Blacksmith Institute's

World's Worst Pollution Problems Report 2010

Top Six Toxic Threats

Six pollutants that jeopardize the health of tens of millions of people

Lead
Mercury
Chromium
Arsenic
Pesticides
Radionuclides

Produced in collaboration with Green Cross Switzerland

This document was prepared by the staff of Blacksmith Institute in partnership with Green Cross Switzerland with input and review from a number of experts and volunteers, to whom we are most grateful.

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This report is available online at ***www.worstpolluted.org***

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BLACKSMITH INSTITUTE

Letter from Blacksmith Institute Founder and President

Dear Reader:

2010 has been an important year in our ongoing effort to identify and clean up sites contaminated by toxic pollution and reduce the devastating health impacts it causes. So far this year, Blacksmith Institute's field investigators have identified and evaluated nearly 1,000 new polluted sites in low- and middle-income countries. While these new data are a great resource, we are saddened to realize that the scope of this problem may be greater than any of us previously thought.

Fortunately, 2010 has been a year of significant progress, and the international community is starting to recognize the importance of this global issue. In September, Blacksmith Institute hosted an international conference in Bellagio, Italy, where leaders from multilateral organizations and environmental ministries convened to share knowledge and outline future steps to address pollution problems.

Ministers and representatives from developing countries presented the scope of toxic pollution in their own countries, and acknowledged that the problem is a priority for their respective Ministries of Environment. The participants concluded that an international response to deal with these issues is needed. Interim solutions must be implemented while a longer-term strategy, such as a fund to specifically address remediation of legacy pollution, is developed.

Seeing so many influential leaders and policy-makers gathered to tackle this important issue provided great hope for the future. We hope that this report increases the global awareness of some of the most damaging pollutants and inspires people to join us in this fight. Our past successes in cleaning up these sites are concrete and measurable, and if scaled up, could be used as models to remediate sites on a global scale. There is still much work to do, but we believe this is an issue that can be solved in our lifetime, and one that can improve the lives of more than one hundred million people.

Richard Fuller
President - Blacksmith Institute

Introduction

Understanding Pollution in 2010

The global health impacts from toxic pollutants such as heavy metals, pesticides and radionuclides, are greater than previously thought. Today, more than 100 million people are estimated to be at risk from toxic pollution at levels above international health standards. This is a public health issue as salient as tuberculosis, malaria, and HIV/AIDS, and one that should receive considerable attention and resources.

Toxic pollution causes immense harm to humans, especially children. Health impacts include physical and mental disabilities, reduced IQ, organ dysfunction, neurological disorders, cancers, reduced life expectancy, and in some cases, death. These pollutants exacerbate other health concerns by weakening the body's immune system, rendering it more susceptible to disease. An initial exposure to toxic pollution can be the undocumented cause of later illnesses, including respiratory infections, tuberculosis, gastrointestinal disorders, and maternal health problems. In addition, while most toxic pollution is localized, some pollutants, such as mercury and persistent organic pollutants (POPs), are transboundary and end up in food chains in oceans and distant countries.

The risk that toxic pollution poses to humans was tragically demonstrated by the lead poisoning disaster that unfolded in Nigeria earlier this year. In the spring of 2010, doctors from Médecins Sans Frontières (also known as Doctors Without Borders) discovered an outbreak of lead poisoning in several villages in northern Nigeria. Men from the villages had brought rock containing gold ore into the villages from small-scale mining operations. The villagers did not know that the ore also contained extremely high levels of lead. The ore was crushed inside village compounds, spreading lead dust throughout the community. The scope of the contamination was unprecedented. More than 160 people died as a result of lead exposure, and hundreds more became ill. Children under the age of five were the most severely affected. The situation in these villages is now improving thanks to the work of the Nigerian Government, Blacksmith Institute, Médecins Sans Frontières, TerraGraphics Environmental Engineering, and other local and international actors. This tragedy should serve as a reminder to us all that toxic pollution is not an abstract problem for future generations, but an acute challenge that impacts millions of lives today.

While the challenges are great, recent successes provide hope for a cleaner future. Blacksmith Institute and its partners have implemented over 40 successful cleanup projects. The case studies in this report highlight some of the strategies available to reduce health impacts from toxic pollution, and demonstrate that this is a problem we can solve.

An Industrial steel processing complex

About the 2010 Report

The 2010 report follows a series of annual reports released by Blacksmith Institute and Green Cross Switzerland. In 2006 and 2007, the organizations released reports highlighting the world's worst polluted places. A report from 2008 described the top ten worst pollution problems, and in 2009, the organizations released a report highlighting case studies of successful cleanup projects. The 2010 report revisits the subject of pollution problems, but draws upon the substantial volume of research the organizations have conducted on polluted sites over the last two years to identify the specific pollutants that are causing the most harm.

Unlike the 2008 report, which covered general pollution issues such as urban air quality and ground water contamination, the 2010 report provides detailed descriptions of the six toxic pollutants that impact the greatest number of people. Since 2008, Blacksmith Institute has increased its ongoing efforts to identify a significant portion of the polluted places in low- and middle-income countries and conduct field assessments to understand the risks at each site. To date, the organization has identified 2,000 polluted sites in 40 countries, and has conducted in-country assessments at over 1,000 of these sites. This research has provided Blacksmith Institute and Green Cross Switzerland a more sophisticated understanding of the scope of toxic pollution globally, and allows for the greater detail found in the 2010 report.

The 2010 report begins by providing an in-depth look at Blacksmith Institute's efforts to identify and evaluate polluted sites. The first section of the report outlines the need for this type of research, the scope of the work, and the methods used to identify and evaluate polluted sites.

The second section of the report focuses on the six toxic pollutants that have the greatest impact on human health. The list of the top six toxic

A woman clears trash from a pond contaminated with chromium

The Top Six Toxic Threats

Top Six Toxic Threats:	Estimated Population at Risk at Identified Sites* (million people)	Estimated Global Impact** (million people)
1. Lead	10	18-22
2. Mercury	8.6	15-19
3. Chromium	7.3	13-17
4. Arsenic	3.7	5-9
5. Pesticides	3.4	5-8
6. Radionuclides	3.3	5-8

* Population estimates are preliminary and based on an ongoing global assessment of polluted sites

** Estimated global impact is extrapolated from current site research and assessment coverage

threats was generated using research from site assessments conducted by Blacksmith Institute field investigators. The number of people currently estimated to be at risk from these sites exceeds 56 million; however, this number will rise as more sites are evaluated. Blacksmith Institute estimates that toxic pollution could jeopardize the health of more than one hundred million people globally. The contamination at the majority of these sites comes from the six pollutants profiled in this report.

The pollutants highlighted here are ranked according to Blacksmith Institute's current estimates of the number of people at risk from known sites contaminated by each pollutant. In order of population at risk, the key pollutants are lead, mercury, chromium, arsenic, pesticides and radionuclides. Each of these pollutants is profiled in a section that defines the basic nature of the pollutant, common pathways to humans, known health risks, industrial contexts in which the material is used or produced, and strategies for cleanup. These chapters also include case studies of site remediation projects.

Oil dumped at a ship-breaking site

Summary of the Top Six Toxic Threats

The six pollutants profiled in this report were selected on the basis of the number of people that Blacksmith Institute estimates are at risk from sites impacted by these contaminants. The population estimates are based on the research conducted by field investigators as part of our ongoing effort to identify and evaluate polluted sites in low- and middle-income countries.

1. Lead:

Lead is a naturally occurring heavy metal and a powerful neurotoxin. Lead is often released during metal smelting and mining, and is a key component in car batteries. Lead can exist in air, water, soil, and food and can enter the human body through inhalation, ingestion or dermal contact. The health effects of lead exposure can include neurological damage, reduced IQ, anemia, nerve disorders, and a number of other health problems. The effects of lead are most severe in children, and at high concentrations, lead poisoning can cause death.

2. Mercury:

Metallic mercury, the elemental or pure form, is a silver-white metal that is liquid at room temperature and commonly seen in thermometers. Mercury is often used in the production of chlorine gas, caustic soda, batteries, and electrical switches, and is also used to extract gold from ore. A person can be exposed to mercury through air, water, food, or dermal contact. Mercury is a powerful neurotoxin and can cause severe damage to the brain and kidneys. Inhalation of mercury can also cause lung, stomach, and intestinal damage, and even death due to respiratory failure.

3. Chromium:

Chromium is a naturally occurring heavy metal that is commonly used in industrial processes. Although it can be released through natural forces, the majority of the environmental releases of chromium are from industrial sources. The industries with the largest contribution to chromium levels include leather tanning operations, metal processing, stainless steel welding, chromate production, and chrome pigment production. Chromium can exist in air, water, soil, and food, and common exposure pathways include ingestion, inhalation, and dermal contact. The primary health impacts from chromium are damage to the gastrointestinal, respiratory, and immunological systems, as well as reproductive and developmental problems. Chromium is a known human carcinogen.

4. Arsenic:

Arsenic is a naturally occurring element that is frequently characterized as a metal, despite having properties of both a metal and a nonmetal. Arsenic is often found in rocks that contain other valuable metals, such as copper and lead. When smelters heat this ore to retrieve the other metals, the arsenic can be released into the air. Arsenic can exist in air, water, soil, or food, and all of these present potential pathways for human exposure. Arsenic has long been recognized as a poison, and large oral doses can cause death. Lower doses of arsenic can cause decreased production of red and white blood cells, and arsenic poisoning is often characterized by visible changes in the skin. Arsenic contamation of ground water is a significant problem in South Asia.

5. Pesticides:

Pesticides are those substances, often chemical in nature, that are used with the intent to repel or eliminate species that have an adverse effect on agricultural or horticultural production. Pesticides are also used to fight tropical diseases like malaria. A "pesticide" can be classified as an insecticide, herbicide, fungicide, nematocide, and molluscicide. A significant volume of the pesticides used each year is washed away by rainfall into nearby surface and ground water, and water is a common exposure pathway. Studies on chronic health effects of pesticide exposure indicate the potential for these chemicals to have neurological, reproductive, and dermatological impacts.

6. Radionuclides:

Radionuclides occur naturally in soil and rocks as a consequence of radioactive decay. While they can be released through natural cycles, most environmental releases are the consequence of industrial processes. Common sources of radionuclide exposure include uranium mining and mine waste dumps, nuclear weapons production and testing, processes related to nuclear energy production, and the production of radiological products for medical use. When radiation strikes a living organism's cells, it can damage those cells. If radiation affects a significant number of cells, the organism may eventually develop cancer, and at high doses, radiation can cause death.

Kids at a waste canal containing chromium

A ship-breaking site in Bangladesh

Note on Population Estimates and Pollutant Rankings

Blacksmith Institute's global assessment of polluted places is an ongoing effort, and the research that has been conducted to date is preliminary. Over the next several years the assessment will expand and the population estimates may change to reflect new research. The site assessment process has not identified or evaluated all polluted sites in low- and middle-income countries. Population estimates that Blacksmith Institute has used to generate this list and rank the pollutants are based on in-country site assessments conducted by field researchers.

The 2010 Conference on Legacy Pollution in Developing Countries

At a conference hosted by Blacksmith Institute in collaboration with the Asian Development Bank and the World Bank, 31 senior-level participants gathered from 16 different organizations to discuss toxic pollution and health risk in low- and middle-income countries. In attendance were five Ministries of Environment (Indonesia, Mexico, Philippines, Senegal and Ukraine), three multilateral development banks (World Bank, Asian Development Bank, and Inter-American Development Bank), three donor agencies (Canadian International Development Aid Agency (CIDA), Japanese International Cooperation Agency (JICA), European Commission (EC), and three UN agencies (UNEP, UNIDO and WHO), as well as Blacksmith Institute and TerraGraphics environmental consulting firm.

The purposes of the conference were 1. To present the scope of toxic pollution in developing countries, highlighting the challenges of pollution and its human health effects, using new data collected by the Blacksmith Institute in collaboration with UNIDO, and with funding from multilateral partners; 2. To look in-depth at success stories, remediation efforts and current programs in place addressing toxic pollution, remediation and effects on health; and 3. To explore next steps in the short-term to long-term to promote awareness of toxic pollution, its health effects and a global response.

Blacksmith Institute presented the preliminary results of its ongoing effort to identify and assess polluted sites, which works with local experts in over 40 countries to identify highly contaminated sites with significant health risk. The assessment process

Burning e-waste at a site in Ghana

has revealed thousands of places where health is endangered, with an estimated population at risk of over 56 million people. Blacksmith Institute estimates that the total population at risk globally could exceed 100 million people. The size of the population at risk implies a public health problem that is of significance in the global health arena.

The conference acknowledged that the international community poorly understands the area of toxic pollution, and that more work must be done to assess hotspots in Africa, the Middle East, Central and Eastern Europe, and Latin America - regions where the assessment effort currently lacks funding. The Asia Pacific region was much better covered due to ADB's contribution, which mandated a focus on that region. Other agencies presented their current efforts and successful programs as case studies.

Ministers and representatives of developing countries presented the scope of toxins in their own countries, acknowledging that the problem is one of priority for their respective Ministries of Environment. Participants indicated varying levels of national capacity within their Governments to deal with these issues. Mexico, for example, is very active in both collecting data on hotspots and implementing remediation projects, and can act as a model to emulate. Other countries, such as Senegal, Indonesia, and the Philippines, have political will but few resources or internal national capacity to address the problems of toxic pollution.

The representatives at the conference concluded that an international response to deal with these issues appropriately is needed, and that there should be interim solutions while a longer-term strategy (to create a fund to specifically address remediation of legacy polluted sites and emergencies) is developed. Initiating such a Fund requires more research with regard to its scope, housing, and implementation methodology. More work is also needed to determine appropriate types of toxic sites that could make use of the Fund. At the minimum, it would be available for remediation of compelling legacy sites in Least Developed Countries; for emergencies (such as the case of severe poisoning in Zamfara, Nigeria); and for technical assistance and capacity building in other developing countries.

Artisanal pollution should receive considerable attention, and could be best integrated into the development agenda because of its clear ties to poverty and livelihoods issues. Emphasis was also placed on the fact that a holistic approach dealing with chemicals throughout their lifecycle should be employed, and that remediation work should be closely coordinated with UN agencies (especially UNEP) efforts in this regard. The group agreed that it made sense that Blacksmith Institute, as an established leader in this field, would be an appropriate agency to continue to lead efforts to develop these plans.

The following general priorities were defined:

1 ▪ There is a need to raise awareness in the international community of toxics issues, data and remediation efforts. UN and multilateral agencies can facilitate introduction of these topics in their governing councils, conferences, and meetings of the member states or states parties at the Conventions dealing with chemicals and toxics. The link to health must be made clear.

2 ▪ Finance, health, and environment agencies in recipient countries are responsible for setting their own development agendas, and need to be educated about the scope of toxins within their countries in order to pursue international resources. Data from the polluted site assessment process needs to be clearly presented to recipient country agencies, and a plan of action should be developed in each country for implementation of projects.

3 ▪ Current efforts must be coordinated, to maximize resources, and all options for a long-term fund should be researched and presented. This should include working within existing mechanisms, such as the UNEP Chemicals Financing Initiative, GEF, the Basel, Stockholm, and POPS Conventions, SAICM, the Montreal Protocol, the new Mercury treaty under development, as well as existing funding mechanisms. Sharing of information, knowledge and experience, especially reviewing different funding models is important.

4 ▪ Additional research in Africa, Latin America, Middle East and Central and Eastern Europe is critical to better understanding the global scope.

5 ▪ Sensitivity of data should be resolved where possible and efforts made to be use data in a more public way to raise awareness, and thus insert these issues into the development agenda.

6 ▪ National capacity in developing countries is crucial to identify hotspots with human health impacts and deal with these issues through policy efforts, regulations and remediation activities. Efforts must continue to build this capacity, and to share knowledge and technology.

7 ▪ Financial support to pursue the above activities is crucial and necessary. All options should be explored, including working with private industry and foundations in addition to the international community.

A child scavenges at a site in Senegal contaminated with lead

Blacksmith Institute's Ongoing Effort to Identify and Assess Polluted Sites

Introduction

The 2010 World's Worst Pollution Problems Report highlights six of the most dangerous and prevalent toxic pollutants. This list was generated from research conducted as part of Blacksmith Institute's ongoing efforts to identify and assess a significant portion of the polluted sites in low- and middle-income countries. To date, sites have been assessed in over 40 countries. An estimated 56 million people face potential health risks from these sites, a number that increases daily as new sites are identified and evaluated.

Context

While polluted sites in high-income countries are generally well researched and mapped, less documentation has taken place in low- and middle-income countries. This information gap has made it difficult for the international community to engage in targeted remediation efforts to reduce risks to human health. To address this problem, the Blacksmith Institute has partnered with Green Cross Switzerland and several multilateral organizations to conduct a survey of polluted sites in those countries that could benefit most from increased monitoring and site evaluation.

Objectives

Blacksmith Institute aims to document sites in low- and middle-income countries where pollution levels exceed international standards and pose a risk to human health. Field investigators identify sites of concern, describe the primary pollutant(s) at the site, analyze the pathway from the pollution source to humans, quantify the potential number of people at risk, measure the concentration of the pollutant(s) at the site, and rate the potential severity of the exposure.

Methodology

Blacksmith Institute's assessment work relies on the research of over 160 field investigators, 15 regional coordinators, and a team of in-house technical experts and researchers who review field reports for quality and accuracy. Sites are identified by investigators and coordinators, partner organizations, media outlets, and by anonymous suggestion. Once a polluted site is identified, a field investigator conducts a site visit, takes environmental samples for laboratory analysis, and submits an Initial Site Assessment report.

Municipal and industrial waste flowing through an urban center

Why Conduct an Assessment of Polluted Places?

In high-income countries, industries are generally well-regulated and the effects from legacy pollution are mitigated by cleanup mechanisms such as the U.S. Environmental Protection Agency (US EPA) Superfund Program. By contrast, low- and middle-income countries often do not have the regulatory framework to adequately monitor toxic pollution, nor do they have the resources necessary to clean up polluted sites.

The international community can contribute to local efforts to clean up these sites. However, such contributions are limited by a lack of understanding of the scope of the problem and an uncertainty about how to identify and prioritize cleanup projects. Blacksmith Institute's efforts to identify and assess polluted sites can facilitate collaborative international efforts to clean up these sites and reduce the risks they pose. Each site is given a Blacksmith Index score from 1 to 10, which indicates the severity of the problem at the site (a "1" representing a lower risk, and a "10" indicating an extreme risk). This model is based on the Hazard Ranking System developed for the Superfund Program. The Blacksmith Index score uses site data such as the concentration levels of the main pollutant relative to international standards, the pathway to humans, and the estimated population at risk. The Blacksmith Index provides a mechanism for prioritizing cleanup efforts and allocating resources to those sites that cause the most harm.

A canal flows with water contaminated with chromium and municipal waste

Scope of the Work

The scope of Blacksmith Institute's site assessment work is limited to sites in low- and middle-income countries, where point source toxic pollution exceeds international concentration standards, and where there is a clear impact to human health. Sites that do not meet all of these criteria are not evaluated. There are many serious and troubling pollution problems around the world that fall outside of this scope, including sewage and greenhouse gas emissions. Excluding these sites from the Blacksmith Institute's assessment process is not meant to diminish the severity or importance of these issues, but rather to focus on the area of Blacksmith Institute's expertise and on those problems that are causing immediate harm to human health.

Geographic Scope

Not all low- and middle-income countries are included in the assessment process. In general, the assessment targets low- and middle-income countries as defined by the World Bank. However, sites in certain countries are not evaluated due to operational hurdles or a lack of applicable sites. For example, the Democratic Republic of Congo, Iraq, and Sudan, will not be evaluated in-person because of ongoing conflict or potentially unsafe conditions for investigators. Other countries, such as North Korea, Myanmar, and Somalia, are excluded because their governments are perceived as uncooperative, too unstable, or non-existent. Countries with very small populations, such as island states or countries with a small industrial base are also excluded. In addition, Lithuania, Turkey, and the Balkan states are not high priorities for investigation because of increased attention to environmental problems in these countries by organizations such as the European Commission and the United Nations Environment Programme. To date, investigators have evaluated sites in over 40 low- and middle-income countries. Additional countries will be added and assessed as the program continues.

Scope Limited to Point Source Pollution

Point source pollution refers to pollution that is emitted from a single fixed location. An example of point source pollution is smoke emitted from a factory chimney, while non-point source pollution includes exhaust from cars. Cars do not have fixed locations, and thus it would be impossible to trace pollution back to a single car. The scope of the assessment process is limited to sites suffering from point source pollution because these sites can be identified, evaluated by an investigator, and targeted for a tailored site cleanup plan.

Scope Limited to Toxic Pollutants

Although there are many types of pollution that cause harm to humans, animals, and ecosystems, the site assessment process focuses only on those defined as "toxic" by the Blacksmith Institute Technical Advisory Board. Notably, this definition excludes sewage, many types of municipal waste, biological oxygen demand, chemical oxygen demand, and greenhouse gasses. The majority of sites identified by the assessment process to date are contaminated by heavy metals, pesticides, other persistent organic pollutants (POPs), radionuclides, poly-aromatic hydrocarbons (PAHs), respirable particulates, and dioxins.

Scope Limited to Pollution Concentrations Above Health Standards

Blacksmith Institute receives many public nominations for potential sites to evaluate. However, the scope of the assessment process is limited to those sites where environmental sampling shows pollution concentrations above

Leather skins at an Indian tannery

international standards and guidelines. The recommended maximum concentration levels used in Initial Site Assessments are set by the World Health Organization (WHO), (US EPA), the European Commission, and other recognized authorities.

Scope Limited to Sites That Pose Health Risks

The scope of this effort is also limited to sites that have the potential to adversely impact human health. The site evaluation process does not ignore other factors, such as ecosystem or wildlife degradation, but these impacts are secondary to direct and immediate human health concerns. Blacksmith Institute recognizes that environmental damage at any level can have a negative impact on human health. However, this project aims to address those sites that pose the most direct and urgent health threats.

The Site Assessment Process

The site assessment process is executed jointly by the Blacksmith Institute and the United Nations Industrial Development Organization (UNIDO), with funding from Green Cross Switzerland and other partners. The site assessment process began in 2009, and will continue through 2011.

