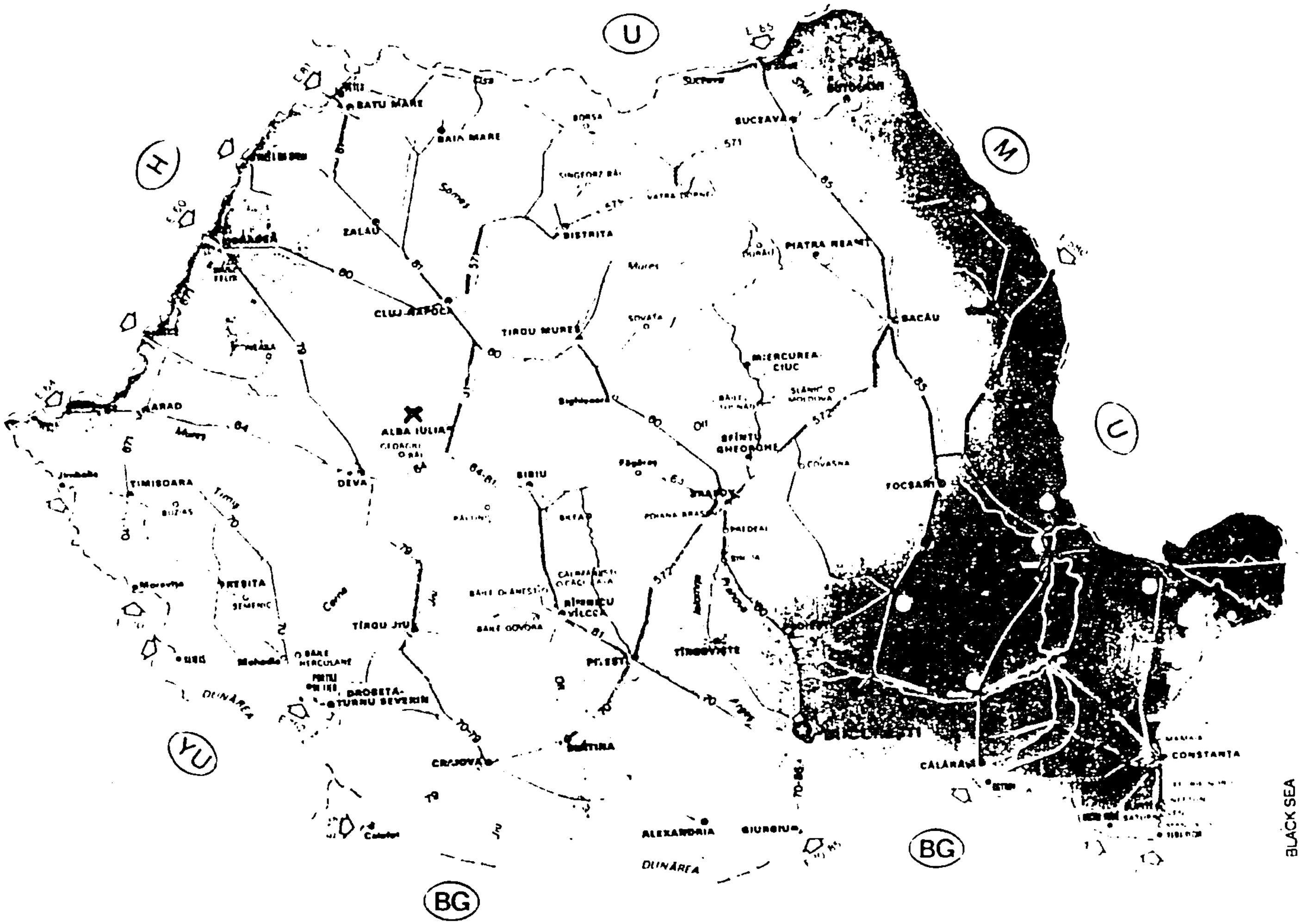
Copper smelting has been conducted in Zlatna since 1747, and copper has been mined in the surrounding mountains since Roman times. The current copper smelting company, Ampellum S.A., is owned by the state and comprises two smelters, one that began operation in 1963 and one in 1988. A third, older smelter was destroyed in 1991. There are three stacks that currently emit gases and particulates to the atmosphere, and the vicinity of the smelter and the valley directly downwind of it are shrouded in smoke and haze. The hillsides on either side of the smelter are barren or covered with dead trees. There is a stream that flows from the smelter into the river in the valley below that is black with tailings runoff. Residents stated that there have been no fish in the river for 20 years.

The community residents live in apartment blocks or traditional single-family dwellings located immediately outside the fence surrounding the smelter. The area surrounding the town of Zlatna is agricultural and also contains a number of small villages. Observation indicated that corn and cereal grains are grown primarily and used to feed livestock. Livestock includes cows, pigs, sheep, goats, and poultry. Other crops include peppers, cabbage, sunflowers, beets, and grapes. Every home, both in town and in surrounding areas, has a vegetable garden for family use, which includes tomatoes, winter squash, grapes, cabbage, beets, peppers, and fruit trees. Residents reported that beans and cucumbers can no longer be grown, except in greenhouses, because of the pollution.

Contaminants of Concern. The ore used in copper smelting contains, in addition to copper and iron sulfides, other heavy metals such as lead, cadmium, arsenic, zinc, and gold. While most of the heavy metals are present at low levels in the ore, the process of smelting concentrates the metals and what is not removed from the waste stream is emitted to the atmosphere as metal oxide-containing particulates. Particulates also contain silicon oxides. Copper smelting also creates sulfur oxides, which can be recovered as sulfuric acid or emitted into the atmosphere, where much of what is

FIGURE 1

LOCATION OF ZLATNA AND ALBA IULIA, ROMANIA



x = Zlatna

emitted is converted to sulfuric acid particulates. Waste products that are not emitted to the atmosphere during the smelting process are recovered as slag and sludge, which are piled on the ground and are sources of dust as well as runoff. Figure 2 illustrates the basic process of copper smelting as conducted at Zlatna, with emphasis on the steps at which contaminants are emitted to the environment.

Environmental monitoring has been minimal at Zlatna. Sampling and analytic capabilities are crude. The local EPA has performed air and surface water monitoring but would not share its data because they were thought to be so primitive as to be meaningless. Annual soil and vegetable samples are taken and analyzed for heavy metal content by the office of the Ministry of Waters, Forests, and Environmental Protection in the city of Cluj-Napoca, which performs such analyses for Alba county, but few data were located. No drinking water analyses were available.

The branch agency of the ministry provided estimates of the total volumes of contaminants calculated to be released monthly from the smelter into the air and water. These are shown in Table 1, which indicates that iron, copper, lead, zinc, arsenic, tin, bismuth, and sulfur oxides are released in substantial quantities.

Air samples are obtained on a regular basis from the grounds of the hospital in Zlatna, using a pump and filter apparatus, by the Institute of Public Health and Medical Research in Cluj-Napoca. These are analyzed for suspended particulates, sedimented particulates, sulfur dioxide, lead, and cadmium, and the cumulative results are published annually in a report that summarizes similar information for numerous locations throughout Romania. Heavy metal contents are analyzed using atomic absorption spectrophotometry, but air flow through the filter is regulated using an approximately 1930's vintage Russian apparatus, so variability among results is likely. Table 2 summarizes these air monitoring data from Zlatna and Alba Iulia for the years 1985-1991. The data indicate that while the contaminant levels have not changed significantly over time in Alba Iulia, sulfur dioxide levels increased by an order of magnitude in Zlatna after the new smelter began operation. In addition, the levels of suspended particulates in Zlatna exceed those in Alba Iulia by an order of magnitude. The lead and cadmium levels exceed those generally found in urban areas of Romania and the United States by an order of magnitude. The lead level is approximately twice the ambient air quality standard in the United States (1.5 $\mu g/m^3$).

Figure 3 depicts the mean levels of suspended particulates, lead, and cadmium in Zlatna, Alba Iulia, and several other locations in Transylvania that were recorded between 1983 and 1987, as well as the percentage of the samples taken that exceeded the permissible exposure concentrations of the time (also shown).

Table 3 shows the results of a survey of heavy metal levels in soil samples taken at points next to and distant from the smelter (Bodor et al. 1992). Mean values for the various sampling points were not reported, only the minimum and maximum values, as shown. These heavy metal levels reflect the deposition of smelter emissions from the atmosphere to the soil, and decrease with increasing distance from the smelter. Levels near the smelter are one to two orders of magnitude greater than background levels.

Table 4 shows the lead, copper, and cadmium levels that were determined in samples of lettuce, onion, and grass in and around Zlatna in 1989 (Zehan 1993). Only

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FIGURE 2

BASIC PROCESS OF COPPER SMELTING AND ENVIRONMENTAL EMISSIONS AT ZLATNA

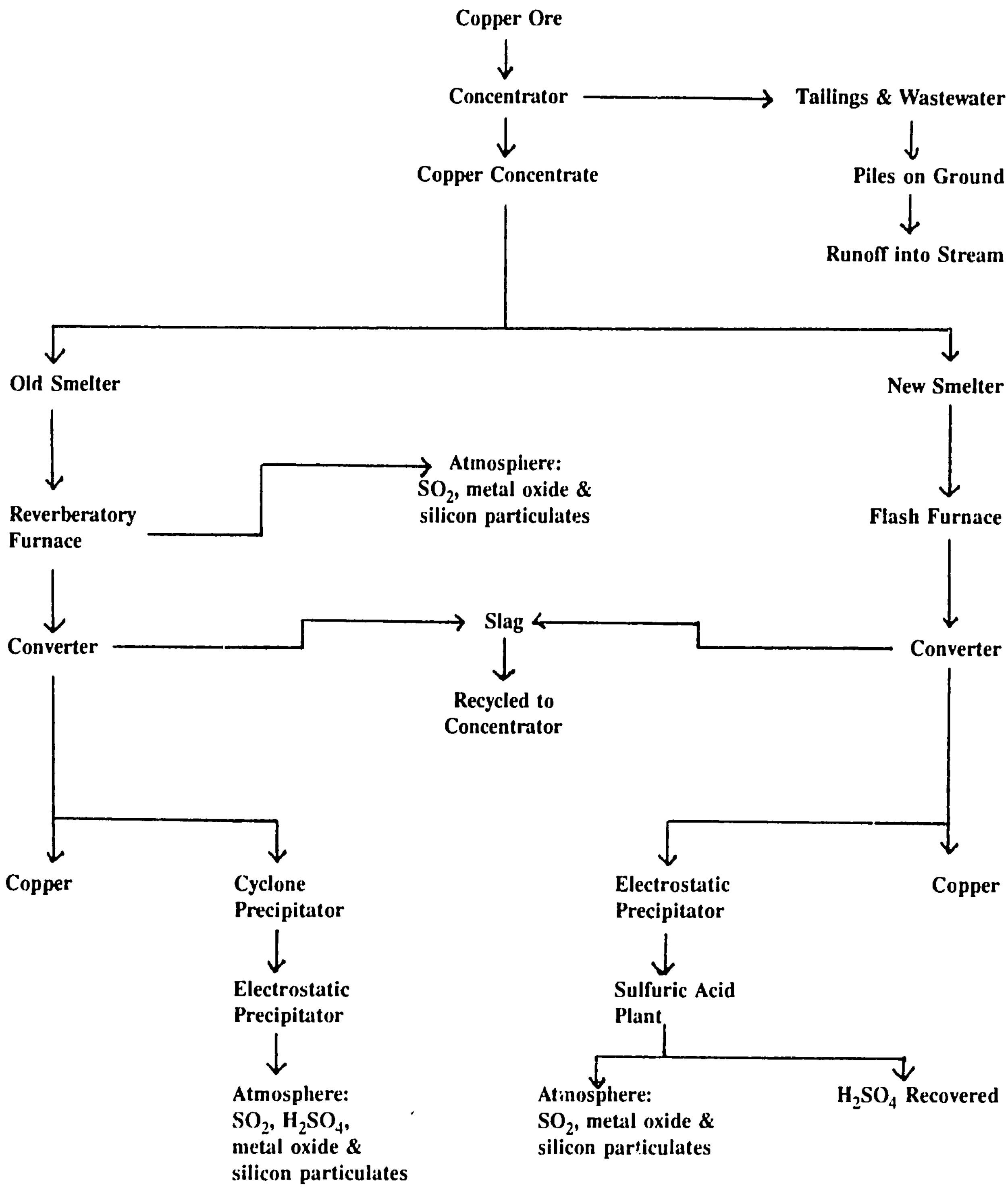

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TABLE 1

ESTIMATED RELEASES OF CONTAMINANTS TO THE ENVIRONMENT

Contaminant	Released to Air (tons/month)	Released to Water (tons/month)
Copper	47	14
Iron	NR	20
Lead	100	1.5
Zinc	91	7
Arsenic	9	NR
Tin	2	NR
Bismuth	1	NR
Cadmium	0.5	NR
Sulfur dioxide	3,800	NR

NR = not reported

Source: Alba Iulia's local Ministry of Waters, Forests, and Environmental Protection

TABLE 2

AIR MONITORING DATA FOR ZLATNA AND ALBA IULIA, 1986-1993

Year	1986	1987	1988	1989	1990	1991	1992	1993	Mean	Standard Deviation
Lead (ug/m3)										
Alba Iulia	0.42	NA	NA	NA	NA	NA	NA	NA	0.42	
Zlatna	2.4	3.93	4.71	2.77	2.34	1.5	NA	NA	2.94	1.07
Cadmium (ng/m3)										
Alba Iulia	7.94	NA	NA	NA	NA	NA	NA	NA	7.94	
Zlatna	34.94	45.29	77.01	71.81	42.1	17.6	NA	NA	48.13	20.60
Sulfur Dioxide (ug/m3)										
Alba Iulia	13	16.9	4.82	4.06	10.05	NA	NA	NA	9.77	4.87
Zlatna	31.82	17.32	257.79	119.49	127.51	141.9	NA	NA	115.97	79.31
Suspended Particulates (ug/m3)										
Alba Iulia	69.62	63.25	30.69	36.16	42.58	39.9	NA	NA	47.03	14.31
Zlatna	183.95	215.48	342.92	251.16	204.1	NA	NA	NA	239.52	56.12

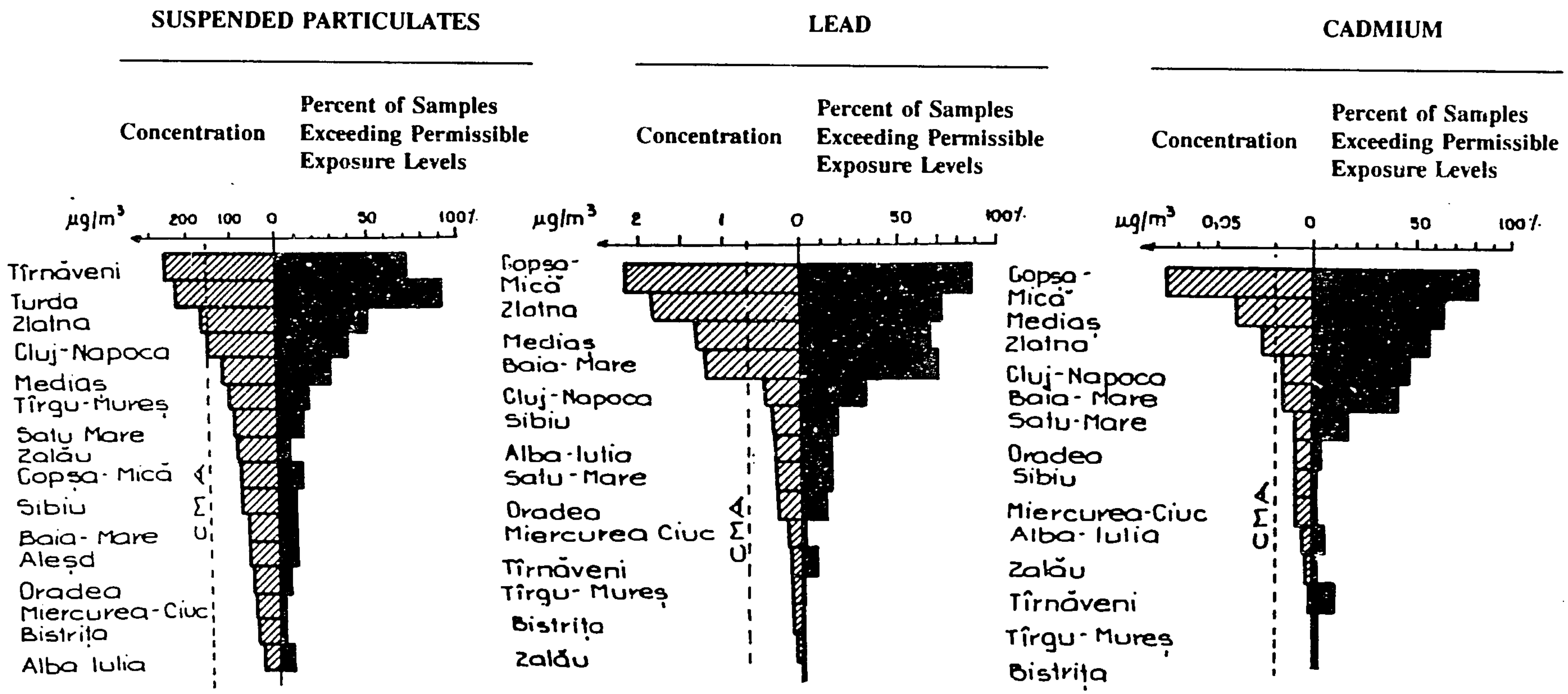
NA = not available

Source: Supravegherea Calitătii Aerului in Principalele Localităti Urbane (Annual Urban Air Quality Surveys), reported by the Ministerul Sănătaţii, Institutul de Igienă si Sănătate Publică Bucureşti

Note: Values are reported here as reported by the Ministry; however, it is unlikely that they are accurate to as many significant figures as shown.

