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How Developing Nations Can Protect Children From Hazardous Chemical Exposures While Sustaining Economic Growth

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ABSTRACT **Increasing worldwide use of chemicals, including heavy metals used in industry and pesticides used in agriculture, may produce increases in chronic diseases in children unless steps are taken to manage the production, use, trade, and disposal of chemicals. In 2020 the developing world will account for 33 percent of global chemical demand and 31 percent of production, compared with 23 percent and 21 percent, respectively, in 1995. We describe present and potential costs of environmental exposures and discuss policy options to protect future generations of children in a sustainable development context. Specifically, we describe the principles of sound chemicals management, as follows: precaution, or the use of cost-effective measures to prevent potentially hazardous exposures before scientific understanding is complete; the right to know, or informing the public—especially vulnerable groups—in a timely fashion about the safe use of chemicals and any releases of chemicals into the environment; pollution prevention, or preventing the use of hazardous chemicals and the production of pollutants, rather than focusing on managing wastes; internalization of environmental and health costs, or ensuring that the consequences of exposures are reflected in the price of chemicals through such approaches as "polluter pays"; and use of best available scientific information in making decisions such as what chemicals to allow into the market. We recommend that industrializing nations in particular employ these principles to prevent disease among their populations while at the same time minimizing the risk to their own economic development.**

The unique vulnerability of children to environmental chemicals has been documented in many reports, including the landmark 1993 US National Research Council report on pesticide exposures.[1] Compared with adults, children are exposed to greater levels of pesticides and other environmental chemicals relative to their body weight.[2] Their developing bodies are also vulnerable to chemical exposures, which can cause lifelong impairment.[3]

Each year since World War II, thousands of new synthetic chemicals have been introduced into international commerce for a variety of uses, ranging from household products and pesticides to pharmaceuticals.[4] It is important to acknowledge the enhancements to modern living produced by many chemicals, especially pharmaceuticals. However, we wish to place in proper context the as yet underrecognized neg-

ative consequences of exposures to chemicals.

The most recent data available identify 143,000 chemicals that have been preregistered with the European Chemicals Agency.[5] Of these, nearly 3,000 have been defined by the US Environmental Protection Agency as high-production-volume chemicals, which means that they are produced in the United States or imported into the country at quantities equal to or greater than one million pounds per year.[6] These include petrochemicals as well as basic inorganic substances, and they are used to make an enormous variety of products.

High-production-volume chemicals are of particular interest to regulatory agencies because there may be widespread exposure to these chemicals. Many lower-volume chemicals are also of concern due to high toxicity and bioavailability—that is, they are absorbed by and have a relatively rapid impact in key organs and cells. Persistent, bioaccumulative, and toxic (known as PBT) chemicals are of particular concern because they last for long periods of time in the environment and accumulate in the bodies of wildlife and humans.

Changing patterns of consumption have led to increased chemical production and use in developing countries, along with increased exposures. The Organization for Economic Cooperation and Development has estimated that in 2020 the developing world will account for 33 percent of global chemical demand and 31 percent of production, compared with 23 percent and 21 percent, respectively, in 1995. In addition, by 2020 developing countries are expected to lead in the manufacture of high-production-volume chemicals.[7] This rapid growth of production and consumption of chemicals occurs against a backdrop of insufficient infrastructure to protect public health and the environment adequately.[8]

This article describes the health implications of chemical exposures in children that have been studied in the developed world. These health effects could be prevented in the developing world and in countries whose economies are in transition—countries such as China that are moving to become more highly developed, market-based economies—if policy interventions were made to limit harmful exposures there.

Few data are available to quantify the potential economic consequences of failing to prevent harmful exposures to children.[9–12] However, this article endeavors to provide a sense of the scope of economic benefits of sound management of chemicals. The article closes by describing policy options for capturing these benefits without disrupting sustainable development objectives in the developing world.