Site assessments are typically conducted by in-country field investigators hired to conduct on-site evaluations, collect environmental samples, and conduct stakeholder interviews. Over 160 field investigators have been hired and trained to date. Each investigator undergoes a three-day in-country training session with Blacksmith Institute staff and technical experts that is designed to familiarize investigators with sampling techniques, recording methods, and other site assessment protocols. On the final day of training, investigators and Blacksmith Institute staff conduct a site visit to demonstrate the proper assessment process at a contaminated site.

To ensure that the type of information collected at each polluted site is uniform, investigators record their research findings in a standardized document called an Initial Site Assessment (ISA). Each ISA contains pollutant concentration data from environmental sampling, GPS coordinates, an estimate of the number of people at risk, a site description, a description of the industry type that is responsible for the release of the pollution, and many other categories of information. Investigators work under the supervision of regional coordinators, who are recognized experts in their field and typically possess a Masters Degree in a physical or biological science, a Ph.D., or an M.D.

An e-waste recycling site in Accra, Ghana

Once an ISA is submitted to Blacksmith Institute's home office in New York, in-house researchers and technical advisors review the assessment for clarity and accuracy. An expert from Blacksmith Institute's Technical Advisory Board conducts a final review and adds comments about potential remediation strategies and estimated cleanup costs.

A boy playing in tannary scraps containing chromium

The Blacksmith Index

Each polluted site that Blacksmith Institute investigates receives a score from 1 to 10 based on the Blacksmith Index (BI). The Index provides a basic numerical value for the risk associated with any site that has been subject to an Initial Site Assessment (ISA). The values provided are relative rather than absolute, and are intended to provide input to the process of setting priorities across sites. The Index is based on the widely used Source-Pathway-Response model of risk assessment. At Blacksmith Institute, this approach is referred to as the Pollution-Pathway-People model. The algorithm was initially developed with the input and advice from the Blacksmith Institute Technical Advisory Board (TAB) members for the first World's Worst Report in 2006, and has been refined subsequently. It calculates a value (an integer from 1 to 10) using standardized basic information collected in the ISA.

Index Formulation

BI = f [(Potential population at risk); (Severity of pollution); (Intensity of Exposure); (Allowance for severe and persistent toxins)]

Tannery effluent flowing into a house

Refinement

In mid-2010, Blacksmith reviewed the formulation of the model in light of the increasing number of sites that had been assessed and the wide range of information that had become available. A calibration exercise was carried out with the involvement of TAB members. A sample of varied projects were evaluated by the Board, using the standard ISA information, and these projects were ranked separately using the Index. The Index results were compared with the rankings from the TAB members and adjustments were applied until the BI consistently reflected the judgments of the TAB. The adjusted formulation is now based on the sum of the log of the population, the log of the severity, and the other two factors. This formulation provides consistent rankings, in terms of risks to human health, across the wide range of sites.

Application

The Blacksmith Index value is calculated for each site, using standard data fields from the Initial Site Assessment. Each site is reviewed for internal consistency to ensure that the BI value reflects the overall character of the site and the scale of the reported impacts. It must be emphasized that the Index provides a relative ranking of sites and is intended to help in setting priorities for more detailed investigation. It is not, of itself, a judgment on the health impacts of any one site.

Conclusion

The ongoing global assessment process is the first attempt to identify and assess sites contaminated with toxic pollution on a global scale. The research from this effort promises to increase our understanding of the scope of toxic pollution and our ability to communicate the global impact. Going forward, the Blacksmith Index will be powerful tool to identify and prioritize sites for in-depth analysis and remediation. The site identification and evaluation process will continue throughout the next twelve months, and additional information and data from this process will be available in 2011.

Top Six Toxic Threats

Lead

Estimated Population At Risk At Identified Sites:
10 Million People

Estimated Global Impact:
18 to 22 Million People

Introduction

Lead is a toxic heavy metal that affects the lives of millions of people every year. Lead occurs naturally in the Earth's crust and is mined for use in products such as pigment in paints, dyes and ceramic glazes; caulk; pesticides; ammunition; pipes; weights; cable covers; car batteries; and sheets to protect people from radiation. Lead is often combined with other metals to form alloys, and, until recently, was commonly added to gasoline to increase octane ratings.

Environmental levels of lead have been increasing for hundreds of years, and are only just starting to decrease in response to greater awareness of its harmful effects. Today, much of the lead in circulation exists in car batteries, also called used lead-acid batteries (ULAB). Of the six million tons of lead that are used annually, approximately three quarters go into the production of lead-acid batteries. [1] Of these batteries, 97% are eventually recycled to retrieve the lead. [2] The high levels of recycling are, in part, due to the increase in lead prices over the last 15 years.

In low- and middle-income countries, common industrial sources of lead pollution include mining, primary and secondary metal smelting, steal and iron production, car battery recycling, and the production of pigments. Lead that is released into the air is brought back to Earth by precipitation or as particulate matter falling to land or surface water. Once lead reaches the top layer of soil, it tends to adsorb to soil particles that can be blown around as dust or be tracked throughout a community by people walking in the impacted area. The lead in the soil can also reach surface water bodies as part of storm water runoff. Water movement through the soil can transport lead to ground water, which is used for drinking water and crop irrigation.

ULABs being transported for recycling

Lead often enters the environment through releases during the mining process for lead and other metals, as well as from factories that make, use, or recycle

[1] H. Roberts. "Changing Patterns in Global Lead Supply and Demand." Journal of Power Sources 116.1-2, (2003): 23–31.

[2] U.S. Department of Health and Human Services. "Toxicological Profile for Lead." Georgia: Agency for Toxic Substances and Disease Registry, 2007.

lead or lead compounds. Lead can also be released into the air by burning coal, oil, or lead-containing waste. Once lead is on the ground it can remain in the upper layer of soil for many years. Lead can migrate into ground water supplies, particularly in areas that receive acidic or "soft" rainwater. Furthermore, levels of lead can build up in plants and animals when the surrounding environment is contaminated.

Common Exposure Pathways and Health Risks

Lead typically enters the body through ingestion, inhalation, or by mother-to-child transmission in-utero or via breast milk. Although it is possible for lead to enter the body through contact with skin, this pathway is not commonly associated with high concentrations in the body. Once lead enters the body, it moves from the blood to the soft tissues and organs, and eventually reaches the bones and teeth. Lead can be stored in bone for up to 30 years. [3]

The health effects of lead poisoning are both acute and chronic, and are particularly severe in children, the most exposed group. [4] These adverse impacts can include neurological damage, reduced IQ, anemia, muscle and joint pain, loss of memory and concentration, nerve disorders, infertility, increased blood pressure, and chronic headaches. because of their smaller size, even small amounts of lead in the bodies of children can be associated with long-term neurological and cognitive defects. When women who are pregnant are exposed to lead, it can result in damage to the fetus and eventual birth defects. At high concentrations, lead poisoning can cause seizures and death.

Children swimming in a creek contaminated with lead

Acute lead poisoning commonly results from people inhaling lead particles in dust or through ingestion of lead-contaminated dirt. [5] This was the case around the Haina ULAB recycling facility Haina in the Dominican Republic, where at least 28% of children required immediate treatment for lead exposure, and 5% had blood-lead levels that put them at risk for neurological damage. [6]

The extraordinary danger that lead poses was recently highlighted by a catastrophe in Dakar, Senegal, where between November 2007 and March 2008, 18 children died from acute lead poisoning due to lead dust and soil exposure from ULAB recycling. Until the contamination was discovered, the main economic activity in the Dakar community of Thiaroye Sur Mer was ULAB recycling. Initial tests of children living in the area found an average blood-lead level of 129.5 µg/dL, drastically exceeding the United States Centers for Disease Control and Prevention action level of 10 µg/dL. [7]

[3] Ibid.

[4] B. Kaul and H. Mukerjee. "Elevated Blood Lead and Erythrocyte Protoporphyrin Levels of Children near a Battery-Recycling Plant in Haina, Dominican Republic." International Journal of Occupational and Environmental Health 5.4, 1999.

[5] United Nations Environment Programme. "New Basel Guidelines to Improve Recycling of Old Batteries." Available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=248&ArticleID=3069&l=en, May 22, 2002.

[6] B. Kaul, et al. "Follow-up Screening of Lead-Poisoned Children near an Auto Battery Recycling Plant, Haina, Dominican Republic." Environmental Health Perspectives 107.11 (1999): 917–920.

[7] P. Haefliger, et al. "Mass Lead Intoxication from Informal Used Lead-Acid Battery Recycling in Dakar, Senegal." Environmental Health Perspectives 117.10 (2009): 1535–1540.

Industrial Sources of Lead Pollution - ULAB Recycling

Industry Overview

Lead-acid batteries are the oldest form of rechargeable battery. These simple electrochemical units are composed of lead plates that rest in a bath of sulfuric acid that is contained within a polypropylene or polyethylene plastic casing. Because of their large power-to-weight ratio and low costs, lead-acid batteries are extremely common in motor devices, and thus are frequently referred to as "car batteries."

Although these batteries can be charged multiple times, eventually this cycle places stress on the lead plates, which begin to deteriorate. Over the course of multiple recharges, the unit can no longer properly store energy for a prolonged period. However, because of variation in the unit's production and operating conditions, there is no set number of recharges one battery can take before its use is compromised. [8] Once units cease to be effective, they are often sent to a ULAB recycler.

Lead bars at a ULAB recycling site

Global Context

Of the total volume of lead used annually, 76% goes toward the production of lead-acid batteries. [9] Recycled lead is a valuable commodity, and the recovery of lead from ULABs can be a significant source of income. The market for reclaiming lead from these batteries has been growing globally, especially in many low- and middle-income countries. In order to make a profitable business from recovered lead, many of these countries have entered into the business of buying these units in bulk. The batteries are often shipped over long distances, primarily from high-income countries, that produce, use, and collect the spent batteries for reprocessing. [10]

Several factors have heightened the risks posed by ULAB recycling. One factor that compounds ULAB risks is the increase in population density in urban centers in low and middle-income countries where informal recycling takes place. In addition, the cumulative effect of high unemployment rates and increased car ownership has lead to the proliferation of informal ULAB recycling. Currently, ULAB recycling occurs in almost every city in low- and middle-income countries. In addition to being located in these densely populated urban regions, ULAB recycling and smelting operations are often performed with few environmental safety controls and with little understanding of the risks involved.

According to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal—an international treaty designed to reduce the movement of hazardous wastes to low and middle-income countries—ULABs are a danger-

[8] Department of the Environment and Heritage. "Used Lead Acid Batteries: Factsheet." Australian Government. Available at http://www.environment.gov.au/settlements/chemicals/hazardous-waste/publications/lead-acid-fs.html, August 2005.

[9] H. Roberts. "Changing Patterns in Global Lead Supply and Demand." Journal of Power Sources 116.1-2, (2003): 23–31.

[10] Trade and Environment. "A Teaching Case: The Basel Ban And Batteries." Available at http://www.commercialdiplomacy.org/case_study/case_batteries.htm, 2002.

ous source of pollution. [11] When the recycling operation is informal and small-scale, recyclers often break batteries open by hand or with an axe. In many cases, informal battery recycling is a subsistence activity undertaken in homes and backyards.

Because global demand for lead is high, ULAB recycling is an economically valuable activity and a large source of recycled lead. This high level of recycling effectively reduces the volume of lead dumped into landfills and minimizes the need to mine lead ore, but it also leads to dangerous conditions around recycling facilities. The lack of education about health risks, combined with a lack of resources, leads to dangerous working conditions at ULAB recycling facilities and severe health risks to local populations.

Exposure Pathways from ULAB Sites

Occupational exposure to lead is common in the informal ULAB recycling business. In the most common scenario, the battery acid—which contains particulates of lead—is dumped on the ground, in a waste pile, or in local water sources. As the valuable lead plates from within the unit are melted, lead ash is emitted into the air and can be inhaled or gather on clothing and surfaces. One study in Pakistan found that children of lead recyclers were more at risk of lead overexposure than other groups, indicating that the probable source of the exposure was dust on the parents' clothing brought in from work. [12]

In general, children are at high risk of exposure to lead at ULAB sites. They often come into contact with lead when playing on the waste furnace slag and when handling rocks or dirt containing the heavy metal. Their close proximity to the ground means that children have more interaction with contaminated soil and dust. The most common route of exposure for children is ingestion, as lead dust often covers clothing, food, soil, and toys where individuals eat, sleep, and play. Exposure to contaminated water is another pathway for lead from ULAB recyclers to enter the body. In Trinidad, most of the existing cases of lead poisoning in children stem from contaminated surface and groundwater used for bathing, drinking, and cooking. [13]

What is Being Done

Blacksmith Institute is implementing cost-effective remediation projects at ULAB recycling sites in the Dominican Republic, Senegal, Jakarta, Manila, and other locations around the world. The efforts focus on eliminating exposure to lead from informal ULAB recycling through several steps. These steps include: monitoring lead levels in blood (primarily in children); partnering with local governments, NGOs, and community leaders to conduct education programs about the dangers of lead poisoning and ULAB recycling; excavating contaminated soil and removing toxic soil and dust in and around homes; and either formalizing the recycling process or providing other sources of income for those who previously have depended on this activity.

Testing soil for lead content

[11] Basel Convention. United Nations Environmental Programme. "The Basel Convention at a Glance." Available at http://www.basel.int/convention/bc_glance.pdf, 2005.

[12] D.A. Khan, et al. "Lead Exposure and its Adverse Health Effects among Occupational Worker's Children." Toxicology and Industrial Health, 2010.

[13] T.I. Mohammed, I. Chang-Yen, and I. Bekele. "Lead Pollution in East Trinidad Resulting from Lead Recycling and Smelting Activities." Environmental Geochemistry and Health 18.3 (1996): 123–128.

Used Lead-Acid Battery Recycling in Dakar, Senegal

In March 2008, Blacksmith Institute was contacted about the death of 18 children under age five in the neighborhood of Thiaroye Sur Mer in Dakar, Senegal. These children all died from acute lead poisoning due to consistent exposure to lead dust in the air, soil and water. The source of lead exposure was quickly determined to be the informal recycling and disposal of ULABs. This practice was a popular way to supplement domestic income, and was typically undertaken by the women of the community. Because this activity was taking place in an informal, domestic setting, the practice was unregulated, often in open-air settings, and exposed some 40,000 people to lead dust.

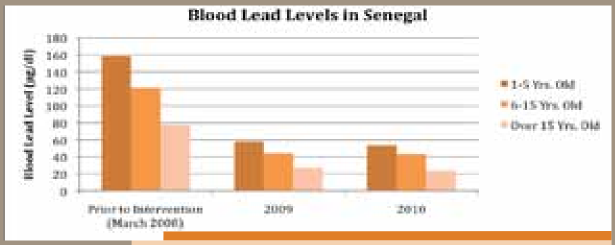
Upon learning of the death of the 18 children, the Senegalese government worked to shut down these illegal lead battery-smelting operations. Blacksmith Institute staff tested the blood-lead levels of 41 children. 100% of the children had blood-lead levels over 10 µg/dL, with several over 150 µg/dL. The World Health Organization states that any test indicating a blood-lead level over 70 µg/dL in children is cause for the declaration of a medical emergency.

Project Strategies

This project has engaged Blacksmith Institute, the Senegalese government, the University of Dakar's Toxicology department, as well as the Senegalese Ministry of Health. The latter two partners have developed an educational program in conjunction with local religious and village authorities to convey the dangers and potential persistence of exposure to lead. On a medical level, the World Health Organization has already committed to treating those who have already been exposed, and the local government has initiated remediation efforts to treat the soil with funding from Blacksmith Institute and other partners. Policy changes are also in effect that are aimed at eliminating the market for informal ULAB recycling by better regulating battery collection, transportation, storage, and recycling practices. The Senegalese Department of Women's Affairs is also working to develop alternate sources of income, helping to reduce the economic incentive to turn toward informal ULAB recycling.

Outcomes and Follow-Up

Following the intervention by Blacksmith Institute and its local partners, the contaminated area has now been remediated. Soil lead concentrations have been drastically reduced from the extreme highs of 400,000 ppm, or 40% lead. While children between the ages of 1 and 5 exhibited blood-lead levels in excess of 150 µg/dL in early 2008, the average blood-lead level in that age group has been reduced to 53.5 µg/dL with the downward trend continuing. Similar decreases were seen across other age groups, pointing to an overall downward trend in blood-lead levels across the board--a significant achievement in a community that was previously in danger of experiencing widespread lead poisoning.



Mean blood-lead levels in Thiaroye Sur Mer among three age groups.

Over 2,500 cubic meters of impacted soil were removed during this project by local contractors and community labor under direct supervision of the Ministry of the Environment and Blacksmith Institute technical experts. Local women who were trained and guided by Blacksmith Technical Advisory Board members have decontaminated more than 80 homes.

The final phase of cleanup is now complete, and the blood-lead levels of children will continue to be monitored. In addition, a new ULAB collection center has been constructed, and is now being used to manage batteries in a safe manner.

Used Lead-Acid Battery Recycling in Haina, Dominican Republic

Bajos de Haina is a community in the Dominican Republic that is situated very close to an abandoned lead smelter. In 2000, the Dominican Secretary of Environmental and Natural Resources identified Haina as a national site of significant concern. According to the UN, the population showed indications of lead poisoning. Over 90% of Haina's residents were found to have elevated blood-lead levels.

Paraiso de Dios is a community located in the municipality of Haina, seven kilometers west of the capital, Santo Domingo, and just west of the bridge crossing the Haina River. The former MetaloXsa Lead-Acid Battery Recycling facility occupieds a 0.45-hectare site, which is located on the top of a hill with a view of the Rio Haina, about 300 meters south, which drains directly into the Bay of Haina. A lack of environmental safety controls at the MetaloXsa facility had caused substantial contamination of the surrounding soil and waterways. Three sides of the site are bordered by homes with dirt floors. Paraiso de Dios is very hilly, and rainwater runoff from this site travels east and south through a highly populated residential neighborhood to the Rio Haina and then to the Bay of Haina. Lead levels in soil throughout the community exceeded US EPA limits for lead by over 10,000 times, some reaching a lead content of 50%.

Project Strategies

Terragraphics Environmental Engineering, in partnership with Blacksmith Institute and the Inter-American Development Bank, designed an intervention for the site with an approximate timeline of two years. In 2007, Blacksmith led the formation of a stakeholder group, conducted meetings with possible funders, and initiated community outreach and education programs. The stakeholder group consisted of the Ministry of the Environment and Natural Resources, the Autonomous University of Santo Domingo, MetaloXsa, and community members, among others, and met regularly to discuss project progress and build consensus on appropriate intervention and remediation activities. In the first year, Blacksmith held community education days encouraging community members to adopt appropriate safeguards to mitigate their lead exposure, and conducted additional blood testing.

Excavation of the site occurred from December 2008 through February 2009. Over 6000 cubic meters of principal threat material were removed from the community and transported to an industrial site for storage in an environmentally sound, monitored pit adjacent to another lead smelter for future processing. In conjunction with the Ministry of Environment and Natural Resources, local crews and contractors were hired and trained, a process enacted to build capacity within the Dominican Republic to perform hazardous waste removal operations, the first of its kind in the country. In addition to removing waste from the formal industrial site, community walkways and backyards were also excavated and backfilled with clean sand and soil. The main pit where the majority of the waste was stored became a public park in late 2009.

In mid 2010, a second round of soil excavations was conducted in contaminated houses and streets surrounding the main site. Under the supervision of Terragraphics Environmental Engineering, another 4,000 cubic meters of soil with elevated lead levels were removed and disposed of properly.

Outcomes and Follow Up

Blacksmith Institute, along with its partner organizations, was able to successfully remove the sources of environmental pollution in Haina. The physical remediation of the polluted soil at this site successfully reduced exposure levels. Crews of local laborers were involved throughout the process, laying the groundwork for a sustainable solution. Blacksmith continues to monitor the blood-lead levels of the children in the community. Additionally, by educating the public about the dangers of lead pollution and ULAB recycling, the possibility of recurrence of lead pollution at this scale is diminished.

Scrap metal recycling

Industrial Sources of Lead Pollution – Mining and Smelting

Industry Overview

Two main forms of smelting exist: primary smelting, which involves the processing of mineral ore, and secondary smelting, which reprocesses scrap metals. Both of these processes have the potential to release heavy metals into the surrounding environment. In addition, the mines from where these metal are extracted often produce piles of waste rock where lead can be blown away as dust or leach into local waterway systems.

Lead often exists in rocks and soil that contain other valuable metals targeted for extraction and smelting. During the process of removing and processing ore, the accompanying lead is often released into the environment. Metals refined through smelting include copper, nickel, lead, zinc, silver, cobalt, and cadmium, among others. Smelting involves the use of heat and a chemical reducing agent, typically a carbon source such as coke or charcoal. The process, invoking the carbon, changes the oxidation state of the metal by removing oxygen from the ore, which leaves behind the metal. Because many ores are not pure, a chemical cleaning agent such as limestone is used to remove impurities.

Tailings from a mine piled next to a town

Global Context

Metal extraction and smelting can be a highly polluting industrial activity. Emissions from primary smelting facilities contribute heavily to global emissions of lead, as well as arsenic, cadmium, and chromium. [14] Certain facilities have been known to emit large quantities of other air pollutants such as hydrogen fluoride, sulfur dioxide, and nitrogen oxide, and various processes among smelters can release large volumes of sulfuric acid into the environment. [15] Estimates from one source concluded that steel production alone within this industry accounts for 5 to 6% of global anthropogenic carbon dioxide emissions. [16]

Metal smelting and refining facilities also emit particulate matter, contaminated effluents, and solid wastes. Many heavy metals are often released as fine particles, either through a chimney or indirectly through other stages of the smelting process. Organic vapors and sulfur oxides, which are a result of the secondary smelting process, can contaminate the air with smog, fine airborne particles, and carbon monoxide. [17]

The additional rock removed from the ore, which is known as slag, often contains significant amounts of contaminants. Slag piles and effluents from smelting facilities also release numerous acids from waste pits into nearby water bodies. [18]

[14] S. Dudka and D.C. Adriano. "Environmental Impacts of Metal ore Mining and Processing: A review." Journal of Environmental Quality 26.3, (1997): 590–602.

[15] S.A. Carn, et al. "Sulfur Dioxide Emissions from Peruvian Copper Smelters Detected by the Ozone Monitoring Instrument." Geophysical Research Letters. 34, 2007.