FIGURE 3

MEAN LEVELS OF SUSPENDED PARTICULATES, LEAD, AND CADMIUM IN ZLATNA AND OTHER LOCATIONS IN TRANSYLVANIA, 1983-1987



Source: Dr. Edith Bretter, Institute of Public Hygiene and Medical Research, Cluj Napoca

TABLE 3

LEVELS OF HEAVY METALS IN SOIL NEAR ZLATNA

Sampling Period	Surface Samples[a]						Deep Samples[b]					
	Lead (ppm)		Cadmium (ppm)		Copper (ppm)		Lead (ppm)		Cadmium (ppm)		Copper (ppm)	
	Minimum[c]	Maximum[d]	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1979-81	27.78	1400	0.20	7.03	22.39	1058	30.00	1267	0	7.22	13.54	1010
1982-84	27.77	1765	0	8.75	25.74	919	27.77	2059	0	7.90	22.06	1103
1985-87	50.00	2121	0.37	19.57	34.38	807	45.00	2215	1.02	18.59	30.94	853
1988-89	47.62	1667	0.27	10.00	57.70	655	32.71	1952	0.27	10.00	39.52	900
1990-91	11.36	2338	0.66	9.20	46.02	884	15.91	813	0	12.10	44.10	896
1992	77.27	1148	0.51	8.47	55.33	466	77.27	1136	0.51	8.14	59.00	499

[a]Surface samples were obtained at 0-2.5 cm for land not farmed and at 0-25 cm for farmed land
[b]Deep samples were obtained at 35-40 cm
[c]Minimum levels were those detected at distances up to 20-30 km distant from the smelter and were considered control values that reflected background levels
[d]Maximum levels were those detected within 0.2-0.5 km of the smelter

Source: Bodor et al. 1992

Note: Values reported as zero are presumed to be non-detects; that is, metals were present at levels below the detection capability of the analytic methodology used.

minimum and maximum levels were reported. Figure 4 shows the extent to which the metal levels vary with distance from the smelter; as would be predicted, levels of lead decrease with increasing distance from Zlatna. The lead levels in Zlatna are two to three times background levels. The levels of cadmium do not show the same pattern.

Table 5 shows the ambient water quality data available for the Ampoi River in the Zlatna region (Zehan 1993). These data indicate that the river water is enriched in several heavy metals downstream of the smelter, particularly cadmium, lead, arsenic, copper, and zinc.

Taken together, these results suggest that the contaminants of concern in the Zlatna community include lead, cadmium, arsenic, and sulfur dioxide. Suspended particulates also present a hazard by virtue of their irritant qualities, in addition to the fact that they are the vehicle that provides the lead, cadmium, arsenic, and sulfuric acid exposure. Because human exposure to iron, copper, bismuth, and tin from the environment is not regulated in the United States, and because these substances, as well as zinc, are considerably less hazardous than the other contaminants, they will not be considered further here.

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TABLE 4

LEVELS OF HEAVY METALS IN PLANTS IN OR NEAR ZLATNA[a]

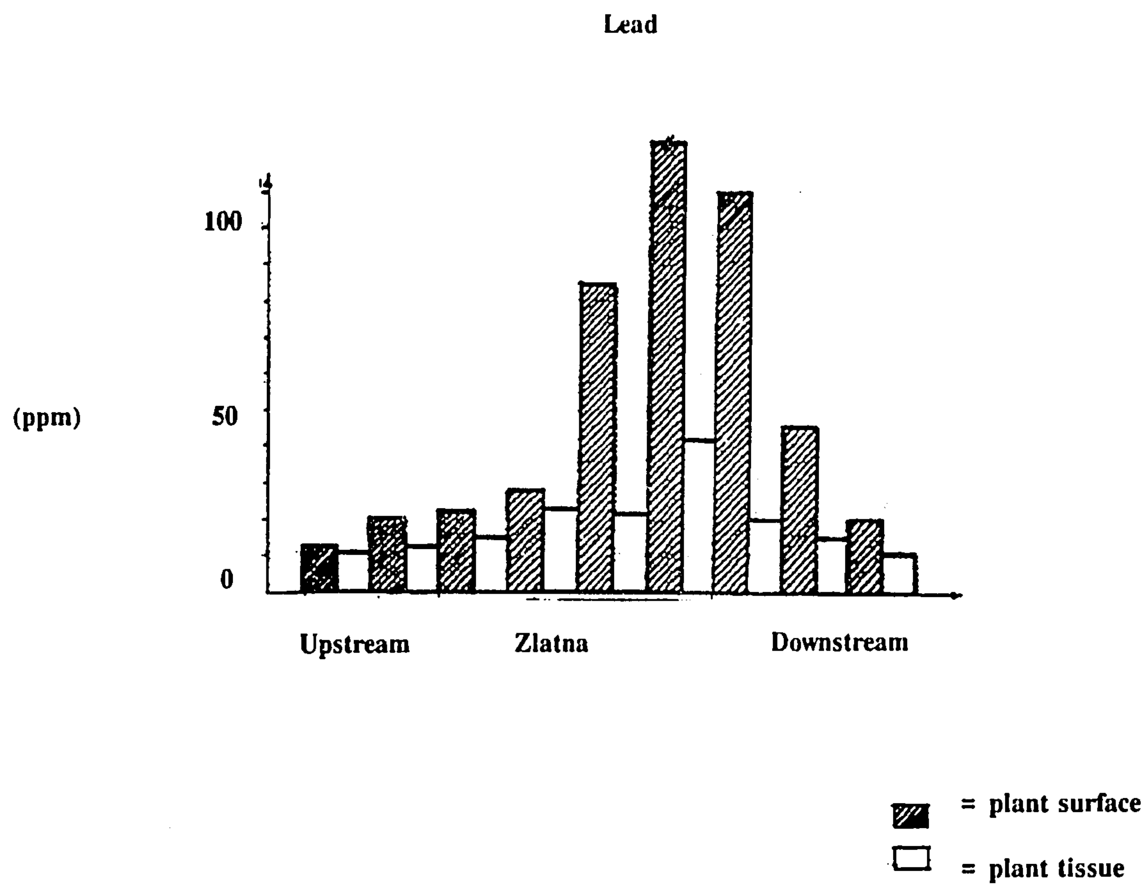
Species	Lead (ppm)	Copper (ppm)	Cadmium (ppm)
Lettuce	53-116	62-140	0
Onion	26-105	56-156	0
Grass	53-184	31-156	0

[a]Normal concentrations of lead were reported by the author to be 0.5-1 ppm for lettuce and 0.03-0.8 ppm for onion. No background concentrations for lead in grass were reported. The normal concentration of copper in vegetables is generally 0.5-1 ppm (ATSDR 1990).

Source: Zehan 1993

FIGURE 4

VARIATION IN MEAN LEAD AND CADMIUM LEVELS IN PLANTS
WITH DISTANCE FROM COPPER SMELTER, 1991



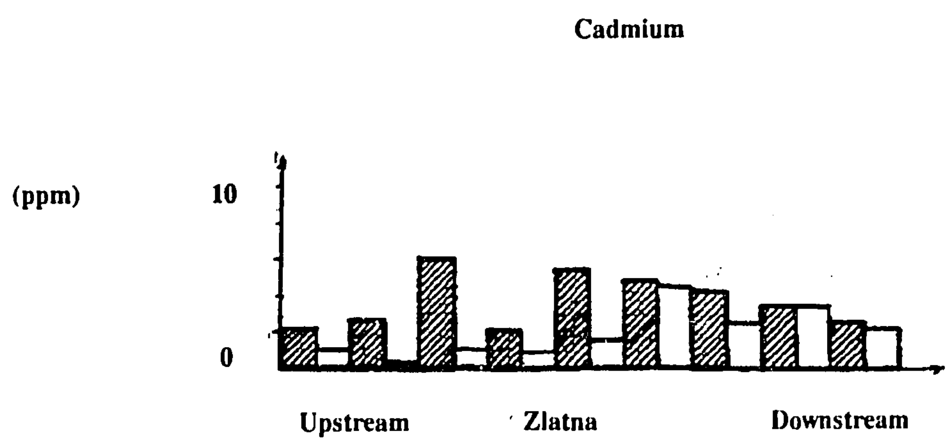


TABLE 5

WATER QUALITY IN THE ZLATNA REGION[a]

Location	pH	Organic Matter (mg/l)	Lead (mg/l)	Cadmium (mg/l)	Copper (mg/l)	Zinc (mg/l)	Chromium (mg/l)	Arsenic (mg/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	NO_2^- (mg/l)	OD (mg/l)	CBO5 (mg/l)
Ampoi River, upstream of Zlatna	6.0	22.12	0.051	0.005	0.023	0.103	0.001	0	0	4.5	0.024	10.21	0.5
Ampoi River, upstream of mine	5.5	11.06	0.015	0.003	0.044	0.099	0.008	0	0.27	4.6	0.015	9.77	3.5
Ampoi River, upstream of smelter	5.5	75.20	0.365	0.002	0.301	2.408	0.010	0	0.34	5.8	0.160	7.83	3.1
Ampoi River, discharge from old smelter	5.5	88.50	0.369	0.003	1.003	0.259	0.342	0	1.10	1.0	0.008	-	-
Ampoi River, downstream from smelter	5.5	104.30	0.365	0.014	1.146	1.063	0.025	0.132	0.20	5.8	0.180	0.180	-
Discharge water, new smelter, settling pond	8.5	12.01	0.125	0.003	0.168	0.094	0.002	0.468	0.15	-	0.047	-	-
Ampoi River, downstream from new smelter discharge	5.5	281.20	0.234	0.027	1.164	0.815	0.007	3.046	1.90	4.0	0.024	10.32	1.1
Ampoi River, upstream of Pătrinjeni[b]	6.5	154.0	0.906	0.021	2.325	2.625	0.045	0.340	0.22	5.0	0.260	8.30	3.1

[a]All samples are water samples, not sediment
[b]Pătrinjeni is the first village downstream from Zlatna

Source: ?

Note: Values reported as zero are presumed to be non-detects; that is, metals were present at levels below the detection capability of the analytic methodology used.

EXPOSURE ASSESSMENT

Human exposure to environmental contaminants resulting from copper smelter emissions is considered here by three primary routes: inhalation, ingestion, and dermal exposure. Due to the paucity of monitoring data available for Zlatna, a quantitative exposure assessment is possible only for inhalation exposure and for incidental soil ingestion. Only qualitative assessments of human exposure for the ingestion of food and for the dermal route is possible. Lead is considered separately from the other contaminants because blood lead levels, not environmental concentrations, are used to measure lead exposure, and blood lead levels result from all three routes of exposure.

The dose estimates generated are applicable to Zlatna community residents. People who work in the smelter, who in general also live in the community, receive even higher doses as a result of their employment.

Inhalation

Inhalation is a primary route of exposure to contaminants generated by the copper smelter. Figure 5 is a map produced by the Ministry of Waters, Forests, and Environmental Protection showing the areas where the growth of trees and vegetation has been reduced by airborne contamination, particularly sulfuric acid. This area of affected vegetation reflects the plume of stack emissions from the smelter and can be used as a crude estimate of human exposure. The area of greatest contamination, as indicated by effects on vegetation, includes the town of Zlatna itself and extends approximately 1 kilometer to the west and 10 kilometers to the east. Most of the metal oxide-containing particulates are likely to be deposited within this area of greatest sulfuric acid contamination because of the heavier nature of the particulates compared to the sulfur oxide aerosols. On this basis it is possible to assume that the populations of Zlatna and most of its surrounding villages are exposed to levels of contaminants similar to those determined through the air monitoring performed on the grounds of the hospital. Because these populations experience little transiency, it is possible to assume that the community residents are exposed to these levels throughout their lifetimes. The mean levels of contaminants recorded during the period 1985-1993 will be used as an approximation of lifetime exposure levels (see Table 2). These exposure levels probably underestimate those experienced before the oldest smelter was destroyed and overestimate those experienced before the newest smelter began operation. Table 6 shows the mean contaminant levels used to estimate inhalation doses for each contaminant. No monitoring data were available for arsenic, but the total emissions estimates shown in Table 1 indicate that arsenic occurs at a level approximately one order of magnitude below that of lead, so one-tenth the lead level will be used for arsenic.

To estimate human inhalation doses of the contaminants from the smelter, the following equation was used:

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FIGURE 5

EFFECT OF AIRBORNE CONTAMINATION ON VEGETATION AROUND ZLATNA

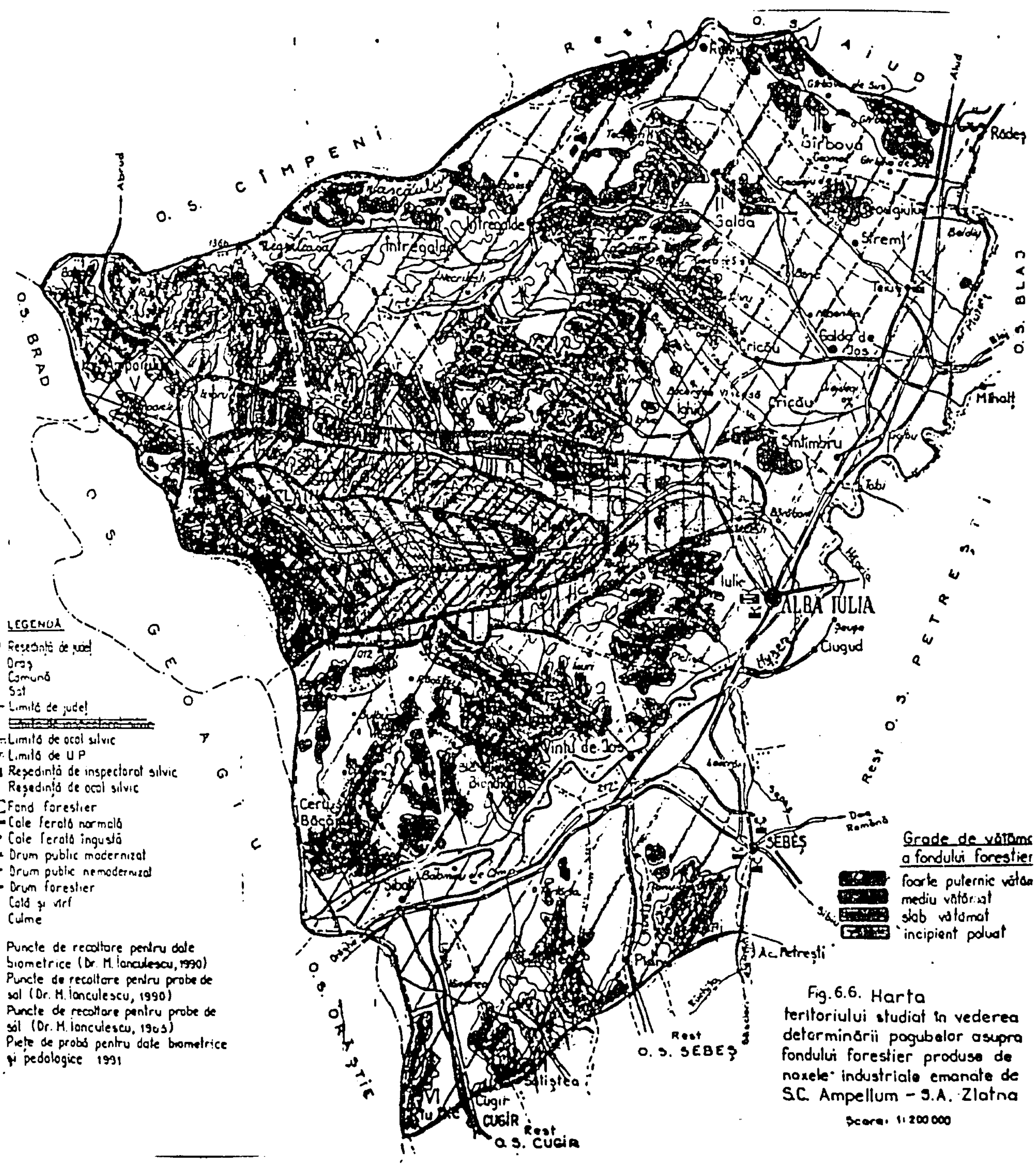

TABLE 6

MEAN CONTAMINANT LEVELS IN AIR[a]

Contaminant	Mean Level in Air ($\mu g/m^3$)
Lead	3
Arsenic	0.3
Cadmium	0.05
Sulfur Dioxide	120
Total Suspended Particulates	240

[a]For raw data, see Table 2

$$\text{Dose (mg/kg/day)} = \frac{C_A \times PM_{10} \times IR \times AF \times CF}{BW}$$

Doses were determined separately for children and adults, and the parameters in the equation were determined as follows:

C_A = Concentration in air ($\mu g/m^3$) = see Table 6

PM_{10} = Fraction of particulate matter that measures < 10 μ in diameter and is therefore respirable = 0.5[1]

IR = Inhalation rate (m^3/day) = 20 m^3/day

AF = Absorption factor = 1[2]

CF = Conversion factor used to convert μg to mg = 1×10^{-3}

BW = Body weight = 70 kg

Table 7 summarizes the dose estimates for inhalation exposure to arsenic and cadmium, which are the contaminants of concern for which health risks can be calculated. These dose estimates were calculated using assumptions about air concentrations, inhalation rates, absorption factors, and body weights that may not apply to all members of the community; actual doses are likely to vary significantly with differences in these parameters within the population and at different locations. A dose estimate for sulfur dioxide was not calculated because its health risks are a function of interactions with many other components of polluted air; the consequences of sulfur dioxide exposure will be considered qualitatively.

Ingestion

Ingestion of contaminants is likely to be another significant source of exposure in the community. Ingestion of contaminants can occur as a result of ingesting contaminated soil or eating contaminated food. Tables 3 and 4 showed that heavy metals were present in the soil and plants around Zlatna at levels one to two orders of

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[1]This number needs work and may be modified after further consultation with U.S. EPA and others

[2]The absorption factor accounts for the fact that not all of the contaminants that are inhaled may be absorbed by the body. However, studies show that both lead and arsenic are absorbed rapidly following inhalation, and that between 50% and 100% of the cadmium deposited in the lungs will be absorbed (ATSDR 1992a,b,c); therefore, in the absence of experimental data on the bioavailability of these metals from inhaled particulates, a conservative absorption factor of 1 will be used.