Health And Economic Consequences

As chemicals have become widespread in the environment in industrialized countries, the prevalence and incidence of chronic health conditions have increased. These conditions include asthma,[13] certain birth defects,[14,15] leukemias,[16] and brain[17] and testicular[18] cancer. One in six US children are now obese,[19] and 2–8 percent are now affected by developmental disabilities.[20]

Although scientific evidence to supplement the temporal association of increasing chemical exposures with obesity is lacking, the National Research Council has estimated that 28 percent of developmental disabilities are due at least in part to environmental factors.[21] Outdoor air pollutants have been confirmed to exacerbate childhood asthma,[22] and benzene, certain pesticides, and 1,3-butadiene, an industrial chemical, have been associated with childhood malignancies.[23–25]

Early warning signs of similarly disturbing trends in developing countries have recently emerged, including a sustained increase between 1982 and 2002 in the incidence of acute lymphocytic leukemia in children in Mexico.[26] Surveys document increases over the past five to ten years in childhood asthma prevalence in many developing countries.[27] Adolescents suffer a large proportion of the one to five million pesticide poisonings that occur each year, with several thousand fatalities—a large portion of which are in developing countries.[28]

The World Health Organization estimates that 5.8 percent of life-years lost because of disabilities in children living in low- and middle-income countries are attributable to lead exposure and air pollution.[29,30] If regulatory efforts are not made to limit exposures to chemicals that are known or suspected to be hazardous, industrialization could result in further increases in the incidence or prevalence of childhood disease attributable to environmental causes.

Children's environmental exposures to chemicals in the developing world also present a large economic burden. In a recent study, the World Bank quantified the direct and indirect costs of childhood disease that can be attributed to urban air pollution, indoor air pollution, water sanitation, and hygiene. Using two countries as illustrative examples, the study's authors found that the total of the direct and indirect costs associated with environmental risk factors was 9.3 percent of the gross domestic product in Ghana and 8.8 percent in Pakistan.[12]

A March 2007 study of the cost of pollution in China found that pediatric and adult health costs associated with air and water pollution had reached 4.3 percent of China's gross domestic product.[31] A report published by the Nordic

Council of Ministers conservatively predicts that the global costs from lost lifetime productivity resulting from the prenatal impact of mercury pollution could amount to as much as $29.4 billion (in 2005 US dollars) in 2020.[32]

Potential Economic Benefits Of Preventing Exposures

The first major case study documenting the health and economic benefits of preventing children's exposures to harmful chemicals[33] followed the US ban on the sale of leaded gasoline. Just as policy makers were considering lifting the ban, data from the National Health and Nutrition Examination Survey documented steep and consistent decreases in children's blood lead levels.[33] Scott Grosse and colleagues showed that these declines produced economic benefits—through increased cognitive potential—of an additional lifetime productivity of $110–$319 billion in each birth cohort in the 2000s, compared with their counterparts in the 1970s.[10]

As a result of the leadership of the United Nations Environment Programme's Partnership for Clean Fuels and Vehicles to eliminate lead in gasoline,[34] the economic rewards of eliminating leaded gasoline are now being achieved in the developing world as well. Peter Tsai and Thomas Hatfield have estimated that globally these benefits range from $1 trillion to $6 trillion per year, with a best estimate of $2.45 trillion per year—or 4 percent of global gross domestic product.[35] Ongoing efforts by the United Nations Environment Programme and the World Health Organization, through an alliance to eliminate lead in paint globally, are likely to yield additional economic benefits.[36]

Efforts to limit exposure to mercury could have similar effects. Kyrre Sundseth and colleagues have estimated that under a scenario of maximum feasible technological reduction for mercury—that is, the implementation of all available solutions and measures, with cost only a secondary consideration—airborne emissions could be reduced by 50–60 percent by 2020.[37] Such an effort would reduce the potential accumulation of mercury in land and water and, by extension, humans' exposure to it.