[16] Ch. Beauman, Chris. "STEEL: Climate Change Poses Stern Challenge", October 8, 2007.

[17] "Secondary smelting of nonferrous metals: Impacts, Risks and Regulations." National Center for Manufacturing Sciences: Environmental Roadmapping Initiative. Available at http://www.ecm.ncms.org/ERI/new/IRRsecsmelt.htm, March 27, 2003.

[18] International Finance Corporation. "Environmental, Health, and Safety Guidelines: Base Metal Smelting and Refining." World Bank Group, April 30, 2007.

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Exposure Pathways from Mining and Smelting

Humans are exposed to contaminants from metal extraction and smelting facilities through inhalation and ingestion. The inhalation of pollutants occurs as a consequence of the gases and fine particles that are released. Layers of this dust can also settle and accumulate in nearby agricultural soil, which contaminates crops. Vegetation studies in China demonstrate that crops such as corn, when grown near smelters, can accumulate heavy metals such as lead and cadmium. [19] One study, done near a zinc smelter, found that the concentrations of mercury, lead, cadmium, and zinc in 20 different vegetables exceeded guidelines for safe human consumption, especially for children. [20] The polluted soil can also contaminate livestock, another potential exposure pathway to humans. [21] Furthermore, discarded liquid and solid waste can contaminate both ground water and surface water resources.

Workers in these metal processing plants and smelters often have a higher risk of exposure to these pollutants than other groups, primarily because they come into direct contact with the substances used throughout the refining process. Dermal exposure from contaminated soil can have lasting health impacts, especially in children. In the community of Morales, Mexico—located near a copper-smelter—over 90% of soil samples exceeded the safe guideline for lead and arsenic contamination. Because of this, the vast majority of children in this community had concentrations of lead in their blood that exceeded the Center for Disease Control and Prevention's action level. [22] Additionally, in La Oroya, Peru, a lead smelter operating since 1992 has been targeted as the source of high levels of lead in the blood of children. A 2002 study found that 80% of children had blood-lead levels two to three times higher than the WHO guideline levels. [23]

A pile of lead slag left open to the elements

[19] Xiangyang Bi, et al. "Allocation and Source Attribution of Lead and Cadmium in Maize (Zea mays L.) impacted by smelting emissions." Environmental Pollution 157.3 (2009): 834–839.

[20] Na Zheng, Qichao Wanga, and Dongmei Zheng. "Health Risk of Hg, Pb, Cd, Zn, and Cu to the Inhabitants around Huludao Zinc Plant in China via Consumption of Vegetables." Science of the Total Environment 383.1-3 (2007): 81–89.

[21] Qiu Cai, et al. "Food Chain Transfer of Cadmium and Lead to Cattle in a Lead-Zinc Smelter in Guizhou, China." Environmental Pollution 157.11 (2009): 3078–3082.

[22] L. Carrizales, et al. "Exposure to Arsenic and Lead of Children Living near a Copper-Smelter in San Luis Potosi, Mexico: Importance of Soil Contamination for Exposure of Children." Environmental Research 101.1 (2006): 1–10.

[23] F. Serrano. "Environmental Contamination in the Homes of La Oroya and Concepcion and its Effects in the Health of Community Residents." Division of Environmental and Occupational Health. School of Public Health. Saint Louis University, February 2008.

Used lead-acid bateries (ULABs)

What is Being Done

Today, processing plants and smelters can be designed and operated in a manner that limits the release of airborne and waterborne contaminants to very low levels. However, such initiatives are costly, and therefore many facilities, especially where regulation is not strictly enforced, do not meet safety standards. Older smelters in low- and middle-income countries frequently lack emission control technologies, and while some components can be upgraded to meet modern standards, these too are costly.

Old or abandoned smelters often have legacy pollution in the surrounding soil and river sediments from the lifetime of the plant's operation. Dust containing heavy metals often spreads toxic pollutants over wide areas, resulting in serious environmental damage. Remediation of such areas has to be focused on removing or curtailing the source of the pollution and then tackling the key pathways that affect the local population.

Blacksmith Institute has initiated several successful projects to reduce health risks from smelters and clean up legacy lead pollution. These efforts, described in part in the accompanying case studies, typically involve the following project steps: 1) meet with local stakeholders to form partnerships and build on local knowledge; 2) identify the pollution source; 3) measure and monitor the concentration levels of the pollutant in the environment and in the affected population; 4) identify and prioritize the areas that require physical cleanup; 5) create a cleanup plan; 6) implement the cleanup plan with local contractors; and 7) monitor the area and affected population to evaluate the impact of the project and the need for further action.

Blacksmith Institute does not initiate or implement cleanup projects alone, but rather works with local partners and contractors who are often responsible for the physical cleanup. This model allows Blacksmith Institute to support the project through technical assistance, planning, and resources, while allowing the community to build its capacity to solve local pollution problems.

Smelter Cleanup in Rudnaya Pristan and Dalnegorsk

People in the Rudnaya River Valley, Russia, experience alarmingly high rates of cancer and other acute, chronic conditions as a result of several different types of industrial pollution. Outdated mining techniques have resulted in cadmium, zinc, lead, boron, and sulfur contaminating the entire city of Dalnegorsk, affecting the air, soil, water, homes, and crops. Neighboring Dalnegorsk is the second largest city in the region, Rudnaya Pristan, which is built around a lead smelting facility and a seaport, and is also among the most lead-contaminated sites in Russia. Citizens of Rudnaya Pristan have high rates of acute respiratory diseases and neurological damage.

Zinc and lead ores were mined in Dalnegorsk and transported in open cars to Rudnaya Pristan for smelting, a practice that ended only four years ago. The areas between the two towns, as well as the towns themselves, have been literally dusted with lead and cadmium, two of the most potent naturally occurring neurotoxins, for nearly 100 years. The heavy metal pollution has contaminated most of the Rudnaya River Valley. Approximately 50% of children randomly tested in this region showed abnormally high blood-lead levels despite the discontinuation of lead smelting in the area.

Project Strategies

The success of this project hinged on a collective effort to both assess the sources of continuing contamination and to promote outreach and educational efforts regarding the hazards of lead poisoning and heavy metal pollution. Success was measured in terms of stopping the continued elevation of children's blood-lead levels, with an eye toward lowering the average level of exposure as much as possible.

Efforts to curb continued lead poisoning involved the identification and cleanup of the most heavily frequented children's play areas. The lead and cadmium-contaminated areas were mapped along the entire valley, allowing the local partners and Blacksmith Institute to make targeted and pertinent recommendations to the residents of the Rudnaya Valley along with more concerted efforts toward remediation.

Following the successful identification of the major problem areas, local partners were able to remove and safely dispose of 2,000 to 3,000 cubic meters of contaminated soil from six heavily trafficked kindergartens (three sites in Dalnegorsk, two in Rudnaya Pristan, and one site in Serzhantovo) and one summer camp, Camp Chaika.

Following the physical removal of the contaminants from children's spaces, the next step was careful medical assessment and monitoring. Blood-lead tests were administered throughout the area to quantify the extent of the contamination and identify the most significantly affected areas. 120 families with children with severely elevated blood-lead levels were presented with literature on how to reduce the

Blood-Lead Levels in Local Children

Age	Mean Blood-Lead Level	Percentage over 10 µg/dL
Under 2 years of age	22.55+2.12 µg/dL	100%
3-6 years of age	25.00+3.95 µg/dL	88.9%
7-12 years of age	17.16+2.7 µg/dL	85.7%
Over 12 years of age	9.53+3.16 µg/dL	0%

negative impact of heavy metal exposure. They were also provided with food additives to facilitate the removal of heavy metals from their systems.

While the most aggressive and hands-on care was given only to the most significantly affected children and their families, over 5,000 families were given pamphlets educating parents on how to limit exposure to lead and other heavy metals. Information on the hazards of heavy metal poisoning was also disseminated through mass media outlets, and in popular children's books.

Testing blood-lead levels

Outcomes and Follow-Up

The results of these efforts have been very promising. Prior to the 2007 heavy metal awareness campaign and reduction of environmental pollutants, 22% of the children of Dalnegorsk and 65% of the children in Rudnaya Pristan had blood-lead levels greater than the acceptable WHO guideline (10 µg/dL). Of those same children, about 2% in Dalnegorsk and 24% in Rudnaya Pristan had very high blood-lead levels (over 20 µg/dL). Just two years later, in 2009, the number of children with lead levels over 10 µg/dL dropped to 9% in Dalnegorsk, and the number with high lead levels (over 20 µg/dL) dropped to less than 1%. In Rudnaya Pristan, results were not quite as dramatic, likely due to the greater severity of lead contamination in that area. In Rudnaya Pristan, while the overall number of children exhibiting lead levels above 10 µg/dL only dropped to 64%, the number with high levels (over 20 µg/dL) did drop considerably to 14%. Those children who exhibited decreased blood-lead levels did so on an average of nearly 50%.

As promising as these results have been in Dalnegorsk, Rudnaya Pristan still remains heavily affected by lead pollution. Currently, upwards of 50% of their children still have a blood-lead level of over 10 µg/dL, and further remediation is urgently needed.

Kabwe Lead Smelter Cleanup

Kabwe, the second largest city in Zambia, has a population of 300,000. It is located about 130km north of the nation's capital, Lusaka. It is one of six cities situated around the "Copperbelt," which was once Zambia's thriving industrial base. In 1902, rich deposits of lead were discovered in the mine and a smelter was constructed in the center of the town. Ore veins with lead concentrations as high as 20% have been mined deep into the earth, and a smelting operation was set up to process the ore. Mining and smelting operations were running almost continuously until 1994 without the government addressing the potential danger of lead. The mine and smelter, owned by the now-privatized Zambia Consolidated Copper Mines, are no longer operating, but have left a city with hazardous concentrations of lead in soil and water.

While in operation, there were no pollution laws regulating emissions from the mine and smelter. In turn, air, soil, and vegetation were all subject to contamination, and ultimately, over decades, millions of lives were affected. Recent findings reveal the extent to which lead has affected the health of Kabwe citizens. In Kabwe, blood-lead concentrations of 300 µg/dL have been recorded in children, and records show average blood-lead levels were between 60 and 120 µg/dL.

Project Strategies

Kabwe's decades of contamination required a complex cleanup strategy. Blacksmith Institute has helped the situation by establishing a local NGO, Kabwe Environmental and Rehabilitation Foundation (KERF), whose function is to bring educational and healthcare services into each community. At Blacksmith and KERF's urging, the World Bank provided a $15 million grant for cleanup purposes, and a subsequent $5 million in funding also was secured from the Nordic Development Fund. These results demonstrate that Blacksmith's initiatives can be leveraged to enable large contributions from major global institutions to allow for the remediation of serious pollution-related problems.

With Blacksmith providing technical assistance and resources, the government's Copperbelt Environment Project (CEP) has worked to determine the magnitude, sources, and pathways of human lead exposure, as well as to improve public awareness in order to end future contamination. In 2003, they began educational outreach to inform the public of behavioral and hygiene changes that would reduce their risk of lead exposure; at times, these have proven to be as simple as preventing children from playing in the dirt and rinsing dust off plates before meals. CEP has also revealed the critical importance of empowering local citizens with better access to clean water, which will free them from reliance on tainted sources. Some areas of Kabwe required drastic remediation, at times calling for entire neighborhoods to relocate. The CEP has conducted a cleanup of the highest threat level contaminated soils, including a contaminated canal and a great number of toxic hotspots in neighborhoods throughout the city.

The CEP is implementing a comprehensive program on risk communication and humanitarian development. Since its inception, the CEP has been implementing an intensive community outreach program aimed at raising awareness as well as providing simple messages on how to avoid lead exposure. This program also strengthens local community organizations and connects them with government initiatives. Working closely with the local authorities, 10 community development staff members have been partnered with the CEP, and its actions are based on a "community facilitator model," where community facilitators or volunteers from each affected area are closely involved in the implementation of projects.

Outcomes and Follow-Up

The Kabwe Lead Education Program is now being implemented in schools, where the CEP is working closely with the Ministry of Education to reach the more than 20,000 children in the areas significantly polluted with lead. This program revolves around a localized curriculum about lead dangers and proper safety precautions. Another aspect of the program, the "Green-is-Clean" campaign, promotes planting grass cover, thereby reducing potential lead exposure through loose soil and dust.

A medical management program has also been developed and is being implemented to reduce the elevated blood-lead levels in children. Presently,

this medical intervention targets children found with elevated blood-lead levels during the citywide survey.

A total of 160 children with blood-lead levels above 45 µg/dL were targeted for the household intervention program. Out of these, 38 children with levels above 70 µg/dL are already in the program, and the CEP continues to scale up the number of children that it serves. In support of all these efforts, the CEP has also embarked on a water project to provide the local community with uncontaminated water sources. The project is also developing playgrounds and parks in all impacted communities that, when completed, will be safe and lead-free play areas for children. Additionally, two Public Information Centers have been built, and more are slated for construction. These centers will serve as educational and community outreach headquarters.

Lead Poisoning in Zamfara State, Nigeria

In early 2010, doctors from Médecins Sans Frontières (MSF) were conducting field visits in Zamfara State, in northwest Nigeria, when they noticed an absence of children in several villages. When these doctors inquired with the local population about the low numbers of children, they were told that most children had died unexpectedly. This was reported to the State Health Authorities, who invited international specialists to investigate the cause of death. Investigations led by the US Centers for Disease Control and Prevention (CDC), in collaboration with Federal and Zamfara State authorities, MSF, Blacksmith Institute, and the WHO, revealed that the outbreak was caused by acute lead poisoning. The source was massive environmental contamination from the informal processing of lead-rich ore to extract gold. Men from the villages had brought rocks containing gold ore into the villages from small-scale mining operations; however, the villagers did not know that the ore also contained extremely high levels of lead. The ore was crushed inside village compounds, spreading lead dust throughout the community.

Blacksmith Institute joined a CDC field investigation that measured blood-lead concentrations in 113 samples from young children in the villages of Yargalma and Dareta. The results showed that 100% of the children had blood-lead levels exceeding 10 µg/dL (the international standard for the maximum safe levels of lead in blood), 96% exceeded 45 µg/dL, and 84% exceeded 70 µg/dL. It was also discovered that there were 78 deaths in Yargalma (30% of the population was less than 5 years old in the village) and 40 deaths in Dareta (20% of the population was less than 5 years old), totaling 118 deaths in these two communities since the beginning of the year. 95% of all deaths were in children under the age of five. As of September 2010, it was estimated that a total of 2,500 children have life-threatening levels of lead in their blood. Further investigation identified at least five additional villages where similar ore processing activities are common. In many areas in all villages sampled, including family homes and compounds, the soil lead concentration exceeded 100,000 ppm, far above the recommended maximum of 400 ppm considered acceptable for residential areas. Ingestion of contaminated soil has been the primary pathway of lead exposure.

Project Strategies

Throughout 2010, the State and Federal health authorities of Nigeria have partnered with WHO, CDC, MSF, and the Blacksmith Institute to address this problem. MSF has offered chelation therapy—a treatment for removing lead from the body—to any children testing at critical levels. To ensure the children do not return to homes contaminated with lead, Blacksmith Institute is conducting environmental decontamination and remediation in several villages in collaboration with local authorities. Local men are being paid to assist with the cleanup operations. Cleanup crews take contaminated soil to a landfill site and bring clean replacement soil to the villages. In addition to soil removal, thorough removal of dust from all interior spaces and compounds is essential. Children who have undergone a course of chelation therapy and are ready for discharge from the treatment centre must return to a clean environment. This project was ongoing at the time this report was written.

Mercury

Estimated Population At Risk At Identified Sites:
8.6 Million People

Estimated Global Impact:
15 to 19 Million People

Introduction

Mercury is a heavy metal that has significant impacts on human health. Mercury comes in three forms—metallic, inorganic, and organic—each with its own degree of toxicity and particular exposure pathways. Metallic mercury is the pure elemental form of the metal, and is extracted from cinnabar ore. After being heated to above 1,000 degrees Fahrenheit, mercury is refined into its liquid form, which is used in products such as thermometers, electricity switches, dental fillings; in the production of caustic soda and chlorine gas; and is used to extract gold from ores containing gold. Another primary form of the metal is organic mercury, most commonly known as methylmercury, and produced when elemental mercury combines with carbon. This is the form of the pollutant that can contaminate food chains.

Mercury naturally enters the environment through the breakdown of minerals into soil, which is then dispersed through the movement of air and water. Since the start of the industrial revolution in the 18th century, the release of mercury into the environment has been heavily amplified. Currently, the anthropogenic release of mercury accounts for up to two-thirds of the total mercury in the environment. [24]

Other common sources of mercury pollution in these countries include industrial mining, chemical manufacturing, solid waste disposal, and metals smelting. Most of these activities involve the heating of mercury, which releases it into the air in vapor form. The mercury is then transported in dust by wind. Mercury can settle into soil or surface waters through rainfall, and often is washed away from these sites along with tailings and sediments into local water bodies. Once in an aquatic ecosystem, elemental mercury can be transformed into methylmercury—a powerful neurotoxin—by bacteria, and can bioaccumulate and move up the food chain.

Mercury used by artisnal gold miners

People are commonly exposed to mercury through the inhalation of vapors produced through the burning of mercury in these various industrial activities; however, many are also exposed to methylmercury through the consumption of contaminated food products such as fish. Once mercury enters the human body, it can permanently damage the brain, kidneys, and the development of a fetus. Exposure to methylmercury can cause arthritis, miscarriages, respiratory failure, neurological damage, and even death. Children are most at risk of mercury exposure, especially in regions adjacent to small- and large-scale gold mines.

[24] U.S. Department of Health and Human Services. "Toxicological Profile for Mercury." Georgia: Agency for Toxic Substances and Disease Registry, 1999.

Artisanal mining operation on a river

Common Exposure Pathways and Health Risks

Mercury is released into the environment both as a vapor from burning processes and as a liquid that contaminates water and soil. In occupational settings such as mining sites, workers are primarily exposed to elemental mercury in the form of these vapors—it is estimated that around 80% of exposure to mercury is through this pathway. [25] People are also exposed to mercury through dermal contact, as the contaminant can be absorbed through the skin.

The use of mercury in industrial processes and products also allows small amounts of the heavy metal to contaminate soils and local water bodies. One study of small-scale mining in Peru estimated that one or two grams of mercury were being released into the surrounding environment for every gram of gold produced. [26] Mercury is also released into the environment through the produciton and disposal of fertilizers, fungicides, and solid wastes. These materials allow mercury to then settle in rivers, lakes, and streams, where it can remain for years.

Once in a water system, microorganisms process mercury, an activity that initiates the contamination of ecosystems and food chains by converting elemental mercury into methylmercury. Methylmercury can then accumulate in the fatty tissues of fish, mollusks, and other food sources, upon which many communities depend for their livelihoods. Additionally, some studies have found that livestock feeding on mercury-contaminated fields can also become a potential source of exposure to humans. [27]

Each of these pathways exposes people to the acute and chronic effects of mercury. Exposure can cause severe developmental problems in children and fetuses, kidney problems, arthritis, memory loss, miscarriages, psychotic reactions, respiratory failure, neurological damage, and death. In terms of the magnitude of these impacts, one study found that over half of artisanal gold miners in two regions of Indonesia were diagnosed with chronic mercury intoxication. [28] However, even less exposed groups—mineral processors and the general population living near mining sites—were also found to have high levels of mercury exposure.

As the most direct pathway, the inhalation of mercury vapor allows the pollutant to reach the brain, potentially causing permanent damage to the brain, the kidneys, and fetal development. Children are the most vulnerable population to mercury exposure, and are particularly at risk for developmental problems. Research also suggests that breast-feeding can be a source of mercury exposure to infants. [29]

There is a growing body of scientific evidence that mercury exposure can negatively impact the human immune system. [30] [31] In particular, one study has observed an association between immune system disorders and exposure to both organic and elemental mercury. [32] Fieldwork in northern Brazil, where artisanal gold mining is widespread, shows preliminary results that indicate an association between these immunologic changes and vulnerability to infectious diseases such as malaria. [33]

[25] Ibid.

[26] Earth Report. "Slum at the Summit." Television Trust for the Environment. Available at http://www.tve.org/earthreport/archive/doc.cfm?aid=1623, 2004.

[27] R.T. Chibunda and C.R. Janssen. "Mercury Residues in Free-Grazing Cattle and Domestic Fowl form the Artisanal Gold Mining Area of Geita District, Tanzania." Food Additives & Contaminants: Part A: Chemistry, Analysis, Control, Exposure & Risk Assessment 26.11 (2009): 1482–1487.

[28] St. Bose-O'Reilly, et al. "Health Assessment of Artisanal Gold Miners in Indonesia." Science of the Total Environment 408.4 (2010): 713–725.

[29] St. Bose-O'Reilly, et al. "Mercury in Breast Milk – A Health Hazard for Infants in Gold Mining Areas?" International Journal of Hygiene and Environmental Health. 211.5–6 (2008): 615–623.

[30] Li Sweet and J.T. Zelikoff. "Toxicology and Immunotoxicology of Mercury: A Comparative Review in Fish and Humans." Journal of Toxicology and Environmental Health. Part B, Critical Reviews 4.2 (2001): 161–205.

[31] P. Moszczynski. "Immunological Disorders in Men Exposed to Metallic Mercury Vapour. A Review." Central European Journal of Public Health 7.1 (1999): 10–14.

[32] R.M. Gardner, et al. "Mercury Induces an Unopposed Inflammatory Response in Human Peripheral Blood Mononuclear Cells in Vitro." Environmental Health Perspectives 117.12 (2009): 1932–1938.

[33] I.A. Silva, et al. "Mercury Exposure, Malaria, and Serum Antinuclear/Antinucleolar Antibodies in Amazon Populations in Brazil: A Cross-Sectional Study." Environmental Health 3.11, 2004.

Industrial Sources of Mercury – Artisanal Gold Mining

Industry Overview

Artisanal mining (ASM) refers to informal operations that extract and process metals on a small, rather than industrial, scale. The most prevalent form of informal mining is artisanal gold mining. This sector is responsible for nearly 20 % of global gold production, which equates to 330 tons of the product. ASM is concentrated in low- and middle-income countries such as Mozambique, where it accounts for up to 90% of national gold production. [34]

A miner burning mercury-gold amalgam

To separate the gold out of the gold-laden silt, ASM miners introduce mercury into the silt, which binds to the gold and forms a hardened mercury-gold amalgam. The remaining silt is then washed away, and the amalgam is heated with blowtorches or over open flames to evaporate the mercury, leaving behind pure gold. This burning process is often done in homes, and thus releases mercury vapors into the surrounding air. Additionally, when mercury is used in ASM, small amounts of the metal are often washed away along with unwanted tailings or sediments into local water bodies.