TABLE 7

DOSE ESTIMATES FOR INHALATION EXPOSURE

Contaminant	**Dose Estimate (mg/kg/day)**
Arsenic	4×10^{-5}
Cadmium	7×10^{-6}

magnitude above the levels considered to be normal background levels.

Soil. Estimating doses of persistent chemicals deposited on soil as a result of airborne emissions and ingested incidentally is based on chemical concentrations in soil and estimates of the amount of this soil that will be consumed as a result of hand-to-mouth activity, which is particularly common in children and smokers. Table 8A summarizes the dose estimates calculated using the maximum surface soil contaminant levels estimated from Table 3 and the following equation:

$$\text{Dose (mg/kg/day)} = \frac{C_S \times I_S \times AF \times CF}{BW}$$

Doses are determined separately for children and adults, and the parameters in the equation are determined as follows:

C_S = Concentration in soil (mg/kg) = see Tables 3 and 8

I_S = Soil ingestion rate (mg/day) = 100 mg/day for children age 1-11
= 50 mg/day for children age 12+ and adults

AF = Absorption factor = 0.5[3]

CF = Conversion factor for mg to kg = 1×10^{-6}

BW = Body weight (kg) = 23 kg for children age 1-11
= 70 kg for children age 12+ and adults

Table 8B summarizes the dose estimates obtained using this equation and the minimum contaminant concentrations reported in Table 3, which come from samples taken distant from Zlatna that are considered to represent background levels and that are useful for the purpose of comparison. The dose levels estimated in Tables 8A and 8B were calculated using default assumptions about physiologic parameters such as body weights and ingestion rates that are based on the U.S. population and may not accurately reflect those of the Romanian population. Actual dose levels vary with the natural distributions of these parameters within a population and among locations.

Food. Most of the food consumed by residents is grown in the immediate environs of the smelter. Deposition of the metal-containing particulates on fruits and vegetables can

[3]In the absence of data on the extent to which soil-bound arsenic and cadmium are absorbed by the gastrointestinal tract, a conservative value of 0.5 will be used.

TABLE 8A

ESTIMATES OF CONTAMINANT EXPOSURE LEVELS FROM SOIL INGESTION: MAXIMUM EXPOSURE

Contaminant	Level in Soil[a] (mg/kg)	Dose (mg/kg/d)		Lifetime Dose[b] (mg/kg/d)
		Children	Adults	
Arsenic[c]	180	4×10^{-4}	1×10^{-4}	1×10^{-4}
Cadmium	11	2×10^{-5}	4×10^{-6}	7×10^{-6}

TABLE 8B

ESTIMATES OF CONTAMINANT EXPOSURE LEVELS FROM SOIL INGESTION: MINIMUM EXPOSURE

Contaminant	Level in Soil[d] (mg/kg)	Dose (mg/kg/d)		Lifetime Dose[b] (mg/kg/d)
		Children	Adults	
Arsenic[c]	37	1×10^{-4}	1×10^{-5}	2×10^{-5}
Cadmium	0.3	7×10^{-7}	1×10^{-7}	2×10^{-7}

[a]These values were obtained by taking a time-weighted average of the maximum concentrations reported by Bodor et al. (1992) and shown in Table 3
[b]These values were obtained by taking a time-weighted average of the doses calculated for children and adults over a 70-year lifetime
[c]Because no soil analyses for arsenic were reported, it is assumed on the basis of the estimated total releases of contaminants to the environment reported in Table 1 that arsenic is present in soil at a level one order of magnitude less than that of lead.
[d]These values were obtained by taking a time-weighted average of the minimum concentrations reported by Bodor et al. (1992) and shown in Table 3

lead to uptake of metals. Growing fruits and vegetables on contaminated soil can also lead to uptake of metals. Livestock consume contaminated grass and may use the contaminated river as a water source (in addition to inhaling contaminated air), leading to contaminated meat and milk.

Monitoring data were available for the levels of lead, copper, and cadmium in lettuce, onion, and grass around Zlatna (Table 4). Lead is considered separately below. Copper was not selected as a contaminant of concern due to its low toxicity, but the levels of copper in these plants is very high. The taste threshold for copper has been reported to be 2.6 ppm (Cohen et al. 1960), so it is possible that produce with copper levels 10 to 100 times this level may not be consumed to the extent necessary to produce toxicity. Cadmium was reported to be undetectable in the plants tested, and the levels of arsenic were not determined.

Because of the absence of adequate monitoring data for heavy metal levels in produce and other foods, it is not possible to perform a quantitative assessment of potential health risks associated with food consumption in Zlatna.

Other Sources. The community drinking water source was reported by local doctors to come from the mountains and to be uncontaminated, but no monitoring data were provided. Groundwater may be contaminated, but did not appear to be a drinking water source for this community, although it may contribute to drinking water consumed by livestock. Because no fish remain in the river, consumption of contaminated fish is not a source of exposure. No other monitoring data useful for evaluating potential ingestion risks were available.

Dermal Exposure

Dermal exposure to contaminated soil is likely to be another source of metals exposure for Zlatna community residents. Because the community surrounding Zlatna is primarily agricultural, and because farming methods are primitive, dermal exposure of farmers to contaminated soil occurs on a continuing basis. In addition, as mentioned above, children both in the town of Zlatna and its surrounding areas are likely to play in contaminated soil. However, metals are not absorbed through the skin to a great extent, especially when they are bound to soil, so dermal exposure is not likely to contribute to metal body burdens to the same extent as inhalation and ingestion exposure. Dermal exposure will therefore not be considered to contribute significantly to health effects for the purposes of quantitative health risk assessment.

Lead

The extent to which human exposure to lead occurs as a result of environmental contamination cannot be estimated on the basis of environmental concentrations, due to its complex pharmacodynamics. Blood lead levels are commonly used as indices of lead exposure. Zlatna community residents are not routinely monitored for blood lead levels, as are smelter workers, but a study was performed ten years ago to determine blood lead levels for a group of school children in Zlatna[4]. These levels were reported to range from 20 to 65 μg/deciliter. Blood lead levels result from inhalation, ingestion, and possibly dermal exposure, and will be used to evaluate the health effects likely to occur in children from lead exposure, as well as the extent to which inhalation contributes to exposure as compared to the other routes. Because children are the group primarily at risk of lead toxicity, this analysis focusses on children.

A pharmacokinetic model, the Uptake/Biokinetic Model, has been developed by the U.S. EPA that permits both estimation of blood lead levels on the basis of environmental lead concentrations and estimation of the contribution of various sources of environmental lead exposure to blood lead levels. This model accounts for rates of lead uptake from various media and its distribution and storage within the body. It was developed for children aged 0-6 years old. The blood lead levels in Zlatna children were determined for older children (ages 7-11), however, so the assumption will be made for modeling purposes that the lower limit of 20 μg/dl is a reasonable estimate of lead levels in younger children.

The model was run as follows. First, the air lead level of 3 $\mu g/m^3$ was entered, based on the air monitoring data (Table 6). Next, the soil lead level of 1,800 mg/kg was entered, also based on monitoring data (Table 3). The model's default value of 4 μg/liter drinking water was assumed, and its default values for daily dietary lead consumption were tripled due to the high levels of lead monitored in local produce and the dependence of the community on local produce. The output of the model is shown in Table 9. Calculated blood lead levels are approximately 20 μg/dl, as assumed. The relative contributions of each source of exposure (food, water, soil and dust, air) show that the primary sources of children's blood lead levels are soil and dust. Based on this model and the assumptions made, soil and dust in Zlatna contribute over 80% of the daily lead uptake by children. Diet contributes about 10% and air contributes about 3%. Although the levels of lead presumed to occur in the air and water for modeling purposes are based on assumptions that may not be accurate for Zlatna, and although the actual amount of lead absorbed by children will vary among individuals and on different days, the important conclusion of this analysis is unlikely to change substantially: soil and dust are the primary source of lead exposure for children in Zlatna.

[4]A similar study will be performed in the next few months. Results are expected in the spring.

TABLE 9

CALCULATED BLOOD LEAD AND LEAD UPTAKES[a]

Age (years)	Blood Level (μg/dl)	Total Uptake (μg/day)	Soil + Dust Uptake (μg/day)	Diet Uptake (μg/day)	Water Uptake (μg/day)	Air Uptake (μg/day)
0.5-1	18.62	62.53	54.00	7.5	0.40	0.63
1-2	18.89	64.03	54.00	8.0	1.00	1.03
2-3	18.70	65.40	54.00	8.5	1.04	1.86
3-4	19.10	66.06	54.00	9.0	1.06	2.00
4-5	19.93	66.60	54.00	9.5	1.10	2.00
5-6	20.13	67.96	54.00	10.0	1.16	2.80
6-7	20.07	68.48	54.00	10.5	1.18	2.80

[a]Calculations were performed using the U.S. EPA Uptake/Biokinetic Model for lead with air and soil monitoring data

DOSE-RESPONSE ASSESSMENT

In this section, the toxicologic characteristics of the contaminants of concern are described. In addition, the health effects that have been documented in Zlatna residents by the Institute of Public Health and Medical Research in Cluj as well as by the Sanitary Directorate of Alba County are reported.

Toxicologic Characteristics of the Contaminants of Concern

Sulfur Dioxide. Sulfur dioxide is formed when materials containing sulfur are burned, and it is therefore emitted to the environment as a result of smelting activities and as a result of the burning of fossil fuels. Its toxicity is related to the fact that it is not emitted alone, but along with a variety of particles. Many of these particles are capable of promoting the conversion of sulfur dioxide to the more irritant sulfuric acid. Very small particles with large surface areas that are enriched in heavy metals such as iron or zinc can convert sulfur dioxide to sulfuric acid, which is then present as a layer on the surface of the particles. Sulfur dioxide is thus the source of atmospheric particulate sulfates, which may be transported long distances in the atmosphere, posing hazards to human health and contributing to acid rain (Amdur 1991).

When sulfur dioxide is inhaled at the concentrations normally found in air pollution, most of it is deposited in the respiratory tract, where it persists and is only slowly removed or absorbed by the body. The respiratory tract is thus the primary target of sulfur dioxide-related toxicity. Short-term exposures to sulfur dioxide lead to irritation of the mucous membranes and constriction of the respiratory tract; people with asthma experience respiratory constriction at doses one order of magnitude lower than people without asthma (Amdur 1991). Respiratory tract cancer mortality among arsenic-exposed smelter workers was reported to be greater when exposures had been to high levels of arsenic (a known human carcinogen) combined with sulfur dioxide (Lee and Fraumeni 1969); sulfur dioxide thus may increase susceptibility to respiratory tract cancer.

When sulfuric acid is inhaled, it is a potent respiratory irritant and produces functional, biochemical, and morphologic changes in the respiratory tract. Sulfuric acid produces bronchial obstruction due to both constriction and increased mucous secretion; it alters the clearance of particles from the lung, thereby interfering with a major defense mechanism; and, it ultimately produces chronic bronchitis. When exposure to sulfuric acid as a surface layer on fine respirable particles occurs, such as in the vicinity of a smelter, chronic irritation occurs in addition to the other symptoms (Amdur 1991).

The Ambient Air Quality Standard for sulfur oxides (measured as sulfur dioxide) in the United States is 80 $\mu g/m^3$, as an annual mean level. The permissible mean level of sulfur dioxide in Romanian industrial areas is 5 mg/m^3, and the permissible level for sulfuric acid and sulfur trioxide is 0.5 mg/m^3.

Lead. Lead occurs naturally in the environment, although most of the lead dispersed throughout the environment results from human activities. Combustion of leaded gasoline is the primary source of human exposure to lead in areas where it is still used. Other important sources of exposure include living in urban areas or near smelters, consumption of produce from family gardens near smelters, smoking, occupational exposure, and secondary occupational exposure (i.e., families of workers using lead). When lead is emitted to the atmosphere, it occurs as particulates that return to soil or to surface water bodies as a result of gravity or when it rains. Most lead is retained strongly on soil and is not transported into surface or ground water, except in the presence of acidic conditions (such as those near smelters). Acidic conditions also promote the uptake and concentration of lead in plants and animals (ATSDR 1992a).

Children are at the highest risk of health effects from lead exposure (ATSDR 1992a). When children are exposed to lead either before or after birth, it may produce effects on normal growth and development, leading to height and weight deficits, intelligence deficits, and attention deficits. Children who live near copper smelters have blood lead levels that are significantly higher than children who do not, and even higher blood lead levels are seen in children who both live near copper smelters and whose fathers are employed there as well (Gagné and Létourneau 1993, Chenard et al. 1987, Morton et al. 1982).

In adults, lead can be toxic to the central nervous system, producing weakness in the fingers, wrists, and ankles. It can increase blood pressure and cause anemia. It can damage the kidneys of both children and adults. Lead may increase the rate of spontaneous abortion and damage the male reproductive system, leading to sterility. Evidence in laboratory animals indicates that lead exposure can be associated with kidney cancer (ATSDR 1992a).

The U.S. EPA's Ambient Air Quality Standard for lead is 1.5 $\mu g/m^3$, averaged over three months. The permissible mean level of lead and its compounds (not including lead sulfide) in air in Romanian industrial areas is 0.05 mg/m^3, and the permissible level of lead sulfide is 0.5 mg/m^3. The U.S. EPA's Maximum Contaminant Level for lead permitted in drinking water is 20 μg/liter. The U.S. Centers for Disease Control recommends that blood lead levels of 10-15 μg/deciliter should not be exceeded in children. The U.S. EPA believes that there may be no threshold, or safe exposure level, for lead exposure and intelligence deficits in children (IRIS 1993).

Cadmium. Cadmium occurs naturally in the earth's crust and is released into the environment primarily as a result of fuel combustion and industrial processes, especially mining and smelting. Cigarette smoke and food are also important sources of cadmium exposure. Like lead, when cadmium is emitted to the atmosphere, it occurs as particulates that return to soil or to surface water bodies as a result of gravity or when it rains. Most cadmium is retained by soil and is not transported into surface or ground water, except in the presence of acidic conditions (such as those near smelters). Cadmium accumulates in food crops, particularly in cereal grains, leafy and root vegetables, and potatoes (ATSDR 1992b).

Intestinal absorption of cadmium is normally low, but can be increased significantly by iron deficiency, which is common in Romanian children, including those in Zlatna. Cadmium is concentrated in the liver and kidney when it is consumed or inhaled by humans or animals, and the kidney is the primary target organ of cadmium's toxicity. Chronic inhalation exposure to cadmium has also been associated with respiratory diseases, including rhinitis (head colds), emphysema, and possibly lung cancer. Osteoporosis and similar bone diseases, as well as high rates of kidney stone formation, have been observed following chronic oral and inhalation exposure to cadmium and are thought to result from calcium deficiency and other metabolic problems induced by kidney toxicity. Cadmium-induced kidney damage does not decline after exposure ceases. Oral exposure to cadmium can reduce iron absorption and has been associated with anemia. Experiments in laboratory animals support associations between cadmium exposure and respiratory tract injury, kidney toxicity, and decreased bone calcium content (ATSDR 1992b).

The International Agency for Research on Cancer (IARC) and the U.S. EPA classify cadmium as a probable human carcinogen for the inhalation route of exposure. Its cancer potency factor[5] is 6.1 $(mg/kg/day)^{-1}$ or 1.8×10^{-3} $(\mu g/m^3)^{-1}$. The U.S. EPA has promulgated Reference Doses (RfDs)[6] for oral exposure to cadmium through food of 1×10^{-3} mg/kg/day and through drinking water of 5×10^{-4} mg/kg/day, based on studies of kidney toxicity in humans. Both the World Health Organization's (WHO's) and the U.S. EPA's guidelines for cadmium in drinking water are 5 μg/liter. The United States does not regulate the level of cadmium in ambient air at present, although it intends to do so. Various states have guidelines for the level of cadmium in ambient air that range from 5.55×10^{-4} to 1.2×10^{-1} $\mu g/m^3$, on an annual average basis (IRIS 1993, ATSDR 1992b).

Arsenic. Inorganic arsenic occurs naturally in many kinds of rock, especially in ores that also contain copper and lead. The primary sources of arsenic contamination in the environment are metal smelting, chemical manufacturing, pesticide application, and coal combustion. Like cadmium and lead, when arsenic is emitted to the atmosphere, it occurs as particulates that return to soil or to surface water bodies as a result of gravity or when it rains. Some forms of arsenic are retained by soil and are not transported into surface or ground water, but water-soluble forms of arsenic may leach out of soil. Arsenic can accumulate in food crops as a result of root uptake from soil or by absorption of airborne arsenic deposited on leaves. Food is the primary source of human exposure to arsenic, although it also occurs in cigarette smoke (ATSDR 1992c).

Arsenic has been recognized as a human poison since ancient times, with large oral doses producing death from fluid loss and circulatory collapse, and smaller oral doses producing gastrointestinal pain, hemorrhage, nausea, vomiting and diarrhea, as

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[5]Cancer potency factors are values used by regulatory agencies to describe the inherent potency of carcinogens for the purposes of limiting their exposure. A cancer potency factor is used to estimate an upper limit on the likelihood that lifetime exposure to a particular chemical could lead to excess cancer deaths.

[6]A Reference Dose (RfD) is considered to be a limit on safe levels of human exposure to a chemical; that is, lifetime exposure to levels of a chemical below its RfD is unlikely to lead to adverse health effects, while lifetime exposure to levels above its RfD are considered less safe.

well as anemia and neurologic toxicity such as headache, lethargy, confusion, hallucination, seizures, and coma. Long-term low-level oral exposure to arsenic may produce cardiovascular toxicity, anemia, liver toxicity, and a pattern of skin changes that includes darkening of the skin and the appearance of small corns or warts. Skin cancer has been associated with long-term low-level exposure to arsenic through drinking water, and there is suggestive evidence of increased risks of bladder, kidney, liver, and lung tumors as well. Long-term inhalation exposure to arsenic can lead to respiratory tract toxicity, gastrointestinal toxicity, cardiovascular toxicity, and neurotoxicity, and has also been associated with increased rates of lung cancer, especially at or near copper smelters. Babies born to women exposed to arsenic dusts at a copper smelter during pregnancy have been reported to have a higher incidence of congenital malformations and lower birth weights than normal, and women who lived near the smelter had higher rates of spontaneous abortion than those farther away. (These effects may have been due to other smelter-related exposures in addition to arsenic, however.) Skin contact with arsenic can cause allergic dermatitis (ATSDR 1992c).