Methyl mercury—a form of mercury that results when microbes transform mercury after it has been deposited in water and that then accumulates in fish and is ingested by humans—has been documented to be toxic to the developing brain.[38] Reductions in exposure to this chemical could contribute $1.8–$2.2 billion in global economic benefits in 2020, with similar benefits for subsequent cohorts of children born with lower levels of exposure because their mothers had eaten less contaminated fish.[37]

Because the uncontrolled release of chemicals into the environment can affect all natural resources, the economic benefits of sound management of chemicals are broader than the reductions in direct and indirect health costs. Contamination of water resources, for example, can have long-lasting economic consequences. Fisheries provide a livelihood for an estimated 43.5 million people worldwide and often produce developing countries' most valuable agricultural exports. Contamination of fisheries thus can have far-reaching health consequences.

Fish is an important source of animal protein in the diet of the world's poorest people.[39] Even with moderate levels of local environmental contamination, mercury concentrations appear to make a major contribution to the body burden—that is, the total amount of a substance in the body, as measured in blood or hair in the case of methyl mercury—of people who eat fish.[38,40]

Other sources of mercury exposure include mineral mining. One study of populations affected by mercury pollution from gold mining activity in the Philippines during the 1980s indicates that all residents of Diwalwal—a major center of gold mining, where water was found to be contaminated—were exposed to high levels of mercury, compared to control populations.[41]

The science of quantifying the potential benefits of managing children's exposure to chemicals to limit harmful health consequences is at an early stage. However, the data presented earlier in this section complement those compiled by the World Bank[12] and the Nordic Council of Ministers[32] and strongly suggest that prevention can produce vast health and economic benefits. And because lead, methyl mercury, and many other chemicals have been shown to affect cognitive development and, by extension, economic productivity, elimination of exposures to these chemicals and those that adversely affect the development of other organ systems may actually accelerate economic development. Eliminating exposures can be achieved through the identification of alternative products or components that reduce or eliminate environmental and health consequences, replacing hazardous chemicals and products used in industry with those that do not pose risks, and better management practices for the use and disposal for those chemicals and products for which less risky substitutes cannot be identified.

International Policy Instruments To Protect Children

Exhibit 1 describes the policy impact of the three major international conventions that protect

EXHIBIT 1

Key International Conventions For Protecting Children From Hazardous Chemicals

Convention	Policy impact
Basel Convention (signed in 1989)	Minimizes, with the aim of eliminating, the generation and transboundary movement of hazardous waste
Rotterdam Convention (signed in 1998)	Ensures international communication about the international trade in thirty-nine pesticides and industrial chemicals that have been banned or severely restricted for health and environmental reasons
Stockholm Convention (adopted in 2001, came into force in 2004)	Protects human health and the environment from persistent organic pollutants (organic compounds such as the pesticide DDT that, when released into the environment, do not readily degrade through biological, chemical, or other processes) Eliminates the production, use, import, and export of these chemicals and requires the environmentally sound destruction of them as wastes Covers 21 chemicals currently

SOURCES (1) United Nations Environment Programme, Secretariat of the Basel Convention. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal [Internet]. Geneva: The Secretariat; [cited 2011 Nov 10]. Available from: http://archive.basel.int/text/17Jun2010-conv-e.pdf. (2) United Nations Environment Programme, Secretariat of the Rotterdam Convention. Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade [Internet]. Geneva: The Secretariat; [revised 2008; cited 2011 Nov 10]. Available from: http://www.pic.int/Portals/5/en/ConventionText/RC%20text_2008_E.pdf. (3) United Nations Environment Programme, Secretariat of the Stockholm Convention. Stockholm Convention on Persistent Organic Pollutants (POPs) [Internet]. Geneva: The Secretariat; [amended 2009; cited 2011 Nov 10]. Available from: http://chm.pops.int/Portals/0/download.aspx?d=UNEP-POPS-COP-CONVTEXT.En.pdf.

children from chemical hazards in the environment. In 2002 heads of state at the World Summit on Sustainable Development called for a global strategic plan, encompassing these three conventions, to ensure the universal implementation of sound chemicals management by 2020.