Once mercury enters the waterways of a region, it begins to be absorbed and processed through various levels of the ecosystem, starting at the base level of bacteria. The bioaccumulation of mercury transforms elemental mercury into methylmercury, one of the most dangerous toxins that can contaminate a food chain.

Global Context

UNIDO estimates that between 10 and 15 million people—including 4.5 million women and 600,000 children—obtain their livelihood through ASM. [35] Studies have found that the majority of women miners work in the amalgam-processing phase, where they are most susceptible to mercury exposure. [36] Research from Blacksmith Institute's ongoing assessment of polluted places indicates that the majority of artisanal mining sites are located in Southeast Asia, Africa, and South America.

Most artisanal miners are from socially and economically marginalized communities, and turn to mining in order to escape poverty, unemployment, and landlessness. [37] The cycle of poverty brings miners into hazardous working conditions where these individuals also face persecution by the government, the risk of mineshaft collapse, and toxic poisoning from the variety of chemicals used in the amalgamation process. Despite this combination of dangers, artisanal mining operations continue to spread as the demand for metals increases and other livelihoods, such as farming, become less economically viable in these regions.

[34] J.A. Shandro, M.M. Veiga, and R. Chouinard. "Reducing Mercury Pollution from Artisanal Gold Mining in Munhena, Mozambique." Journal of Cleaner Production 17.5 (2009): 525–532.

[35] M.M. Veiga and R. Baker. "Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small Scale Miners, Report to the Global Mercury Project: Removal of Barriers to Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies." GEF/UNDP/UNIDO, 2004.

[36] J.J. Hinton, M.M. Veiga, and C. Beinhoff. "Women, Mercury and Artisanal Gold Mining: Risk Communication and mitigation." Journal de Physique IV 107.1 (2003): 617–620.

[37] P. Tschakert and K. Singha. "Research on Small-Scale Gold Mining in Ghana." Pennsylvania State University, Department of Geography, October 11, 2006.

UNIDO estimates that the methods used in ASM to extract and process gold results in the release of an estimated 1,000 tons of mercury per year, which constitutes about 30% of the world's anthropogenic mercury emissions. [38] Additionally, as much as 95% of all mercury used in artisanal gold mining is released into the environment, constituting a danger to economies, environments, and human health. [39]

Exposure Pathways from Artisanal Mining

ASM releases mercury into the environment as a vapor during the amalgam burning process. ASM workers and their immediate family members subsequently inhale these toxic vapors. One study in Tanzania found that out of all workers engaged in the ASM sector, those working directly with amalgam burners had the highest levels of mercury in their blood, hair, and urine. [40]

Using mercury in the amalgam process also allows small amounts of the heavy metal to contaminate soil and local water bodies through discarded tailings and sediments. [41] When soil becomes contaminated with mercury, the pollutant can also impact food sources. One study of a small-scale gold mining site in China found that the total elemental mercury concentrations in consumed vegetable and wheat samples significantly exceeded the Chinese safety limit. [42] And as noted with methylmercury, fish and shellfish also become a source of exposure once rivers and lakes are contaminated with elemental mercury.

What is Being Done

Each of Blacksmith Institute's several mercury programs around the world share a common objective: to introduce mercury-reducing technologies to artisanal mining communities in order to lessen its impact on human health and the environment. Blacksmith, in conjunction with UNIDO's Global Mercury Project, has initiated a series of appropriate technology demonstrations to limit the mercury emissions affiliated with ASM. Dr. Marcello Veiga, Chief Technical Advisor to the Global Mercury Project, developed a ground-breaking and inexpensive adaptation of retort technology, which typically costs between $3 and $8 US. Through the use of this device, mercury can be used in the gold extraction process without contaminating the environment.

There are a number of cleaner technology alternatives to current methods of mercury amalgamation. The use of retorts during the mercury burn-off stage is a simple and highly cost-effective method of controlling the release of mercury into the environment by allowing for the efficient capture and reuse of mercury and minimizing occupational exposure. Experience has shown that the largest barrier to the uptake of such technology is education. Blacksmith is working to break the cycle of dangerous mercury use by supplying ASM miners with the education and technology needed to minimize their exposure to mercury and its release into the environment.

[38] M.M. Veiga and R. Baker. "Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small Scale Miners, Report to the Global Mercury Project: Removal of Barriers to Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies." GEF/UNDP/UNIDO, 2004.

[39] M.M. Veiga, et al. "Pilot Project for the Reduction of Mercury Contamination Resulting From Artisanal Gold Mining Fields in the Manica District of Mozambique", 2005.

[40] St. Bose-O'Reilly, et al. "Health Assessment of Artisanal Gold Miners in Tanzania." Science of the Total Environment 408.4 (2010): 796–805.

[41] J.E. Gray, et al. "Mercury and Methylmercury Contamination Related to Artisanal Gold Mining, Suriname." Geophysical Research Letters 29.23, 2002.

[42] Xinbin Feng, et al. "Gold mining Related Mercury Contamination in Tongguan, Shaanxi Province, PR China." Applied Geochemistry 21.11 (2006): 1955–1968.

Mercury Risk Mitigation in Kedougou, Senegal

The Kedougou region of Senegal was chosen for a pilot mercury project because of its large gold deposits and the many artisanal gold miners in the area, who use mercury in the gold extraction process. The Saboldala gold deposit in Kedougou is estimated to yield about one million ounces of raw gold over a 230 square kilometer area.

As described earlier in this report, artisanal gold miners extract gold-laden rock, grind it into fine sand, and then mix it with mercury to form an amalgam. The amalgam is then subjected to high heat, either with a blow torch or over an open flame, and the mercury evaporates into the atmosphere, a process that leaves behind a substance that is roughly 80% pure gold.

The use of mercury capture technology known as a "retort" during the mercury burn-off stage is a simple and highly cost-effective method of controlling the release of mercury into the environment. This device allows for the efficient capture and reuse of mercury while minimizing occupational exposure.

Project Strategies

The primary goals of this project were both to sensitize workers and their families to the harmful health effects of mercury exposure, and to popularize the use of the mercury retorts among miners. To achieve this, Blacksmith Institute staff and partners organized local meetings to discuss the use and importance of the retorts. Workers were also shown the process of fitting retorts for their use over their current instruments.

Adding mercury to sediment containing gold

Using this approach, project staff organized nine information sessions over the course of three months, which were designed to reach almost 4,000 people in eleven villages across the region. Project staff visited 23 artisanal mining sites to support the miners and gather information relative to the evolution of the retorts and to the quantity of mercury circulating around the villages.

Outcomes and Follow-Up

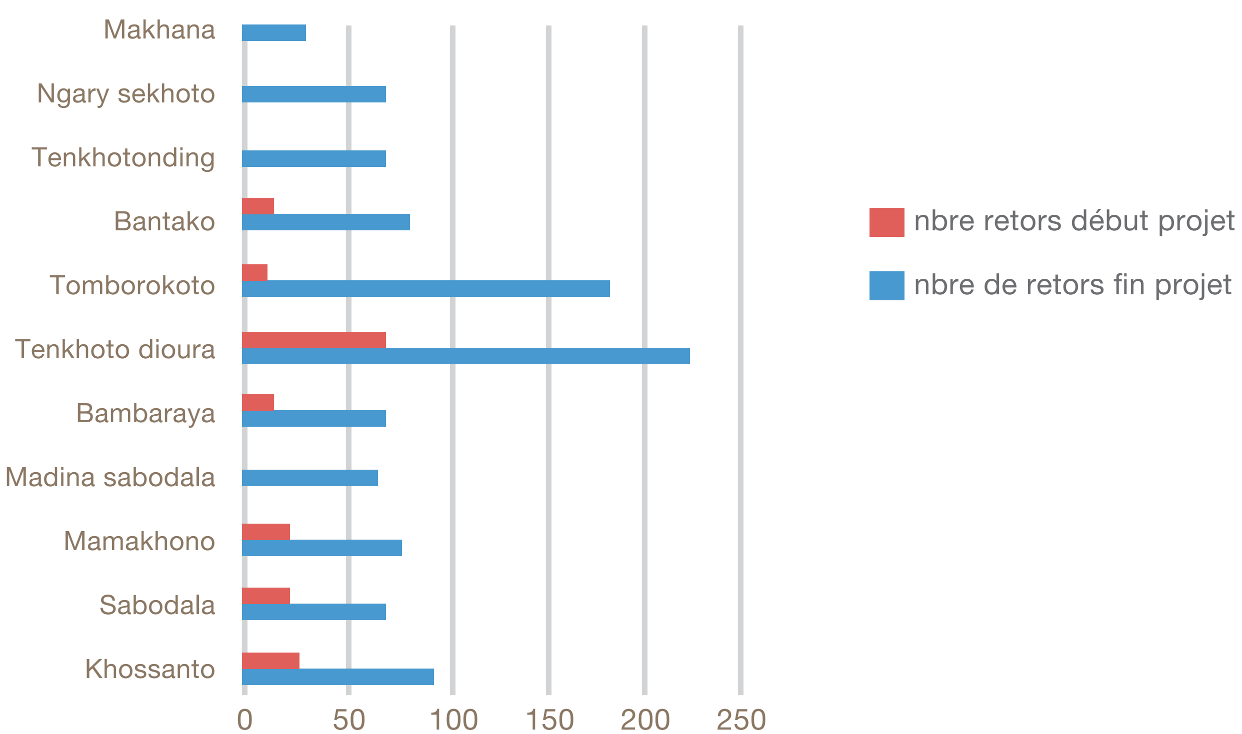
This project resulted in an increase in the use of retorts at all sites; however, the usage at each site remained highly varied. At some sites, 95% of miners employed retort technologies in the process, while at others only 5% adopted its use. Over the entire area, the number of total retorts has increased by over 400%.

The introduction of retorts in small-scale gold mining communities has been very successful. To encourage further progress, work in Senegal must continue. Retorts in larger quantities and sizes are in high demand, which will require additional support from donors and other stakeholders. Regulation of the sale, stockpiling, and usage of mercury must also be implemented.

Further steps that Blacksmith Institute will implement in 2010 include:

- Supporting miners in acquiring better retorts;
- Executing studies that monitor local mercury levels;
- Continuing to educate miners on the benefits of retorts;
- Equipping workers with gloves and masks to minimize direct exposure;
- Continuing to work with local authorities, media, and existing partners;
- Creating a health panel to detect signs of high levels of contamination; and
- Creating a system that formalizes and controls the circulation of mercury.

Number of Retorts used at Target Senegalese Mining Sites



Number of retorts at the beginning of the project (red) and at the end (blue)

Chromium

Estimated Population At Risk At Identified Sites:
7.3 Million People

Estimated Global Impact:
13 to 17 Million People

Introduction

Chromium is a naturally occurring heavy metal that is commonly used in industrial processes and can cause severe health effects in humans. Although it can be released through natural forces, the majority of the environmental releases of chromium are from industrial sources. The industries with the largest contribution to chromium levels include leather tanning operations, metal processing, stainless steel welding, chromate production, and chrome pigment production. Chromium can be found in many consumer products, including wood treated with copper dichromate, leather tanned with chromic sulfate, and stainless steel cookware. [43]

Of the chromium sites identified so far by Blacksmith Institute, roughly 75% are located in South Asia. Of these, nearly a third are associated with tannery operations, with mining and metallurgy sites also contributing significantly. The high concentration of chromium sites in South Asia is primarily due to the abundance of tanneries in the region. Many of the tanneries have poor environmental controls.

Common Exposure Pathways and Health Risks

Chromium can exist in air, water, soil, and food, and common exposure pathways include ingestion, inhalation, or dermal contact. Chromium is commonly found in two forms: trivalent chromium (chromium III) and hexavalent chromium (chromium VI). Chromium III is the most stable

Water contaminated with chromium at a tannery site

form of the element, and occurs naturally in animals, plants, rocks, and soils. Chromium VI rarely occurs in nature, and is usually the product of anthropogenic activities.

The health effects of chromium depend on the route of exposure and the form of the chromium. For example, inhaling chromium can cause damage to the respiratory system, whereas dermal or oral exposures generally do not. Gastrointestinal effects are generally associated with oral exposure, but not with dermal exposure. In addition, chromium VI typically causes greater health risks than chromium III. The reasons for the increased danger of chromium VI versus chromium III are complex, and relate in part to the varied paths of cellular uptake between the two forms. [44]

The primary health impacts from chromium are damage to the gastrointestinal, respiratory, and immunological systems, as well as reproductive and developmental problems. Chromium VI is a known human carcinogen, and depending on the exposure route, can increase the rate of various types of

[43] U.S. Department of Health and Human Services. "Toxicological Profile for Chromium." Georgia: Agency for Toxic Substances and Disease Registry, 2008.

[44] Ibid.

Kids playing in tannery scraps containing chromium

cancers. Occupational exposure to chromium VI, which often occurs through inhalation, has been linked to increased rates of cancer in the respiratory system. According to the WHO, over 8,000 workers in the tanneries of Hazaribagh, India suffer from gastrointestinal, dermatological, and other diseases, and 90% of this population die before the age of 50. [45] Separate studies in Kanpur, India also show that there is a significantly higher prevalence of morbidity in these workers, mostly from respiratory diseases owing to chromium exposure. [46]

Chromium III is considered to be less dangerous than chromium VI, although some investigations have demonstrated that chronic exposure to this form, especially in occupational settings, can significantly damage lymphocyte DNA. [47] Studies have also indicated that the broader category of chromium accumulation in the human body can have an adverse effect on the ability to metabolize iron, important because iron is essential to red blood cells. [48] As most of the human body's iron is contained in these cells, iron deficiency anemia can occur when the body cannot absorb enough of the metal.

Industrial Sources of Chromium – Tanneries

Industry Overview

The global leather industry is composed of three sectors of activity: animal husbandry and slaughter, tanning, and product manufacturing. Tanning is the stage in which raw leather is processed and made more durable so that it can be made into various products in the subsequent segment of the industry. Tanning is composed of three stages as well: the pretreatment of animal hides, the application of a tanning agent, and finishing the material with treatments such as drying and shining. However, these stages are not static categories, and the overall tanning process can include the sizing of hides, weaving, bleaching, carbonizing, and dyeing, as well as finishing. [49]

The tanning of hides is a diverse practice, and includes the processing of both light and heavy leather materials. Light leather materials will eventually be manufactured into the tops of shoes and into a number of various leather products, while heavy leather materials will become belts, straps, leather used for machinery, as well as the soles of shoes. The types and concentrations of the chemicals used in the pretreatment, tanning, and finishing stages of production are also varied. Chromium is one of the most widely used chemicals throughout this process. However, other raw materials used in this process can include limestone soda ash, sulfuric acid, and sodium chlorate. The wastewater effluent from tanneries can be a dangerous source of pollutants, and often contains dissolved and suspended organic and inorganic

[45] J. Maurice. "Tannery Pollution Threatens Health of Half-Million Bangladesh Residents." Bulletin of the World Health Organization 79.1, 2001.

[46] Subodh Kumar Rastogi, Amit Pandey, and Sachin Tripathi. "Occupational Health Risks among the Workers Employed in Leather Tanneries at Kanpur." Indian Journal of Occupational Medicine 12.3 (2008): 132–135.

[47] M.G. Medeiros, et al. "Elevated Levels of DNA-Protein Crosslinks and Micronuclei in Peripheral Lymphocytes of Tannery Workers Exposed to Trivalent Chromium." Mutagenesis 18.1 (2003): 19–24.

[48] C. Kornhauser, et al. "Possible Adverse Effect of Chromium in Occupational Exposure of Tannery Workers." Industrial Health 40.2 (2002): 207–213.

[49] V.M. Correia; T. Stephenson, and S.J. Judd. "Characterisation of Textile Wastewaters – A Review." Environmental Technology 15.10 (1994): 917–929.

Tannery effluent flowing into surface waters

solids, potentially toxic metal salts, chrome, and electrolytes such as sodium chloride and sulfide. [50] However, as mentioned above, the chemical composition of these effluents is subject to variation due to the diversity in the processes employed and the range of chemicals used within each stage of processing. In general, these effluents can cause environmental problems related to their high chemical oxygen demand and elevated chromium concentrations. [51]

Global Context

Because of the relatively inexpensive cost of labor and materials, over half the world's tanning activity occurs in low- and middle-income countries. Between 1970 and 1995, the percentage of low- to middle-income countries contributing to the global production of light leather increased from 35% to 56%, and from 26% to 56% for the production of heavy leather materials. [52] The results of Blacksmith Institute's efforts to assess polluted sites have shown that tanning facilities are highly concentrated in Nepal, Bangladesh, and India, but also frequently cause adverse health impacts in Southeast Asia, South America, and Africa.

At these sites, tanneries not only discharge contaminated wastewater into rivers, but also dump a large amount of chromium-mixed solid wastes—such as skins, hides, and fats—onto the banks of rivers and on fields near residential areas and villages. This leads to the contamination of water sources with cadmium, iron, magnesium, chromium, calcium, nickel, lead, and zinc from the addition of tanning agents, while the skin and hide treatment processes release sodium, potassium, magnesium, and copper. [53]

Effluents from tanning operations can also contaminate soils with magnesium, manganese, copper, cadmium, nickel, and lead. In addition, the pipelines and canals that transport wastewaters away from these industrial facilities often run through villages, where they occasionally leak into surrounding soils or are used to irrigate crops.

Exposure Pathways from Tanneries

People can be exposed to the contaminants produced by tanning through various pathways. The most common occupational hazard is inhalation of chromium at the work site. However, the populations near a tannery are often exposed to pollutants through contaminated water. People use the water from contaminated rivers and streams for several purposes, including irrigation, swimming (mostly children), bathing, and washing dishes and clothing. There is also a high risk of this hazardous waste water mixing with the ground water, which is extracted for drinking water. In the largest tannery region of Bangladesh, Hazaribagh, more than 200

[50] R. Jenkins, J. Barton, and J. Hesselberg. "The Global Tanning Industry: a Commodity Chain Approach." Environmental Regulation in the New Global Economy: the impact on industry and competitiveness: Edward Elgar Publishing (2004): 157–172.

[51] Z. Song, C.J. Williams, and R.G.J. Edyvean. "Sedimentation of Tannery Wastewater." Water Research 34.7 (2000): 2171–2176.

[52] R. Jenkins, J. Barton, and J. Hesselberg. "7. The Global Tanning Industry: a Commodity Chain Approach." Environmental Regulation in the New Global Economy: the impact on industry and competitiveness: Edward Elgar Publishing (2004): 157–172.

[53] Saadia R. Tariq, Munir H. Shah, N. Shaheen, A. Khalique, S. Manzoor, and M. Jaffar. "Multivariate Analysis of Selected Metals in Tannery Effluents and Related Soil." Journal of Hazardous Materials 122.1-2 (2005): 17–22.

Kids swimming in tannery waste-water

tanneries generate 7.7 million liters of liquid waste and 88 million tons of solid waste every day. The direct discharge of these wastes has contaminated the ground and surface water with dangerously high concentrations of chromium, as well as cadmium, arsenic, and lead. [54] The contamination of rivers also allows these pollutants to accumulate in common fish and shellfish species, which are used as local food sources.

These effluents eventually contaminate nearby soils with heavy metals. Studies, such as one in Syria, indicate that the chromium-contaminated soil poses a significant health hazard, as the direct inhalation and ingestion of soil allows chromium to accumulate in both humans and livestock. [55] In addition, the chromium-laced solid wastes from tanneries are often converted into poultry feed—as is the case in areas of Bangladesh—and can thus impact livestock and humans. [56]

Soil contamination can also negatively impact agriculture. Commonly, the wastes generated during tanning are added to commercially available organic fertilizers, and chromium can accumulate in standard food crops. [57]

Women wash clothes in effluent contaminated with chromium from a dye plant

What is Being Done

Blacksmith Institute has experience mitigating risks from chromium waste. Ground water contaminated with chromium VI can be treated by introducing an electron donor into well water to convert chromium VI to the less toxic chromium III. When soils and solid waste pose health risks, excavation and removal are cost-effective measures to break the pathway between the contaminant and the local population. Additionally, recent research has targeted the use of particular salt-tolerant bacteria, such as those from the Arthrobacter genus, as potential agents to reduce chromium levels in tannery waste-contaminated soil. [58] Similar studies demonstrate the ability of bone charcoal—a granular material produced by charring animal bones—to remove chromium from water. [59] Vermiculture, in which worms are used to concentrate heavy metals, is another potentially cost-effective form of bioremediation. The construction of waste treatment facilities and secure landfills can also significantly reduce health risks, and these methods are often used in tandem to remediate polluted sites.

[54] Bhuiyan, et al. "Investigation of the Possible Sources of Heavy Metal Contamination in Lagoon and Canal Water in the Tannery Industrial Area in Dhaka, Bangladesh." Environmental Monitoring and Assessment, 2010.

[55] A. Möller, H. W. Müller, A. Abdullah, G. Abdelgawad, and J. Utermann. "Urban Soil Pollution in Damascus, Syria: Concentrations and Patterns of Heavy Metals in the Soils of the Damascus Ghouta." Geoderma 124.1-2 (2005): 63–71.

[56] A.M. Hossain, et al. "Heavy Metal Concentration in Tannery Solid Wastes Used as Poultry Feed and The Ecotoxicological Consequences." Bangladesh Journal of Scientific and Industrial Research 42.4 (2007): 397–416.

[57] V.P. Grubinger, W.H. Gutenmann, G.J.Doss, M.Rutzke, and D.J. Lisk. "Chromium in Swiss Chard Grown on Soil Amended with Tannery Meal Fertilizer." Chemosphere 28.4 (1994): 717–720.

[58] M. Megharaj, S. Avudainayagam, and R. Naidu. "Toxicity of Hexavalent Chromium and Its Reduction by Bacteria Isolated from Soil Contaminated with Tannery Waste." Current Microbiology 47.1 (2002): 51–54.