The IARC and the U.S. EPA classify arsenic as a known human carcinogen. Its cancer potency factors are 5×10^{-5} $(\mu g/liter)^{-1}$ for oral exposure through drinking water and 4.3×10^{-3} $(\mu g/m^3)^{-1}$ or 50 $(mg/kg/day)^{-1}$ for inhalation exposure. The U.S. EPA has also promulgated an RfD of 3×10^{-4} mg/kg/day for oral exposure, on the basis of the skin effects seen in humans. Both the U.S. EPA and the WHO guidelines for arsenic levels in drinking water supplies are 0.05 mg/liter. The United States does not regulate the level of arsenic in ambient air at present, although it intends to do so. Various states have guidelines for the level of arsenic in ambient air that range from 2.0×10^{-4} to 6.7×10^{-1} $\mu g/m^3$, on an annual average basis (IRIS 1993, ATSDR 1992c). The permissible mean level of arsenic in air in Romanian industrial areas is 0.01 mg/m^3.

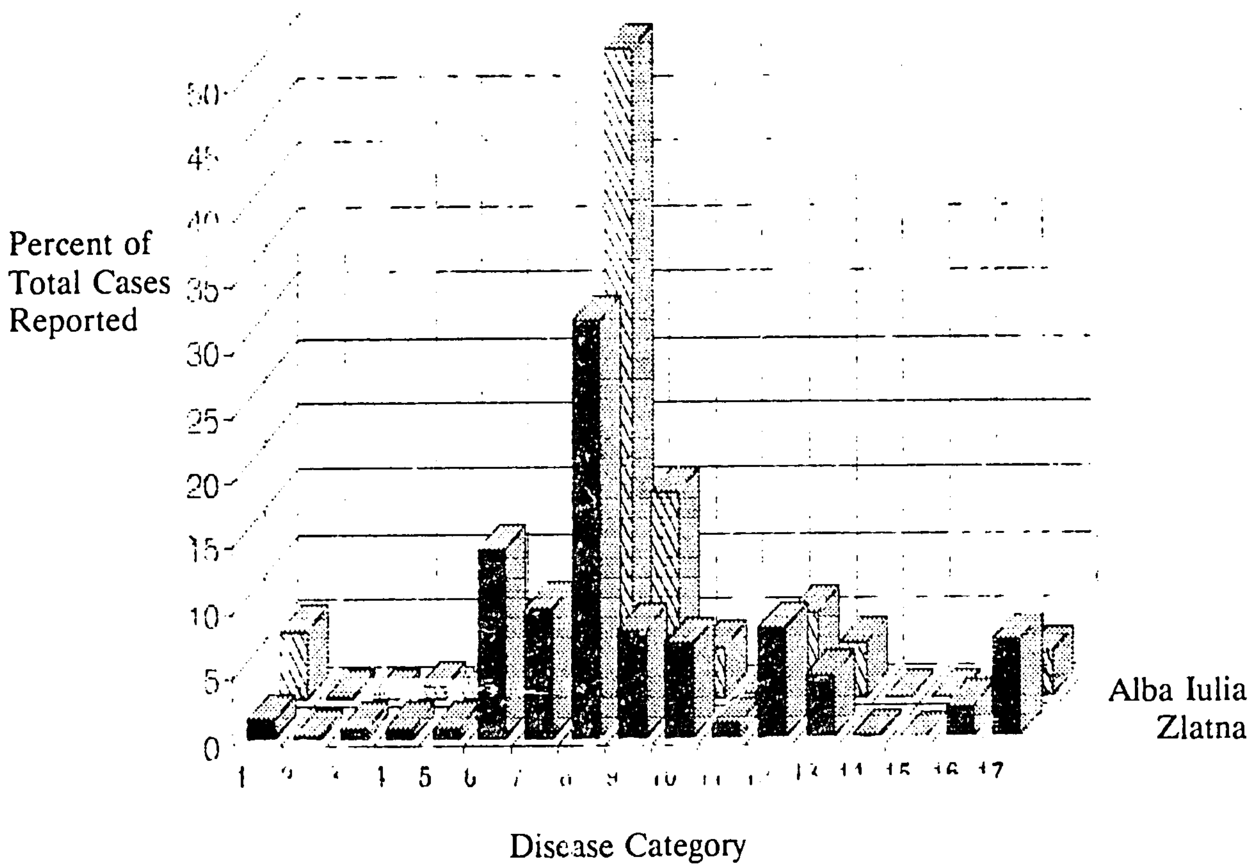
Health Effects Documented in Zlatna

There are few morbidity data available for Zlatna that are useful for evaluating potential impacts of the smelter on public health. The distribution of cases among 17 general disease categories in 1992 did not differ significantly between Zlatna and Alba county (Figure 6). This comparison was available for one year only and does not permit an analysis of the possibility that differences may exist in the incidence of specific diseases between the two locations, however, because these data reflect first reporting for each category, not disease incidence. In general, birth rates have tended to be lower and mortality rates have tended to be higher in Zlatna as compared to both Alba county as a whole and to Romanian national statistics (Figures 7 and 8).

An analysis of birth weight data for the first seven months of 1993 performed by the Sanitary Directorate of Alba county indicated that there was no difference in the distribution of weights between Zlatna and Alba (Zlatna mean = 3,183 ± 491 g; Alba mean = 3,168 ± 518 g; see Appendix). An analysis of height and weight data performed by the Institute of Public Health and Medical Research in Cluj showed that children aged 7-11 in Zlatna are 25% smaller than controls (Dr. Eugen Gurzău, personal communication). A possible explanation for this discrepancy is that exposure to lead,

FIGURE 6

DISTRIBUTION OF GENERAL MORBIDITY IN ZLATNA AND ALBA COUNTY, 1992



Legend

1 = Infectious Parasitic Dis.
2 = Tumors
3 = Endocrine & Nutritional
4 = Blood Disorders
5 = Mental Disorders
6 = Central Nervous System & Eyes, Ears, Nose, and Throat
7 = Circulatory Diseases
8 = Respiratory Diseases
9 = Digestive Diseases
10 = Urogenital Diseases
11 = Complications of Pregnancy, Birth, or Neonatality
12 = Skin Diseases
13 = Bone & Joint Diseases
14 = Congenital Malformations
15 = Perinatal Diseases
16 = Not Defined
17 = Accidents

FIGURE 7

BIRTH RATE IN ZLATNA COMPARED TO ALBA COUNTY AND ROMANIA

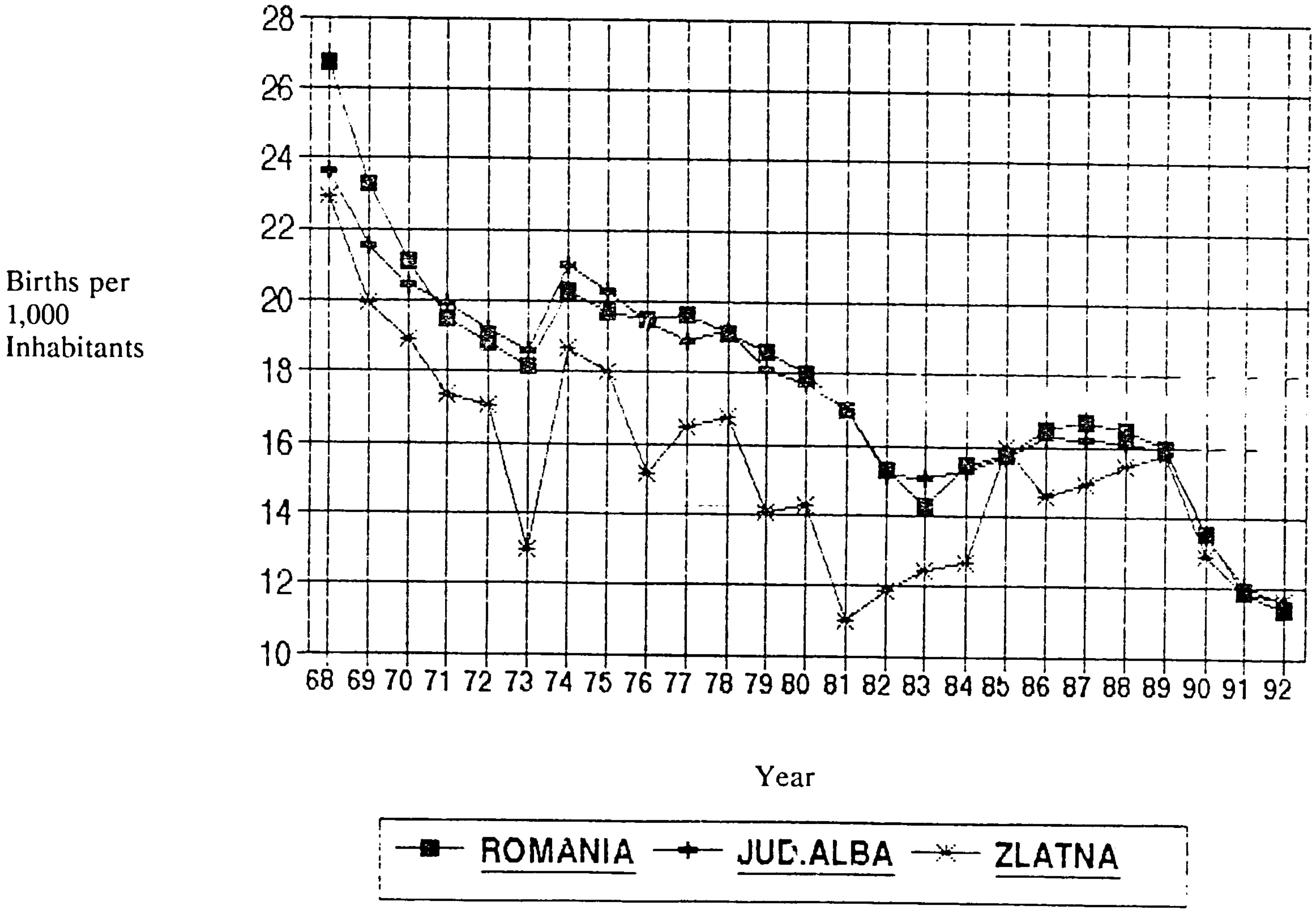
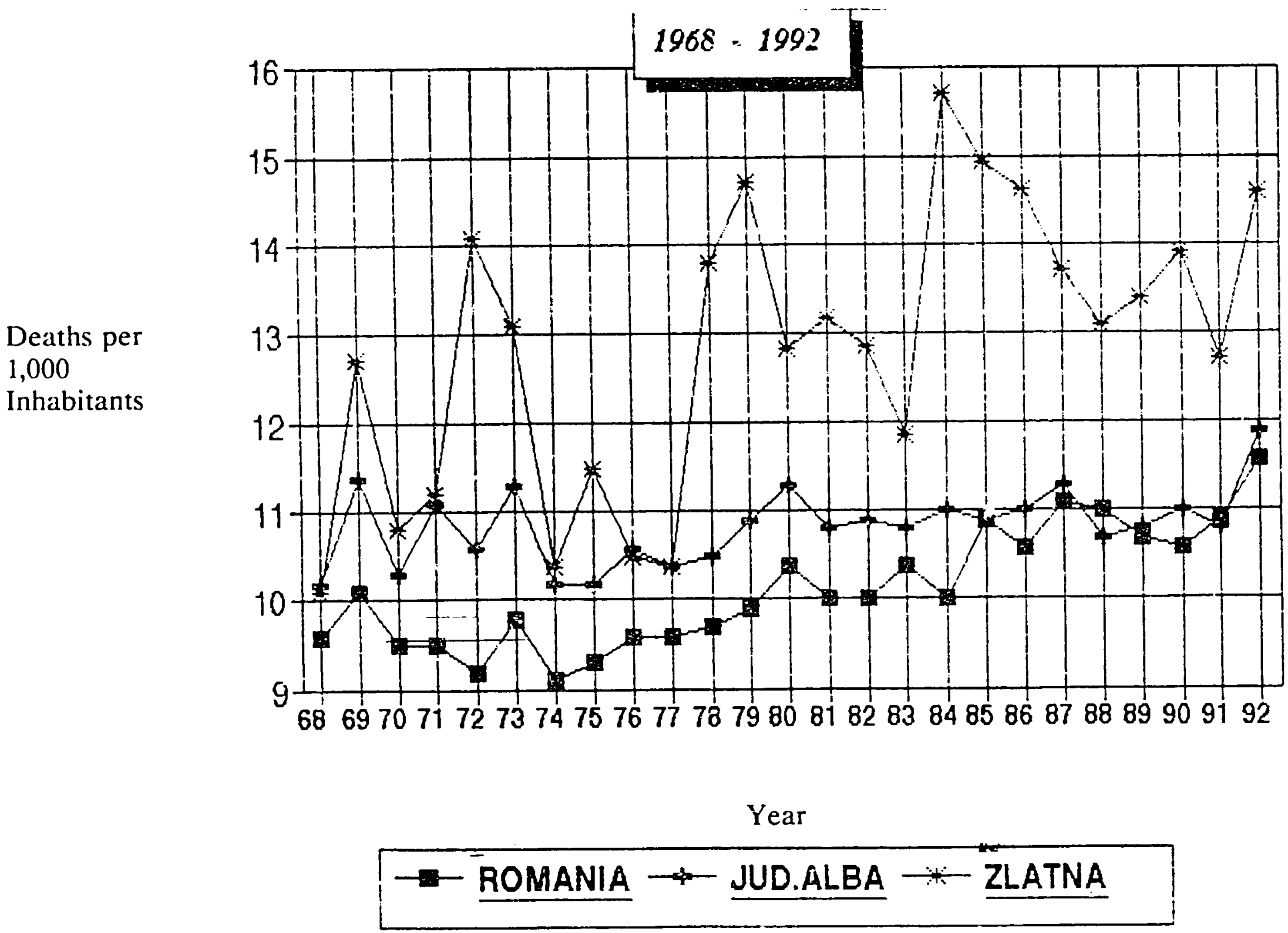


FIGURE 8

DEATH RATE IN ZLATNA COMPARED TO ALBA COUNTY AND ROMANIA



which reduces growth rates, occurs to a greater extent in Zlatna after birth than it does *in utero*. Blood pressure, another indicator of lead toxicity when increased, was reported in the same study to be 15 mm higher among children in Zlatna than in controls.

A study performed in 1980 of 16,000 children throughout Transylvania indicated a 40% prevalence of musculoskeletal defects among children tested in Zlatna compared to 11% among controls; these included pigeon chest, scoliosis, and various skeletal defects in chest structure (Dr. Edith Bretter, personal communication). These developmental defects are likely to have resulted from many factors, including a variety of nutritional deficiencies such as protein, calcium, and magnesium, but may also be related to lead exposure. Childrens' blood lead levels were reported at that time to range from 20 to 65 μg/deciliter (in the U.S., blood lead levels of 10 μg/deciliter or greater are cause for alarm).

Earlier in 1993, lung function tests were performed on children by the Institute in Cluj. Spirometry showed that impairment of lung function among children in Zlatna was 25% more common than among controls, and that 10% of the children had impairment that was not reversible after treatment (bronchodilation) (Dr. Eugen Gurzău, personal communication). Morbidity studies of 19 localities in Transylvania reported that over the period 1983-1989, tuberculosis occurred in Zlatna with an incidence rate that was 50% greater than that of controls, acute upper respiratory tract diseases at a rate 49% greater than controls, chronic respiratory diseases at a rate 41% greater than controls, and bronchial asthma, 103% greater than controls (Dr. Eugen Gurzău, personal communication). While these studies were not controlled for smoking, it is likely that because most Romanian adults smoke, that smoking rates were similar among residents of Zlatna and controls. The atmospheric conditions at Zlatna, particularly the sulfur dioxide and sulfuric acid, are thus very likely to play a role in respiratory disease etiology.

Further studies of the health consequences of exposure to heavy metals and respiratory irritants among children in Zlatna are under way, with results expected in the spring of 1994.

A compilation of tumor incidence data for the year 1992 in Zlatna and in Alba county is shown in Table 10 (complete data in Appendix). Tumor incidence rates appear to be significantly elevated in Zlatna as compared to Alba for a number of sites; however, the population size in Zlatna is so much smaller than that of Alba that a single case of a particular tumor in Zlatna can falsely suggest a rate greatly in excess of that in Alba. These comparisons are thus likely to be misleading due to the small sample size, to the fact that only one year was reported, to the absence of controls for smoking and age adjustment, and to the fact that data for both sexes were combined. However, the fact that these records are kept suggests that the data are available to perform more sophisticated epidemiologic analyses. Tumors that are likely to be elevated due to the heavy metal and irritant exposures in Zlatna include those of the respiratory tract and skin, and possibly the bladder, kidney, and liver.

TABLE 10

TUMOR INCIDENCE DATA IN ZLATNA AND ALBA COUNTY FOR THE YEAR 1992

Tumor Site	Number of Cases		Rate per 100,000	
	Alba	Zlatna	Alba	Zlatna
Oral cavity and lips	19	1	4.61	10.63
Liver	26	2	6.30	21.27
Lung	82	4	19.88	42.54
Bone	15	1	3.64	10.63
Malignant melanoma	5	1	1.21	10.63
Other malignant skin cancer	9	1	2.18	10.63
Breast	64	3	15.51	31.90
Cervix	47	2	11.39	21.27
Uterus	17	3	4.12	31.90
Kidney	5	1	1.21	10.63

Source: Titus Olea, Statistician, Sanitary Directorate of Alba County (see Appendix for complete data set)

RISK CHARACTERIZATION

In this final step of the health risk assessment for Zlatna, information on dose levels for the contaminants of concern is combined with dose-response information to obtain estimates of the likelihood that adverse health effects could result from chemical exposures. This information is developed for each route of exposure and for cancer and noncancer effects.