Sound chemicals management is defined as the use and production of chemicals in ways that minimize serious adverse effects on human health and the environment.[42] At its core are five principles: precaution, or the use of cost-effective measures to prevent potentially hazardous exposures before scientific understanding is complete; the right to know, or informing the public—especially vulnerable groups—in a timely fashion about the safe use of chemicals and any releases of chemicals into the environment; pollution prevention, or preventing the use of hazardous chemicals and the production of pollutants, rather than focusing on managing wastes; internalization of environmental and health costs, or ensuring that the consequences of exposures are reflected in the price of chemicals through such approaches as "polluter pays"; and the use of the best available scientific information in making decisions such as what chemicals to allow into the market.

Government officials, along with stakeholders including representatives of the private sector and nongovernmental organizations, adopted the Strategic Approach to International Chemicals Management in 2006, to ensure that sound chemicals management will be implemented globally by 2020. The approach is an international policy framework that expresses a global political commitment to sound chemicals management. It establishes global objectives and provides modest funding for implementation activities in developing countries. Ongoing collaborative international projects under the rubric of the approach include a project to improve transparency about chemicals used in products and a project to reduce the sale of lead paint in developing countries.

The approach notes the "dependency on pesticides in agriculture, exposure of workers to harmful chemicals and concern about the long-term effects of chemicals on both human health and the environment." It also points out that global production, trade, and use of chemicals are rapidly increasing, causing a particular burden on developing countries and countries with economies in transition.[42]

Major challenges in implementing the sound management of chemicals include dependence on outdated technologies; lack of regulatory capacity; failure to integrate chemicals management into national development and planning; and concerns that implementing it would hinder economic development. The United Nations Environment Programme's Global Chemicals Outlook Project is currently framing such challenges in the context of the wide-reaching benefits from improved chemicals management in developing countries. This project will describe trends and indicators for chemical production,

trade, use, and disposal; associated health and environmental impacts; and the economic benefits of and possible approaches to sound management of chemicals, including the promotion of safer alternatives.[43]

Policy Options For Developing Countries

Industrializing nations face multiple constraints that may seem to limit their ability to implement sound chemicals management. Nonetheless, such countries have a variety of policy options to use in protecting children from exposures to toxic chemicals. Product labeling and environmentally preferred product procurement—that is, selecting products based on both cost and environmental impacts—by government agencies and the private sector can encourage the use of alternatives that are safer than toxic chemicals.

Requiring communication about chemical releases—as the US Environmental Protection Agency does in its Toxic Release Inventory, a publicly available database containing information on toxic chemical releases and waste management activities in the United States[44]—helps provide the public with information that can ultimately limit exposure. When communities are notified about possible exposures of concern, they can initiate measures to limit the ingestion of contaminated water, for example. And in the longer term, they can work with polluters to identify better waste management practices or other ways to prevent pollution.

Similarly, legislation such as California's Safe Drinking Water and Toxic Enforcement Act of 1986 can create systems to provide the public with information on toxic substances in consumer products, enabling people to make informed purchasing decisions and driving markets to provide safer products.[45]

Chemical registration and characterization such as the Registration, Evaluation, Authorization and Restriction of Chemicals program of the European Union strives to ensure that all chemicals are screened for their potential toxicity.[46] In the absence of such an approach, hazards are likely to be identified only through retrospective epidemiological studies, which document harms that have already occurred.

There is growing interest in the use of cost internalization approaches to finance public programs of sound chemicals management.[47] Under these approaches, chemical producers and users are assessed fees and other charges to help pay the cost of government services to prevent exposure to hazardous chemicals.[48] When applied effectively, these approaches can create incentives to reduce pollution.[49,50]

For example, emission charges can limit releases while ensuring that polluters pay for the economic harm attributable to pollution and its health and environmental effects. (Such economic damages are typically defined by economists in terms of market externalities, unless they are incorporated into the market price of a produced good.) With legislation authorizing approaches similar to the US Environmental Protection Agency's Superfund program, countries can legally require responsible parties to clean up chemical waste sites or reimburse the government for doing so.

