# THE PUBLIC HEALTH IMPACT OF CHEMICALS: KNOWNS AND UNKNOWNS

International Programme on Chemical Safety

World Health Organization

WHO/FWC/PHE/EPE/16.01



Editorial consultant: Vivien Stone

Cover photos (top to bottom): iStock/Dirk Freder, iStock/Lisa_Rivali, Shutterstock/Mikhail Malyshev.

Design and layout by L'IV Com Sàrl, Villars-sous-Yens, Switzerland.

Printed by the WHO Document Production Services, Geneva, Switzerland.

## ACKNOWLEDGEMENTS

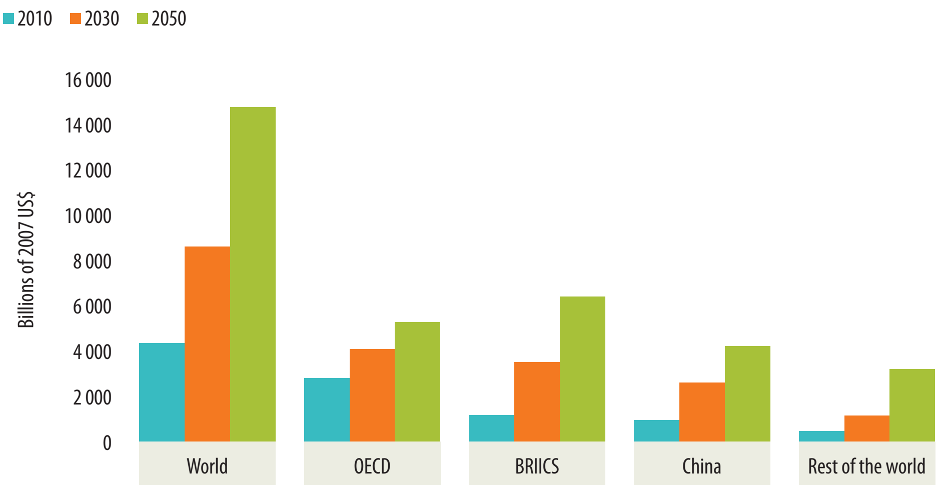
Thanks are due to J Wolf, A Prüss-Ustün and C Vickers from the Department of Public Health, Environmental and Social Determinants of Health, World Health Organization, Geneva, for their work in producing this publication.


**Removing the most toxic pesticides from agricultural practice and reducing access to pesticides would prevent many poisonings.**

# INTRODUCTION

Exposure to various chemicals occurs every day and through multiple routes such as ingestion, inhalation, skin contact and via the umbilical cord to the unborn child. Many chemicals are harmless or even beneficial; others are a threat to our health and to the environment. Chemicals production continues to increase and, with it, the potential for chemical exposure. As shown in Figure 1 the fastest growth in chemical production is projected to be in non-OECD countries. The chemicals explored in this publication are hazardous to human health and exposure could potentially be reduced or removed through environmental management. They include pesticides, asbestos, various other household and occupational chemicals, ambient and household air pollution, second-hand tobacco smoke, lead and arsenic. Estimates of health impacts are presented for a selection of chemicals with sufficient evidence for global quantification.

**Figure 1. Projected chemicals production (sales) by region, "Baseline" scenario, 2010–2050**




Source: *OECD Environmental Outlook to 2050: The Consequences of Inaction*, (Chapter 6: Health and Environment) (OECD, 2012, doi: http://dx.doi.org/10.1787/9789264122246-en).

## METHODS TO QUANTIFY POPULATION HEALTH IMPACTS

The population attributable fraction (PAF) is the proportional reduction in death or disease that would occur if exposure to a risk were removed or maximally reduced to an alternative level. To quantify population health impacts from exposure to chemicals, a systematic literature review compiled estimates and summaries of chemical exposure and links between the respective chemicals and disease or injury. The preferred source was global estimates of population impacts for selected chemicals based on comparative risk assessment (CRA), followed by estimates based on more limited epidemiological data or, finally, expert opinion (see Prüss-Ustün et al, 2016[1] for details on methods).