Cancer

Two of the contaminants of concern, cadmium and arsenic, are regulated in the U.S. as carcinogens by both the oral and inhalation routes of exposure. Table 11 shows the doses estimates for these metals in Zlatna, their cancer potency factors, and the cancer risk estimates obtained by multiplying these two values. The analysis indicates that the excess lifetime cancer risk[7] due to inhaling heavy metals present in the air in Zlatna results primarily from arsenic and is unlikely to exceed about 2×10^{-3}; that is, no more than 2 of every 1,000 exposed people is likely to develop cancer as a result of exposure. This risk estimate is uncertain because the dose level used to estimate arsenic exposure was not based on monitoring data, but on the basis of total emission data and the assumption that arsenic was present at a level one-tenth that of lead, for which monitoring data were available.

In the U.S., a risk of 1×10^{-6} (one excess cancer case out of every one million exposed people) is considered "acceptable" as a policy matter; a risk of 1×10^{-4} is considered unacceptable and requires remedial activity. In this context, a risk of 1×10^{-3} is likely to be unacceptable. This policy context may not be appropriate for air pollution in Zlatna, however, and this risk level should be compared to that of other, uncontaminated areas of Romania. The presence of sulfur dioxide in the air at high levels is likely to further increase respiratory cancer risk due to its irritant qualities.

The excess lifetime cancer risk estimate from oral exposure to arsenic (cadmium is not regulated as a carcinogen by the oral route), which is based only on dose estimates for oral exposure to soil, is about 2×10^{-4}. In the policy context described above, this risk level may be considered unacceptable; although, as also discussed above, U.S. policy contexts may be inapproriate for Romania. This risk level can be compared to that calculated for the background levels of arsenic in the control soil samples, for which the excess lifetime cancer risk is about 4×10^{-5}. The risk in Zlatna is thus one order of magnitude greater than background risk.

It is very likely that arsenic exposure also occurs through contaminated food, especially that grown or produced in the area immediately surrounding the smelter. A quantitative estimate of oral exposure to arsenic from food was not possible. If the contribution of food to the risk of cancer from oral exposure to arsenic were considered,

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[7]Excess lifetime cancer risk is the risk of cancer that results from exposure in addition to that which would be expected to occur normally.

TABLE 11

CANCER RISK ESTIMATES

Contaminant of Concern	Inhalation			Oral		
	Dose (mg/kg/day)	Potency $(mg/kg/day)^{-1}$	Risk	Dose (mg/kg/day)	Potency $(mg/kg/day)^{-1}$	Risk
Arsenic	4×10^{-5}	50	2×10^{-3}	1×10^{-4}	1.75[a]	2×10^{-4}
Cadmium	7×10^{-6}	6.1	4×10^{-5}	NA	NA	NA
		Total	2×10^{-3}		Total	2×10^{-4}

[a]Based on adjusting the potency factor for arsenic in drinking water, 5×10^{-5} $(\mu g/liter)^{-1}$, for a 2 liter daily water consumption rate and a 70 kg person

NA = not applicable; cadmium is not regulated as a carcinogen by the oral route of exposure it would increase the estimate made on the basis of soil ingestion alone.

Noncancer Effects

Cadmium and arsenic are also regulated by the U.S. EPA due to their abilities to elicit noncancer effects by the oral route of exposure. Table 12 shows the doses estimated for these metals in Zlatna, their RfDs, and their hazard indexes, which are estimates of the likelihood that noncancer effects could occur obtained by dividing the dose estimates by the RfDs. The hazard index for each metal is below 1, indicating that adverse health effects other than cancer are unlikely to occur as a result of ingesting soil in Zlatna. However, as noted for cancer, this result does not include the contribution to risk that food contaminated with arsenic may make; including contaminated food would make noncancer risks from arsenic more likely.

Sulfur dioxide is present in the air of Zlatna at a level that exceeds the U.S. air quality standard. Respiratory disease morbidity occurs to a significantly greater extent in Zlatna than other areas, and respiratory tract impairment has been documented among the children of Zlatna. This morbidity and impairment are likely to result in part from sulfur dioxide and sulfuric acid exposure.

Lead is present in the blood of children in Zlatna at levels that are associated with growth, intelligence, and neurobehavioral deficiencies. The primary source of blood lead is contaminated soil and household dust, but food may also contribute.

TABLE 12

NONCANCER RISK ESTIMATES

Contaminant of Concern	Dose (mg/kg/day)	RfD (mg/kg/day)	Hazard Index
Arsenic	1×10^{-4}	3×10^{-4}	0.3
Cadmium	7×10^{-6}	1×10^{-3}	7×10^{-3}

CONCLUSIONS AND RECOMMENDATIONS

Emissions from the copper smelter in Zlatna are increasing the risks of adverse effects on the health of the surrounding community. The contaminants likely to be primarily responsible for the adverse effects are arsenic, lead, and sulfur dioxide. The presence of arsenic increases respiratory cancer risk; that risk is increased further by the presence of high levels of sulfur dioxide. Sulfur dioxide also impairs respiratory tract function and increases the risk of acute and chronic respiratory disease. Blood lead levels among children occur at levels that have been reported to be associated with growth, intelligence, and behavioral deficits. In addition, because monitoring data in Zlatna are not extensive, there may be exposures and health effects that this analysis was unable to quantify.

Reducing emissions from the smelter to the air will reduce the risks of respiratory tract diseases, including cancer. The primary sources of blood lead are soil and household dust, not air, however. Controlling exposures to soil and dust is more difficult than reducing air emissions, and may require measures such as restricting childrens' access to soil, promoting personal hygiene practices such as requiring smelter workers to shower and change clothes before returning to their homes, and promoting other dust control measures in homes such as frequent wet-mopping.

Environmental monitoring activities should be conducted on a regular basis and should include air, water, and soil sampling as well as sampling of foods representative of those grown or produced around Zlatna. Food may be an important additional source of heavy metal exposure. Monitoring results should be used to measure the impact of remedial measures such as reducing air emissions and should be made available to interested parties or published regularly. A regular monitoring program is likely to require a financial investment in modern monitoring equipment.

In addition to monitoring contaminant levels in environmental media, blood lead levels should be measured regularly in children, along with indicators of its toxicity such as IQ and growth rates. A concerted effort should be made to reduce lead exposure due to the insidious effects it can have on young children.

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AREAS OF QUALIFICATION

- Toxicology
- Environmental Risk Assessment
- Cancer Dose-Response Modeling

PREVIOUS AND CURRENT POSITIONS

- Project Director, Committee on Risk Assessment Methodology, Board on Environmental Studies and Toxicology, National Research Council/National Academy of Sciences, Washington, D.C.; 1992-1993
- Vice President, Environmental Health and Toxicology, Meta Systems, Inc., Washington, D.C.; 1989-1990.
- Manager, Toxicology, RCG/Hagler, Bailly, Inc., Washington, D.C.; 1988-1990.
- Project Manager, ICF/Clement Associates, Fairfax, Virginia; 1986-1988.
- Staff Officer, Complex Mixtures Committee, National Research Council, Washington, D.C.; 1985-1986.
- Postdoctoral Fellow, Department of Applied Biological Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts; 1984-1985.
- Scientist, Energy Resources Company, Cambridge, Massachusetts; 1977-1979.

EDUCATION

College	Date	Major	Degree
Massachusetts Institute of Technology	1984	Toxicology	PhD
Wellesley College	1977	Molecular Biology	AB

RELEVANT WORK EXPERIENCE

Dr. Charnley has 15 years of experience in environmental toxicology and risk assessment. She provides toxicologic and other expertise in support of litigation and health risk assessments, including evaluating chemical toxicity and performing dose-response modeling. She has conducted laboratory research, published, and consulted in areas related to the experimental and applied aspects of toxicology and the mechanisms of carcinogenesis. She has developed cancer dose-response models to predict human risks from environmental contaminants, with particular emphasis on biological mechanisms of action. She has applied these models to a number of chemicals for regulatory purposes and has developed criteria for various contaminants in environmental media. Dr. Charnley is a member of the U.S. Army Science Board.

Toxicity Profiles

For: Health and Welfare Canada, Agency for Toxic Substances and Disease Registry, National Aeronautics and Space Administration, U.S. Environmental Protection Agency, State of California Department of Health Services, private clients

Dr. Charnley has authored numerous toxicity profiles of environmental contaminants, critically reviewing scientific literature and providing qualitative and quantitative assessments of the potential human health hazards associated with exposure. These assessments have been used to establish criteria for contaminants in environmental media. The chemicals reviewed include chlorinated hydrocarbons, polychlorinated biphenyls, heavy metals, polycyclic aromatic hydrocarbons, freons, phthalates, and pesticides. In addition, she has evaluated in detail the potential adverse health effects associated with implanted materials such as metal hip replacements, bone cement, and silicone breasts.

Site-Specific Risk Assessments

For: U.S. Environmental Protection Agency, private clients

For a number of Superfund and industrial sites, Dr. Charnley has identified the chemicals of concern, modeled exposure doses, and performed quantitative assessments of the potential risks to public health as a result of exposure. In addition, she has reviewed the technical adequacy of risk assessments performed by other organizations.

Biologically-Based Cancer Dose-Response Modeling

For: U.S. Environmental Protection Agency, Gas Research Institute, American Industrial Health Council, private clients

Dr. Charnley has supported the development of a cancer dose-response model that is consistent with the biological mechanisms of action of carcinogens. This model has been applied to a number of potential carcinogens, including tumor promoters, tumor initiators, and complex mixtures of agents. For example, a comparative potency approach to the assessment of cancer risk from complex mixtures of polycyclic aromatic hydrocarbons such as those found at former manufactured gas sites was developed for a consortium of utilities, the Gas Research Institute, and the U.S. EPA. A biologically-based assessment of the potential cancer risk due to exposure to a pesticide was prepared for its manufacturer; since this estimate was considerably lower than empirical estimates of its risk, it enabled them to prevent cancellation of its registration. In addition, data needs for more widespread application of the model have been evaluated for the American Industrial Health Council and will serve as a basis for the design of a long-term research program.

Litigation Support

For: U.S. Department of Justice, private law firms

Dr. Charnley has provided scientific and technical support for cases of liability and toxic tort. She has identified and prepared expert witnesses, evaluated the qualifications of and assisted in the deposition of opposing witnesses, identified and researched scientific questions key to the issues of the case, performed and critiqued risk assessments, and assisted the preparation of lines of inquiry for direct and cross-examination.

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WORKER HEALTH AND SAFETY ASSESSMENT

AMPELLUM S.A.

ZLATNA, ROMANIA

BY: MELITON M. GARCIA

OCTOBER 11 - 15, 1993

World Environment Center
419 Park Avenue South, Suite 1800
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DECEMBER 1993

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ASSESSMENT

OF THE

OCCUPATIONAL HEALTH AND SAFETY PROGRAM

AT THE COPPER SMELTER

OPERATED BY

AMPELLUM COMPANY, S.A., IN ZLATNA, ROMANIA

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November 1993

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EXECUTIVE SUMMARY

At the request of World Environment Center (WEC), this specialist joined other specialists invited by WEC in a fact finding visit to a copper mining and smelting operation owned by Ampellum, S.A., in Zlatna, Romania. The purpose of the visit was to render an opinion regarding the environmental and occupational health and safety conditions at these operations. The specialists, also, had opportunities to meet with USAID representatives and with representatives of various Romanian government ministries and academic institutions. The visit was made in the company of Mr. Tom McGrath and Mr. Liviu Ionescu of WEC during October 9 - 21, 1993.

This specialist was specifically charged with the responsibility to evaluate the occupational health and safety conditions at the smelter. As a result, this report will only address those issues related to this assignment.

The smelter was visited during October 11 - 15, 1993. During this period meetings were held with management and technical representatives of Ampellum to learn about their programs related to occupational safety and health. In addition, visits were made to the various workplaces in the smelter to observe the actual operations and ambient conditions for the purpose of assessing the potential risks to personnel as they perform their tasks. The assessments were general in nature as no actual environmental measurements were made to quantify the magnitude of potential exposures to occupational stress agents.

In general, it can be said that management and technical personnel contacted are cognizant of the existence of serious hazards in the work environment. They appear to recognize their responsibility to minimize or eliminate the exposures, however, they feel they are limited in fulfilling their responsibilities due to their lack of adequate resources to better identify, evaluate, and control the potential safety and health hazards. These resources include personnel trained in the science of occupational health and safety, monitoring equipment to quantify the potential stress agents, and funding to implement the controls necessary to obviate exposures.

As a result of our discussions and visits to the actual workplaces, the following major deficiencies were noted:

1. While the company employs an occupational physician and a safety representative, there appears to be no formal program for occupational safety and health. As a result, a comprehensive study has not been made by the Company to adequately identify real and potential occupational hazards nor quantify the potential risk.

The existence of real and potential health hazards was evident to this specialist as cursory tours were made of the various workplaces. Exposures to toxic airborne contaminants such as mineral dusts, metal fumes, acid gases and mists, and organic vapors; contact with corrosive liquids; exposure to physical agents such as noise, heat and cold stress, and vibration; and exposure to ergonomic hazards appear to be a daily experience to the persons working in the smelter and its ancillary operations.

From an industrial safety standpoint, personnel were observed performing tasks that could easily lead to serious injuries. Most of the unsafe acts and work practices observed were the result of having to perform their tasks under unsafe conditions and with unsafe or inappropriate equipment and tools. For example, poor housekeeping practices and poor lighting may result in slips and falls; absence of protective shields on milling machines and abrasive grinding wheels can lead to serious eye injuries; and improper rigging on a crane can result in fatal injuries to personnel working under suspended loads.

2. When engineering or administrative control of hazards are missing or not feasible, personal protective clothing must be provided to the workers and their use should be enforced. In these operations, use of personal protective clothing and equipment appeared to be optional. Workers were seen performing hazardous operations without the benefit of safety shoes, safety glasses or goggles, hard hats, respiratory protective devices, or other protective devices commensurate with the potential hazard. While it was mentioned by management personnel that protective clothing and equipment were available to anyone desiring it, it was evident, by their absence, that adequate supplies and appropriate devices were probably not on hand.

4. The occupational medical program did not appear to be organized nor equipped to treat illnesses or injuries other than minor first-aid cases. It was observed that the plant physician lacked the necessary facility, furnishings, and equipment to allow proper diagnoses and treatment of a worker suffering from an acute, but transitory illness. As a result, these cases are referred to the local hospital in Zlatna or to a medical facility in Alba Iulia. This practice may result in greater discomfort for the patient, increased lost workdays, decreased productivity by the worker, and increased emotional stress to the worker and his/her family.

5. Based on information obtained from the plant physician lead poisoning is a serious threat to the welfare of the workers in the smelter. Unfortunately, there does not appear to be any program directed towards preventing disease nor in identifying the persons affected until they become frank cases of lead poisoning.

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This preoccupation with lead poisoning appears to keep the plant physician from identifying other potential occupational diseases.

6. There is a serious need for trained specialists in occupational health, industrial hygiene and safety. Unfortunately the Institute of Hygiene and Public Health is not yet able to satisfy this need.

7. There is a need to train management and workers in the recognition of occupational hazards and on the safe practices that are necessary to prevent exposures to toxic materials, ergonomic stresses, and sources of uncontrolled energy.

Based on the findings, the following action is recommended:

1. Health and safety personnel employed by Ampellum should be given the opportunity to receive training in the recognition, evaluation, and control of occupational health and safety hazards. This training can be obtained by attending workshops, seminars, and professional conferences and short courses offered in the U.S.A. and in Europe.

2. A person(s) certified in the practice of industrial hygiene and safety should be retained by Ampellum for a period of time to work with the company's health and safety personnel to provide on-the-job training. The consultant would assist in organizing a proactive health and safety program in the smelter.

4. Sufficient and properly selected industrial hygiene equipment be purchased to perform the basic monitoring activities necessary to quantify the real and potential exposures to stress agents. An expenditure of about $50,000 (dollars) would provide an appropriate inventory of basic equipment.

5. The occupational medical program needs to be strengthened by providing a medical dispensary that is equipped with appropriate medical instruments and furnishings to improve the diagnosis and treatment of occupational illnesses and injuries.

6. A training program needs to be organized to inform the management and technical personnel and the hourly employees regarding the recognition of occupational health and safety hazards and action that they can take to minimize or eliminate the hazards.

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INTRODUCTION

This report is being submitted by Meliton M. Garcia, a health and safety professional residing in Idaho Falls, Idaho. This specialist participated in this project as a private individual and not under sponsorship of his current employer.

At the invitation of World Environmental Center (WEC), this specialist agreed to participate in this project under sponsorship of WEC/USAID, Contract No. LA94R04382. The assignment given to this specialist was to evaluate the occupational health and safety program at a copper smelter operated by Ampellum, S.A.. The project was conducted during October 9 - 21, 1993. This specialist was a member of a group of four specialists, each having specific and different assignments. The group was accompanied by WEC representatives, Messrs. Tom McGrath and Liviu Ionescu during most of the visit to Romania.

FINDINGS

Ampellu, S.A. is located within the community of Zlatna, Romania. Zlatna, with a population of about 9800, is surrounded by a number of rural communities; its nearest urban community is Alba Iulia.

Ampellum, S.A. operates a smelter and a number of ancillary processes. It employs about 2500 people and operates four workshifts per day. Workers live in Zlatna and in the surrounding communities. The products produced at this facility include: electrolytic copper, sulfuric acid, copper sulfate, magnesium sulfate (technical and pharmaceutical grades), iron sulfate, and aluminum powder. The latter is not a by-product of the smelting process.

During the week of October 11-15, meetings were held with the management and technical personnel of Ampellum. During these meetings, information was obtained regarding the operating philosophy of the company and a description of the types of operations being conducted. In addition, walk-through visits were made in the plant to get acquainted with the operations and the prevailing conditions in the workplaces. These visits provided this specialist with an opportunity to observe the work practices of the employees, to look for real and potential occupational hazards, and to subjectively assess the efficacy of control methods and devices. The following summarizes, in a general way, the observations of this specialist:

1. Smelting operations

   Workers are potentially exposed to:

   a. High levels of copper concentrate dust containing lead and other metal sulfides and oxides.
   b. Fugitive emissions of sulfur dioxide.
   c. Heat or cold stress, depending on the time of the year.
   d. High noise levels.
   e. Ergonomic stresses resulting from material handling tasks.