[59] S. Dahbi, et al. "Removal of Trivalent Chromium from Tannery Waste Waters Using Bone Charcoal." Analytical and Bioanalytical Chemistry 374.3 (2002): 540–546.

Kanpur Chromium Remediation Project

Kanpur is the ninth-largest city in India, and one of its most severely polluted. Its eastern districts feature about 350 industrial leather tanneries, many of which discharge untreated waste into local ground water sources and the Ganges River. These pollutants include toxic levels of heavy metal contaminants such as chromium, mercury, and arsenic. Chromium is popular in the tanning industry because it makes leather goods stronger. The hexavalent chromium in tanning waste is known to cause cancer, liver failure, kidney damage, and premature dementia.

Noraiakheda is a settlement of 30,000 people within Kanpur that has developed on top of a plume of chromium VI, which is emitted in toxic sludge from an old chemical plant that had supported the region's tanneries. The sludge is a source of pollution and a danger to human health. Flammable methane trapped inside the sludge catches fire during the hot summer months, thus releasing harmful toxins into the air. Summer heat and winds also distribute dust particles from the sludge, which contain chromium and other toxins that are harmful when inhaled. The chromium from the sludge leaks into the river, subsoil, and ground water, the primary sources of drinking water for the surrounding community. A 1997 study conducted by the Central Pollution Control Board on the ground water quality in Kanpur revealed chromium VI concentrations of 6.2 mg/L; the Indian government places the maximum allowable level for public consumption at 0.05 mg/L.

Project Strategies

Highly toxic chromium VI can be converted to a less harmful chromium III by introducing an electron-donating chemical that will cause a reduction reaction. In addition to being safer for human exposure, the newly created chromium III also binds more easily with subsurface sediments to keep it out of the water supply. Though proven in laboratories and at other work sites, this technique had never been used in India. Blacksmith Institute initiated a two-pronged approach aimed at both chemically neutralizing the chromium and warning locals of the hazards. For the awareness-raising campaign, Blacksmith supported Ecofriends, a local environmental NGO in Kanpur. For chemical remediation of the chromium, Blacksmith worked with Ecocycle/GZA (engineering consultants who could supply some of the needed materials) and the Central Pollution Control Board in order to undertake the first such project in India. Other collaborators included the Industrial Toxicology Research Center, Indian Institute of Technology-Kanpur, and National Geophysical Research Institute.

As part of the remediation, Blacksmith and its partners dug four new wells in a portion of the contaminated ground water system. One of the wells was an injection well used to introduce the electron donor chemical, and the other three were water quality monitoring stations that would test for 16 health criteria, including heavy metal concentrations. Once baseline samples had been taken, the chemical was added through the injection well and then the monitoring sites were subsequently sampled multiple times.

Outcomes and Follow-Up

The intervention from Blacksmith and Ecofriends succeeded in installing two new submersible water pumps that would supply the Noraiakheda area with safe, potable drinking water. The chemical remediation was also successful, with levels of chromium VI dropping at all the test sites, sometimes to undetectable levels.

Blacksmith has now proven that its techniques for chemically treating toxic chromium will work in Indian sites. The next step will be to expand implementation throughout broader areas as needed. GZA has prepared an action plan for larger-scale remediation throughout Kanpur, which is expected to cost $2-4 million.

Arsenic

Estimated Population At Risk At Identified Sites:
3.7 Million People

Estimated Global Impact:
5 to 9 Million People

Introduction

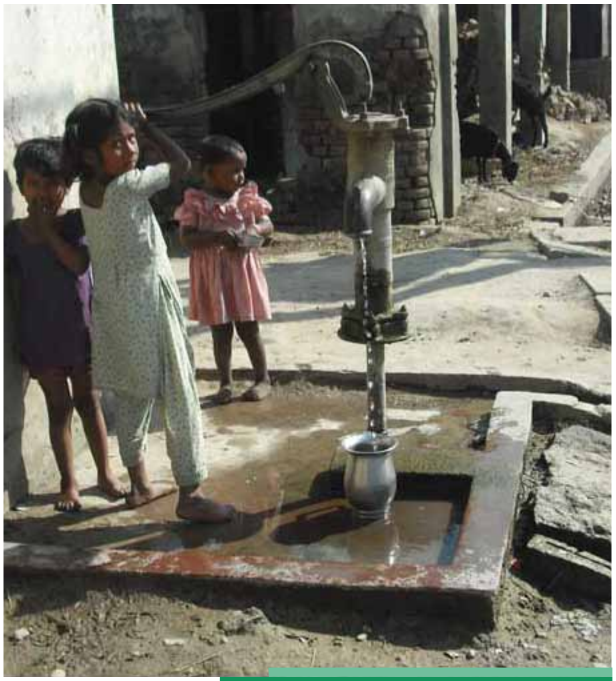
Arsenic is a naturally occurring element that is frequently characterized as a metal, despite having properties of both a metal and a nonmetal. In its elemental state, arsenic is a grey solid material; however, arsenic is often found in the environment combined with other elements. These arsenic compounds are generally white or colorless powders that have no smell or taste, making them difficult to detect in food, water, or air.

Arsenic is often found in rocks that contain other valuable metals, such as copper and lead. When smelters heat this ore to retrieve the other metals, the arsenic is often released into the air as dust. Arsenic is also found in coal, and can be released through coal-fired power plants or incinerators that burn arsenic-containing products. Arsenic itself is also mined and used in industrial processes. Additionally, about 90% of the arsenic produced each year is used to pressure-treat wood to preserve it and resist rotting and decay. [60] Arsenic is also used in the production of chemical pesticides.

Once arsenic is released into the environment, it attaches to other particles and can easily spread as wind-blown dust. Once in the air, arsenic can stay airborne for many days and travel great distances. Arsenic can also dissolve in water, and thus can easily contaminate lakes, rivers, and ground water resources. Drinking arsenic-contaminated water is a serious health risk to humans. Although organic arsenic can accumulate in some types of fish and shellfish, this form of the element is much less harmful. [61]

Common Exposure Pathways and Health Risks

Arsenic can exist in air, water, soil, or food, and all of these present potential pathways for human exposure. Very low concentrations of arsenic are common in soil; however, in areas within the vicinity of arsenic-rich deposits, the natural concentration of arsenic in soil can increase over a thousand fold. In these areas, it is common to find ground water that is also contaminated with high concentrations of arsenic. For this reason, concentrations of arsenic in ground water are often much higher than those in surface water. This is a particular problem in India, Nepal, and Bangladesh, where naturally occurring arsenic contaminates wells used by



A well containing dangerous levels of arsenic

[60] U.S. Department of Health and Human Services. "Toxicological Profile for Arsenic." Georgia: Agency for Toxic Substances and Disease Registry (2007): 2.
[61] Ibid.

millions of people. Arsenic's ranking in the list of the six top toxic threats is largely due to the number of people affected by naturally occurring arsenic contamination of ground water in South Asia.

Because of arsenic's ability to cling to other particles and travel as dust, the inhalation of this element is a common exposure pathway. Workers in the fields of copper and lead smelting, mining, wood treatment, or pesticide application can be exposed to high levels of arsenic in workplace air. Arsenic can also be ingested through food. Seafood is the most common consumption pathway of arsenic, although it can also be found in cereals, mushrooms, and poultry. The arsenic found in most seafood is a type called arsenobetaine, which is less harmful than other forms of the element.

Arsenic has long been recognized as a poison, and large oral doses can cause death. Lower doses of arsenic can cause decreased production of red and white blood cells. One common characteristic effect of arsenic poisoning is visible changes to the skin. People exposed to arsenic often have patches of dark skin, "corns," and "warts." Arsenic is also a human carcinogen, and exposure can result in cancer of the liver, bladder, lungs, and skin. **[62]**

This contaminated well is the village's only source of drinking water

Industrial Sources of Chromium – Industrial Mining and Smelting

Industry Overview

Industrial mining refers to formal, large-scale mineral extraction operations. Typical minerals extracted at these sites include manganese, copper, tin, lead, nickel, aluminum ore, iron ore, gold, and coal, and the toxicity and value of these materials can range from inert to hazardous, and from common to precious. Smelting refers to the process of heating ores to concentrate and process metals from the ore. Arsenic is found in rocks containing many other elements, and is often released in the process of mining and smelting other metals.

Mining and smelting sites often pose serious risks to local communities, particularly to children. Arsenic cannot be destroyed, and thus remains in surface soil long after the event that released the arsenic has ceased. Because of this, many people do not realize that the soil near them contains high concentrations of the element. Children near mining and smelting sites often interact with soil that carries legacy arsenic pollution from former industrial activities. Children live at ground level, and because of hand-to-mouth behavior can ingest dangerous quantities of arsenic.

Global Context

Industrial mining is a large sector of the global economy. In 2005, the overall value of this mode of mineral extraction was 800 billion USD. From this revenue, 52% came from coal and uranium, 27% came from metals, 14% came from crushed rock, 5% came from industrial minerals, and 2% came from diamonds. **[63]** Many of these valuable materials are extracted in low- and middle-income countries, primarily those located in South America and Africa.

[62] Ibid.

[63] Raw Materials Group, Stockholm 2006.

A frequent pollution problem caused by industrial mines comes from the disposal of mineral wastes. The activities associated with the extraction phase, especially in open-pit mining, typically generate the highest quantities of solid wastes, of which industrial mining has two primary forms: waste rock and tailings. Waste rock is the material removed to access the ore, while tailings are the materials left once the valuable ores are separated from their original sediments in a mineral processing plant. [64] Both forms of waste typically contain the target minerals in low concentrations, as well as other potentially dangerous metals and elements. Additionally, mine waste may also contain toxic residues of chemicals used in the separation process, such as cyanide and mercury.

Exposure Pathways from Mining and Smelting

At some sites, mine wastes are illegally dumped in nearby unprotected piles or waterways. The accumulation of these tailings in riverbeds can cause flooding, which spreads metals, including arsenic, into local farmlands. Furthermore, mine waste rock often generates acid drainage, and when air and water come into contact with metal sulfide minerals, the resulting sulfuric acid solutions can leach into surface and ground water.

The chemicals often used in the processing of minerals and ore during the extraction phase can leach into nearby surface water and ground water resources. Some mining sites deposit their waste materials in structures meant to protect against migration caused by wind and rain. Yet, once created, these structures can be susceptible to leaks and other damages, thus spilling contaminated tailings into the environment. Many of the elements within these wastes are toxic and present at concentrations that can harm human health. Many of these harmful elements and chemicals occur in both mineral waste repositories and the exposed walls of extraction sites. Mineral-contaminated dust can be transported by wind, taken up by agricultural plants, and can bioaccumulate in the tissues of fish and other food sources. In an Armenian town located near a lead mine, the highest levels of lead were found in dust samples from both inside and outside of homes, indicating the extent to which these materials can be transported into human dwellings. [65]

Effects of arsenic exposure

Materials such as arsenic, asbestos, and crystalline silica can easily be transmitted via wind, and radioactive minerals from specific extraction sites pose their own set of health risks, explored later in this report. All together, these minerals and metals can enter the human body through a variety of means, including inhalation, dermal absorption, and ingestion of water and food.

What is Being Done

Environmental regulation of industrial mining aims to reduce the risks these operations pose to environmental and human wellbeing. However, the problems posed by industrial mining arise when governments do not have the capacity or will to set strict emission and waste disposal rules, and when these laws fail to be properly enforced. In these cases, some mining companies voluntarily undertake emission reduction programs, most often under pressure from civil society groups.

Blacksmith Institute is working with governments and a range of civil society groups in China, Brazil, Russia, and Chile to both educate community members of potential health risks and initiate a multi-stage cleanup process. Remediation projects often include sealing or removing contaminated soil, isolating and storing legacy tailings with protective lining, and installing spill collection systems, drainage ditches, dams, and temporary containment ponds.

[64] Superfund Basic Research Program. “Mine Tailings.” The University of Arizona. Available at http://superfund.pharmacy.arizona.edu/Mine_Tailings.php, 2008.

[65] V. Petrosyan, et al. “Lead in Residential Soil and Dust in a Mining and Smelting District in Northern Armenia: A Pilot Study.” Environmental Research 94.3 (2004): 297–308.

Wenshan Arsenic Mining Remediation

This project was initiated in late 2006 in Yunnan, China through dialogue between Blacksmith Institute and the Yunnan Environmental Protection Bureau (EPB). The primary problem at the site was the contamination of local water supplies with arsenic and other metals, which originated from small abandoned metal mines and processing facilities. The local pollution problems were severe and, because heavy metals do not degrade in the environment, the erosion of these materials added to the cumulative pollution load on the river system. The objective was to develop practical approaches for this type of situation in collaboration with the Yunnan and local EPBs, which would be a model for other mountain villages with similar problems. The project was structured to provide direction and momentum for a wider effort by the Province to address mining pollution and water contamination challenges.

Project Strategies

In May 2007, a technical team from Blacksmith, together with officials from Yunnan EPB and local governments, made visits to the three mine areas in the mountains. Engineers and technical staff from the different government agencies joined the visiting specialists for the visits. A detailed report was prepared covering a number of sites in the three mining areas, and it was agreed that the pilot remediation would be implemented at one particular site, known as Wenshan No.4.

The strategies for remediation included the construction of a retaining wall to create a stable tailings storage area along with the installation of an impermeable lining for the zone. The dumped arsenic residues were then moved to this secure area and placed in compacted layers to ensure stability. The surface of the completed storage area was vegetated using local species suited to the environmental conditions, and drainage ditches were installed along the sides of the final storage area to divert surface water flows. Controls were also put in place to prevent unauthorized access and to deter the scavenging of remaining structures.

Outcomes and Follow-Up

Surface water drainage samples were taken by the Wenshan County EPB at the request of Blacksmith in order to provide a baseline level against which the post-remediation contamination data could be compared. The reported arsenic concentration in the drainage from the site before the project was 1.07 mg/L, which is more than twenty times above the suggested safe level (0.05 mg/L). The arsenic content in the drainage systems after remediation was 0.048 mg/L, which is just within safe consumption limits. The authorities planned a program of sampling during the rainy season in order to provide a better picture of the project's success in containing the contamination and reducing off-site transport.

The success of the pilot project has been recognized by authorities in Yunnan, and has reinforced the value of the approaches and the potential for developing the broader program. A large part of the success of the pilot project was due to the commitment and efforts of the Wenshan County Government with the backing of Wenshan Prefecture and the Province.

According to the Wenshan County EPB, there are at least five old smelters in the county that need to be addressed, and there are an estimated one million tons of polluted material that needs to be controlled. Wenshan Prefecture is preparing a comprehensive plan to address related issues in all the affected counties. The new national policy on environmental protection in rural areas is providing a favorable context to progress with remediation efforts. Blacksmith and the Yunnan EPB are continuing the dialogue with Wenshan Prefecture and County about possible ways to provide technical and financial support to the remediation efforts. The team will also follow up with the Provincial authorities on the lessons learned from the project, and how these lessons can be applied more broadly.

BLACKSMITH INSTITUTE

Pesticides

Estimated Population At Risk At Identified Sites:
3.4 Million People

Estimated Global Impact:
5 to 8 Million People

Introduction

Pesticides are those substances, often chemical in nature, that are used with the intent to repel or eliminate species that have an adverse affect on agricultural or horticultural production. Pesticides are also used to fight tropical diseases like malaria. This class of pollutants falls under the umbrella of agrochemicals or agrotoxins—which can also include fertilizers—and was initially developed to improve agricultural output, enhance crop growth, and repel or eliminate pests that hinder high yields. Pesticides began to be used on a large scale as early as the 15th century, when chemicals such as arsenic and lead were added to soil to eliminate insect species. The push toward further use of chemicals came between the 17th to 19th centuries, when a range of compounds—including nicotine sulfate, pyrethrum, and rotenone, to name a few—were extracted from natural products for their efficiency in allowing plant yields to increase without being hindered by various parasites. [66]

The term pesticide encompasses a variety of compounds that are used for different purposes in agriculture. A "pesticide" can be classified as an insecticide, herbicide, fungicide, nematocide, or molluscicide. Pesticides work by interfering with essential biological mechanisms of their target species, primarily through actions such as paralyzing an insect's nervous system. However, since these mechanisms are not specific to one species, these chemicals potentially harm other organisms, including humans.

Examples of especially harmful pesticides include the organophosphate and organochlorine classes of pesticides. Organophosphates affect an organism's nervous system by disrupting the enzymes that regulate specific neurotransmitters, and most of the pesticides within this group are insecticides. Certain organophosphates were also produced during World War II for the potential use as chemical warfare agents. [67] Examples of organophosphates include chlorpyrifos, methyl parathion, azinphos methyl, and malathion. Likewise, the category of organochlorine pesticides includes chemicals so harmful—such as DDT, chlordane, and lindane—that their use is banned in many countries. Other pesticides with serious health impacts include glyphosate, methyl bromide, metadof, duron, and novaquat. Many of these above compounds are listed as Highly Hazardous or Restricted Use Pesticides.

Common Exposure Pathways and Health Effects

A significant percentage of the millions of tons of pesticides used each year is washed away by rainfall into nearby surface and ground water. Additionally, because many commonly used pesticides are classified as Persistent Organic Pollutants (POPs)—chemicals that have long life spans and can bioaccumulate in human and animal tissue—a range of non-pest organisms absorb these pesticides. Some sources have concluded that over 98% of sprayed insecticides and 95% of herbicides contaminate sources other than the intended target organisms, such as the air, water, bottom sediments, and food sources. [68]

Pesticides enter and pollute the environment primarily through their direct application in

[66] G.T. Miller. "Living in the Environment" (12th Ed.). Belmont: Wadsworth/Thomson Learning, 2002.

[67] U.S. Environmental Protection Agency. "About Pesticides." Available at http://www.epa.gov/pesticides/about/types.htm, September 30, 2010.

[68] G.T. Miller."Chapter 9." Sustaining the Earth. 6th ed. Pacific Grove, California: Thompson Learning, Inc., (2004): 211–216.

An effluent pool near a chemical production facility

agricultural fields, since large volumes of these chemicals are used in excess and indiscriminately to large swaths of land. The leaching of chemicals at pesticide storage facilities is another major exposure pathway. The primary pathway of human exposure, however, is direct dermal contact and absorption of chemicals. Surveys of general knowledge of pesticide application in many low- and middle-income countries indicate that pesticides are typically used without protective equipment. [69] Often, farmers and workers in these countries lack both access to and finances for basic protective gear and equipment. A survey of over 2000 workers in Asia, Africa, and Latin America found that between 47% and 59% of workers reported suffering from headaches and dizziness after the application of pesticides. The majority of these workers also reported not using protective gear. [70]

These chemicals also enter the human body through inhalation when one breathes in dust or chemical spray. Outside of these occupational forms of exposure, people are also impacted through drinking ground water that has been polluted from runoff from fields or leachate from production and storage facilities. Another significant pathway exists through contact with and ingestion of food items sprayed or contaminated with pesticides. Between 1993 and 1994, around 600 cases of food poisoning were reported in Vietnam that stemmed from eating contaminated produce. [71] Related studies in Vietnam have also indicated that people can be exposed to organochlorines—even now illegal ones such as DDT—through the consumption of seafood in which the compounds have bioaccumulated. [72] The World Health Organization, in conjunction with the United Nations Environment Programme, has found that each year 3 million agricultural workers suffer from acute cases of pesticide poisoning, many of which occur in low- and middle-income countries. An additional 20,000 unintentional deaths and 735,000 cases of chronic illness occur as impacts of these chemicals. [73] However, the health impacts of pesticides cannot be generalized, as each depends on the specific substance or chemical used in the product.

Acute effects of pesticide exposure can include headaches, nausea, dizziness, and convulsions, all of which were documented health impacts in a survey of over 2,000 agricultural workers in Africa, Asia, and Latin America. [74] Additionally, the extent of acute pesticide poisoning in many agricultural workers in these countries is often underreported and based on inadequate information. [75] Certain insecticides, such as the organochlorine lindane, are highly persistent in the environment and are clearly capable of affecting the human nervous system. [76] Lindane has been linked to breast and other cancers, as well as fertility problems. It is associated with skin irritation and nausea, and can even cause convulsions and death at high levels of acute exposure.

The economic costs of these acute effects can be significant. A recent study in Nepal found that the average cost of illness resulting from pesticide exposure

[69] C. Wesseling, et al. "Agricultural Pesticide Use in Developing Countries: Health Effects and Research Needs." International Jornal of Health Services 27.2 (1997): 273–308.

[70] Pesticide Action Network International. "Communities in Peril: Global Report on Health Impacts of Pesticide Use in Agriculture." Available at http://www.pan-international.org/panint/files/PAN-Global-Report.pdf, 2010.

[71] H.D. Nguyen, et al. "Impact of Agro-Chemical Use on Productivity and Health." International Development and Research Center. Available at http://www.idrc.ca/es/ev-8428-201-1-DO_TOPIC.html, 2003.

[72] D.D. Nhan, et al. "Organochlorine pesticides and PCBs Along the Coast of North Vietnam." The Science of the Total Environment 237-238 (1999): 363–371.

[73] WHO and UNEP. "Public Health Impacts of Pesticides used in Agriculture". Geneva, Switzerland, 1990.

[74] Pesticide Action Network International. "Communities in Peril: Global Report on Health Impacts of Pesticide Use in Agriculture." Available at http://www.pan-international.org/panint/files/PAN-Global-Report.pdf, September 22, 2010.

[75] M.H. Litchfield. "Estimates of Acute Pesticide Poisoning in Agricultural Workers in Less Developed Countries." Toxicological Reviews 24.4 (2005): 271–278.