Financial measures can be used to encourage the development of safer alternatives to hazardous chemicals. For example, Sweden and three US states (Massachusetts, California, and Maine) are among the jurisdictions that use fees to promote sound chemicals management.[45,50–52] In Massachusetts, under the Toxics Use Reduction Act of 1989, facilities that use large quantities of toxic chemicals are required to pay a fee, which is used to fund a variety of state services to help companies reduce their use of these chemicals. The services include research to identify safer alternatives to toxic chemicals for specific applications; the creation of demonstration sites to showcase safer technologies; training in toxics use reduction and resource conservation for industry professionals, and one-on-one, on-site technical assistance for facilities working to reduce or eliminate specific chemicals of concern.[51]

California's fee on the sale of perchloroethylene, a toxic solvent used in such applications as dry cleaning and automobile repair, is used to provide grants and training to dry cleaners, helping them make the transition to safer processes.[45] A Maine law uses a fee levied on the manufacturers of children's products to fund alternatives assessment research, if the manufacturer fails to assess alternatives on its own.[52]

A survey of governments by the United Nations Environment Programme found that many developing countries and countries with economies in transition are successfully using financial measures such as charges on resource use, waste disposal charges, and deposit-refund systems to achieve a variety of environmental goals. For example, Chad has adopted a deposit-refund system for pesticide bags as a way to minimize secondary environment and health impacts from improper disposal of the bags.[47]

These programs are most effective in countries whose chemical policy goals are aligned with related economic, environmental, and social goals and that have institutional capacity for implementing the programs. A number of

international efforts are under way to encourage countries to improve the alignment of various goals. For example, the United Nations Health and Environment Linkages Initiative[53] works to enhance coordination between the environmental and health sectors in developing and transitioning countries. It also aims to build additional capacity for countries to manage the chemicals within their borders and to incorporate chemicals management goals into a broader development assistance agenda.

Barriers And Opportunities For Action

Major barriers may exist to the institution of policies to protect children from chemicals. Countries already well along in the process of industrialization face particular challenges in protecting children from chemical hazards in the environment. For example, in a systematic review of Mexican policy tools to protect children from chemical exposure, Enrique Cifuentes and colleagues found only one specific measure (clinical treatment for and secondary prevention of—that is, preventing additional complications from—elevated blood lead levels) to reduce developmental neurotoxicity and other health effects in children. They found no specific tools to prevent asthma.[54]

The same authors identified barriers through a sample of interviews with government and nongovernment officials. The barriers included state centralization of power, leading to decisions being made about environmental hazards without input from health officials; inadequate communication within governmental agencies as well as between academics and environmental and public health advocates; and political resistance to internalizing the costs of environmental exposures to children.[54] Yet in general, efforts to address environmental health issues affecting children are gaining momentum,[55] even as concerns about the economic impact of chemical regulations to protect children remain high, especially in countries where chemical production is viewed as a pathway to development.

Fortunately, it is possible to promote economic development based on sound chemicals management and internalize the costs of that management. For example, the "polluter pays" principle holds that the health and environmental costs of pollution and wastes generated by chemical production and use should be borne by those responsible—such as the chemical or product manufacturer. This principle was first adopted by governments at the first Earth Summit in 1992 and subsequently reaffirmed at the First Global Ministerial Environment Forum in 2000 and the First International Conference on Chemicals Management in 2006. In a similar manner, ongoing coordination of international agencies with industrialized countries that provide financial and technical support and industrializing countries that will execute policy changes may be necessary to reallocate costs of chemical exposure to producers, possibly at a global or regional level.

EXHIBIT 2

Policy Prescriptions For Preventing Childhood Diseases Of Environmental Origin In The Developing World

Policy prescription	Details
Think internationally	Toxic exposures and their consequences for children's health are, unfortunately, not limited to developed countries Developing countries, just like developed ones, have an urgent need to reduce children's exposures to heavy metals, persistent organic pollutants, and other toxic chemicals Government agencies providing development assistance overseas should include capacity building for improved chemicals management in existing development assistance packages
Think preventively	Reducing or eliminating exposures to toxic substances presents important opportunities to protect and improve children's health In many cases, the best way to accomplish this is simply to replace toxic chemicals with safer substitutes
Think comprehensively	Multiple factors affect children's health Poverty, income inequality, and poor nutrition increase children's vulnerability to the adverse effects of toxic chemicals Eliminating toxic exposures can increase children's ability to overcome other stressors, making broader public health and economic development efforts more likely to succeed

SOURCE Authors' analysis.