   Workers were observed performing tasks that pose eye injury hazards without the benefit of eye protective devices. No respiratory protective devices were in use to protect against dust and irritating acid gases. Few hard hats were being worn in this area where the potential for head injuries is high. Personnel were observed wearing tennis shoes and other types of soft-toe footwear. Heavy loads were being hoisted with a crane whose lifting hook did not have a safety clip to prevent the cables from slipping out of the hook. Numerous tripping hazards were observed on the walking and working surfaces.

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2. Sulfuric Acid Plant

The potential for exposure to sulfur dioxide is very real. It was noted that large amounts of this gas were escaping through the shaft bearing of a large blower located at ground level. The gas was dispersing to other areas in the smelter and was causing extreme respiratory and eye irritation to unsuspecting and uninvolved personnel.

While not observed, it is anticipated that there is a potential for contact with the sulfuric acid which leaks from pumps, valves and pipe connections.

Use of respiratory protection or chemical safety goggles by personnel working in this area was not observed.

3. Copper Sulfate Plant

Judging from the extent of corrosion of the equipment and the structures, one can anticipate that contact with sulfuric acid and copper sulfate liquor is a real possibility. This contact can cause serious dermatitis problems. Personnel were not wearing personal protective equipment.

During the solvation process, air is blown into the solution to ensure proper mixing of the material. Induction of the air is caused by discharging high pressure steam through an ejector. This process creates high noise levels in the area. Hearing protective devices were not being used by personnel working in this area.

The final product, granulated copper sulfate, is bagged and shipped to storage or to the customer. These bags, weighing 50 kilograms, are manually handled by the workers. This creates a serious potential for back injuries or muscle strain and stress. Use of smaller bags and/or mechanical lifting devices would reduce or eliminate this potential hazard.

4. Magnesium Sulfate Plant

This facility was not visited because no production was in progress. However, one can anticipate that the major potential hazards cited for the copper sulfate operation can be observed here since the processes are similar.

5. Aluminum Powder Plant

Bulk aluminum metal is melted in a high temperature furnace. The liquid metal is allowed to flow through a spigot into a stream of high velocity compressed air being discharged to the atmosphere. The compressed air causes the liquid metal to aerosolize and cool thus creating an aluminum powder that is collected in a settling chamber. The powder is then separated into varying size fractions. Those fractions having a diameter greater than 63 micrometers are then fed into ball mills containing toluene for further size reduction. The toluene acts as a carrier of the fine aluminum powder. This mix is placed in externally heated vessels to drive off the toluene and collect the aluminum powder. The toluene is recovered and recycled. Because there is a loss of toluene through leaks in the process vessels, fresh toluene is added to maintain the required volume of the carrier liquid.

The potential exposure to toluene vapors is evident as one walks around the process equipment and buildings. Acute or prolonged exposure could result in central nervous depression and could lead to inattention of the worker to safe work practices so important in this facility.

It was noted that the employees are well aware of the flammability hazard posed by toluene. They, also, are cognizant of the potential for a metal dust explosion resulting from the pyrophoricity of the fine aluminum powder. As a result, a higher safety awareness is evident in these workers.

6. Maintenance Shops

In order to maintain the plant equipment operating, the machine shop and the welding shop are kept quite busy. Unfortunately, there appears to be a total disregard for the need to use appropriate barriers to prevent eye injuries. Workers were observed operating lathes, milling machines, and hand held and pedestal grinding wheels without the benefit of safety glasses, goggles or machine guards. These work practices pose imminent danger to the workers and could result in loss of sight.

In the welding shop, only the welders used eye protection while welding. Personnel assisting the welders held their hand in front of their eyes to prevent flash burns. There were few shields set up to isolate one welding operation from another; as a result, personnel not directly involved with a welding project were subject to flash burns. Safety glasses were not being worn by anyone in this shop.

The potential for exposure to welding fumes is real due to the number of concurrent welding operations taking place in one room.

7. Analytical Laboratory

A number of conditions and work practices were noted that can result in serious injury to laboratory employees. For example:

a. Analytical personnel were observed drawing chemical reagents into transfer pipettes by using their mouths. The potential for causing injury to the tissue in the mouth and to the teeth or to the internal organs as result of ingesting hazardous chemicals should be obvious.

b. The samples of ore and mineral concentrates undergo digestion in vessels containing strong mineral acids. These procedures are performed inside laboratory fume hoods. Unfortunately, air flow through these hoods is minimal and any disturbance of the ambient air in the room caused by the person walking past the hood or by air drafts in the room can draw the contaminants into the room. To prevent this from occurring, the efficiency of the exhaust ventilation fans must be upgraded and the ventilation system, as a whole, must be repaired.

c. Before an ore or a copper concentrate sample can be analyzed, it must be crushed and pulverized. This process generates considerable amounts of dust. To prevent exposure to the dust, it is essential that local exhaust ventilation devices must be installed on the crushing and grinding equipment. If dust collection devices are not efficient, personnel performing these operations should wear appropriate respiratory protective equipment.

d. Personnel handling any chemical reagents and glassware contaminated with these reagents should be encouraged to wear appropriate protective gloves. This will prevent contact of the skin with corrosive and toxic materials and eliminate the potential for exposure through skin absorption or ingestion of these materials.

8. Toxicology Lab

This lab is occupied by the Director of Safety and his staff. The lab has been set up to analyze air samples that are collected by the technicians in the workplace. A quick review of the equipment and sampling methodologies used for collecting samples of air contaminants raises doubt that few, if any, quality samples can be taken. It was noted that the two sampling pumps are old and worn out and the plastic hoses used to connect the pump to the sampling impingers are brittle and do not provide a tight seal on the suction port of the impinger. The condition of this equipment is not conducive to maintaining an aggressive sampling program.

Except for the two sampling pumps, no other type of equipment is available to perform the assessments required to characterize the type nor the magnitude of potential exposures to chemical, physical, or ergonomic stress agents.

Having met the safety staff, it is evident that these specialists are competent and have the initiative to perform the necessary tasks related to evaluating exposures of the employees, however, they need training to upgrade their industrial hygiene skills and they need state-of-the-art industrial hygiene monitoring equipment to perform the assessments.

During the week, this specialist, also, had the opportunity to meet with medical personnel at the smelter, at the local hospital, and at the center for the treatment of occupational disease in Alba Iulia. These meetings provided an opportunity to obtain information concerning the prevalence of occupational diseases occurring at the plant, the local community, and in the district. Unfortunately, the data is not complete nor readily available. However, the consensus expressed by these medical personnel was that lead poisoning among the workforce is the most prevalent occupational disease.

On Monday morning, October 18th, the group attended meetings in Bucharest with personnel from USAID to be informed about our observations and suggestions regarding what could be done to assist Ampellum improve their programs to control environmental pollution and occupational hazards. Also, in attendance at this meeting were representatives of the International Foundation of Electoral Systems (IFES) and the Harvard Institute for the International Development (HIID). These representatives presented summaries of their respective programs. Considerable discussion resulted.

During the afternoon, this specialist spent some time with Dr. Mary Ann Micka of USAID discussing training that could be promoted to increase the number and competency of individuals concerned with the practice of occupational health.

On Tuesday, October 19th, the WEC team and representatives of USAID, IFES, and HIID met with representatives of the Ministries of Health, Environment, and Agriculture and from the Institute of Hygiene. This presented a good forum for discussing our findings and for exchange of information regarding the Romanian government's future direction in promulgation of environmental and occupational health and safety legislation. The governmental representatives were pleased to get our input and were solicitous of any help which we might render to further their efforts in these important issues.

In addition, on Tuesday, afternoon, the WEC team had the opportunity to visit with the Dean of the Department of Nonferrous Metallurgy and with faculty representatives from the Politechnical Institute. Following this meeting, we had the pleasure of visiting with Dr. Radu Dornean, General Manager of Cast Research Instruments. The company is developing and manufacturing instrumentation to be used for environmental pollution monitoring. Dr. Dornean gave us a guided tour of his company's research and manufacturing facilities.

On Wednesday, October 20th, this specialist, in the company of USAID representative, Dr. Mary Ann Mica, met with Dr. Mircea Tat of the Institute of Hygiene and Public Health. Present at this meeting was Dr. Boll of the Ministry of Environmental Protection. The meeting was at the Institute. Discussions centered around the educational opportunities in Romania for persons to obtain degrees in Occupational Medicine and in Industrial Hygiene and Industrial safety. There is a great need in Romania for occupational physicians, industrial hygienists and safety professionals. Discussions, also, included a review of the current legislative activities related to the promulgation of occupational health and safety standards. This work could be expedited if qualified professional were retained to assist in the development of the standards.

CONCLUSIONS AND RECOMMENDATIONS

A review of the occupational health and safety program at the smelter and its ancillary operations indicate that the program is not well defined and that compliance with recognized good practices in the prevention of occupational illness and injuries is below acceptable standards. This appears to be due to a number of factors, such as: (a) The program is reactive rather than proactive in identifying, evaluating and controlling health and safety hazards. Attention seems to be directed only to those situations where workers are being injured, but the root causes are not being recognized and controlled. (b) Personnel assigned to function as safety and health professionals lack training that will upgrade their abilities to execute a proactive program. (c) Instrumentation needed to perform industrial hygiene evaluations is unavailable. (d) The occupational medical program responds only to first-aid cases. It lacks the facilities and the medical equipment to diagnose and treat occupational diseases. (e) Appropriate types of personnel protective clothing and equipment are unavailable or their use is not enforced. (f) Training is not provided to the workers to inform them of the real and potential hazards and the safe work practices that are necessary to obviate exposure.

Real and potential exposure to toxic chemical substances, to physical agents,and to ergonomic stresses were evident throughout the smelter and ancillary operations. While some evidence was presented that suggests that some effort has been made to assess exposure to some chemical agents, the methodologies used to make these assessments are questionable and the extent of these efforts is minimal at best.

If a reduction of occupational illnesses and injuries is to occur at Ampellum, it will be necessary to consider the following actions as a minimum:

1. Company personnel responsible for the health and safety program must receive training at recognized institutions and by qualified professionals so as to up-grade their skills in health and safety program management and in hazard recognition, evaluation, and control.

2. A certified safety professional should be retained by the company to provide on-the-job training to the company safety and health personnel. This will expedite the development and efficiency of the company safety program.

3. Instrumentation needs to be purchased to permit the assessment of personnel exposure to agents that produce occupational illnesses.

4. The medical program and its facilities and equipment need to be up-graded to allow the resident physician to diagnose and treat frank cases of occupational illnesses.

5. Training that is specific to recognized hazards should be given to the workers to apprise them of the nature of the hazards and the safeguards and safety practices necessary to avoid and eliminate the exposure.

6. Proper personal protective clothing and equipment must be selected for the specific hazards and must be supplied in sufficient quantities to encourage the workers to use them. Supervisors must enforce the use of this equipment where engineering controls or administrative methods of exposure control are not feasible.

7. The exhaust ventilation system in the analytical laboratory which services the fume hoods needs to be up-graded by repairing the duct work, cleaning the fans, making sure that the fan belts are not slipping, and balancing the airflow through each hood. The air velocity at the face of the hood, with the sash open, should be at least 80 feet per minute for each square foot of hood opening.

8. The methods used in the analytical laboratory to handle and transfer chemical reagents need to be evaluated and up-graded to eliminate the chances of contact of the toxic and corrosive liquids with the skin, eyes and mouth. Appropriate protective clothing must also be provided and lab personnel must be encouraged to use these devices.

CURRICULUM VITA

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Education

Bachelor of Science	Mining Engineering (1959), New Mexico Institute of Mining and Technology, Socorro, NM
Master of Public (MPH)	Industrial Hygiene (1963), University of California, School of Public Health, Berkeley,CA

Professional Certifications

Certificate No. 682	Comprehensive Practice of Industrial Hygiene (CIH)
Certificate No, 689	Certified Safety Professional (CSP)

Work Experience

Jan 1993 - Present **EG&G Idaho, Inc.** **ER&WM Department**	Program Manager, Quality Assurance Program for Exhaust Ventilation Air Cleaning Systems; Alternate Member of the Independent Safety Review Committee
Nov 1988 - Dec 1992 **EG&G Idaho, Inc.** **ER&WM Department**	Lead Industrial Hygienist; Primary and Alternate Member of the Independent Safety Review Committee
Sep 1980 - Nov 1988 **University of Arizona** **College of Eng. & Mines**	Industrial Hygienist, Bureau of Geology and Mineral Technology; Director, San Xavier Mine Laboratory; Adjunct Professor, Department of Mining and Geological Engineering, College of Engineering and Mines; Principal Investigator for a number of funded research projects
Jan 1980 - Sep 1980 **Tenneco Automotive Co.**	Manager for Corporate Safety and Industrial Hygiene matters and oversight responsibilities for Safety and Industrial Hygiene matters at Monroe Automotive Equipment Company
Apr 1978 - Sep 1979 **Los Alamos National Laboratory**	Ventilation Engineer, Group H-5
Jul 1974 - Apr 1978 **Tenneco, Inc**	Manager, Occupational Health, Loss Control Department (Corporate)

Nov 1969 - Jul 1974 Gulf Oil Corporation	Regional Industrial Hygiene Engineer, Medical Department (Corporate)
Jun 1967 - Nov 1969 The Boeing Company Commercial Airplane Div.	Senior Industrial Hygiene Engineer, Industrial Hygiene Unit, Industrial Relations Department
Jun 1963 - Jun 1967 The Boeing Company Commercial Airplane Div.	Industrial Hygiene Engineer, Medical Department
Jul 1961 - Aug 1962 State of New Mexico Dept. of Public Health	Industrial Hygiene Technician, Uranium Miners Study
Jun 1959 - Jul 1961 San Manuel Copper Corporation	Junior Mining Engineer

Private Consultant

Oct 1979 - Nov 1979	Industrial Hygienist, Newport News Shipbuilding and Dry Dock Company
Jul 1986 - Nov 1986	Industrial Hygienist, Tabershaw & Pike, Inc. Principal focus was development of an asbestos analytical lab and building inspection program
Nov 1986 - Nov 1988	Vice President, Technical Services, Tabershaw and Associates, Inc. Principal focus was management of asbestos inspection and abatement.
Miscellaneous	Expert Witness in matters related to Industrial Hygiene and Safety for numerous legal firms

Funded Research

1987	Principal Investigator, "Characterization of Carcinogenic Compounds Produced by Detonation of Explosives," Arizona Mining and Mineral Resources Research Institute, U.S. Bureau of Mines Grant No. G1174104, Amount: $16,000
1984 - 1986	Principal Investigator, "Gases from Explosives Detonated in Underground Mines," U.S. Bureau of Mines Contract No.J0145008, Amount: $131,911
1984	Principal Investigator, "Shift Rotation Data on Driver Alertness from Large Mobile Equipment Operators," U.S. Bureau of Mines Contract No. H0245001, Amount: $11,847

1981 - 1982 — Co-principal Investigator, "Monitoring of Gases from Explosives Detonated in an Underground Mine," U.S. Bureau of Mines Contract No. H0395098, Amount: $122,249

Technical Contributions

Books and Monographs

Direct Reading Colorimetric Indicator Tubes Manual, First Edition, American Industrial Hygiene Association, (1976)

Manual of Recommended Practice for Combustible Gas Indicators and Portable, Direct Reading Hydrocarbon Detectors, First Edition, American Industrial Hygiene Association, (1980)

Industrial Hygiene Aspects of Plant Operations, Volume III, Engineering Considerations in Equipment Selection, Layout, and Building Design, Edited by Lester V. Cralley and Lewis J. Cralley, Macmillan Publishing Co., Inc., (1985)

Inplant Practices for Job Related Health Hazards Control, Volume I, Production Processes, Edited by Lester V. Cralley and Lewis J. Cralley, John Wiley & Sons, (1989)

Journals

"Analysis of Gases Produced by Detonations in An Underground Mine," Meliton M. Garcia and Satya Harpalani, Transactions of the Institute of Mining and Metallurgy, (1988)

U.S.B.M. Reports

"Monitoring of Gases from Explosives Detonated in an Underground Mine," Final Report, Contract No. H0395098, U.S. Department of the Interior, Bureau Of Mines, 79 pages, (June 1982)

"Shift Rotation Data On Driver's Alertness from Large Mobile Mine Equipment Operators," Final Report, Contract No. H0245001, U.S. Department of the Interior, Bureau of Mines, 99 pages, (October 1984)

"Gases from Explosives Detonated in Underground Mines," Final Report, Contract No. J0145008, U.S. Department of the Interior, Bureau of Mines, 97 pages, (June 1986)

Miscellaneous

"Historical Perspective in Mine Health and Safety," Mel Garcia, Fieldnotes, Vol. 11, No. 3, The Arizona Bureau of Geology and Mineral Technology, (Sepetember 1981)

"Asbestos - Toward a Perspective," H. Wesley Feirce and Meliton M. Garcia, Fieldnotes, Vol. 13, No. 1, The Arizona Bureau of Geology and Mineral Technology, (Spring 1983)

"Mine Equipment Operators' Perceptions Concerning Alertness and Shift Rotation," Jon A. Wagner, James C. Duchon, and Meliton M. Garcia, Proceedings of the Human Factors Society, Vol. I, p. 571-575, 30th Annual Meeting, (1986)

"Gases from Explosives Detonated in Underground Mines," Satya Harpalani and Meliton M. Garcia, Proceedings, 3rd U.S. Mines Ventilation Symposium, p. 207-212, (1987)

Conferences, etc.	Numerous presentations in national and international conferences, seminars, and workshops related to industrial hygiene and safety.

Professional Organizations

1971 - Present	American Industrial Hygiene Association (AIHA) Served as committee member in: Committee on Gas and Vapor Detection (1978-80) Committee on Management (1981-82)
1981 - 1988	Arizona Section - AIHA Served as: Member of the Board of Directors (1983-84) President-elect (1984-85) President (1985-86)
1981 - 1988	Association of Arizona Mine Safety Engineers Served as: Secretary (1983-84) President (1984-85)
1981 - 1986	Southwest Safety Congress Served as: Member of the Board of Directors (1981-86) Program Chairman (1982-83)
1985 - 1986	Southern Arizona Safety Council Served as Member of the Board of Directors
1971 - 1993	American Society of Safety Engineers (ASSE)
1981 - 1988	Southern Arizona Chapter - ASSE
1989 - 1993	Snake River Chapter - ASSE

1992 - Present	American Conference of Governmental Industrial Hygienists, Inc. (ACGIH)
1971 - Present	American Academy of Industrial Higiene (AAIH)
1971 - Present	Board of Certified Safety Professionals (BCSP)

ENVIRONMENTAL ASSESSMENT

COPPER MINES

ZLATNA, ROMANIA

BY: JOHN W. WILSON, PH.D.

