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A quarter century of the Pacific Basin Consortium: looking back to move forward

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Abstract: The Pacific Basin Consortium (PBC) was formed 25 years ago to address significant public health challenges to vulnerable populations imposed by environmental threats in the region, including areas surrounding the rim of and in the Pacific Ocean. Originally focused on toxic waste pollution, the PBC has broadened its efforts over the years, embracing a health focus and more of a balance between engineering and public health. This move was informed by the PBC's close relationship with the National Institutes of Health (NIH) National Institute of Environmental Health Sciences (NIEHS) Superfund Hazardous Substances Basic Research and Training Program (Superfund Research Program, or SRP), which played a dynamic role in the PBC from its early days. In addition, a sub-focus on children's environmental health emerged, which helped set the agenda for children's environmental health research in the region. Progress has also been made in reducing harm from some threats, particularly via extensive interventions to remediate arsenic in drinking water in Bangladesh, western Thailand, and Vietnam. However, many of the environmental health problems in the Pacific Basin region persist, including air pollution, inadequate safe drinking water, undernutrition, and a growing electronic waste problem. In the Pacific Basin and elsewhere, people with the lowest incomes often live in areas with the worst pollution. Although it is difficult to implement, dynamic strategic networking efforts are vital to understanding and correcting the inequities that persist in global environmental health. The PBC can help accomplish this by continuing and expanding its work to foster and enhance collaborations and communications between environmental health and engineering investigators and to integrate investigator-initiated research. As the PBC looks forward, there is also a need to exert increased effort to establish and maintain partnerships, to develop community-based primary-care and health services for vulnerable populations, as well as to connect with researchers in the eastern side of the Pacific basin and those in smaller island states.

Keywords: air pollution; cooperative research; drinking water; electronic waste; environmental justice; environmental threats; Superfund Research Program.

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Introduction

As in any region of the world, the Pacific Basin faces its own unique health problems. Throughout the region, which includes the lands around the rim of and in the Pacific Ocean, environmental threats to vulnerable populations present a significant public health challenge. Specific threats include air pollution, inadequate safe drinking water, undernutrition, and a growing electronic waste problem. The Pacific Basin Consortium (PBC) works to address such problems. Formed in 1986 to address toxic waste pollution, the consortium has, in subsequent years, attracted an ever-widening audience and membership, including many investigators from the National Institutes of Health (NIH) National Institute of Environmental Health Sciences (NIEHS) Superfund Hazardous Substances Basic Research and Training Program (Superfund Research Program, or SRP). Today, the PBC has evolved into a forum for individual researchers and engineers, as well as organizations with diverse professional expertise, to come together and discuss the most pressing environmental and health issues of our time, engage in cooperative research, and develop and disseminate innovative strategies for addressing these issues. Critical to the PBC mission is the interplay between the biomedical sciences and the engineering sciences, whereby the observed human health effects of environmental exposures can be assessed and prevented.

As the PBC reaches the milestone of its 25th year, the problems that it aims to solve are growing in complexity. One-quarter to one-third of all ill health in the world today seems to be attributable to environmental factors. Environmental quality plays a major role in both the infectious diseases and undernutrition that tend to affect the poorest population groups, as well as in the occupational exposures and emissions that tend to affect groups that live in more developed countries. Here, we review how the PBC has evolved, highlight the challenges it now faces in helping to solve the most pressing environmental health problems in the region, and suggest a way forward.

The beginning of the PBC

In 1986, toxic waste pollution was becoming a particularly serious problem in the Pacific Basin because of rapid industrial growth in the region. That year, to help address these concerns, a group of scientists and engineers from seven countries formed the PBC on Hazardous Wastes. The group aimed to facilitate dialogue and cooperation among scientists, industry professionals, government officials, students, and policy makers. When first formed, the PBC included members from Australia, Canada, Japan, Korea, Mexico, Taiwan, and the United States. Representatives from the seven countries met on September 3–5, 1986, in Honolulu, Hawaii, during which they developed a broad plan for creating research facilities in each country. (Some of the key players in the formation of the PBC and in its subsequent evolution can be found in Table 1.)

