HAPI

Health
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Toxics, Health, and Place

A RESEARCH BRIEF
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Photo by Ann Forsyth

The HEALTH AND PLACE INITIATIVE (HAPI) investigates how to create healthier cities in the future, with a specific emphasis on China. Bringing together experts from the Harvard Graduate School of Design (HGSD) and the Harvard School of Public Health (HSPH), it creates a forum for understanding the multiple issues that face cities in light of rapid urbanization and an aging population worldwide.

Health and Places Initiative
http://research.gsd.harvard.edu/hapi/
Harvard Graduate School of Design

The Research Briefs series summarizes recent research on links between human health and places at the neighborhood or district scale and provides background for a number of other forthcoming products—a set of health assessment tools, planning and urban design guidelines, urban design prototypes, and neighborhood cases. While the Research Briefs draw out implications for practice, it is these other tools that really provide specific, real-world guidance for how to create healthy places.

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Big Ideas

- Exposure to environmental toxins can cause many severe health effects on any organ of the body: anything from respiratory infections, to birth defects, cancer, or death.
- Fetuses, infants, and children are especially susceptible to health impacts from toxic exposure.
- Air pollution (indoor and outdoor) causes the greatest health impacts due to toxic exposure; other examples are from occupational and accidental household exposures.
- Current research on environmental toxicology can be roughly divided into two approaches: the disease impact of particular chemicals and the effect of proximity and thresholds of toxins on health.
- Unfortunately, many specific thresholds for environmental exposure have not been found for environmental toxins.
- Where reasonable, planners should buffer residential places away from noxious land uses and sources of pollution.
- Policy makers should regulate toxic chemicals, especially toxic and industrial waste disposal, and ensure compliance with regulations.
- Measures should also be taken to protect water quality, clean up former industrial and waste sites before residential use, and reduce vehicle emissions.
- The HAPI Research Brief of Air Quality, Water Quality, and Housing are closely related to this topic.

What the Research Says

Health Issues

Pruss-Ustun et al. (2011) conducted a systematic review of 95 articles between 1990 and 2009, focused on what they term knowns and unknowns related to the burden of disease (measured as disability-adjusted life years) due to chemical exposure. They provide a table of main disease groups with suspected or confirmed linkage to chemicals.

Photo by Ann Forsyth

Occupational exposures to dusts, gases, and irritant chemicals have been linked to respiratory infections and chronic respiratory diseases.

Table 1. Main disease groups with suspected or confirmed linkage to chemicals.

Diseases	Examples of exposures	Examples of associated outcomes
Respiratory infections and chronic respiratory diseases	Occupational exposures to dusts, gases, irritant chemicals, fumes Second-hand smoke; occupational exposures to cleaning-agents, pesticides, hairdressings chemicals etc. Second-hand smoke Occupational exposure to asbestos Metal dusts, particulate matter	Chronic Obstructive Pulmonary Disease (COPD) Asthma onset and exacerbation Acute lower respiratory infections Asbestosis Bronchitis, pneumoconiosis, silicosis
Perinatal conditions	Material exposure to pesticides or other chemicals	Low-birth-weight and preterm infants
Congenital anomalies	Maternal exposure to pesticides, polychlorinated biphenyls (PCBs), polychlorinated dibenzofurants (PCDFs), lead, mercury, other endocrine disruptors	Various birth defects
Diseases of the blood	Lead, arsine, naphthalene, benzene	Anaemia, methaemoglobinemia
Cancers	Occupational exposures to carcinogens, aflatoxins in flood, second-hand smoke, outdoor air pollution by carbon particles associated with polycyclic aromatic hydrocarbons, asbestos, arsenic; volatile organic compounds such as benzene, pesticides, dioxins, etc.	Numerous cancer sites, including of the lung, skin, liver, brain, kidney, prostate, bone marrow, bladder
Neuropsychiatric and developmental disorders	Lead, methylmercury, polychlorinated biphenyls (PCBs), arsenic, toluene, etc.	Cognitive development, mental retardation, Parkinson disease, Attention-deficit disorder, Minamata disease
Sense organ diseases	Carbon disulfide, mercury, lead	Hearing loss
Cardiovascular diseases	Ultrafine particles in polluted air, lead, arsenic, cadmium, mercury, pollutant gases, solvents, pesticides, second-hand smoke	Ischaemic heart disease, cerebrovascular disease
Diabetes mellitus	Arsenic, N-3-pyridylmethyl-N'-p-nitrophenyl urea (rodenticide), 2,3,7,8-Tetrachlorodibenzo-p-dioxin	Diabetes Type II
Systemic auto immune diseases	Crystaline silica dust	Systemic sclerosis, systemic lupus, erythematosus, rheumatoid arthritis, systemic small vessel vasculitis
Endocrine diseases	Ethanol, hexachlorobenzene	Porphyria
Genito-urinary diseases	Beryllium, cadmium, lead	Calculus of kidney, chronic renal diseases
Digestive diseases	Ethanol, chloroform, carbon tetrachloride, manganese	Hepatitis, cholestasis, pancreatitis
Skin diseases	Antiseptics, aromatic amines, cement, dyes, formaldehyde, artificial fertilizers, cutting oils, fragrances, glues, lanolins, latex, metals, pesticides, potassium dichromate, preservatives	Atopic dermatitis, allergic and irritant contact dermatitis, chloracne, hyperkeratosis
Musculoskeletal diseases	Cadmium, lead	Osteoporosis, gout
Oral conditions	Fluoride	Dental fluorosis
Poisonings	Accidental ingestion of household products, occupational exposures and accidents, intentional self-harm by ingestion of pesticides	Unintentional poisonings, self-inflicted injuries