## CHEMICALS AND THE SUSTAINABLE DEVELOPMENT GOALS

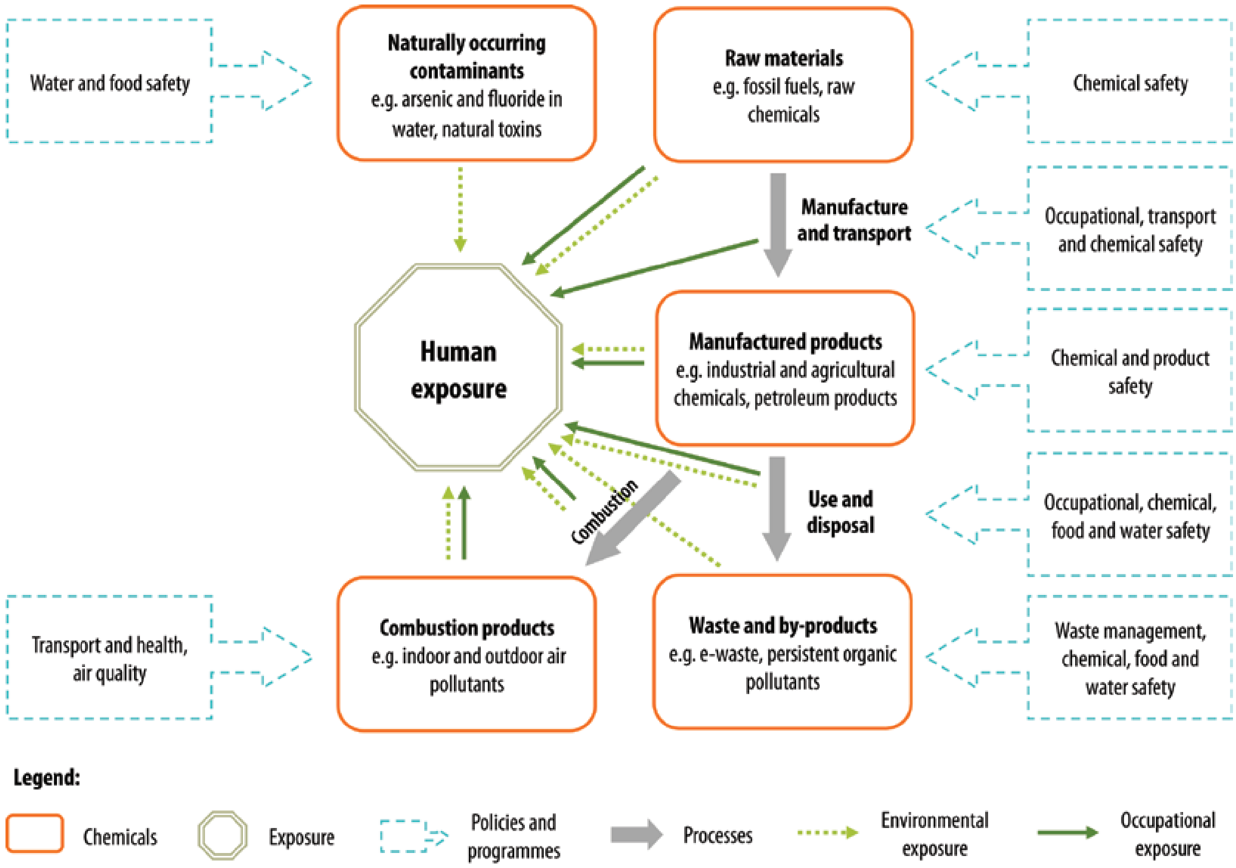
Reducing exposure to hazardous chemicals is essential to achieving the Sustainable Development Goals (SDGs), which aim:

By 2020, to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment (Target 12.4).