A decade after that first meeting, the PBC began focusing on health, specifically a balance between engineering and public health. During the annual meeting in 1996 in Kuala Lumpur, Malaysia, the PBC focused on hazardous waste and global health. Over the years, the consortium has attracted a widening audience, including individuals and organizations interested in other environmental and health issues.

Homing in on children's health

In 2000, the PBC began to attend to the issue of children's environmental health, which would evolve into a full-fledged sub-focus for the organization. That year, a satellite meeting in Manila, the Philippines, brought together attendees representing 15 countries to focus on children as a population uniquely vulnerable to the environmental health problems in Asia. Through open discussion, the meeting increased the visibility of the existing programs targeted at environmental threats to the health of children within the different governments in Asia, and it also promoted regional cooperation on the issue.

Shortly after, in March 2002, as a direct result of the Manila meeting, the International Conference on Environmental Threats to the Health of Children was held in Bangkok, Thailand. The Conference brought together more than 300 representatives from 35 countries and organizations to increase awareness about environmental health hazards affecting children in Southeast Asia and the Western Pacific as these regions were going through rapid industrialization. The hazards addressed included historic problems like bacteria in drinking water and indoor air pollution from wood heating and cooking, as well as newer threats, including asbestos in construction, arsenic in groundwater, lead emissions from the use of leaded gasoline, and untreated manufacturing wastes

Table 1: Key players in the PBC through the years.

Name	Affiliations	Role in the PBC
Bob Arnold	Professor of Chemical and Environmental Engineering; University of Arizona SRP Grantee	Involved early on; currently the PBC vice-chair
David Carpenter	Director of the Institute for Health and the Environment, University at Albany; SRP grantee	Helped shift the PBC to focus more on human health
Peter Sly	Deputy Director, Queensland Children's Medical Research Institute; Advisor to the WHO, Public Health and Environment Section	Currently the PBC Chair
David Nelson	Engineer and founder of WorldRegs, LLC; Has expertise in multinational environmental corporate policies	Was on the PBC board of directors
Richard Cirillo	Director of the Decision and Information Sciences Division, Argonne National Laboratory	Helped form the PBC; led the 1988 PBC meeting on waste disposal, international trade of hazardous materials, landfill limitations on national islands, and fragile ecosystems in the Pacific Basin
Kirk Smith	Professor of Global Environmental Health, UC Berkeley	Helped start the PBC as a fellow of the East-West Center; previously the founder and head of the Energy Program of the East-West Center in Honolulu

in landfills. The meeting provided participants with the latest scientific data on children's vulnerability to environmental hazards as well as models for future policy and public health discussions on ways to improve children's health. The resulting Bangkok Statement was an important first step in creating a global alliance committed to developing active and innovative national and international networks to promote and protect children's environmental health (1).

In subsequent years, PBC researchers continued to help set the agenda for children's environmental health research in that part of the world. For instance, several PBC researchers collaborated to explore ethical issues on conducting biomarker research in children, especially in vulnerable communities in developing countries. The team emphasized the importance of biomarker research and identified ethical issues that are not insurmountable, but that should be given careful consideration (2).

All of these discussions and collaborations have helped stimulate other efforts to understand and prevent environmental contributors to children's health problems, including many of the research projects that are now a part of the Children's Health and Disease Prevention Research Centers jointly sponsored by the National Institute of Environmental Health Sciences and the U.S. Environmental Protection Agency. The PBC continues to nurture this important subfocus. The PBC meeting in 2009 featured a major symposium on lead exposure in children, resulting in the Perth Declaration for the Global Reduction of Childhood Lead Exposure. The most recent PBC meeting in 2013 included a training session and a series of talks about children's health.