Source: Pruss-Ustun et al. 2011, 4, used with permission.

Overall, it is obvious that exposure to environmental toxins is a concern to human health.

Example: Pruss-Ustun et al.'s (2011) systematic review of 95 articles between 1990 and 2009 found, "In total, 4.9 million deaths (8.3% of total) and 86 million Disability-Adjusted Life Years (DALYs) (5.7% of total) were attributable to environmental exposure and management of selected chemicals in 2004" (Pruss-Ustun 2011, 1). Many of the tools to combat these involve regulations. "The known burden due to chemicals is considerable…public health interventions [that] manage chemicals and limit their public health impacts… should be implemented at national and international levels" (Pruss-Ustun 2011, 1).

There is a rich literature on various forms of toxic chemicals, with many systematic reviews of multiple studies of specific toxins. However, not all are related to issues controllable by the planning and environmental design fields.

Examples: Studies have focused on such chemicals as organic solvents are used in "dry cleaning, paint thinner, nail polish removers and glue solvents, spot removers, detergents, perfumes, nail polish and chemical synthesis" (Barragan-Martinez et al. 2012, 1), brominated flame retardants (Kim 2014, 1), and insecticides (Koureas 2012, 1).

See also HAPI Research Briefs on Air Quality, Water Quality, and Housing.

Photo by Ann Forsyth

Children are especially susceptible to negative health effects from environmental hazards.

Place Issues

Pruss-Ustun et al. (2011) conducted a systematic review of 95 articles between 1990 and 2009, focused on what they term knowns and unknowns related to the burden of disease due to chemicals. They provide a table of sources and pathways of human exposure to a few selected chemicals (Table 2). As can be seen, some of the exposure is due to individual behaviors but the environment is key in several areas, including the built or urban environment of buildings, neighborhoods, and cities.

Table 2. Examples of sources and pathways of human exposure to a few selected chemicals.