[76] Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. "Toxicologic Profile for Alpha-, Beta, Gamma- and Delta-Hexachlorocyclohenxane." Available at http://www.atsdr.cdc.gov/toxprofiles/tp43.pdf, August 2005.

was 114 Nepalese Rupees per person, nearly one-third of one's total expenditure on health services. Healthcare costs for people suffering from pesticide-related illness were nearly eight times higher than for those not directly exposed to pesticides. [77] Additionally, the results of a study of farmers in Vietnam indicated a high prevalence of poisoning by organophosphates and carbamates, where a high percentage of subjects were not only acutely, but also chronically, poisoned. [78]

Studies on chronic health effects of pesticide exposure indicate the potential for these chemicals to have neurological, reproductive, and dermatological impacts. [79] Chronic head and stomach aches, loss of vision, birth defects, damage to the central nervous system, immune system deficiencies, pulmonary diseases, respiratory difficulties, deformities, DNA damage, disruption of the hormonal system, and death are all possible outcomes of pesticide exposure. Exposure to pesticides has also been proven to be an important risk factor in the development of cancer. The use of insecticides has been associated with cancers of the prostate, pancreas, liver, and other organs. [80] More recently, studies of contact with organophosphates have shown that exposure to the residues of these compounds on fruits and vegetables may double a child's risk of attention deficit hyperactivity disorder. [81]

Industrial Sources of Pesticides – Agricultural Application

Industry Overview

Agriculture is often one of the most important sectors in the economies of low- and middle-income countries. Studies indicate that GDP growth from agriculture benefits the income of these countries' populations by two to four times that of GDP growth in other economic activities. [82] In terms of enhancing this sector, agrochemicals were initially developed to improve agricultural output, enhance crop growth, and repel or eliminate pests that hindered high yields. Of the latter, chemical pesticides were often too effective, harming other organisms besides the intended pests and polluting the environment through various pathways. Today, the practice of intense pesticide and fertilizer application is recognized as harmful to both ecological and human health. The overuse of agricultural fertilizers, which are also included under the category of agrotoxins, can release urea, nitrogen, phosphates, and heavy metals, which can also have harmful ecological and health impacts.

[77] K. Atreya. "Health Costs from Short-Term Exposure to Pesticides in Nepal." Social Science & Medicine 67.4 (2008): 511–519.

[78] S. Dasgupta, et al. "Pesticide Poisoning of Farm Workers – Implications of Blood Test Results from Vietnam." International Journal of Hygiene and Environmental Health 210.2 (2007): 121–132.

[79] C. Wesseling, et al. "Agricultural Pesticide Use in Developing Countries: Health Effects and Research Needs." International Jornal of Health Services 27.2 (1997): 273–308.

[80] K. Jaga and C. Dharmani. "The Epidemiology of Pesticide Exposure and Cancer: A Review". Reviews on Environmental Health 20.1 (2005): 15–38.

[81] M.F. Bouchard, et al. "Attention-Deficit/Hyperactivity Disorder and Urinary Metabolites of Organophosphate Pesticides." Pediatrics, 2010.

[82] K. Aseno-Okyere, et al. "Advancing Agriculture in Developing Countries through Knowledge and Innovation." International Food Policy Institute, 2008.

Global Context

The extensive use of agrochemicals in low- and middle-income countries has created a tension between the need to ensure local food security and the desire to protect the public from the adverse effects of these compounds. [83] Many of these countries are in transitional phases where agricultural workers are migrating to urban centers to secure a higher income, which leaves fewer people responsible for food production. Many of these same countries have become food exporters for higher-income regions. These combined pressures have led to an increased reliance on chemical pesticide use, especially in rural regions. [84]

Such was the case during the Green Revolution, a series of internationally-sponsored developments and technology initiatives between the late 1940s and 1970s that sought to increase agricultural production, primarily in India. These programs centered on not only expanding industrial irrigation infrastructure and developing new hybrid seed varieties, but also heavily increasing the use of agrochemicals, primarily synthetic fertilizers and potentially harmful pesticides. The primary criticisms of these initiatives rested upon the increasing disparity between rural and industrial farmers due to the latter's access to credit and land, which in turn furthered dependence on the use of pesticides to increase yields, especially in rural areas.

In general, the application of agrochemicals has significantly increased since their advent in the 1940s. Roughly 2.3 million tons of industrial pesticides are now used per year, 50 times the amount used in 1950. Current statistics indicate that over $40 billion was spent globally on pesticide use in 2008. [85] Following the dangerous nature of many of these pesticides used in low-income countries, surveys done by the Pesticide Action Network in Asia found that seven out of ten of the most commonly used pesticides are classified as Highly Hazardous. In most of these regions, it was also found that safe storage for these chemicals was lacking, few facilities existed to recycle empty containers, local awareness of hazards was low, and proper training was often unavailable.

Because of the recognition of the extent to which many agrochemicals adversely impact human health, many pesticides, particularly organophosphates and organochlorides, are banned in high-income countries. In 1985, the International

Pesticide storage tanks

[83] C.N. Kesavachandran. "Adverse Health Effects of Pesticides in Agrarian Populations of Developing Countries." Reviews of Environmental Contamination and Toxicology 200 (2009): 33–52.

[84] C. Ponting. "A New Green History of the World: The Environment and the Collapse of Great Civilizations". Penguin Books, New York, 2007.

[85] Pesticide Action Network International. "Communities in Peril: Global Report on Health Impacts of Pesticide Use in Agriculture."Pesticide Action Network International. Available at http://www.pan-international.org/panint/files/PAN-Global-Report.pdf, September 22, 2010.

A drain flowing with effluent from a chemical production facility

Code of Conduct on the Distribution and Use of Pesticides was adopted. It was then amended in 1989, and further revised in 2002. This piece of legislation set standards to guide national laws. However, because many of these formerly restricted and banned pesticides are highly effective and cheap to produce, many are still actively used throughout low- and middle-income countries. [86] This often results in the creation of black markets beyond the control of governments.

The majority of the world's rural poor are engaged in agriculture. [87] In many of these areas, regulation and local awareness of pesticide health hazards is low, and therefore many older, highly toxic, and inexpensive pesticides are applied extensively. [88] Due to this context, farmers in these nations are heavily burdened by pesticide use, and this burden particularly falls on women, children, and infants. [89] While these countries use only 20% of the world's agriculture, their populations suffer 99% of global deaths from pesticide poisoning. [90]

Exposure Pathways from Agricultural Application

Pesticides used in agriculture often migrate to nearby streams, rivers, lakes, and ground water sources through rainfall runoff. Many of these then go on to accumulate in the tissue of aquatic organisms. In some cases, almost 100% of sprayed insecticides and herbicides end up contaminating the environment beyond impacting their intended agricultural pest targets. [91]

Those engaged in agriculture are exposed to pesticides through dermal exposure. In the majority of low- and middle-income countries, pesticides are typically applied without the use of protective equipment, more often than not due to a lack of access to and finances for such gear. [92] The active chemicals in pesticides also enter the human body through inhalation when one breathes in chemical sprays during pesticide application in fields. People are also impacted through drinking ground water and consuming produce that has been polluted.

What is Being Done

International efforts to eradicate toxic pesticides include the Stockholm Convention on Persistent Organic Pollutants, an agreement developed by the United Nations Environment Programme. The Convention seeks to reduce or eliminate the production of the most toxic pesticides and other persistent organic pollutants. [93] The Food and Agriculture Organization of the United Nations (FAO) also tries to introduce globally modern agricultural practices with the aims to minimize the future use of pesticides, respond more effectively to pest outbreaks, and reduce the creation of new stocks.

[86] C. Wesseling, et al. "Agricultural Pesticide Use in Developing Countries: Health Effects and Research Needs." International Journal of Health Services 27.2 (1997): 273–308.

[87] K. Aseno-Okyere, et al. "Advancing Agriculture in Developing Countries through Knowledge and Innovation." International Food Policy Institute, 2008.

[88] D.J. Ecobichon. "Pesticide Use in Developing Countries." Toxicology 160.1-3 (2001): 27–33.

[89] L.R. Goldman. "Childhood Pesticide Poisoning: Information for Advocacy and Action." World Health Organization, Geneva, Switzerland, 2004. Available at http://www.who.it/ceh/publications/pestpoisoning.pdf, September 22, 2010.

[90] J. Jeyaratnam and K.S. Chia. "Occupational Health in National Development." Singapore: World Scientific, 1994.

[91] G.T. Miller. "Chapter 9." Sustaining the Earth. 6th ed. Pacific Grove, California: Thompson Learning, Inc. (2004): 211–216.

[92] C. Wesseling, et al. "Agricultural Pesticide Use in Developing Countries: Health Effects and Research Needs." International Jornal of Health Services 27.2 (1997): 273–308.

[93] Stockholm Convention on Persistent Organic Pollutants. "Measures to Reduce or Eliminate POPs." Available at http://chm.pops.int/, 2009.

Apart from international legislation, community-based education programs for farmers have a significant role in reducing the use of hazardous pesticides. Governments, often with international support, typically run such programs, but in some cases pesticide producers concerned with safe and responsible usage of their product offer them to retailers. In some cases, local NGOs provide education, such as "Plagbol" (Plaguicidas Bolivianas), a Bolivian organization that offers telephone advice and training programs for the appropriate use of pesticides. [94]

Blacksmith Institute has supported programs to develop "best practices" for pesticide application and to identify local reduction strategies. In Cambodia, farmers and their families living around the Tonle Sap Lake are being harmed from the contamination of food and water supplies due to inappropriate pesticide use. As safety measures are often ignored or misunderstood, Blacksmith Institute is currently raising funds and working to provide local training in appropriate pesticide application and storage. A plan to raise awareness about alternatives to chemical pesticides is being developed with local partners. Green Cross Switzerland works closely with the UN and other organizations to build capacity within countries of the Former Soviet Union on the inventory, repacking, safe storage, and final elimination of their substantial stocks of obsolete pesticides.

Industrial Sources of Pesticides – Production and Storage

Industry Overview

Despite international conventions, a number of Highly Hazardous or Restricted Use Pesticides continue to be produced, stored, and used. Some categories of pesticides that continue to be stored include persistent organic pollutants, organochlorines, organophosphates, and carbamates. Specific pesticides include heptachlor, chlordane, DDT, dieldrin, aldrin, endosulfan, and profenofos.

Often, the facilities where large amounts of now-banned pesticides are stored are themselves very old, and have fragile infrastructures and limited maintenance: drums of toxic chemicals are stored in the open, and containers deteriorate and leak over time. In these regions, storehouses are commonly regarded as hazardous waste sites. Because of temporal gaps between when production and storage facilities were constructed and when they were closed, many of the areas where these buildings were built became urban centers, surrounded by residential zones, offices, and markets. [95]

Corroded drums containing pesticide

[94] E. Jors. "Acute Pesticide Poisonings among Small-Scale Farmers in La Paz County, Bolivia." Department of International Health Institute of Public Health, University of Copenhagen, 2004.

[95] Food and Agriculture Organization of the United Nations. "Prevention and Disposal of Obsolete Pesticides." Available at http://www.fao.org/ag/AGP/AGPP/Pesticid/Disposal/en/103115/103122/index.html, 2009.

Chemical production facility

Global Context

The majority of stocks of old, hazardous pesticides can be found in low- and middle-income countries. While many pesticide production facilities were originally constructed following the Green Revolution to meet agriculture demands, they now too remain abandoned. Farmers in these areas purchase harmful pesticides because they are cheap, and because the perceived risk of not using them is too high. As of 1996, the Food and Agriculture Organization of the United Nations estimated that the total number of obsolete pesticide stocks in African countries amounted to 15,000 to 20,000 tons. [96] Current figures for the Former Soviet Union point to obsolete stocks of at least 350,000 tons. Blacksmith Institute's site assessment efforts have shown that many of these abandoned storage and production facilities are located in Russia, Central Asia, India, Pakistan, and Nepal. In many of these areas, the key pesticide pollutant is DDT.

Exposure Pathways from Pesticide Production and Storage

Leaks from pesticide storage facilities pose a threat human health through contaminated water and soil. Soil can remain contaminated long after an initial exposure, and because many storage facilities are located near homes, dermal contact and inhalation of dust are likely pathways.

DDT is an organochloride pesticide that is commonly found in many of these storage sites, is highly persistent in the environment, and does not easily degrade by biological, physical, or chemical processes. Furthermore, DDT can travel long distances and accumulate in human bodies due to its solubility in fats. Even in small amounts, DDT can injure human health and health of other organisms. It is harmful to the stomach, intestines, liver, and kidneys, and can affect the nervous system. DDT can cause reproductive, developmental defects and cancer and tumors, and can potentially cause learning disabilities in children.

What is Being Done

International efforts to reduce pesticide stockpiles are making measurable differences. The Africa Stockpiles Programme is an example of one multilateral effort to clean up such sites and prevent their recurrence. This program currently operates in Ethiopia, Mali, Morocco, Nigeria, South Africa, Tanzania, and Tunisia.

[96] A. Wodagene and H. van der Wulp. "Obsolete Pesticides in Developing Nations." Pesticides News 32 (1996): 12–13.

Radionuclides

Estimated Population At Risk At Identified Sites:
3.3 Million People

Estimated Global Impact:
5 to 8 Million People

Introduction

Radionuclides occur naturally in soil and rocks as a consequence of radioactive decay. A radionuclide is described as an atom with an unstable nucleus. Radioactivity is produced when this unstable nucleus, which is characterized by excess energy, either forms this energy into radiation particles within the nucleus or into an atomic electron. When materials decay, they emit radiation and eventually disintegrate over time. Radioactive materials reduce this activity within their "half-life," which is defined as the time required for reducing the activity of a radioactive substance to half of its initial value. Radioactive half-lives span from fractions of a second to millions of years. Those materials that emit radiation over long periods have the most adverse effects on human health. The main categories of harmful radioactive materials emitted during radiation are identified as Alpha, Beta, Gamma, and Neutron radiation. [97] Radioactive materials cannot be treated, and only lose their harmful effect when they have finished decaying. Because this can take millennia, these materials must be stored appropriately.

While radionuclides occur naturally in the environment, those categorized as harmful are typically of anthropogenic origin, released through industrial processes. Hundreds of radionuclides exist, and the Nuclear Regulatory Commission separates radioactive materials into high-level or low-level classes. [98] High-level radioactive material primarily results from the fuel used by a reactor to produce electricity, while low-level wastes includes material that either has a short decay period or has become contaminated with or activated by nuclear materials. These materials can include clothing used in the nuclear industry, medical materials, or radiation sources from inside of reactors. Similarly, the US Environmental Protection Agency has classified radionuclides into "heavy" or "light" nuclides: heavy refers to elements that have over 83 protons, and are thus also categorized as unstable, while light refers to elements that have fewer than 83 protons. [99]

A town affected by radiation from uranium mining

[97] United States Nuclear Regulatory Commission. "Backgrounder on Radioactive Waste." Available at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/, April 12, 2007.

[98] Ibid.

[99] U.S. Environmental Protection Agency. "Commonly Encountered Radionuclides." Available at http://www.epa.gov/rpdweboo/radionuclides/index.html, October 1, 2010.

Uranium mining and the use of nuclear reactors are common sources of radionuclides, which are primarily contained within radioactive wastes. Typical radionuclides produced through nuclear reactors via the splitting of elemental atoms are thallium-201 and iridium-192. The processing of uranium in such reactors likewise produces isotopes such as cesium-137 and strontium-90, which take a significantly long time to decay. Additionally, uranium-238 decays to form radium-226, which has a half-life of 1600 years. **[100]** Because many of these radioisotopes remain active in industry by-products and wastes for such long periods of time, they are also known as transuranic wastes. **[101]** Other commonly encountered radionuclides include cobalt-60, plutonium, radium, radon, technetium-99, thorium, and uranium. **[102]**

Radionuclides are used for a variety of purposes, many of which can be highly beneficial. Radionuclides are useful both for their chemical properties and as sources of radiation. For example, radioisotopes are used in biomedicine in the diagnosis, treatment, and research into disease. Radioactive elements that emit gamma rays can be used as tracers to monitor bodily states and the functioning of organs, while others, such as radium and radon, can be used in the treatment of certain cancerous tumors. **[103]** Additionally, in scientific research into genetics, radionuclides allow scientists to label molecules and study processes such as DNA replication. Another primary usage of radionuclides, specifically the element uranium, is for energy production.

Common Exposure Pathways and Health Risks

Radionuclides can be released into the environment through accidents, poor waste disposal, or other means. Some levels of radiation are naturally present in surface and ground water, but other degrees of radiation exposure come from contact with rocks and soil that have been contaminated with the artificially produced radionuclides mentioned above, such as radon. Often, contaminated soil and rock are the by-products of wastes and tailings from mineral extraction sites, where ores such as uranium are taken for their radioactive properties and industrial uses.

Once elements such as uranium have been processed in sites such as nuclear reactors, radiation exposure can also occur through leaks and industrial failures. Exposure to radiation can also occur when radionuclides are used in excess during medical treatments. These levels of exposure and the effects they produce are called radiation poisoning. Some major pathways to commonly encountered hazardous radionuclides are through inhalation (uranium and radon), food contamination (radium), and occupational exposure at mining and processing sites. **[104]**

Acute health effects due to a large radiation exposure begin with nausea, vomiting, and headaches. With increased exposure a person may also experience fatigue, weakness, fever, hair loss, dizziness disorientation, diarrhea, blood in stool,

[100] Agency for Toxic Substances and Disease Registry. "Case Studies in Environmental Medicine. Radon Toxicity." Public Health Service, U.S. Department of Health and Human Services, 1992.

[101] United States Nuclear Regulatory Commission. "Backgrounder on Radioactive Waste." Available at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/, April 12, 2007.

[102] U.S. Environmental Protection Agency. "Commonly Encountered Radionuclides." Available at http://www.epa.gov/rpdweboo/radionuclides/index.html, October 1, 2010.

[103] U.S. Environmental Protection Agency. "Radionuclides (Including Radon, Radium and Uranium)." Available at http://www.epa.gov/ttn/atw/hlthef/radionuc.html, November 6, 2007.

[104] Ibid.

low blood pressure, and ultimately death. Chronic and long-term effects may also occur.

Uranium is known as a radioactive toxicant capable of damaging the kidneys and genetic code, which can result in health problems passed to the following generations. Radon is a human lung carcinogen and particularly damaging to miners who extract ores containing radioactive elements. Radon is also the second leading cause of lung cancer death in uranium miners. [105] [106] Studies also show that long-term exposure to radon leads to an elevated risk of leukemia. [107] Chronic exposure to radium through the inhalation pathway can lead to leukopenia, a decrease in the number of white blood cells, which places an exposed individual at an increased risk for contracting infections. [108]

When ionizing radiation strikes an organism's cells, it may injure the cells. If radiation affects a significant number of cells, it can eventually lead to cancer. At extremely high doses, this type of exposure can cause dealth. In general, there is no safe level of radiation exposure. Individuals exposed to non-lethal doses may experience changes in blood chemistry, as well as nausea and fatigue. Children are particularly vulnerable, as radiation has an effect on the cellular level. As children grow, they divide more and more cells, and more opportunities exist for radiation to interfere with the development process—in terms of fetal development, this can result in smaller head or brain size, poorly formed eyes, abnormal growth, and mental retardation. [109]

Industrial Sources of Pesticides – Uranium Mining and Radioactive Waste Disposal

Industry Overview

Uranium mining is the process of extracting uranium ore from the ground. Most mining of uranium is volume-intensive and takes place as open-pit mining, primarily due to the typically low concentrations of the element. The actual uranium content of the ore can be as low as 0.1% to 0.2%; therefore, large amounts of ore must be mined to extract any significant quantity of the material. [110]

Two of the primary means to extract this volume of uranium are open-pit mining and in-situ leaching. In open pit mining, ore is removed through drilling and blasting methods. Meanwhile, water is used to limit the levels of airborne dust particulates. With in-situ leaching—also known as solution mining—a leaching liquid is injected via wells into an ore deposit. The resulting liquid, which contains significant traces of uranium, is then pumped to the surface. Because of its low production costs and decreased disturbance of the extraction surface, the latter method is used more and more extensively.

However, open-pit mining is still a widely used means to extract uranium ore. The resulting ores are crushed and leached in a uranium mill, where

[105] M. Al-Zoughool and D. Krewski. "Health Effects of Radon: A Review of the Literature." International Journal of Radiation Biology 85.1 (2009): 57–69.

[106] B. Vacquier, et al. "Mortality Risk in the French Cohort of Uranium Miners: Extended Follow-up 1946–1999." Occupational and Environmental Medicine 65.9 (2008): 597–604.

[107] M. Möhner, et al. "Leukemia and Exposure to Ionizing Radiation among German Uranium Miners." American Journal of Industrial Medicine 49.4 (2006): 238–248.

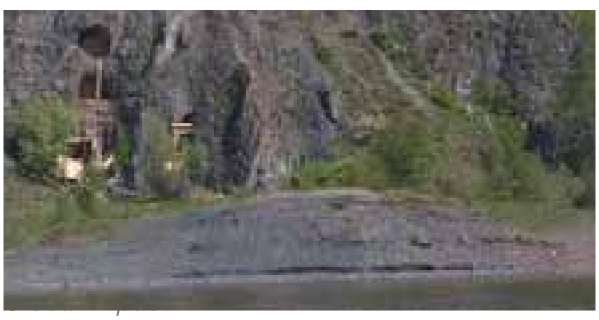
[108] Occupational Safety and Health Administration. "Occupational Safety and Health Standards, Toxic and Hazardous Substances." Code of Federal Regulations. 29 CFR 1910.1000, 1998.

[109] Radiation Protection: Health Effects." U.S. Environmental Protection Agency. Available at http://www.epa.gov/rpdweboo/understand/health_effects.html, August 28, 2008.

[110] P. Diehl. "Uranium Mining and Milling Wastes: An Introduction." WISE Uranium Project. Available at http://www.wise-uranium.org/uwai.html, August 15, 2004.

chemical agents such as sulfuric acid or alkaline solution are used to remove the elemental uranium. Because other metals are present in the ore—such as iron, arsenic, and lead—the uranium is further separated from the resulting leaching solution. The final raw product from this extraction process, the pure uranium, is known as “yellow cake,” and is typically sold as U^{308}. One of the most common uses of the resulting uranium radionuclides is as fuel for nuclear power plants.

One of the main by-products of these nuclear reactors is radioactive waste; however, radioactive materials also result from other fuel processing plants, power generation facilities, military exploits, and hospitals and medical research facilities.



Today, 76% of the world’s demand for uranium is for power generation, and demand for uranium is increasing globally. [111] However, due to limitations inherent in the uranium extraction process, mining is undertaken in only a small number of countries; because uranium concentrations in ore can be as low at 0.1% to 0.2%, concentrations must be high

Uranium mine shafts pose radiation risks long after the mine has closed

enough to counter the financial costs of extraction. According to the World Nuclear Association, roughly 63% of global uranium production from mines comes from Kazakhstan, Canada, and Australia. Additionally, Kazakhstan accounts for 27% of the global uranium supply from mines.