The Superfund Research Program as an early partner

The SRP has played a vital role in the PBC from nearly its beginning. In 1986, the same year that the PBC was formed, the SRP was mandated by the US Congress to begin providing grantees research funding to improve understanding of how hazardous waste sites across the US can be remediated and how unwanted human exposure to these wastes can be prevented. The SRP and the PBC first formed their now ongoing relationship at the 1990 PBC meeting in Hawaii, and many SRP investigators have been involved in the PBC since its early days (Table 2). SRP grantees regularly participate in the PBC conference program and facilitate PBC goals to discuss pressing environmental health issues, engage in cooperative research, as well as develop and disseminate innovative strategies for addressing these issues and creating sustainable, affordable alternatives.

The research funded by SRP and its integration of biomedical research and non-biomedical research align well with the PBC mission. The SRP funds research related to remediation approaches; detection technologies; fate and transport modeling; bioavailability and ecotoxicity; and ecological and human risk assessments. A cornerstone of the SRP is that the evolution and maturation of hypothesis-driven basic research leads to increased opportunities for the translation of results into applied,'product-oriented' research that can be used for informing decisions about risk assessment.

SRP collaborates with several institutions in the Pacific Basin Region. Examples include several long-term investigations of the health effects from arsenic in drinking water in Bangladesh, from researchers at Columbia University. The researchers have assessed health effects from exposure to arsenic and manganese in water from conception to adolescence to adulthood, (3–10) worked to reduce arsenic exposure for 24,000 men and women, and endeavored to understand the processes affecting water quality in low-arsenic aquifers (11–15). In other examples, SRP investigators at Harvard University have conducted integral studies in metal toxicity in a cohort in Mexico that began in 1994. In addition, they have investigated the effects of metal exposure in Bangladesh (16–19).

Table 2: Superfund Research Program investigators involved in the PBC from the early days.

Name and affiliation	Role in PBC
Bob Arnold, Professor of Chemical and Environmental Engineering, University of Arizona	Involved early on; currently the PBC vice-chair
Martyn Smith, Professor of Toxicology, UC Berkeley	Has conducted work to understand the effects of childhood arsenic exposure in Chile and India
The late Patricia Buffler, Professor of Epidemiology and Public Health, UC Berkeley	Conducted and presented work on molecular epidemiology of childhood leukemia and was involved in several collaborations
David Carpenter, Director of the Institute for Health and the Environment, University at Albany	Helped shift the PBC to more of a focus on human health; currently the PBC treasurer and involved in several PBC collaborations

Tackling problems of growing complexity

In 2015, the PBC provides a forum for individual researchers and engineers, as well as organizations with diverse professional expertise and geographic backgrounds, to come together to discuss the most pressing environmental and health issues of our time, engage in cooperative research, and develop and disseminate innovative strategies for addressing these issues. Critical to the PBC mission is the interplay between the biomedical sciences and the engineering sciences, whereby the observed human health effects of environmental exposures can be assessed and prevented. In order to fulfill its mandates, the PBC has developed a framework that integrates the many different disciplines required to address the complex, fundamental issues related to environmental exposures. For instance, in studying arsenic contamination as a large part of the problem of unsafe drinking water, the PBC has included investigators studying not only arsenic health effects and routes of exposure, but also mechanisms behind various water treatment methods, disposal of arsenic-bearing residuals from water treatment, and the special link between arsenic exposure and cardiovascular disease (20).

Some of the health and hazardous waste problems the PBC originally set out to tackle have improved, whereas others remain much the same. Progress has been made in specific areas like the extensive interventions to remediate arsenic in drinking water in Bangladesh, western Thailand, and Vietnam. On the one hand, increased industrialization and accompanying reductions in poverty have brought improvements in environmental health in some parts of the region. As development helps people earn incomes, the immediate threats from lack of access to adequate food and drinking water can be alleviated.

On the other hand, some environmental health problems are exacerbated by development. The relationships among poverty, development, and exposure to toxic substances and other environmental health risks are complex. As development increases, new threats emerge, including occupational exposure to toxic substances and emissions from manufacturing or waste disposal (21). Another downside of development comes in the form of increased burden on public health infrastructures and city or town infrastructures.