Exposure media	Example sources of exposure and exposure pathways	Examples of chemicals
Outdoor air	Inhalation of toxic gases and particles from vehicle and industrial emissions, or naturally occurring sources such as volcanic emission or forest fires	Sulfur dioxide, nitrogen oxides, ozone, suspended particulate matter, lead, benzene, dioxins and dioxins-like compounds
Indoor air	Inhalation of pollutants released during indoor combustion of solid fuels, tobacco smoking, or from construction materials and furnishings, contaminants in indoor air and dust	Suspended particulate matter, nitrous oxide, sulfur oxides, carbon monoxide, formaldehyde, polyaromatic hydrocarbons (PAH), mercury, lead dust from lead-based paints, benzene, asbestos, mycotoxins, phthalates, polybrominated diphenyl ether fire retardants (PBDEs)
Drinking water	Ingestion of drinking water contaminated with toxic chemicals from industrial effluents, human dwellings, agricultural runoff, oil and mining wastes, or from natural sources	Pesticides, herbicides, fertilizers, metals (copper, lead, mercury, selenium, chromium), arsenic, fluoride, nitrate, cyanide, industrial, solvents, petroleum products, disinfection by-products
Food	Consumption of food contaminated with chemicals at toxic levels through agricultural practices, industrial processes, environmental contamination, and natural toxins	Pesticides, methylmercury, lead, cadmium, dioxins, aflatoxin
Non-food consumer products	Exposure by ingestion, inhalation or dermal exposure to toxic chemicals contained in toys, jewelry and decoration items, textiles, or food containers, consumer chemical products	Lead, mercury, cadmium, phthalates, formaldehyde, dyes, fungicides or pesticides
Soil	Ingestion (particularly for children) or inhalation of soil contaminated through industrial processes, agricultural processes or inadequate household and industrial waste management	Heavy metals, pesticides, and persistent organic pollutants
Occupation exposure	Chronic or acute exposures through inhalation, dermal absorption, or secondary ingestion of toxic chemicals or by-products of industrial processes such as agriculture, mining or manufacturing	Pesticides, benzene, heavy metals, solvents, suspended particulate matter
Human to human	Fetal exposure to toxic chemicals during pregnancy (through placental barrier) or through consumption of contaminated breast milk	Heavy metals, pesticides, benzene, etc.

Source: Pruss-Ustum 2011, 3, used with permission.

Residential proximity is a factor in the effect of environmental toxins on health.

Example: In a systematic review of 94 studies examining residential proximity to environmental hazards and health outcomes, Brender et al. (2011) conclude, "Residential proximity to roads; to coke works, copper smelters, refineries, nuclear power plants, or other stationary point sources of air pollution; or to hazardous waste sites were associated with asthma, respiratory illnesses, heart disease, non-Hodgkin's lymphoma, end-stage renal disease, or adult leukemia" (Brender et al. 2011, 49).

Example: Porta et al.'s (2009)'s systematic review (49 papers included) of the health effects of solid waste management found some evidence for negative effects, though it was limited: In "populations living within two kilometers of landfills there was limited evidence of congenital anomalies and low birth weight…and for populations living within three kilometers of old incinerators, there was limited evidence of an increased risk of cancer" (Porta 2009, 1).

Example: Sepulveda et al. (2010) reviewed over 130 articles from the past 15 years on the effects of toxics released by recycled electronic equipment. They found, "Very high levels of lead, polybrominated diphenylethers, polychlorinated dioxins and furans and polybrominated dioxins and furans [were found] in air, bottom ash, dust, soil, water and sediments in waste electrical and electronic equipment recycling areas of [China and India]" (Sepulveda 2010, 1).

See also HAPI Research Briefs on Air Quality, Water Quality, and Housing.

Vulnerable Groups

Table 3. Groups vulnerable to health effects from toxins[1]

Group	Health Effects	Sources of Toxins
Pregnant women	Low-birth weights and congenital malformations	$PM_{2.5}$ particulate matter, dioxins, close proximity to waste/landfill sites, incinerators, industrial areas (especially contaminated with lead), pesticides, insecticides (OP, PYR), roadways and dense traffic (less so)
Children	Cancer, respiratory issues, lead poisoning, unintentional acute poisonings	$PM_{2.5}$ particulate matter, lead poisoning, dioxins, proximity to waste/landfill sites, incinerators, traffic-related pollution, pesticides, insecticides (OP, PYR), gas stations, repair garages, nuclear power plants, brominated flame retardants
Men	Occupational exposure and systemic sclerosis, neurological and reproductive effects	Organic solvents, insecticides (OP, PYR)
Residential proximity (adults) (more likely disproportionately borne by low-income, communities of color)	See Table 2	Roads, cokeworks, copper smelters, refineries, nuclear power plants, other stationary point sources of air pollution, hazard waste sites

1. Barragan-Martinez 2012, 10; Brender et al. 2011, S38, S49; Kim et al. 2014; Koureas et al. 2011, 155; Porta 2009, 4, 6-7; Pruss-Ustun et al. 2011, 5; Sepulveda 2010, 36

Things for Certain (or semi-Certain)

Air pollution causes the most disease burden due to toxins (especially indoor air pollution).

Example: Pruss-Ustun et al.'s (2011) systematic review (95 articles) provided an overview of the global burden of disease attributable to environmental exposure and management of selected chemicals. They conclude, "By far the largest disease burden is related to air pollution mixtures with 70% of the total" (Pruss-Ustun et al. 2011, 10) (see Figure 1).