Following the above three nations, other key uranium producing countries include Namibia, Russia, Niger, and Uzbekistan. In line with and adding to these statistics, Blacksmith Institute has identified Ukraine, Kazakhstan, Tajikistan, Kyrgyzstan, Russia, Uzbekistan, China, and India as some of the countries most impacted by uranium mining and radioactive wastes. Likewise, many of the above countries that fall under the classification of low- to middle-income nations practice uranium mining and processing without strict industrial safety standards.

[111] World Nuclear Association. “World Uranium Mining.” Available at http://www.world-nuclear.org/info/inf23.html, May 2010.

Radiation levels measured durring a site assessment

Because most uranium ores only contain roughly 0.1% to 0.2% uranium, 99.9% of the ore remains. Between both the other elements and metals in the ore and the chemical agents used in the milling stage, the remaining sludge is highly toxic, often containing heavy metals and contaminants such as arsenic and various chemicals. As long-lived radionuclides such as thorium-230 and radium-226 are not removed, this sludge can also contain 85% of the initial radioactivity of the ore. [112] Additionally, the waste rock produced during open pit mining is discarded as waste piles, and thus often contains elevated concentrations of radioisotopes. The by-product of extraction and milling can be a toxic and radioactive tailings sludge.

Exposure Pathways from Uranium Mining and Waste Disposal

Unless properly managed for long-term stability and security, mining wastes and milling tailings from radioactive ores present serious threats to human health. through their potential to leak these radioactive materials. Unfortunately, uranium mining in low- and middle-income countries is often not regulated with the type of oversight available in high-income countries, and production rather than safety is often the priority. In some instances, tailings have even been used in home construction.

Although tailings often have only low-grade radioactivity, they can be dangerous because of the large quantities that are stockpiled in small areas. Additionally, water that is pumped away from the mine during operations can contaminate local surface waters. Proximity to radioactive materials—both waste dumps and infrastructure built from mining wastes—can result in exposure to Gamma particles and Neutron radiation.

Contamination of food and water sources can occur from dust transported by wind from uranium mine sites and waste deposits. One study in Kazakhstan demonstrated that wind had transported dust particles contaminated with uranium and thorium from a uranium-mining site to plants outside the

[112] P. Diehl. "Uranium Mining and Milling Wastes: An Introduction." WISE Uranium Project. Available at http://www.wise-uranium.org/uwai.html, August 15, 2004.

city of Aktau. [113] Other studies have shown how—because of the long half-lives of many of these radioactive materials—even legacy uranium mines can lead to exposure through food crops and contaminated agricultural soils. [114]

What is Being Done

Some countries have well-regulated industries and manage radioactive waste appropriately. In particular, there are government regulations in place, both nationally and internationally, for managing high-level radioactive wastes. However, in many countries, typically low- and middle-income nations, inforcement of legislation is lax and there is insufficient industry or government effort to properly address the issues that arise from radioactive waste. Blacksmith Institute is identifying local partners and locations where possible remediation projects can be implemented to address some of the highest priority challenges.

The approaches to dealing with uranium mining wastes are similar to those required to contain and stabilize any mining waste, with the additional need to reduce or eliminate critical pathways such as use of contaminated water sources or food production on radiation-polluted soils. Given the poor and remote areas where uranium mining is often located, the options for impacted populations may be very limited. Blacksmith Institute has been successful in Krasnoufimsk, Russia, where over 80,000 tons of radioactive materials—including thorium and uranium—had been stored for decades, leading to a high incidence of cancer. Working with the local government and a partner NGO, Blacksmith was able to construct safer and more secure warehouses for the waste, as well as raise local awareness about the scope of the problem.

Blacksmith Institute has also had success in the village of Romanovka, Russia, where abandoned ditches from a nearby uranium mine have been exposed to open air, exposing residents to radioactive substances in air and water, which possibly have lead to a cancer cluster in this community. Through local partnerships with the Baikal Center for Public Environmental Expertise, Blacksmith has recently worked to cover the ditches with fresh and safe soil. The Center also conducted a teaching workshop to educate community members of the potential risks, raise public awareness of mining impacts, and recommend personal steps to avoid future exposure.

Testing site radiation levels

[113] R. Lennartz and M. Zoriy. "Biomonitoring of Environmental Pollution by Thorium and Uranium in Selected Regions of the Republic of Kazakhstan." Journal of Environmental Radioactivity 101.5, (2010): 414–420.

[114] O. Neves, M.M. Abreu, and E.M. Vicente. "Uptake of Uranium by Lettuce (Lactuca sativa L.) in Natural Uranium Contaminated Soils in Order to Assess Chemical Risk for Consumers." Water, Air, & Soil Pollution 195.1-4, (2008): 73–84.

Romanovka's Uranium Mine Remediation

The village of Romanovka is located 50 km from the Talakan uranium mine. Uranium concentrates are transported across the River Vitim by ferries and cargo boats. Some of the mine's abandoned ditches, known to be radioactive, were exposed to the open air for years, and studies showed a correlation between air- and water-borne exposure to this uranium supply and a cancer cluster in the local community. However, as is frequently the case with mining in low- and middle-income regions, there had been no technical documentation throughout this mine's history; therefore, proving a causal link was difficult. The village is also located just 1.5 km from other natural uranium deposits, and residents are known to raise crops and livestock in those zones.

Project Strategies

To assist in the monitoring and evaluation process, Blacksmith Institute provided technical expertise and resources to measure the concentration and exposure levels at this site. This included providing radiometers and training local partners in their use; mapping the district for canals, ditches, and other zones of high radioactivity; and providing heavy earthmoving equipment (bulldozers, excavators, and front-loaders) necessary to seal or remove the contaminated soil.

In August of 2006, Blacksmith Institute's local partner—the specialists of the Baikal Center for Public Environmental Expertise—visited and examined the site in order to judge the severity of radiation and the effectiveness of proposed solutions. This kind of radioactivity output is measured in micro-Roentgens per hour (mR/h). According to the data from the Baikal Center for Public Environmental Expertise, the levels of radiation in two ditches near the mine were 800 and 2,350 µR/h. Surrounding the ditches for an area of 100 m was a zone of increased radiation levels, which tested at 50-75 µR/h. The background radiation levels a person will encounter in a major

city are approximately 10-15 µR/h. A common safety threshold for long-term exposure is 35 µR/h.

The small Holoy River washes away uranium deposits near the surface in this region. River sediments closest to these deposits showed high radioactivity, 500-600 µR/h. Vegetation in the Holoy exhibited elevated levels of both uranium and thorium. Likewise, the uranium deposits had contaminated other small local water bodies. Based on this information, Blacksmith's Technical Advisory Board recommended sealing the toxic ditches and educating villagers about these hazards.

Outcomes and Follow-Up

On September 9, 2006, the specialists and volunteers of the Baikal Center, in the presence of local administration and environmental committee staff, covered the two hazardous ditches with fresh and safe soil. The Center also conducted a teaching workshop to educate community members about potential health risks, raise public awareness of mining impacts, and recommend personal steps to avoid future exposure.

Future monitoring of the site will be necessary to make sure no new hazardous ditches or radiation accumulation threaten public health. Locals should be encouraged to practice farming as far from the ground-level uranium deposits as possible.

Conclusion

Building on Past Reports

The 2010 World's Worst Pollution Problems Report builds on the volume of pollution literature that Blacksmith Institute and Green Cross Switzerland have produced over the last five years. Specifically, the 2010 report updates and compliments the information provided in the 2008 World's Worst Pollution Problems report.

In 2008, Blacksmith Institute and Green Cross Switzerland released the first World's Worst Pollution Problems Report. The report outlined more than 20 different pollution issues that affect human health in low- and middle-income countries. While the 2008 report highlighted some specific issues such as artisanal gold mining, many of the topics were more general, such as urban air quality. In producing the 2008 report, the authors found that for some important topics, such as ULAB recycling, the available literature was sparse and insufficient to quantify the effects of the problem. Without the ability to quantify and compare the relative effects of various issues, it was difficult to know which problems were most severe and how to prioritize resources for cleanup projects. This desire to quantify pollution effects was one of the reasons that Blacksmith Institute began its effort to identify and assess polluted sites globally.

The detailed focus of this latest report reflects the increased knowledge that the organizations have gained over the last two years through their ongoing site assessment work. The 2010 report relies on information from over 2,000 sites in 40 countries. This work will continue through the next year and additional information will be available in 2011.

Leather drying at a tannery site

Revealed in the Data: Results of Ongoing Assessment Work

Blacksmith Institute's ongoing assessment work is an effort to identify and assess the highest priority legacy and artisanal pollution problems in low- and middle-income countries around the world. Blacksmith Institute employs its Initial Site Assessment (ISA) protocol to quickly determine key criteria at each polluted site. Sites are identified through a range of means: knowledge of the local coordinators and agencies is combined with nominations from the public and other organizations to create a list of potentially polluted sites. Local investigators who carry out assessment work then visit the most plausible sites from this long list.

To date, more than 2,000 sites have been identified and 1,000 toxic hot spots have been visited and assessed. These 2,000 sites affect the health of an estimated 56 million people. We estimate that this number reflects approximately half of the total number of sites contaminated by legacy and artisanal pollution. This would indicate that pollution of this sort likely affects a population of more than 100 million people in low- and middle-income countries.

This assessment work is the first attempt to gain an understanding of the scale of the effect of pollution on human health globally. The numbers presented here are not meant to be definitive. Rather they should be taken as indicative and preliminary. Detailed epidemiological studies are not undertaken as part of our assessment work. Populations are estimated based on well-understood exposure pathways, pollutant concentration samples, stakeholder interviews, and other data.

The message presented in the data is that pollution from artisanal and legacy sources is a public health concern on the scale of well known infectious diseases such as Malaria or Tuberculosis. An International plan is needed to deal with this threat.

Highly turbid river water near a gold mine

An International Plan to Deal with Polluted Hotspots: The Health and Pollution Fund

Toxic pollution is found throughout low- and middle-income countries, and is an issue that requires international cooperation to address. It is a significant cause of disease and death, and disproportionately harms children. This problem includes contaminated sites from industry and mining, where the polluter is long gone or insolvent, yet the damage to human health is ongoing. Technologies for cleaning up these problems are well known, but little has been done because of inadequate resources at the local level, and insufficient technology transfers. Affected communities and local authorities often struggle to do what they can with very limited financial and technical resources.

There is a growing international acceptance that tackling legacy toxic pollution problems needs to be supported by resources from the industrialized countries that have often benefited from the original industrial activities. To date, such support has been very much on an ad-hoc basis.

Blacksmith Institute is leading an effort to create an international fund for the purpose of addressing toxic pollution. The Health and Pollution Fund would be an integrated framework for a sustained and reliable effort and would be coordinated by the major bilateral and multilateral donors, as well as representatives from the governments that have the largest legacy pollution problems. The Fund will finance remediation of the worst pollution sites, implementing activities that mitigate the most severe impacts to people, especially children. This work directly supports the Millennium Development Goals, as it significantly improves health and reduces poverty.

The amount of financing that would be needed to clean up the worst of the polluted legacy sites may approach $1 billion. This estimate includes sites in China, India and Russia. If, for these countries, donor countries wish to offer only technical assistance and some funding for pilot projects, the financing required would be substantially less and may amount to roughly $400-500 million.

Funding the cleanup of polluted sites should be an area of involvement for donors for at least three reasons:

- The initial cost per disability adjusted life-year (DALY) of cleanup projects is in the $5-50 range, or comparable to bed-nets and vaccinations;
- Unlike vector and communicable diseases, remediating a toxic site is a one-time intervention; and
- Funding requirements are finite; once sites are cleaned, simple processes to avoid re-contamination are straightforward and local ownership for this work would be expected and required.

Within Our Lifetimes: Dealing with the Worst Sites

Mitigating the negative impacts of pollution on human health in low- and middle-income countries is not an insurmountable task. Blacksmith Institute and Green Cross Switzerland have shown that remediation projects in this field are cost effective and produce measurable results. The solutions for many of the problems highlighted in this report are well known, and with proper funding, can be implemented on a global scale. It is our challenge to utilize these solutions to address this health concern and achieve global environmental health equity for future generations.

Appendix

Blacksmith Institute Technical Advisory Board

Nicholas Albergo
President, HAS Engineering & Scientists

Nicholas Albergo is the President and CEO of HSA Engineers & Scientists, and engineering consulting firm based in Florida. The firm has over 300 employees and ten offices located throughout the southeast United States. He received his undergraduate and graduate degrees in civil, environmental and chemical engineering. Currently, he serves as the ASTM E50.02 Vice Chair on Environmental Assessment, Risk Management and Corrective Action. Mr. Albergo possesses extensive domestic and international experience in contamination assessment, degradation and migration analysis, water/wastewater treatment and permitting, and soil & groundwater remedial strategy. He has chaired numerous scientific conferences, and has over 180 technical publications to his credit. He has provided expert testimony in many complicated litigation matters in the U.S. and abroad and also serves as an arbitrator on the AAA Roster of Neutrals.

Casey Bartrem
TerraGraphics Environmental Engineering, Inc.

Andrew Biaglow, Ph.D.
Associate Professor, United States Military Academy, West Point, NY

Dr. Biaglow has been on the faculty of West Point for 15 years, where he founded the chemical engineering program and serves as its director. Dr. Biaglow received his B.S. in chemical engineering from Case Western Reserve University and his M.S. and Ph.D. in chemical engineering from the University of Pennsylvania. He was a consultant to the Hoechst Celanese Corporation, where he worked on the development of highly acidic solid acids for use in polyethylene terephthalate production process. At Exxon Corporation, he was a consultant on the development, synthesis and characterization techniques for solid superacid catalysts for use in carbonylation reactions. In 2009, Dr. Biaglow submitted a patent disclosure for the development of novel heat pumping system for fractional distillation.

Thomas G. Boivin
President, Hatfield Consultants

Margrit von Braun, Ph.D. P.E.
Administrative Dean and Founder, Environmental Science Program, University of Idaho.

Dr. von Braun is the Dean of the College of Graduate Studies and has been on the University of Idaho faculty since 1980. She received her BS in Engineering Science and Mechanics at the Georgia Institute of Technology, her MCE in Civil Engineering at the University of Idaho, and her Ph.D. in Civil/Environmental Engineering at Washington State University. She was awarded the College of Engineering Outstanding Faculty Award in 1992. Dr. von Braun was a Kellogg National Leadership Fellow from 1993 to 1996. Her research areas include human health risk assessment, hazardous waste site characterization with a focus on sampling dust contaminated with heavy metals, and risk communication.

Pat Breysse, M.D.
Director of the Division of Environmental Health Engineering
Department of Environmental Health Sciences
Johns Hopkins Bloomberg School of Public Health

Pat Breysse is currently the Director of the Director of the Division of Environmental Health Engineering in the Department of Environmental Health Sciences at the Johns Hopkins Bloomberg School of Public Health. He is also the Director of the Center for Childhood Asthma in the Urban Environment. This is a large multi-investigator research program funded by the U.S. Environmental Protection Agency, and D. National Institute for Environmental Health Sciences. Dr. Breysse is an active researcher with over 120 peer-reviewed publications. His research focuses on air pollution and risk assessment. Dr. Breysse serves or has served on numerous government committees and panels including the U.S. National Toxicology Program, National Institute for Occupational Safety and Health, and National Academy of Sciences.

Mary Jean Brown, ScD, RN
Chief of the Healthy Homes and Lead Poisoning Prevention Branch, U.S. Centers for Disease Control and Prevention; Adjunct Assistant Professor of Society, Human Development and Health, Harvard School of Public Health.

Dr. Brown is the designated federal official for the CDC Advisory Committee on Childhood Lead Poisoning. She has spent more than 25 years working on childhood lead poisoning and its prevention. She conducted research designed to evaluate the impact of home visiting on the blood and environmental lead levels, a benefit-cost analysis of removing lead paint from housing before children are lead poisoned and a study of the effect of housing policies on the blood lead levels of poisoned children. She has also studied community-level housing factors that predict risk for nonfatal pediatric injuries.

The Healthy Homes and Lead Poisoning Prevention Branch provides technical assistance and advice internationally, especially to those countries with developing economies, related to healthier metal mining and smelting and clean up of ambient lead contamination.

Grant S. Bruce
Vice-President, Hatfield Consultants

Tim Brutus
Risk Management Specialist
New York City Department of Environmental Protection

Mr. Brutus is currently the Risk Management Specialist for the New York City Department of Environmental Protection for the downstate reservoirs that bring all of the water into New York City. His previous experience is on complex multi-technology remediation projects with CH2M Hill, Inc. He has extensive site investigation experience including, but not limited to, indoor and outdoor air sampling, multiple groundwater and soil sampling techniques and technologies. He has also contributed to other non-profit organizations restoring contaminated brownfields to their former use as wetlands and worked in analytical laboratories in New York and New Jersey.

Jack Caravanos, Ph.D., CIH, CSP
Director, MS/MPH program in Environmental and Occupational Health Sciences
Hunter College

Jack Caravanos is an Assistant Professor at Hunter College of the City University of New York where he directs the MS and MPH program in Environmental and Occupational Health Sciences. He received his Master of Science from Polytechnic University in NYC and proceeded to earn his Doctorate in Public Health (Env. Health) from Columbia University's School of Public Health in 1984. Dr. Caravanos holds certification in industrial hygiene (CIH) and industrial safety (CSP) and prides himself as being an "environmental health practitioner". He specializes in lead poisoning, mold contamination, asbestos and community environmental health risk.

Dr. Caravanos has extensive experience in a variety of urban environmental and industrial health problems and is often called upon to assist in environmental health assessments (i.e. lead/zinc smelter in Mexico, health risks at the World Trade Center, ground water contamination in NJ and municipal landfill closures in Brooklyn). Presently he is on the technical advisory panel of the Citizens Advisory Committee for the Brooklyn-Queens Aquifer Feasibility Study (a NYC Department of Environmental Protection sponsored community action committee evaluating health risks associated with aquifer restoration).

Denny Dobbin

President, Society for Occupational and Environmental Health

Mr. Dobbin has over 40 years occupational hygiene experience as an officer in the US Public Health Service and as an independent. His assignments included seventeen years with the National Institute for Occupational Safety and Health, US Centers for Diseases Control and Prevention (and its predecessors) where he managed research programs and developed policy including a two year assignment with the U.S. Congress in the Office of Technology Assessment. He worked on toxic chemical issues at the U.S. Environmental Protection Agency. He managed a Superfund grant program for model hazardous waste worker and emergency responder training for ten years at the National Institute of Environmental Health Sciences, U.S. National Institutes of Health. Since 1997 he has worked independently on occupational, environmental and public health policy issues for non-profit, labor and other non-governmental organizations.

Mr. Dobbin is the president of the Society for Occupational and Environmental Health, an international society and is past Chair of the Board of Directors of the Association of Occupational and Environmental Clinics. He is past Chair of the Occupational Health and Safety Section, American Public Health Association. He was the 1998 honoree for the OHS/APHA Alice Hamilton award for lifetime achievement in occupational health. He is an elected fellow of the Collegium Ramazzini, an international occupational and environmental health honor society. Mr. Dobbin is a member of the American Conference of Governmental Industrial Hygienists where he served as recording secretary of the Physical Agents Threshold Limit Value committee and chaired the Computer and Nominating committees. He has participated in the American Academy of Industrial Hygiene specialist the National Public Health Policy Association and Society of Risk Assessment. He is a Certified Industrial Hygiene Specialist (ret).

Mr. Dobbin holds a B.S. in Electrical Engineering from the University of Idaho, and a M.Sc. in Occupational Hygiene from the London School of Hygiene and Tropical Medicine, London, UK.

Bruce Forrest, M.D., MBA

President, Forrest & Company, Inc.

Bruce Forrest brings over 20 years of academic and pharmaceutical industry experience and has worked on over 60 publications with special emphasis on the development of vaccines and biologicals. Dr. Forrest is a medical graduate from the University of Adelaide in Australia, where he also pursued postgraduate doctoral research with an emphasis in mucosal immunology and vaccines. He has a Masters of Business Administration from the Warwick Business School in the United Kingdom.

During his period in the pharmaceutical industry, Dr. Forrest was the clinical leader for the successful NDA reviews and approvals of a live, tetravalent rotavirus vaccine in Europe; for the seven-valent pneumococcal conjugate vaccine in the US and Japan as well as managing closely the relationships with China on this approval; and overseeing the NDA approvals in Japan for etanercept and gemtuzumab ozogamicin, as well as submissions for bazedoxifiene and temsirolimus. He has designed and implemented extensive global clinical programs that have involved as many as 38 countries, and has extensive experience in the conduct of large-scale efficacy trials including pneumococcal conjugate vaccine efficacy trials in native American communities and in Soweto, South Africa.

Josh Ginsberg, Ph.D.

Senior Vice President, Global Conservation Program, Wildlife Conservation Society

.Joshua Ginsberg was born and raised in New York and is currently the Senior Vice President, Global Conservation Program, at the Wildlife Conservation Society (WCS). At WCS, Dr. Ginsberg has served as the Vice President for Conservation Operations (2004-2009), as Director of the Asia and Pacific Program (1996 -2004), and as Acting Director of the WCS Africa Program for ten months in 2002. He received a B. Sc. from Yale, and holds an M.A. and Ph.D. from Princeton in Ecology and Evolution. Dr. Ginsberg spent 17 years as a field biologist/conservationist working in Asia and Africa. He serves on the NOAA/NMFS Hawaiian Monk Seal Recovery Team and was Chair of the Team from 2001-2007. Dr. Ginsberg has held faculty positions at Oxford University and University College London, and is an Adjunct Professor at Columbia University, where he teaches conservation biology and has supervised 16 Masters and four Ph. D. students. He is an author of over 50 reviewed papers, and has edited three books on wildlife conservation, ecology and evolution.

Dr. Yu Yang Gong
Managing Director, ESD China Limited

Dr Gong is currently the Managing Director of ESD China Limited, and has served as the Vice President for the Louis Berger Group (USA), and Regional Manager for ERM China. He is a licensed Professional Engineer registered in the United States with over 20 years of diverse consulting and academic experience, primarily in the USA and China.