Persistent threats to health and the environment in the Pacific Basin today stem from manufacturing, energy production, fossil fuel consumption, unsustainable resource use, and agriculture. All of these activities are associated with growing problems of hazardous waste, air and water pollution, and occupational exposures. The megacities like Mexico City and Santiago, Chile, still have some of the worst air pollution in the world (22, 23). In China, rapid industrialization and a coal-intensive energy economy has led to severe air pollution, including production of a third of the total global mercury emissions (23). In addition, China is still a major contributor to the world's sulfur dioxide emissions, despite a large decrease from the energy industry beginning in 2006 (24). Household air pollution (pollution from indoor burning of combustion fuels for cooking and heating) is a problem unto itself and is also a major contributor to overall ambient air pollution (25).

As in the past, inadequate safe drinking water jeopardizes human health in many different countries in the region. In addition to the traditional problems of bacterial contamination of groundwater, contamination of water from agricultural and industrial processes is an ever-growing issue, with health effects attributed to several contaminants in potable water, including arsenic and other metals, chlorinated hydrocarbon, and organophosphate pesticides (1). Going forward, the PBC must initiate more studies on the health effects of contamination of water by all of these various pollutants, using its extensive work on arsenic contamination in groundwater as a model.

Unaddressed threats

Undernutrition and stunting (short height for age) are entrenched problems that threaten the long-term health of children in the region and that have not been fully addressed by PBC research. Malnutrition as a whole, which includes stunting, wasting, fetal growth restriction and vitamin deficiencies, caused almost half (45%) of all childhood deaths in 2011 (26). In addition, stunting is associated with long-term effects on motor skills, lower IQs, and low levels of school achievement (27). Only 36 countries account for 90% of all the children who are stunted, and many of the affected countries are in South-central and southeastern Asia, where maternal undernutrition and stunting are serious, prevalent problems (28).

The stunting problem is made all the more difficult to tackle because it is passed on to subsequent generations. Women who are already malnourished become even more so during the extra demands of pregnancy. As a result, their offspring can experience intrauterine growth restriction and, subsequently, childhood malnutrition. This cycle is caused in part by poverty and food insecurity, which lead to many households lacking the resources to provide the extra nutrition women need during pregnancy. Even in households in which food insecurity is not a problem, lack of education and lack of power among women can also lead to unequal food distribution in the household, with expectant mothers' food needs still going unmet (28). Thus, adolescence, when many women in developing countries marry and begin to have children, is a crucial time for interventions that involve nutrition education and counseling (28). The stunting problem is aggravated by the high incidence of infectious illnesses in developing countries in the region. For instance, diarrhea caused by infectious illnesses increases stunting risk, perhaps via the malabsorption of nutrients (29).

Meanwhile, an environmental health threat that is gaining increasing attention is the recycling of electronic waste (e-waste), an ever-growing practice in the Pacific Basin. The practice poses health risk both to those who work in this largely unregulated industry as well as those who live near these operations. At present, China is the largest recycling site for e-waste, which contains such hazardous materials as lead, mercury, chromium, certain chemicals in plastics, and flame retardants (30). Workers are often exposed to these chemicals through direct contact or inhalation. People playing or living in or near informal recycling facilities can be exposed either directly via inhalation or skin contact or indirectly through pollution of food or water (31). More focus is needed to evaluate and prevent health risks caused by exposure to e-waste, particularly in children.

Overarching all of these challenges is the uncertainty of climate change; predicted shifts in habitat and storm frequency as well as the rising sea level will only exacerbate environmental problems in the Pacific Basin. For example, climate change is likely to worsen undernutrition through a variety of means, including effects on crop production, impacts on infectious diseases in humans, plant pests and diseases, labor productivity, and water availability. It has been estimated that climate change will have a significant impact on both moderate and severe stunting (32).