OCTOBER 11 - 15, 1993

World Environment Center
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DECEMBER 1993

ENVIRONMENTAL ASSESSMENT OF TECHNOLOGY, HEALTH AND SAFETY CONDITIONS IN THE SMELTER AND MINES NEAR ZLATNA, ROMANIA

MINING OPERATIONS REPORT

by

DR. JOHN W. WILSON

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ENVIRONMENTAL ASSESSMENT OF THE TECHNOLOGY, HEALTH AND SAFETY CONDITIONS IN THE SMELTER AND MINES NEAR ZLATNA, ROMANIA

EXECUTIVE SUMMARY

More than 35,000 people are employed in the Zlatna area by the operating mines, concentrators and Ampellum Company Smelter. Although only two operating mines were examined in some detail, it is clear that the mines are extremely labor intensive, use very old mining and transportation techniques, and have little or no mechanization. The equipment that is used in the mines is old, often obsolete, and requires significant maintenance in order to keep it running.

In general, health and safety regulations exist and are enforced by the Romanian authorities in the work areas.

Personal inspections of surface and underground mines revealed acceptable ambient dust levels in and around the mine working areas, satisfactory mine ventilation circulation, air velocities, air quantities and air quality. Workers wear hard hats, coats and other protective clothing, but are not required to wear eye glasses.

Mine water, albeit highly acidic, was adequately drained and collected at the lower level of the mine for pumping out of the mine. However, serious pollution problems are in existence due to the disposal of this acid mine water directly into a nearby stream. Pumping problems exist at the Hanes mine due to rapid corrosion of pump parts.

Since there are many families that live near to the polluted stream adjacent to the Hanes mine that obtain their water from water wells, a detailed hydrogeological survey should be implemented to establish the effects of this acid water pollution on other aquifers and run-off water in the area between the mine and the town of Zlatna.

The Hanes mine has been classified as a "No Smoking" mine. This being the case, all acetylene/carbide lamps should be withdrawn from the mine and all miners issued with battery cap lamps.

A ground water study should be carried out in the lower areas around the Rosia Poieni mine to determine whether the run off water from the open pit mine is contaminating local streams in the area.

ENVIRONMENTAL ASSESSMENT OF THE TECHNOLOGY, HEALTH AND SAFETY CONDITIONS IN THE COPPER SMELTER AND MINES NEAR ZLATNA, ROMANIA

JOHN W. WILSON

INTRODUCTION

The World Environment Center (WEC) has a cooperative agreement with the United States Agency for Industrial Research and Development (USAID) to provide US private sector expertise to transfer technology and skills to Eastern European industry and government representatives so that they can more effectively reduce industrial and urban pollution, improve solid, hazardous and toxic waste management, improve industrial health and safety practices, improve energy conservation and management, and increase community awareness in environmental and energy related areas.

One of the cooperative agreement programs is associated with a copper smelter and mines that operate in the Zlatna area of Romania. WEC assembled a specialist team to travel to Zlatna to environmentally assess the technology, health and safety conditions at the copper smelter, in and around the mines and the nearby communities, and to develop practical low cost recommendations for improvements.

ASSIGNMENT

This report describes the observations and recommendations of the Technical Expert that was assigned the following tasks defined by WEC, and associated with the mines in the Zlatna area.

1. Review available information on the copper mines, including mining, engineering, health and safety conditions.
2. Assess the technology used at the mines and compare with modern methods.
3. Conduct an environmental assessment at the mines, particularly for fugitive dust emissions.
4. Review and assess the health and safety conditions of the workers at the copper mines.
5. Make recommendations to reduce pollution generation through low cost technology, and improve the health and safety conditions of the workers.

OBSERVATIONS AND COMMENTS ON THE MINES VISITED

The Ampellum Company smelter located in Zlatna receives copper concentrates from approximately ten mines, two of which were examined during the technical assessment described here. Observations made at the Hanes and Rosia Poieni mines are described below.

HANES MINE

The entrance to the Hanes mine, located 18 km by road from the smelter, is approximately 700 meters above sea level and consists of underground mining operations carried out in two separate areas that are served by a common mine portal and sub-vertical shaft system.

Approximately 300 tons of ore are mined daily from the "Stock" and No. 11 vein mining areas. This ore is transported out of the mine by small mine cars filled at loading points located in horizontal tunnels sited below the working areas, up a vertical shaft, and then hauled by diesel locomotives out of the Hanes portal. Outside of the mine all ore is transferred to an aerial ropeway 8.5 km in length that takes the ore to the copper concentrator located near the Appellum Smelter.

Overall, there are 1130 persons employed at the Hanes Mine that carry out underground mining, surface and underground transportation work, operate the concentrator plant, perform mine engineering and the exploration programs for the Hanes and Laga mines. This latter mine is still in the exploration and development phase and does not produce mineral ore at the present time. However, when it is ready for production it will utilize the Hanes Mine portal and aerial ropeway.

The mining methods used in the Hanes Mine are mining industry standards that are used for exploiting similarly configured ore bodies. Operations at the Hanes mine are extremely labor intensive, low in productivity, with only a small number of old pieces of equipment in use.

The ores mined are "low grade" and contain less than one percent copper. The stock and vein mining areas do however, contain approximately 2 grams per tonne of gold and 25 grams per tonne of silver which, when concentrated, produces a grade of 25 grams per ton of gold in the concentrated ore.

The mine currently operates to a depth of 280 meters below the Hanes portal or adit, that is, approximately 600 meters below the top of the mountain. Water from rain and other forms of precipitation percolates through the strata, and along with the water used by the miners for dust suppression, gravitates to the lower level of the mine to be pumped to the Hanes portal and out of the mine for discharge into the nearby stream. Because of the high pyrite content of the ore body (from iron sulfide) the water is extremely acidic and causes serious corrosion problems to the mine pumps, steel rails etc. in the mine, and significant pollution to the nearby stream. The pH is quoted as being between 1.5 and 2.1

Productivity is extremely low at this mine, although environmental conditions, with the exception of the lack of effort to neutralize the acid water, seem to be satisfactory. Government regulations are in place and their inspectors monitor and enforce mine ventilation, air quality, dust levels and noise levels in the mine and at the working faces. Although the mine is classified as a fiery mine (i.e. no smoking allowed) it was noted that workers used carbide lamps and management mentioned the difficulty in preventing workers from smoking underground. Non-smoking violations are undesirable but are not as serious as they would be in a coal mine or other type of mine where hydrocarbons are encountered in the working area.

At the current rate of production, reserves of mineable ore from the Hanes mine are sufficient to last approximately 10 years, excluding the new reserves under exploration at the Laga mine. If an effort is made to improve productivity by increasing tonnage rather than reducing the labor force, it is unlikely that a meaningful improvement will occur because of the existing narrow galleries, confined small shaft and restricted rock handling facilities. A major capital investment program would be necessary to ensure a profitable operation by competitively mining the veins and overall ore reserves at the Hanes mine. Currently, more than 600 people are employed at this mine to transport and concentrate the mined ore at the concentrator located adjacent to the Ampellum Smelter. The concentrator is extremely old with equipment that requires excessive maintenance. The crushers, screens, mills and flotation cells are typical of equipment manufactured in the 1950's and the building that houses the equipment is run down and in need of repair.

Vacuum filters are used to prepare the concentrate for shipment to the smelter and the waste is pumped in a slurry form to old settling ponds some distance from the concentrator/smelter site. Time and logistics did not permit a visit to the settling ponds, however, it was stated by several independent sources that limited waste settlement occurs in these settling ponds and the overflow of clear water is discharged into a nearby river (not the same stream in the vicinity of the Hanes mine portal), creating contamination of the river.

A new water treatment plant is currently under construction that will, when approved by the local EPA and put into operation, chemically treat the water separated at the new settling ponds before discharging into the river. Copies of this water treatment plant design should be provided to confirm these objectives. This system is planned to be in operation by March 1994.

The Hanes mine concentrator operates three shifts per day with a schedule providing for maintenance of the aging equipment. The concentrator produces up to three products on a daily basis, namely 8-10 tons of collective concentrate, 10-12 tons of copper concentrate and 12-15 tons of gold/pyrite concentrate.

In reviewing the mineral analyses of the Stock Area and No. 11 vein exposures in the mine, it appears that the mine is a low grade marginal copper mine with amounts of gold and silver that would classify the mine as a low grade gold mine. This combination of metals probably justifies the continuation of this small mine.

ROSIA POIENI MINE

This surface mine is located approximately 40 km north of Zlatna and near to the town of Abrud. The mine supplies approximately 1500 tonnes of copper concentrate to the Ampellum Smelter per month. The mine is a standard open pit operation using rotary drills to excavate 25 cm diameter holes for blasting, 5-6 cubic metre shovels to load the ore, and 35-50 tonne trucks to transport the ore to the concentrator. Approximately 200,000 tons per month of ore containing an average of 0.4% copper per tonne of ore is produced monthly. There are several other small surface and underground mines in this area that supply concentrates to the Ampellum Company Smelter in Zlatna.

The concentrator is located approximately three kilometres from the open pit mining operations, and, to concentrate the copper ores for the Ampellum smelter, it is equipped with crushers, an autogenous mill and ball mills, classifiers, hydrocyclones and froth flotation cells.

The mine employs approximately 800 workers, of whom 500 are associated with mine production and the balance on transportation, maintenance, services at the concentrator, etc.

There was no evidence of water pollution at this mine, however, the management made reference to small amounts of stream pollution caused by abandoned ancient mines in the general area.

The equipment in use was extremely old and required much maintenance. A "grave yard" of old trucks and loaders are displayed at the entrance to the mine.

General health and safety procedures associated with surface mines were in practice at Rosia Poieni mine. However, a more thorough study of in-pit dust creation, water quality, reclamation plans etc. should be carried out at the mine, in the concentrator and at the tailings ponds and refuse areas.

RECOMMENDATIONS

Possible short term relatively low cost improvements for environmental issues at the Hanes mine, include:

1. The installation of a water treatment facility near the mine entrance and before the water is discharged into the stream. This plant should provide for the settling out of heavy metals and raising the pH of the mine water from its present acidic level of 1.5 to 2.0, to the acceptable level.

2. The purchase and installation of stainless steel pumps to ensure greater reliability and lower maintenance costs than currently being experienced.

3. Ensure that the acetylene/carbide lamps currently used in the mine are withdrawn from the mine and replaced with sufficient battery/cap lamps for all workers employed underground.

4. Conduct a ground water hydrogeological study in the region adjacent to the Hanes mine. This will determine the extent to which the present water pollution of the stream has affected the lower water aquifers used to supply water from deep wells to people living in the area.

Insufficient time was available at the Rosia Poieni mine to identify and define possible environmental improvement procedures. It is recommended, however, that an environmental assessment be made of water quality at the mines located in this region, including the mines of Rosia Montana, and the streams potentially affected by the mining and concentrator operations in the region.

CAPTIONS FOR PHOTOGRAPHS

Figure No.	Description
1.	WEC representatives, members of the Expert Team and employees of Ampellum and Hanes Mining Companies.
2.	The Chief Engineer and mine Geologists and Management of the Hanes mine, with the mining Expert in fore ground.
3.	Narrow gage rails and marshaling yard for dispatch of ore from Hanes mine to the Concentrator in Zlatna via aerial ropeway.
4.	Acid mine water in stream 5 km down stream from Hanes mine portal.
5.	Polluted stream flowing through old mine equipment scrap area.
6.	Ore car arriving at concentrator from Hanes mines via aerial ropeway.
7.	Manual unloading of mineral ore before sending empty car back to Hanes mines via aerial ropeway.
8.	Old dilapidated concentrator building at Zlatna.
9.	Lower pipe transports waste material (tailings) to tailings settling ponds.
10.	Stock pile area for concentrated ore before transporting to Ampellum Co. Smelter.
11.	Casual water near to concentrator/smelter. Note copper coloration.
12.	River immediately upstream of concentrator and smelter site.
13.	Mining benches at the Rosia Poieni surface mine.
14.	Loading of ore and drilling holes for next blast, using old model machines, Rosia Poieni mine.
15.	Rosia Poieni mine concentrator in foreground with Rosia Montana mine on horizon.