By 2030, to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination (Target 3.9).

By 2030, to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally (Target 6.3).

**Figure 2. Human exposure to chemicals throughout their life cycle and selected programmes relevant to their prevention**




Source: Knowns and unknowns on burden of disease due to chemicals: A systematic review, Prüss-Ustün et al (2011).

Coal-fired power stations contribute to ambient air pollution and are a major source of mercury emissions.

# POPULATION HEALTH IMPACTS FROM THE ENVIRONMENT BY DISEASE GROUP

Just over one third (35%) of **ischaemic heart disease**, the leading cause of deaths and disability worldwide, and about 42% of **stroke**, the second largest contributor to global mortality, could be prevented by reducing or removing exposure to chemicals such as from ambient air pollution, household air pollution, second-hand smoke and lead.[1]

Chemicals such as heavy metals, pesticides, solvents, paints, detergents, kerosene, carbon monoxide and drugs lead to **unintentional poisonings** at home and in the workplace. Unintentional poisonings are estimated to cause 193 000 deaths annually with the major part being from preventable chemical exposures.[1,2]

The list of chemicals classified as human carcinogens with sufficient or limited evidence is long.[3] Occupational carcinogens are estimated to cause between 2% and 8% of all **cancers**.[4] For the general population it is estimated that 14% of lung cancers are attributable to ambient air pollution, 17% to household air pollution, 2% to second-hand smoke and 7% to occupational carcinogens.[1,2,5]

A centuries' old scene – a worker washes leather before it is dyed (Fez, Morocco). Many chemicals used in the leather tanning industry have been linked to various forms of cancer.

Exposure to certain chemicals, such as lead, is associated with reduced neurodevelopment in children and increases the risk for attention deficit disorders and intellectual disability. Parkinson's disease has been associated with exposure to pesticides. Other links between **mental, behavioural and neurological disorders** are suspected; evidence, however, is more limited.[1]

Air pollution and second-hand smoke are risk factors for **adverse pregnancy outcomes** like low birth weight, prematurity and stillbirths. Antenatal exposure to second-hand smoke for example was estimated to increase the overall risk for stillbirths by 23% and for congenital malformations by 13%.[6] There are, furthermore, potential links between various chemicals and adverse pregnancy outcomes or congenital malformations, though evidence is limited.[1]

**Cataracts**, the most important cause of blindness worldwide, can develop from exposure to household air pollution. Exposure to cookstove smoke was estimated to be responsible for 35% of cataract disease burden in women and 24% of the overall cataract disease burden.[2,7]

Second-hand smoke and air pollution are also responsible for 35% of **acute lower respiratory infections**, including pneumonia, bronchitis and bronchiolitis, the most important cause of mortality in children, and are also linked to upper respiratory infections and otitis media.[1,2,5]

More than a third (35%) of overall chronic obstructive pulmonary disease **(COPD)** burden is caused by exposure to chemicals in second-hand smoke, air pollution or occupational gases, fumes and dusts.[2,5] Second-hand smoke and air pollution can induce reduced lung function and a predisposition for pulmonary disease in unborn and young children.[1]

Second-hand smoke and air pollution can lead to the development of, and increased morbidity from, **asthma**. Air pollution additionally provokes asthma exacerbations and increases related hospital admissions. Asthma from occupational asthmagens is among the most frequent diseases related to the workplace.[1]

Over 800 000 individuals die from **suicides** every year.[2] About 20% of suicides could be prevented through restricting access to poisons (estimate based on expert survey and limited epidemiological data). Self-poisoning with pesticides is the main means of suicide in India, China and some central American countries.[1,2,8,9,10]