Another complicating factor, namely, vast differences in infrastructure and technological capabilities among countries that are adjacent to each other, create inequities in exposures and in environmental policy and regulations. For example, China's extensive development and industrialization may cause more pollution for nearby Vietnam, which has little resources to combat the problem. Within countries, the large number of internal migrants who leave poor, rural areas to find work in cities complicates the effective monitoring of exposures and diseases. In China, for instance, cancer and other disease cases are registered according to province of birth. Thus, cases among the large number of internal migrants may not be registered because these individuals are living outside their home province. Such situations complicate the measurement of exposure and disease as well as the creation of interventions and public health policies. The development of infrastructure and policy must take into account these regional challenges.

Moving forward

As we can see, the problems in the Pacific Basin region are growing ever more complex. These complexities heighten the importance of networks like the PBC. Basic science researchers, clinician-researchers, and public health officials are each accustomed to looking at questions in a specific way. However, such complicated problems require a transdisciplinary approach – bringing together researchers from different disciplines to transcend their fields to develop an entirely new language and way of looking at a problem. Combating these challenges will require a more intentional integration of disciplines to achieve a fundamental understanding of biological, environmental, and engineering processes (i.e. basic science) as well as the utilization of this knowledge to contribute to solving environmental exposure-related issues (i.e. applied science).

In addition, there is a need to obtain improved and more coordinated data collection and management on environmental exposures, to form regional and countrywide snapshots of exposures. Then, scientists must interrogate these data to better recognize how these exposures are linked to disease outcomes. To develop better prevention and intervention methods, scientists must consider the entire environmental pathway, including understanding the mechanisms and interactions between infectious agents, environmental exposures, and genetics and predisposition.

Accordingly, it would be of significant advantage to develop a dynamic strategic network to understand the relationship between environmental exposure and ill health. The PBC can help accomplish this goal by continuing and expanding its work to foster and enhance collaborations and communications between environmental health and engineering investigators and to integrate investigator-initiated research. There is also a need to increase its efforts to establish and maintain partnerships as well as to develop community-based primary-care and health services for vulnerable populations. The PBC has been quite successful in bringing together researchers in western pacific countries, the US, and Canada. However, it has been less successful at connecting with researchers in the eastern side of the Pacific basin and in smaller island states. Going forward, the consortium would do well to strive to be more conclusive and more informed from a geographic and geopolitical standpoint.

In these efforts, the PBC would do well to emulate elements of the SRP model. For example, in its research on arsenic, the SRP has conducted research to identify arsenic's health effects and the impact of nutrition on those effects, and to better understand the fate and transport of arsenic in groundwater. Subsequently, SRP is translating this research by communicating health findings to a broader audience, including federal, state, and local government partners; collaborating with other organizations to encourage well testing and inform the general public of the potential for arsenic concentrations in well water; installing deep wells to extract water containing less arsenic; encouraging the use of these deep wells; and applying arsenic remediation approaches to hazardous waste sites.

Other networks use an approach that emulates the SRP and can serve as additional models. One is the Asia Phenome Project, which will build upon existing epidemiologic studies by adding a host of modern measurement tools that, taken together, will provide the most detailed phenotypic definition of a population in any epidemiologic study to date. Another is the SE Asia-USA Global Human Health Sciences and Technology Initiative; this virtual infrastructure houses a team of scientists and engineers who conduct research in exposure biology, framed on emerging global health issues. Activities include the development of biomarker technology to accurately predict human biologic response to exposure induced by external agents. The initiative also practices disease intervention focused on a broad, informatics-based program aimed at identification of chemical agents that result in reduction in disease burden.

Although these are complex, such networking efforts are vital in correcting the inequities that persist in global environmental health. Somewhere between \$50–\$60 billion is spent every year for health research, but only 10% of that amount is used to conduct research on the health problems of 90% of the world's people. However, people in the poorest countries tend to be most at risk from the environmental problems discussed here. For example, in the Pacific Basin region and elsewhere, people with the lowest incomes often live in areas with the worst air pollution (20). In the mega-cities mentioned previously, children of low socioeconomic status are more highly exposed because they are more likely to live in high-density dwellings, live in the same building as a high-polluting business, or live close to high-traffic areas, factories, gas stations, or mechanical shops (33). By expanding its networking efforts and building on its past successes, the PBC is in a position to change some of these statistics.

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