FIGURE 1

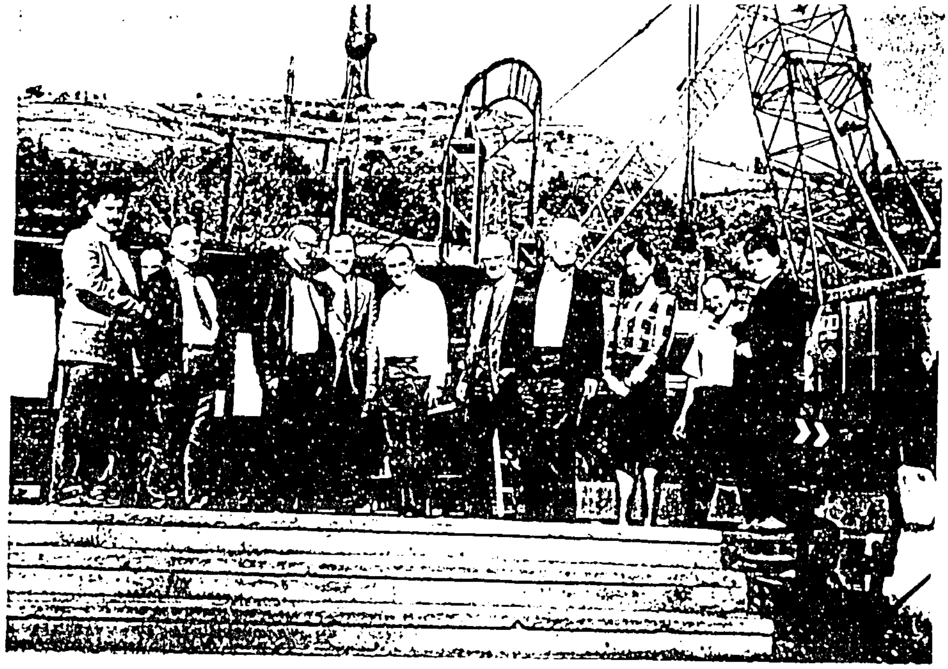


FIGURE 2

FIGURE 3

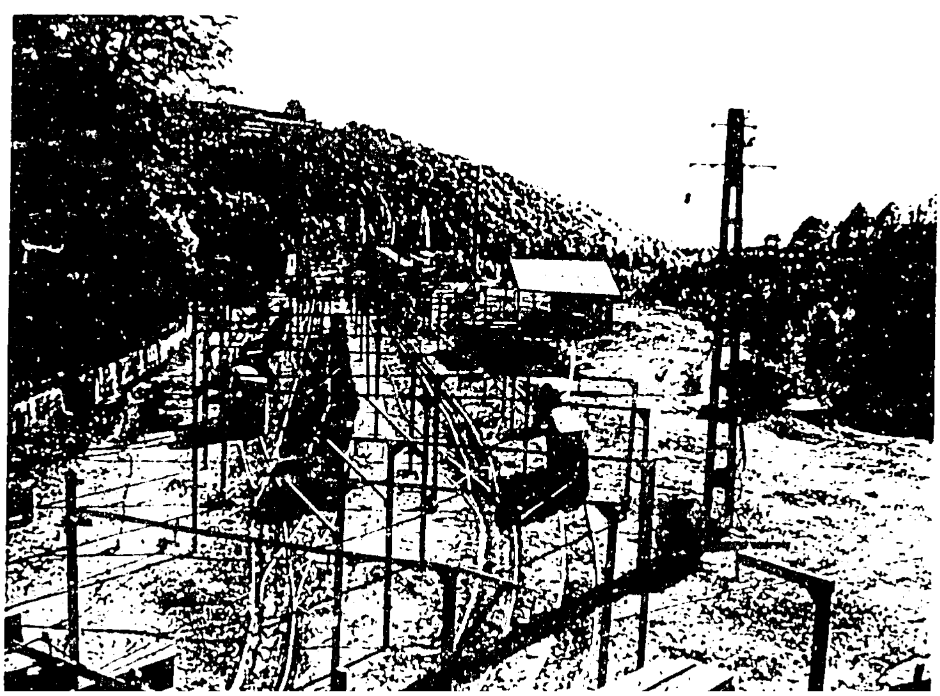


FIGURE 4

FIGURE 5

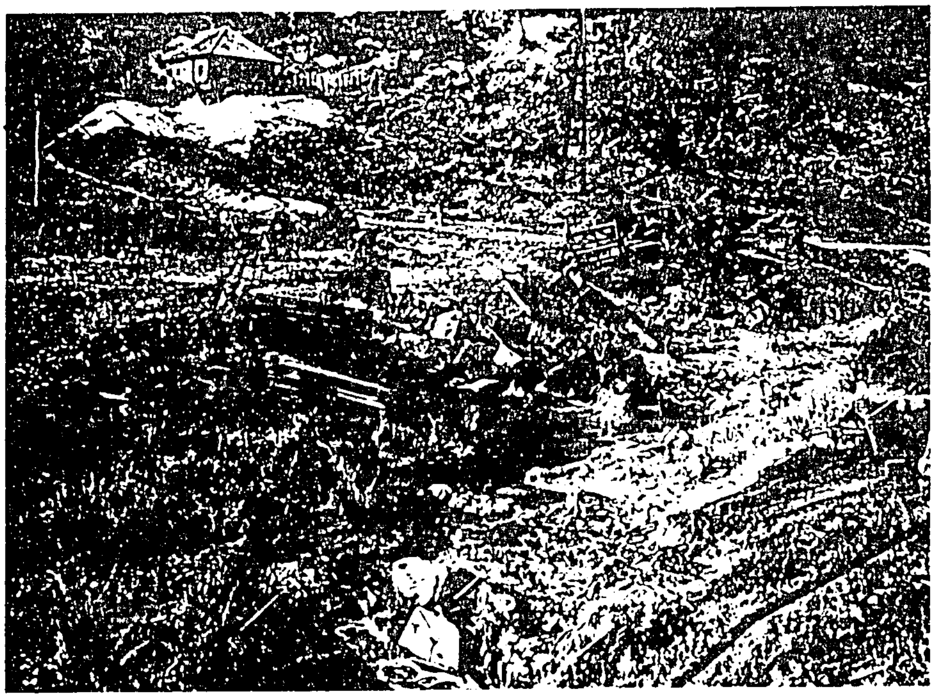


FIGURE 6

FIGURE 7

FIGURE 8

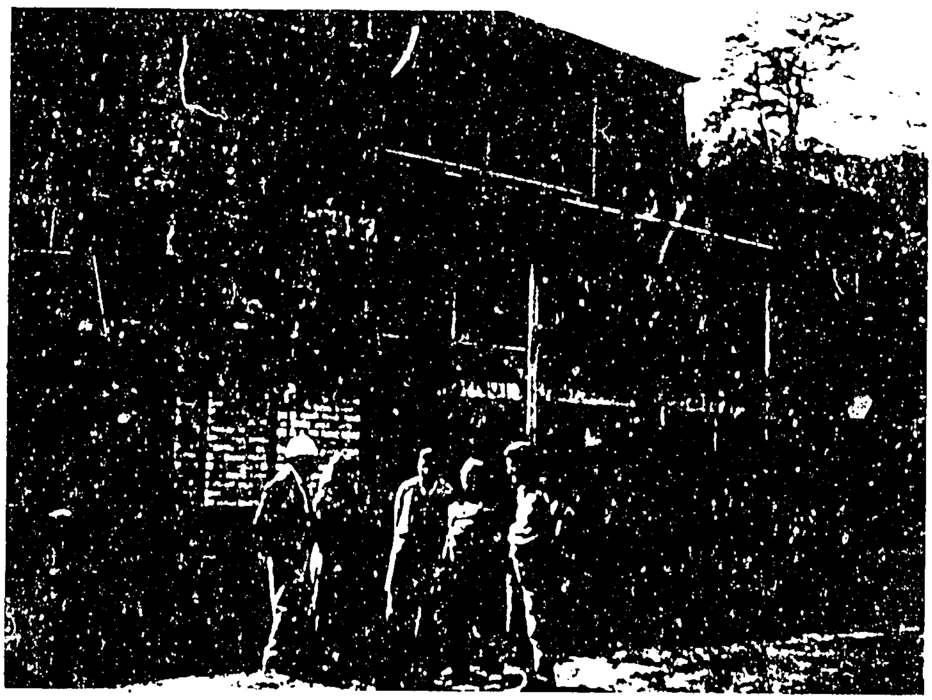


FIGURE 9

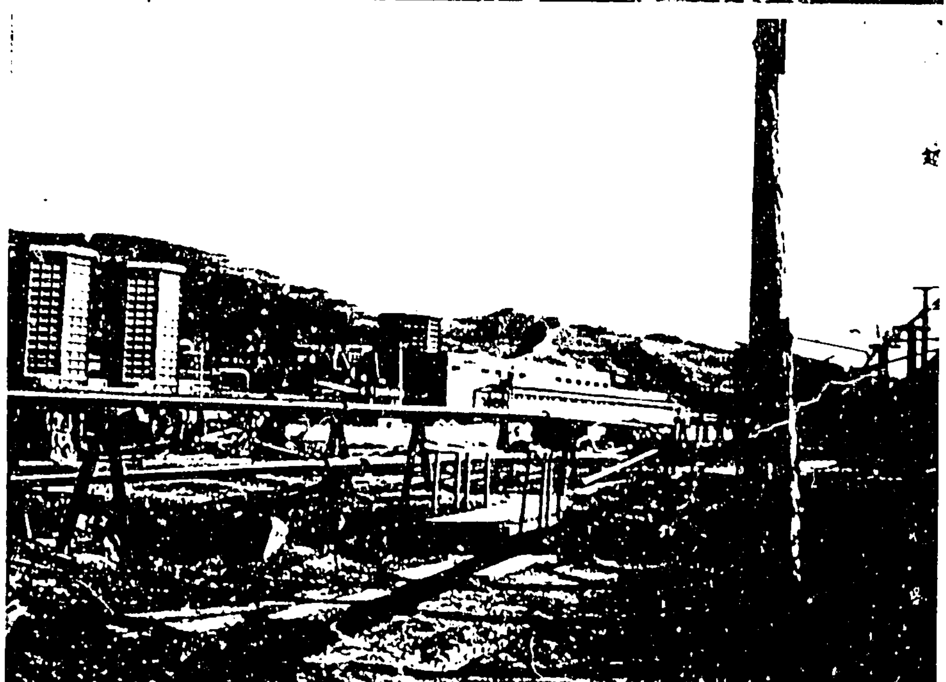


FIGURE 10

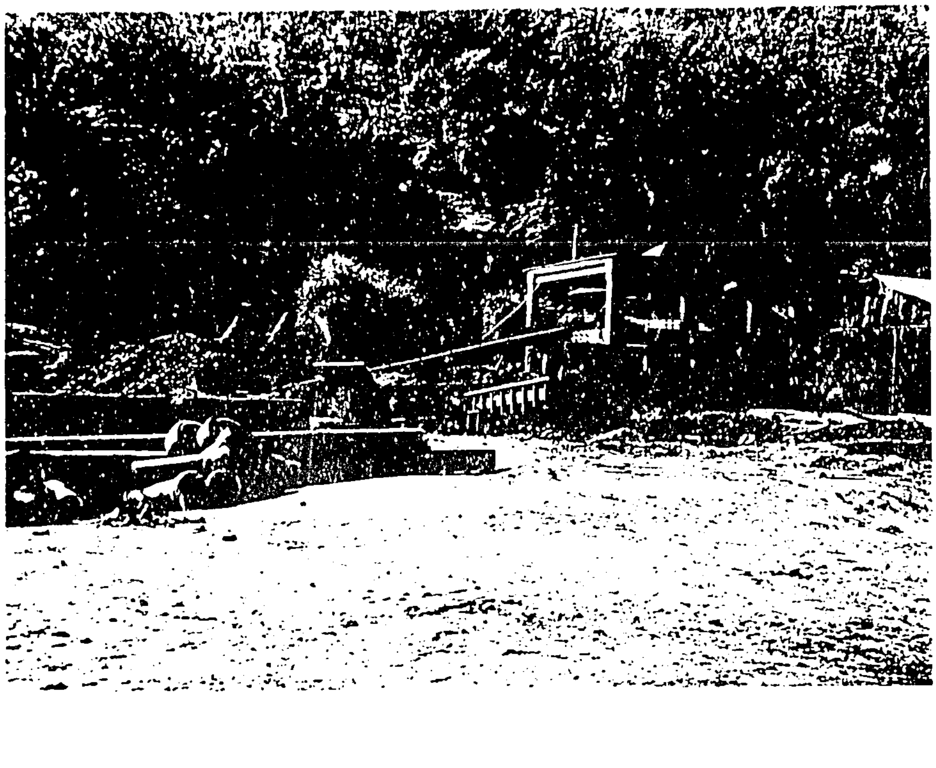


FIGURE 11

FIGURE 12

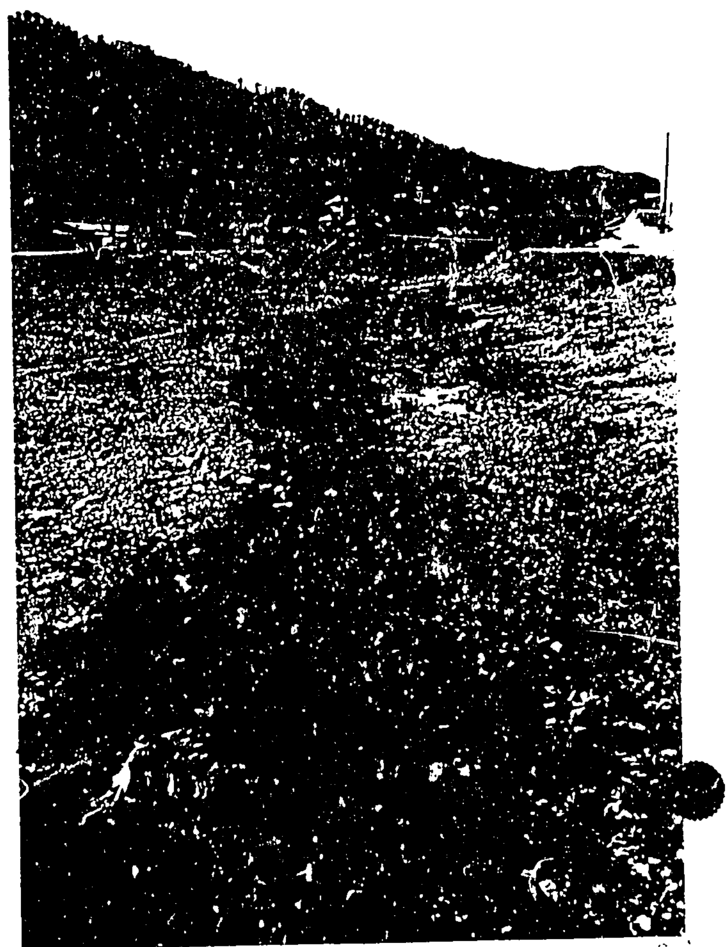
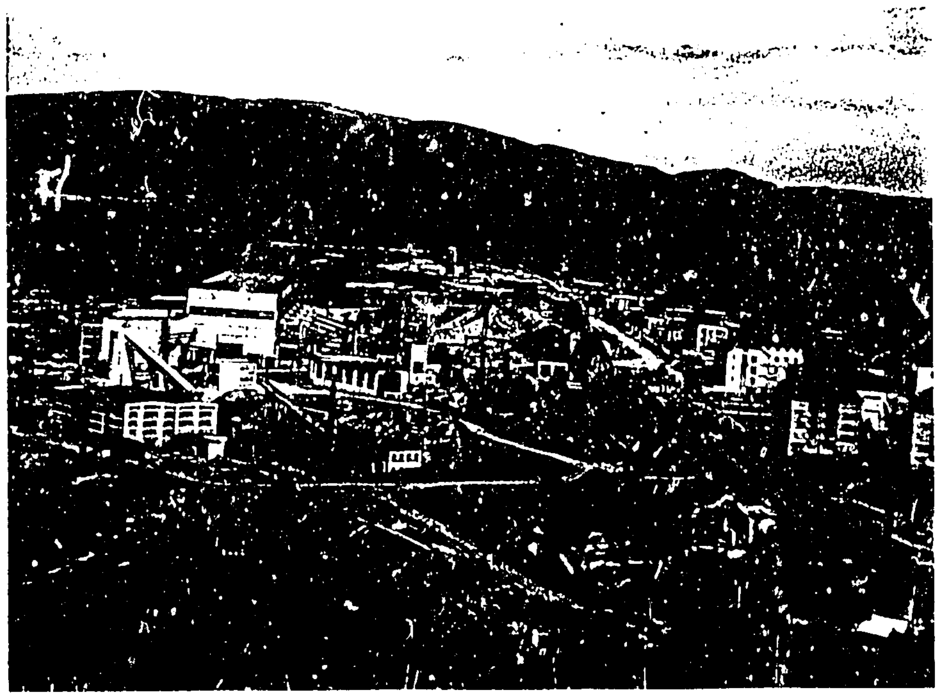


FIGURE 13

FIGURE 14

FIGURE 15



TRIP SCHEDULE FOR DR. JOHN W. WILSON : WEC TEAM VISIT TO ZLATNA AND ALBA IULIA, ROMANIA

Oct. 10 1993	2:30 PM-arrive at Otopeni Airport on AF flight from Paris-travel originating in St Louis. Meet up with rest of WEC Team. 5:00 PM- WEC team leaves in rented van for Sibiu. 10:30 PM- arrive in Sibiu. Spend night in Hotel at Sibiu.
Oct. 11 1993	8:00 AM- Leave Sibiu for Zlatna. 10:00 AM- Arrive in Zlatna at Ampellum Company Offices. 10:30 AM- Meet with representatives from Ampellum, Mines, and Municipality. Rest of day Dr. Wilson meet with personnel from Hanes mine. 7:00 PM- Team travels to Alba-Iulia-check in at Hotel.
Oct. 12 1993	8:00 AM- Leave Alba-Iulia for Zlatna. 8:45 AM- Arrive at Ampellum offices and Dr. Wilson meet with mine management before going underground at the Hanes mine. 7:00 PM- Team meets and travels to Alba-Iulia. 7:45 PM- Arrive at Hotel in Alba-Iulia.
Oct. 13 1993	8:00 AM- WEC team leaves for Alba-Iulia for Zlatna. 8:45 AM- Arrive at Hanes mines office to prepare for visit to Rosia Poieni Surface mine. 9:00 AM- Travel to Abrud and Rosia Poieni mine, inspect mine and concentrator at Rosia Poieni. 6:00 PM- WEC team meets and leaves for Alba-Iulia. 6:45 PM- Arrive in Alba-Iulia. 7:15 PM- WEC team meets with the USAID team, E.T.P. representatives and other environmental officials from Alba-Iulia.
Oct. 14 1993	8:00 AM- AID and WEC teams leave Alba-Iulia for Zlatna. 8:55 AM- Arrive at Ampellum and Dr. Wilson continue assessment of mine with management and engineers from Hanes mine. 4:00 PM- Presentation of WEC activities to regional authorities and press of Alba County in Alba-Iulia. 5:30 PM Return to Hotel in Alba-Iulia.
Oct. 15 1993	8:00 AM- WEC team leave Alba-Iulia for Zlatna. 8:45 AM- Arrive at Ampellum offices and Dr. Wilson and Mr. Garcia tour the concentrator operations of Hanes mine. 2:00 PM- Presentation of preliminary recommendations to management of Ampellum and Hanes mine. 5:00 PM- Return to Hotel in Alba-Iulia with representatives of Hanes mine and Ampellum Co.
Oct. 16 1993	9:00 AM- Leave Alba-Iulia for Bucharest via towns with industrial factories under environmental review. 5:00 Arrive in Bucharest. Check in at Hotel.
Oct. 17. 1993	WEC Zlatna team free. Tour of Bucharest and time for rest.

Oct. 18 1993	8:30 Am- WEC Zlatna team of Experts prepare for de-briefing of their respective findings. 10:00 AM- Travel to USAID offices and WEC team de-brief members of USAID, ETP and other US agencies based in Bucharest. 4:00 PM- Return to Hotel in Bucharest. 8:00 PM- Visit by Mr. Treger, Ampellum Company.
Oct. 19 1993	9:00 AM- WEC Zlatna team travel to government offices for final de-briefing sessions. 10:00 AM- De-brief the MOI, MOE and Council for Economic Re-Structuring, re-Zlatna project with help of AID representatives.
Oct. 20 1993	Visit to Bucharest Polytechnica to discuss activities at the metallurgical and materials Institute. Visit to equipment manufacturer that builds environmental equipment for the Romanian EPA authorities.
Oct. 21 1993	Return to USA. 6:30 AM- Depart Bucharest for USA. 9:30 PM- Arrive St. Louis, Missouri. 12:00 Midnight- Arrive Rolla, MO.

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SYNOPSIS OF RESUME

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POSITIONS HELD: 1990 – Present
Chairman and Professor, Department of Mining Engineering, University of Missouri-Rolla; Specialties: organization and management, feasibility studies, acquisitions and mergers, longwall, metalliferous and coal mining systems, rock mechanics, etc.

1989 – 1990:
Vice President and General Manager, TransAfrican Mining Ltd., a Bermuda corporation with gold mining interests in Africa.

1987 – 1989:
Vice President Operations, Golder Associates Inc., Consulting Engineers in Hazardous Waste, Civil Engineering, Groundwater, Geo-Technical Engineering, Mining Engineering.

1985 – 1987:
President, Chief Operating Officer and Director, ADMAC, Inc., Water jet high-tech equipment for industrial, construction and mining applications. Plants in USA, Taiwan, Germany and Africa.

1980 – 1985:
President, Sii Mining Equipment Companies, (Division of Smith International Inc.). Expendable products for construction, mining and water well industries. Plants located in USA, Canada, Australia, Europe and Africa.

1977 – 1980:
President, ADA Mining Corporation, (subsidiary of Adams Resources, Inc.). Coal mines in Kentucky and Illinois.

1976 – 1977:
Assistant to President and Chief Operating Officer, Consolidation Coal Company, Pittsburgh, PA. Management support, coal mining acquisitions, foreign investments for coal mines.

1975 – 1976:
Director of Mine Engineering and Planning, Consolidation Coal Company, Pittsburgh, PA. Economic analysis, feasibility studies, mine planning for surface and underground operations, equipment selection, etc.

1967 – 1975:
Consulting Engineer, Anglo American Corporation, Southern Africa. Planning mining layouts in coal, gold, diamond and base metal mines in Zambia, Zimbabwe, Swaziland, Botswana, Namibia and Lesotho. Development and introduction of mechanized mining techniques for use in underground hard rock mines.

1962 – 1967:
Manager, Underground Operations, Douglas Colliery, Witbank, South Africa. Responsible for mining operations at large high production coal mine.

1958 – 1962:
Miner, National Coal Board, England. Junior/Senior Management positions at underground coal mines in Northern England.

EDUCATION:

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Ph.D., University of Witwatersrand, 1971
PMD., Business School, Harvard University, Boston 1972

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1961 Mine Managers Certificate (Coal) England
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1967 Mine Managers Certificate (Metalliferous) South Africa
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Fellow Institute Mining Engineers, England
Fellow South African Institute Mining & Metallurgy, South Africa
Member American Institute Mining Engineers, U.S.A.
Chartered Engineer, England
Associate Member, Mine Managers of South Africa
Member Canadian Institute Mining
Chairman, Rapid Excavation and Tunnelling Conference, 1987
Executive Member USNCT, AIME Representative
Advisory Member ASME–SMERI Committee
Secretary UTRC, AIME Representative
Member Institute of Shaft Drilling Technology
EUR ING European Federation of National Engineering Associations