See also the HAPI Research Brief on Air Quality.

In general, living near at least some actively used hazardous waste or industrial sites, cropland with pesticide applications, heavy road traffic, or nuclear power plants is associated with impacts on human health.

Example: Brender et al.'s (2011) review of residential proximity to environmental hazards and health outcomes states, "Several studies have found that living near hazardous waste sites, industrial sites, cropland with pesticide applications, highly trafficked roads, nuclear power plants, and gas stations or repair shops is related to an increased risk of adverse health outcomes" (Brender et al. 2011, S37).

Things up in the Air

Environmental exposure to brominated flame retardants or BFR (commonly used in furnishings household objects), is potentially harmful to human health with inconclusive evidence.

Example: Koureas et al.'s (2012) systematic review of exposure to insecticides and human health found, "Regarding the association between biomarker levels [of brominated flame retardants] and neurologic effects in occupationally exposed males, DNA damage, birth outcomes and neurobehavioral deficits as a consequence of children's exposure, some suggestions are provided, but the results are inconclusive" (Koureas et al. 2012, 166).

Example: A systematic review of health consequences of exposure to brominated flame retardants states, "Possible evidence" exists for a relationship between BFR exposure and alteration of thyroid hormone levels, neurodevelopmental disorders, diabetes, and reproductive health, particularly decreased birth weight and longer time to pregnancy and possibly cancer but more well designed research is needed to support these tentative but biologically plausible associations" (Kim et al. 2014, 16).

There is inconclusive evidence of a relationship between residential proximity to solid waste management sites (composting, solid waste, landfills, incinerators) and health effects. This is likely contingent on how well these sites are managed and regulated.

Example: Porta et al.'s (2009) systematic review (49 included articles) of the health effects of solid waste management found, "the overall evidence was inadequate to establish a relationship between a specific waste process [composting, solid waste, incinerator] and health effects" (Porta et al. 2009, 8).

Implications

In these HAPI Research Briefs we aimed to find implications for planning and design at roughly the neighborhood level. These could include quantifiable standards, more qualitative but yet evidence-supported insights, and other good practices. Not every topic has a full complement of these implications.

Standards

Development should be sited at some distance from solid waste dumps and nuclear facilities—with the distance varying by type of facility and available pollution control technologies.

Example: As noted above, Porta et al.'s (2009) systematic review of the health effects of solid waste management found a small but significant risk of living near such facilities: "For populations living within two kilometers of landfills there was limited evidence of congenital anomalies and low birth weight with excess risk of 2 percent and 6 percent, respectively. The

excess risk tended to be higher when sites dealing with toxic wastes were considered. For populations living within three kilometers of old incinerators, there was limited evidence of an increased risk of cancer, with an estimated excess risk of 3.5 percent" (Porta et al. 2009, 8).

Example: United States Nuclear Regulatory Commission (NRC) regulations describe different buffer distances commonly used to control land use and population growth near nuclear power plants in the United States. There are three zones required by the United States NRC: an exclusion zone (based on potential radiation exposure, very close to the plant, such as 0.4 miles, where no homes are allowed), a low population zone (based on potential radiation exposure, approximately 2–3 miles from the plant, surrounding the exclusion zone) and a population center distance (at least one and one-third times the distance from the reactor to the outer boundary of the low population zone, but locations near large populations may need greater population center distance — e.g. 10 miles, 30 miles) (Nuclear Regulatory Commission Regulation 100.11; Pearlman and Waite 1984, 16-18).

One useful definition of the precautionary principle comes from the United Nations Rio Declaration on Environment and Development which says, "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (United Nations 1972).

Example: "The evidence at this time is sufficient to justify the application of the precautionary principle to protect people from the deleterious effects of living near environmental hazards. Even in the absence of complete scientific proof, enough evidence of potential harm being done exists to justify taking steps to rectify the problem and to protect the public from potentially harmful exposures when all available evidence points to plausible risk" (Brender et al. 2011, S50).

Table 4 below gives an overview of toxics and locations limited to those most amenable to urban planning and policy interventions (excludes occupational exposures, self-inflicted, unintential acute poisonings). They are listed in descending order of importance based on health impacts (based on Pruss-Ustun 2011).

Insights

Use a precautionary principle to site developments and environmental hazards. However, one issue is how cautious to be as buffering spreads out development which can have unintended consequences (e.g. harder to walk for transportation).