### Chemicals and air pollution

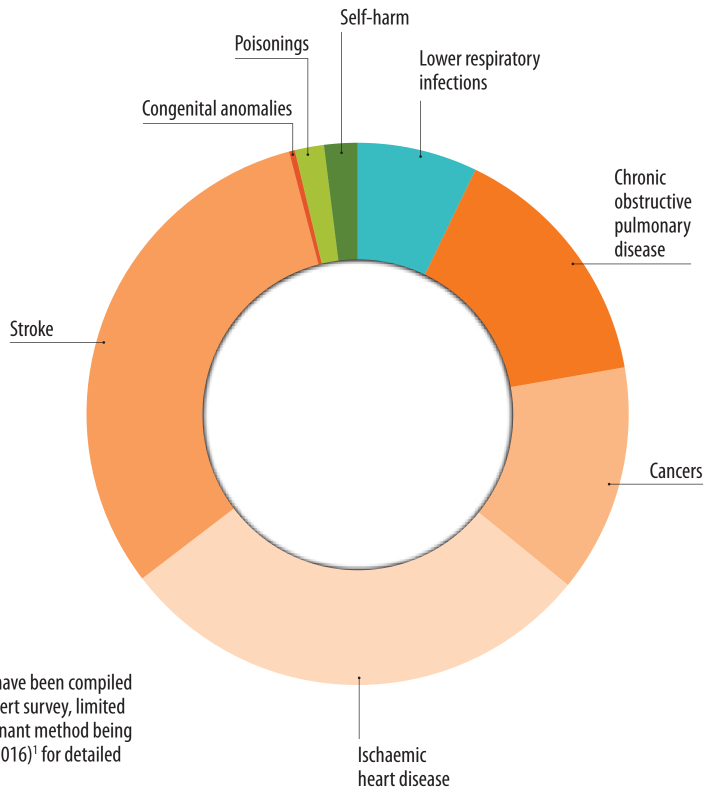
Air pollutants from ambient and household sources are a mixture of many components including, for example, carbon monoxide (CO), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$) and particulate matter, the last containing substances such as acids, organic chemicals, metals, soil and dust particles.[11] The way chemicals are managed can directly contribute to air pollution. One example is the use of pesticides in agriculture, which can volatilize and suspend into the air when sprayed.[12] Phasing out leaded gasoline has reduced the amount of airborne lead. However, the largest sources of air pollution are combustion and other processes from energy generation, industry and transport.[13] Nevertheless, because of the chemical composition of air pollution which can vary to a large extent depending on prevailing pollution sources, the assessment of health hazards from these chemicals remains important.

**Table 1. Overview of the disease burden preventable through sound management and reduction of chemicals in the environment (2012)**