Financing for programs to manage chemicals and clean up wastes could also be included in ongoing international and bilateral economic development aid programs. Such financial assistance has been useful in funding environmental protection.[45,50–52] However, there has been little experience to date in funding programs to protect children from exposure to dangerous chemicals.

The cost internalization programs in Sweden and three US states suggest possible mechanisms for financing chemicals management in developing countries. The global chemical industry has annual revenues of more than $3 trillion per year.[56] If mechanisms were created so that the industry itself effectively financed chemicals management, at a cost of just 0.1 percent of the industry's annual revenues, more than $3 billion would be available for that purpose.

Countries could adopt such cost internalization procedures individually or regionally, depending on the political context. This exceedingly small cost relative to the total turnover of the chemical industry is unlikely to affect product prices, but it would yield far greater amounts than what donor governments would be expected to supply in grant aid on a continuing and sustainable basis.

Conclusion

Industrializing nations confront serious challenges as they try to resolve the conflicting demand for economic growth and need to protect children from environmental hazards. However, increases in chronic health conditions similar to those that have occurred in the United States and other developed countries are a real possibility for developing countries unless they take steps to reduce exposures to dangerous chemicals. Such increases could hinder rapid economic development. As we have argued, sound chemicals management can be instituted without limiting the economic growth that is a primary goal for so many nations.

Those working in the field of maternal and child health would do well to monitor the progress of efforts to improve chemicals management at the national and international levels because these policy measures will have a direct impact on children's health.[57] As we described above, sound chemicals management policies are key to the prevention of chronic childhood conditions and their associated costs. Important initiatives include ongoing work to implement the Strategic Approach to International Chemicals Management; efforts to develop a binding international treatment on mercury; and efforts to reform chemicals policy within individual countries.

There are also implications for international economic development efforts. Donor countries providing economic development assistance to developing countries would do well to include chemicals management in the larger development agenda. This includes helping developing countries create the necessary government capacity to regulate and manage chemicals and examining the potential health and environmental impacts of new industrial development projects.

The success of chemicals management efforts can be tracked through a variety of indicators, including monitoring the presence of persistent organic pollutants in human tissues and breast milk, in wildlife, and in food such as eggs. Success can also be assessed through epidemiologic indicators, including the prevalence or incidence of disease and disability associated with environmental exposures, and policy indicators, such as the adoption of pollution release and transfer registries—for example, the Toxic Release Inventory of the US Environmental Protection Agency[44]—that increase individual and community awareness of potential exposures of concern.

In Exhibit 2 we suggest three broad principles that should underlie efforts to prevent diseases of environmental origin in the developing world. Because many of the economic benefits of proactive prevention would accrue over many years in the future, it will be critical to quantify and document the future sustainable benefits likely to be produced through sound chemicals management. ■

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In this month's *Health Affairs*, Leonardo Trasande and coauthors report on their study examining the risks to children's health of increasing production and use of potentially toxic chemicals both in the United States and in developing countries. The study found that as developing countries produce and use larger shares of toxic chemicals, they place their populations at greater risk of exposure. The authors argue that sound chemicals management, advocated by international treaties and agreements, can allow countries to continue expanding their economies, while also safeguarding the health of their populations and environments.

Trasande is a faculty member in pediatrics and environmental medicine at the New York University (NYU) School of Medicine, and in health policy at the Robert F. Wagner School of Public Service at NYU. His research focuses on identifying the role of environmental and other factors in chronic childhood disease, and on documenting the economic costs of failing to prevent them proactively. He serves on a United Nations Environment Programme Steering Committee that is developing a Global Outlook on Chemicals Policy, and on the Executive Committee of the Council for Environmental Health of the American Academy of Pediatrics.

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