Photo by Ann Forsyth

Residential proximity to environmental hazards is associated with negative health outcomes. Residential proximity is disproportionately borne by low-income communities.

Table 4. Planning and policy interventions to mitigate exposure to toxins in the urban environment.[2]

Toxics and Sources	Interventions
Indoor air pollution (solid fuel combustion, second-hand smoke, construction materials and furnishings)	• Smoke-free policies • Residential lead hazard control • Basic housing amenities (stoves, ventilation, etc.) • Regulation/certification of materials
Outdoor air pollutants (vehicle and industrial emissions, residential proximity to vehicle and industrial emissions)	• Site/map environmentally burdensome facilities and land uses • Regulatory and enforcement efforts concerning pollution • Active promotion of environmental health justice • Establishment of protective buffer zones around noxious land uses (e.g. prohibit schools near highways, cognizant of pesticide drift when planning residential locations) • Environmental mitigation and cleaning of former dumping areas of industrial and household wastes before used for residences • Promoting emission-reducing technologies and reduction in vehicle miles traveled
Single chemicals with longer term effects (mining, smelting, industrial and agricultural activities, discharge of industrial wastes, burning of fossil fuels, especially coal)	• Site/map environmentally burdensome facilities and land uses • Water quality protection (e.g. source protection, upgraded sanitation and sewage, buffer zones, regulations, land use controls) • Establishment of protective buffer zones around noxious land uses (e.g. prohibit schools near highways, cognizant of pesticide drift when planning residential locations) • Environmental mitigation and cleaning of former dumping areas of industrial and household wastes before used for residences

2. Brender et al. 2011, S50; Porta 2009, 3; Pruss-Ustun 2011; See Air Quality, Water Quality and Housing syntheses

Photo by Ann Forsyth

Establishment of protective buffer zones around noxious land uses, and environmental cleaning of dumping areas are important strategies to mitigate exposure to toxins in the environment.

Sources

Barragán-Martínez, Carolina, Cesar A. Speck Hernández, Gladis Montoya-Ortiz, Rubén D. Mantilla, Juan-Manuel Anaya, and Adriana Rojas-Villarraga. 2012. "Organic solvents as risk factor for autoimmune diseases: A systematic review and meta-analysis." *PLoS ONE* 7(12): e51506.

Brender, Jean D., Juliana A. Maantay, and Jayajit Chakraborty. 2011. "Residential proximity to environmental hazards and adverse health outcomes." *American Journal of Public Health* 101 (S1): S37–52.

Kim, Young Ran, Fiona A. Harden, Leisa-Maree L. Toms, and Rosana E. Norman. 2014. "Health consequences of exposure to brominated flame retardants: A systematic review." *Chemosphere* (0).

Koureas, Michalis, Andreas Tsakalof, Aristidis Tsatsakis, and Christos Hadjichristodoulou. 2012. "Systematic review of biomonitoring studies to determine the association between exposure to organophosphorus and pyrethroid insecticides and human health outcomes." *Toxicology Letters* 210 (2) (4/25): 155–68.

Pearlman, Kenneth and Nancy Waite. 1984. "Controlling land use and population growth near nuclear power plants." *Journal of Urban and Contemporary Law* 27(1/3): 9–234.

Porta, Daniela, Simona Milani, Antonio Lazzarino, Carlo Perucci, and Francesco Forastiere. 2009. "Systematic review of epidemiological studies on health effects associated with management of solid waste." *Environmental Health* 8(1): 60.

Pruss-Ustun, Annette, Carolyn Vickers, Pascal Haefliger, and Roberto Bertollini. 2011. "Knowns and unknowns on burden of disease due to chemicals: A systematic review." *Environmental Health* 10(1): 9.

Sepúlveda, Alejandra, Mathias Schluep, Fabrice G. Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken, and Andreas C. Gerecke. 2010. "A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from china and india." *Environmental Impact Assessment Review* 30(1): 28–41.

United Nations. 1972. Report of the United Nations Conference on the Human Environment, Rio de Janeiro, 3-14 June 1972. http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm

United States Nuclear Regulatory Commission. 2014. Regulation 100.11. Determination of exclusion area, low population zone, and population center distance. http://www.nrc.gov/reading-rm/doc-collections/cfr/part100/part100-0011.html. Website last reviewed and updated July 10, 2014. Accessed July 22, 2014.