He has his B.Sc. and M. Sc. from Beijing University in China, and Ph.D. from Buffalo University in USA. He has both industrial and academic experience in the following areas: Soil and Groundwater Pollution Control Regulation and Policy Development, Contaminated Site Investigation (SI/RI); Risk Assessment (e.g., RBCA), Site Remediation, Solid/Hazardous Waste Management, Surface Water and Groundwater Quality Modeling, Contaminated Facility Decontamination, Waste Reduction and Reuse, and Asbestos/Lead Based Paint Abatement. His experience in hazardous waste and contaminated site regulation and policy development is best represented in his capacity serving as an international expert for World Bank, ADB and other international agencies (US TDA and Germany GTZ) and work in several developing and developed countries (USA, Israel, Sri Lanka, Japan, China etc).

Dr. Gong's experience in Contaminated Site Investigation and Remediation includes, Environment Site Assessment and Characterization (ESA, PA/SI/RI), Treatability/Pilot Study, FS, EE/CA, In-Situ and On-Site Remediation System Design and Costing, System Installation and O&M. He has 15 years hands on experience in technologies such as Incineration, Thermal Desorption, Chemical Oxidation & Reduction, SVE, Bioventing, Air Sparging, Bioslurping, Bioslurry, Soil Washing, Pump and Treat, Funnel and Gate (with treatment wall/barrier), Natural Attenuation, Institutional Control (such as capping); Excavation/dredging and Secured Landfill Disposal.
Dr Gong is a task member for the WEF book Hazardous Waste Treatment Process and has numerous publications/presentations in site investigation and remediation. His PhD thesis is on PCBs fate and transport. Currently he serves as a Technical Adviser for Ministry of Environmental Protection (MEP) for its POPs contaminated land cleanup program, participating PCB NIP review, contaminated facility decontamination guideline and POPs Contaminated Site Priority Action Plan preparations. He is also an invited technical advisor for the Guideline for Chongqing Contaminated Site Soil and Groundwater Investigation, Risk Assessment and Restoration. He serves in a similar capacity to Beijing City, Zhejiang and Jiangsu provinces.

David J. Green
Owner and CEO of Phoenix Soil, LLC; United Retek of CT LLC; American Lamp Recycling, LLC; Green Globe, LLC; and Jayjet Transportation, LLC.

David Green received his M.ed in chemistry and has owned and operated hazardous waste remediation companies since 1979. His companies have conducted in-situ and ex-situ treatments of hazardous materials on over 16,700 sites in the US, China, UK, and central Europe. The technologies incorporated include, low temperature thermal desorption, solidification/stabilization and chemical treatment. David serves as Chairman of the Local Emergency Planning Commission and the Director of Operations for

Connecticut's Department of Homeland Security USAR Team.

David Hanrahan, M.Sc.
Director of Global Programs, the Blacksmith Institute

David Hanrahan oversees the technical design and implementation for Blacksmith of over 40 projects in 14 countries. Prior to joining Blacksmith, David worked at the World Bank for twelve years on a broad range of environmental operations and issues, across all the Bank's regions. During much of this time he was based in the central Environment Department where he held technical and managerial positions and participated in and led teams on analytical work and lending operations.

Before joining the World Bank, he had twenty years of experience in international consultancy, during which time he also earned postgraduate degrees in policy analysis and in environmental economics. His professional career began in Britain in water resources for a major international engineering consultant. He then moved to Australia to build the local branch of that firm, where he helped to develop a broad and varied practice for public and private sector clients. He later returned to the UK and became Development Director for an environmental consultancy and subsequently Business Manager for a firm of applied economics consultants. In 1994 he was recruited by the World Bank to join its expanding Environment Department.

David Hunter, Sc.D.
Professor of Epidemiology and Nutrition, Harvard University School of Public Health

Dr. Hunter received an M.B.B.S. (Australian Medical Degree) from the University of Sydney. He continued his formal education at Harvard University, receiving his Sc.D. in 1988. Dr. Hunter is a Professor of Epidemiology and Nutrition, Harvard School of Public Health. Dr. Hunter is involved with several large, population-based cohort studies, including the Nurses' Health Study (I and II), Health Professionals Follow-up Study, and the Physicians' Health Study. Among the goals of these large cohort studies is to investigate gene-environment interactions, including the impact of lifestyle factors, on disease causation. Disease endpoints of interest for some of these cohorts include cardiovascular disease, diabetes, and osteoporosis. He is also involved in long running studies of nutritional influences on HIV progression in Tanzania.

Eric Johnson
Member of the Board of Trustees, Green Cross Switzerland

Eric Johnson has a broad perspective on the environment and chemical contamination. He began his career as an editor of Chemical Engineering and Chemical Week magazines. He then became involved in the selection, assessment and remediation of industrial sites. One of his major projects was the remediation and conversion of a former aluminum smelter to alternate land-use. Mr. Robinson was an early adopter of life-cycle assessment. That, combined with his experience in environmental impact assessment, led to his 1996 appointment as editor of Environmental Impact Assessment Review – a leading peer-reviewed journal in the field.

Mr. Johnson has analyzed numerous environmental issues that touch on the chemical industry including: alternative fuels, brominated flame retardants, CFCs and replacements, ecolabels (for detergents, furniture polishes, hairsprays and personal computers), GHG emissions and trading, plastics recycling, PVC and the chlorine-chain, REACH, socially-responsible investing, tri-butyl tins and TRI and environmental reporting. In 1994 he organized the first Responsible Care conference for plant managers in Europe. Currently, his main work is in comparing the carbon footprints of various sources of energy. He has worked internationally, concentrating mainly on the US and Europe. Mr. Johnson is an active member of the Board of Green Cross Switzerland.

Barbara Jones, M.Sc.
Principal, Cardinal Resources

Donald E. Jones
Founder of Quality Environmental Solutions, Inc.

Donald Jones is the founder of Quality Environmental Solutions, Inc. and was previously Director of the IT Corporation national program for clients with hydrocarbon-related environmental problems and development of environmental management programs. He has served as an elected Board of Health member and was appointed as Right-To-Know and Hazardous Waste Coordinator in the State of Massachusetts. Mr. Jones currently serves on the Local Water Board, as technical consultant to the local Facilities Board and provides editorial review of technical papers and publications for the National Ground Water Association.

Mukesh Khare , Ph.D.
Professor, Department of Civil Engineering, Indian Institute of Technology Delhi, India
Former Atlantic LNG Chair Professor in Environmental Engineering, Faculty of Engineering, University of West Indies, St Augustine, Trinidad and Tobago
Fellow, Wessex Institute of Great Britain
Principal Member, International Sustainable Technological Association (ISTA), Arizona State University, USA
Principal Reviewer, Research Management Group, USA
Member Research Review Committee, National Research Foundation, Pretoria, South Africa
Consultant (Air Pollution), Government of Delhi, India

Prof. Mukesh Khare is serving as Professor in the Department of Civil Engineering at Indian Institute of Technology Delhi, India. Professor Khare received his PhD in Faculty of Engineering (Specialized in Air Quality) from the University of Newcastle Upon Tyne, UK in 1989. He has published to date more than 35 refereed research articles in professional journals, 40 articles in refereed conferences/seminars, 2 books: Modeling Vehicular Exhaust Emissions, WIT Press, UK; Artificial Neural Networks in Vehicular Pollution Modeling, Springer, USA; 03 contributed chapters in books/handbooks, published by WIT Press, and Elsevier, USA. Additionally, he has published about 20 technical reports on research/consultancies conducted for government agencies and private industries. Prof. Khare continues to serve as peer reviewer for several government ministries grants programs and state programs and consultant/advisor to the Government of Delhi, India. He is also serving as reviewer to many journals and publishing houses. Prof. Khare is in the editorial board of International Journal of Environment and Waste Management and Guest Editing one of its special issues on Urban Air Pollution, Control and Management.

Prof. Khare's research has focused on local scale urban air quality modeling targeting the predictions of episodes at urban roads/intersections, mainly arising out from undefined low-level/line sources. Current research areas include formulation of air quality models and their validation; indoor air quality in air-conditioned and naturally ventilated buildings and exposure assessment of related pollutants on indoor occupants. He has also worked extensively in the area of industrial wastewater treatment particularly application of Rotating Biological Contactor Systems to treat industrial and sewage wastes. Prof. Khare and his research group have carried out a number of on-site assessments of air pollutants and designed a number of effluent treatment plants to treat the corresponding wastes from various types of industries.

Philip J. Landrigan, M.D., M.Sc.
Director, Center for Children's Health and the Environment,
Chair, Department of Community and Preventive Medicine, and
Director, Environmental and Occupational Medicine, Mount Sinai School of Medicine

Dr. Landrigan is a pediatrician and an international leader in public health and preventive medicine. Dr. Landrigan's pioneering research on the effects of lead poisoning in children led the US government to mandate removal of lead from gasoline and paint, actions that have produced a 90% decline in incidence of childhood lead poisoning over the past 25 years. His leadership of a National Academy of Sciences Committee on pesticides in children's diets generated widespread understanding that children are uniquely vulnerable to toxic chemicals in the environment. The findings of the NAS Committee secured passage of the Food Quality Protection Act in 1996, a major US federal pesticide law and the first environmental statute to contain specific protections for infants and children. Dr. Landrigan served as Senior Advisor to the US Environmental Protection Agency where he was instrumental in helping to establish the EPA's Office of Children's Health Protection. Dr. Landrigan has been a leader in developing the National Children's Study, the largest study of children's health and the environment ever launched in the United States.

Ian von Lindern, Ph.D.

CEO and Chairman, Terra Graphics Environmental Engineering, Inc.

Dr. Ian von Lindern is Chairman and CEO of TerraGraphics Environmental Engineering in Moscow, Idaho. He holds a B.S. in Chemical Engineering from Carnegie-Mellon University and M.S. and Ph.D. degrees in Environmental Science and Engineering from Yale University. Dr. von Lindern has 35 years of national and international environmental engineering/science experience. He has directed over 40 major health/environmental investigations involving primary and secondary smelters and battery processors, landfills and uranium mill tailings at several major mining/smelting sites in the U.S. including ASARCO/Tacoma, WA; East Helena and Butte/Anaconda in MT; and internationally in North America, Asia, Africa, Australia and Latin America. Dr. von Lindern has worked for the State of Idaho on various projects involving the Bunker Hill/Coeur d'Alene Basin Hill Superfund Site for over 30 years as the lead Risk Assessor. In that capacity he had extensive experience in applying exposure and bio-kinetic lead modeling in assessing human health risk, developing cleanup criteria and remedial design. He is currently Senior Project Manager implementing the human health cleanup at the Idaho Superfund Site. He is currently involved in an International Initiative with the University of Idaho and non-government organizations to adapt the lead health response lessons learned in the U.S. to developing countries. Five international cleanup projects are underway including China, Russia, the Dominican Republic and Dakar, Senegal, and Zamfara, Nigeria, where severe mortality and morbidity effects occurred in recent years. Dr. von Lindern has served as a U.S. EPA Science Advisory Board (SAB) Member on five occasions reviewing the scientific basis for lead regulatory policy.

Ira May

Senior Geologist ERT Inc (www.ertcorp.com) in Laurel, MD.

Mr May recently retired from the US Army Environmental Center where he was the Chief Geologist for over 20 years. He has extensive experience with the cleanup of hazardous wastes at military facilities throughout the United States. He is presently working on the cleanup of ranges where munitions were used throughout the world. He was in charge of the Army's groundwater pump and treat optimization efforts. He is an expert on the analysis of efficacy of remediation efforts. He has been involved in the cleanup of and the development of new technologies for Superfund cleanups for almost 30 years. He has been involved as a technical advisor to Blacksmith Institute with projects in the Philippines and the Ukraine.

Jerome A. Paulson, M.D.

Associate Professor of Pediatrics, George Washington University School of Medicine & Health Sciences Associate Professor of Prevention and Community Health and Research Associate Professor of Environmental & Occupational Health, George Washington School of Public Health and Health Services.

In addition to his work at George Washington University, Dr. Paulson is the Medical Director for National and Global Affairs of the Children's Health Advocacy Institute at the Children's National Medical Center. Dr. Paulson is also one of the co-directors of the Mid-Atlantic Center for Children's Health and the Environment.

Dr. Paulson serves on the American Academy of Pediatrics Committee on Environmental Health and the Children's Health Protection Advisory Committee for the US Environmental Protection Agency. He also serves on the Pediatric Medical Care Committee of the National

Commission on Children and Disasters and part of the National Conversation on Public Health and Chemical Exposures organized by the Agency for Toxic Substances and Disease Registry. In October 2004 he was a Dozor Visiting Professor at Ben Gurion University in Beer Sheva, Israel. He lectured there and throughout Israel on children's environmental health. He was a recipient of a Soros Advocacy Fellowship for Physicians from the Open Society Institute and worked with the Children's Environmental Health Network, and has also served as a special assistant to the director of the National Center on Environmental Health of the CDC working on children's environmental health issues. He has developed several new courses for the GW School of Public Health about Children's Health and the Environment. He is the editor of the October, 2001 and the February and April 2007 editions of Pediatric Clinics of North America on children's environmental health. He has served on numerous boards and committees related to children's environmental health.

Anne Riederer, Sc.D.

AAAS Science and Technology Policy Fellow, U.S. Environmental Protection Agency

Dr. Riederer is currently an American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellow hosted by the Assistant Administrator of the Office of Research and Development at the U.S. Environmental Protection Agency. She is also adjunct faculty in the Department of Environmental Health at the Rollins School of Public Health, Emory University (Atlanta, USA), where she served as Research Assistant Professor and Co-Director the Global Environmental Health Program from 2004-2010. She received her B.S. in Neuroscience from Brown University in 1989, an M.S. in Foreign Service from Georgetown University in 1991, and an Sc.D. in Environmental Science and Engineering from Harvard School of Public Health in 2004. Her research focuses on assessing exposures of children and women of childbearing age to developmental neurotoxins, including pesticides, heavy metals, and other environmental contaminants. From 1998-2004, Dr. Riederer held a U.S. Superfund Basic Research Program Training Fellowship to study lead, mercury and PCB exposures at the former Clark Air Base, Philippines. From 1991-1998, she worked for Hagler Bailly Consulting on air, water and waste regulatory program development for the Philippines, Indonesia, Viet Nam, Mexico, and Egypt for various bi- and multilateral development agencies. She directed the company's Manila, Philippines office from 1994-1998.

Dave Richards

Independent Environmental Adviser

David Richards works as an independent environmental adviser in the areas of environmental policy and strategy, external engagement and multi-stakeholder initiatives, and strategic environmental risk management. He spent 32 years in the mining industry, 19 of those at operating mines and advanced development projects. For 28 years he was an employee of Rio Tinto. His background is in economic geology and geochemistry, and since 1992 he has worked in corporate environmental policy development and assurance. He has been involved in several multi-stakeholder initiatives including the Mining, Minerals and Sustainable Development (MMSD) project (2000 – 2002), the IUCN-ICMM Dialogue (2002 – present), the Millennium Ecosystem Assessment (2004 – 2005), the Post Mining Alliance (2005 – present) and the Business & Biodiversity Offset Programme (BBOP) (2007 – present). He helped to develop geochemical Risk Assessment tools and has extensive experience in site-based strategic multi-disciplinary risk reviews.

Dr. Stephan Robinson

Unit Manager (Water, Legacy), Green Cross Switzerland

Stephan Robinson holds a Ph.D. in experimental nuclear physics from Basel University. In 1994, he joined Green Cross Switzerland where he first worked as International Director of its Legacy of the Cold War Programme. He mainly worked on the facilitation of chemical weapons destruction in both Russia and the U.S., which included the operation of a network of up to twelve local and regional public outreach offices, the organization of a Russian National Dialogue on chemical weapons destruction, but also practical community projects aimed at improving emergency preparedness and the health infrastructure. Other activities include the clean-up of a major oil spill at a nuclear missile site in the Baltic area; the scientific investigation of a site of former chemical weapons destruction (open pit burning site); different risk assessments of military facilities; an inventory of the Soviet nuclear legacy; and epidemiological studies of public health impacts by chemical weapons storage. With chemical weapons destruction progressing, he changed responsibilities in 2008. He is today coordinating different GEF projects in the Former Soviet Union addressing together with UN organisations, governments, and other stakeholders the legacy of the massive use of pesticides, and works on a series of other pollution-related issues (heavy metals, mining tailings).

Paul Roux

Chairman, Roux Associates, Inc. (www.rouxinc.com)

Paul Roux received an M.A. in Geology from Queens College, City University of New York, and a B.S. in Engineering Science from C.W. Post College, Long Island University. He is a certified Professional Geologist and Hydro geologist, has served on the Editorial Board of Ground Water Monitoring and Remediation and currently serves on the Board of Registration of the American Institute of Hydrology.

Mr. Roux has over 35 years of experience with contaminated soil and groundwater remediation at industrial plants and landfills. He has worked at a number of the largest and most complex Superfund sites in the US, as well as major chemical and petroleum facilities. Roux Associates, which was founded in 1981, currently has more than 230 professional employees in five offices. The firm provides a broad range of consulting and project management services to solve complex environmental, health, and safety problems associated with air, water, land and interior pollution; hazardous materials; and toxic waste treatment and disposal. Roux Associates was twice named one of America's 500 fastest-growing private companies by Inc. Magazine and, since 1996, has been listed as one of the Top 200 Environmental Consulting Firms by Engineering News Record.

Leona D. Samson, Ph.D.

Ellison American Cancer Society Research Professor
Director, Center for Environmental Health Sciences
Professor of Biological Engineering, Massachusetts Institute of Technology

Leona Samson received her Ph.D. in Molecular Biology from University College, London University, and received postdoctoral training in the United States at UCSF and UC Berkeley. After serving on the faculty of the Harvard School of Public Health for eighteen years, she joined the Massachusetts Institute of Technology in 2001 as a Professor of Biological Engineering and the Director of the Center for Environmental Health Sciences. Dr. Samson's research has focused on how cells, tissues and animals respond to environmental toxicants. Dr. Samson has been the recipient of numerous awards during her career, including the Burroughs Wellcome Toxicology Scholar Award (1993-98); the Charlotte Friend Women in Cancer Research Award (2000); the Environmental Mutagen Society Annual Award for Research Excellence (2001). In 2001, Dr. Samson was named the American Cancer Society Research Professor, one of the most prestigious awards given by the society. The ACS Professorship was subsequently underwritten by the Ellison Foundation of Massachusetts. In 2003, she was elected as a member of the Institute of Medicine of the National Academies of Science, and she will become the President of the Environmental Mutagen Society in 2004.

Kelvin Telmer, Ph.D

Executive Director, Artisanal Gold Council; Chair, IUGS-GEM
Professor, SEOS, University of Victoria

Dr. Telmer has worked for more than 20 years as an environmental geochemist and geologist for mining and consulting companies and academia in Latin America, Asia, and Africa, as well as in Canada, the U.S. and Europe. He directs The Artisanal Gold Council (www.artisanalgold.org), which he founded to improve the environment and livelihoods of small-scale gold mining communities (ASGM). He does this through innovative field programs and educational campaigns. He is an internationally recognized leader in this field and collaborates with the United Nations, World Bank, private sector, governments, and civil society to develop technologies, programs and policies to reduce the use of mercury while improving gold recovery in small-scale mining. Dr. Telmer has designed and implemented mercury emissions reduction technologies and introduced a variety of mineral processing techniques to improve gold recovery. Dr. Telmer is currently a principal consultant for the United Nations Environment Programme's Global Mercury Partnership on ASGM and participates in the development of the UN's forthcoming global mercury treaty.

Brian Wilson
Program Manager
International Lead Management Center
MRSC - Member of the Royal Society of Chemistry

Brian Wilson is the Program Manager for the International Lead Management Center located in North Carolina, USA. He is responsible for the design and implementation of multi-stakeholder lead risk reduction programs. Before joining the ILMC he worked for 15 years with the oil industry followed by 18 years with MIM Holdings in the Metals Industry. He left the United Kingdom and MIM UK as the Group Personnel Manager in 1996 to join ILMC after a career that spanned smelter production, industrial relations and human resource management. Brian has worked with UNEP, UNCTAD and the Basel Secretariat on Lead Risk Reduction and Recycling projects in the Far East, Russia, Central and South America, the Caribbean and West Africa.

Jay Vandeven, MS.
Principal, ENVIRON International Corporation

Jay Vandeven is a Principal in the Arlington, VA office of ENVIRON International Corporation. ENVIRON is an international consultancy, providing chemical risk management services to public and private sector clients from a platform of more than 70 offices worldwide. He has been a consulting environmental engineer for twenty-five years, focusing on the sources, fate and transport, and remediation of chemical and radiological compounds in all environmental media. Mr. Vandeven has worked on some of the largest Superfund sites in the U.S. as well as contaminated sites in Eastern Europe. He routinely counsels clients on negotiations with regulatory authorities and represents clients in environmental disputes. Mr. Vandeven is also a member of the committee that administers the ENVIRON Foundation, an internally managed philanthropic initiative that provides financial assistance to projects worldwide that promote protection of human health and a sustainable global environment, particularly with respect to the impact of chemicals and society's use of the Earth's resources.

About Blacksmith Institute

www.blacksmithinstitute.org

Blacksmith Institute (www.blacksmithinstitute.org) is an international not-for-profit organization dedicated to solving life-threatening pollution issues in the developing world. A global leader in this field, Blacksmith addresses a critical need to identify and clean up the world's worst polluted places. Blacksmith focuses on places where human health, especially that of women and children, is most at risk. Based in New York, Blacksmith works cooperatively in partnerships that include governments, the international community, NGOs and local agencies to design and implement innovative, low-cost solutions to save lives. Since 1999, Blacksmith has completed over 50 projects; Blacksmith is currently engaged in over 40 projects in 19 countries.

Since 2006, Blacksmith Institute's yearly reports have been instrumental in increasing public understanding of the health impacts posed by the world's worst polluted places, and in some cases, have compelled cleanup work at these sites. Previous reports have identified the top ten world's worst polluted places or pollution problems. Blacksmith reports have been issued jointly with Green Cross Switzerland since 2007. Read the reports at www.worstpolluted.org

About Green Cross Switzerland

www.greencross.ch

Green Cross Switzerland facilitates overcoming consequential damages caused by industrial and military disasters and the clean-up of contaminated sites from the period of the Cold War. Central issues are the improvement of the living quality of people affected by chemical, radioactive and other types of contamination, as well as the promotion of a sustainable development in the spirit of co-operation instead of confrontation. This includes the involvement of all stakeholder groups affected by a problem.

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