| Chemicals/groups of chemicals | Disease outcomes considered (population attributable fraction of DALYs) | Deaths (% total deaths) | DALYs (% total DALYs) | Method |
|---|---|---|---|---|
| **Chemicals in acute poisonings** | | | | |
| Chemicals involved in preventable, unintentional acute poisonings (methanol, diethylene glycol, kerosene, pesticides etc.) | Unintentional poisonings (73%) | 137 300 | 7 825 000 | Expert survey[c] |
| Chemicals involved in unintentional occupational poisonings (already included in the above poisonings) | Unintentional poisonings (occupational) (14%) | 27 100 | 1 505 000 | CRA[d] |
| Pesticides involved in self-inflicted injuries | Self-inflicted injuries (20%) | 156 200 | 7 714 000 | Limited epidemiological data[c] |
| **Single chemicals with mostly longer term effects** | | | | |
| Lead[a] | Idiopathic intellectual disability (9.8%); IHD (4%); stroke (4.6%) | 674 000 | 13 936 000 | CRA[d] |
| **Chemicals in occupational exposures (longer term effects)** | | | | |
| Occupational lung carcinogens (arsenic, asbestos, beryllium, cadmium, chromium, diesel exhaust, nickel, silica) | Trachea, bronchus, lung cancer (6.6%) | 99 100 | 2 546 000 | CRA[d] |
| Occupational leukaemogens (benzene, ethylene oxide, ionizing radiation) | Leukaemia (1.1%) | 3 000 | 118 000 | CRA[d] |
| Occupational particulates – causing COPD (dusts, fumes/gas) | COPD (12%) | 233 500 | 10 970 000 | CRA[d] |
| **Air pollutant mixtures** | | | | |
| Ambient air pollutants (particulate matter, sulfur dioxide, nitrogen oxides, benzo[a]pyrene, benzene, others) | ALRI (7.9%); COPD (9.4%); IHD (24%); lung cancer (14%); stroke (25%) | 3 732 500 | 100 125 000 | CRA[c] |
| Household air pollutants from solid fuel combustion (carbon monoxide, nitrogen oxides, sulfur oxides, benzene, formaldehyde, polyaromatic compounds, particulates, others) | ALRI (33%); cataracts (24%); COPD (24%); IHD (18%); lung cancer (17%); stroke (26%) | 4 261 500 | 144 789 000 | CRA[c] |
| Second-hand smoke (nicotine, formaldehyde, carbon monoxide, phenols, nitrogen oxides, naphthalenes, tar, nitrosamine, PAHs, vinyl chloride, various metals, hydrogen cyanide, ammonia, others) | ALRI (9.3%); IHD (3.6%); lung cancer (1.8%); otitis (2.3%); stroke (4%) | 601 900 | 19 931 000 | CRA[d] |
| **Subtotal chemicals without air pollution** | Considered diseases: poisonings, leukaemia, lung cancer, IHD, stroke, intellectual disability, COPD | 1 303 100 (2.3%) | 43 109 000 (1.6%) | |
| **Total[b]** | Considered diseases: poisonings, leukaemia, ALRI, IHD, stroke, lung cancer, COPD | 7 375 500 (13.4%) | 231 140 000 (9.4%) | |

Data sources: [c] Prüss-Ustün et al (2016),[1] [d] population attributable fractions from IHME (2014),[5] disease statistics from WHO (2015).[2]
Notes: DALYs: disability-adjusted life years; CRA: comparative risk assessment; COPD: chronic obstructive pulmonary disease; IHD: ischaemic heart disease; ALRI: acute lower respiratory infection. Only outcomes qualified as strong evidence were considered. On average and due to occupational exposures, men suffer a larger share of the disease burden attributable to chemicals compared with women (approximately 55% versus 45%).
[a] Based on limited evidence. [b] For calculation of total disease burden see Prüss-Ustün et al (2016);[1] the total does not correspond to the sum of the risks because of partial overlap.

**Figure 3. Total deaths attributable to chemicals by disease (includes risks assessed in Table 1 and additional environmental burden exclusively caused by chemicals)[1]**




Note: The estimates in figures 3–6 have been compiled by using various methods (CRA, expert survey, limited epidemiological data), the predominant method being CRA. See Table 1 and Prüss-Ustün (2016)[1] for detailed information.

**Figure 4. Percentage of global disease burden (in DALYs) attributable to chemicals by age**

Children are particularly vulnerable to both acute and chronic effects of chemicals, including acute poisonings, exposure to air pollution and prenatal exposure to chemicals. Older adults are more vulnerable to chronic effects from air pollution and exposure to various carcinogens.


Notes: Includes risks assessed in Table 1 and additional environmental burden exclusively caused by chemicals.[1] DALYs: disability-adjusted life years.

**Figure 5. Deaths attributable to chemicals (without ambient air pollution from combustion sources), by sex**

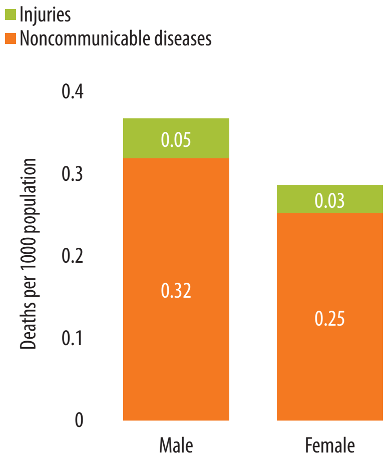
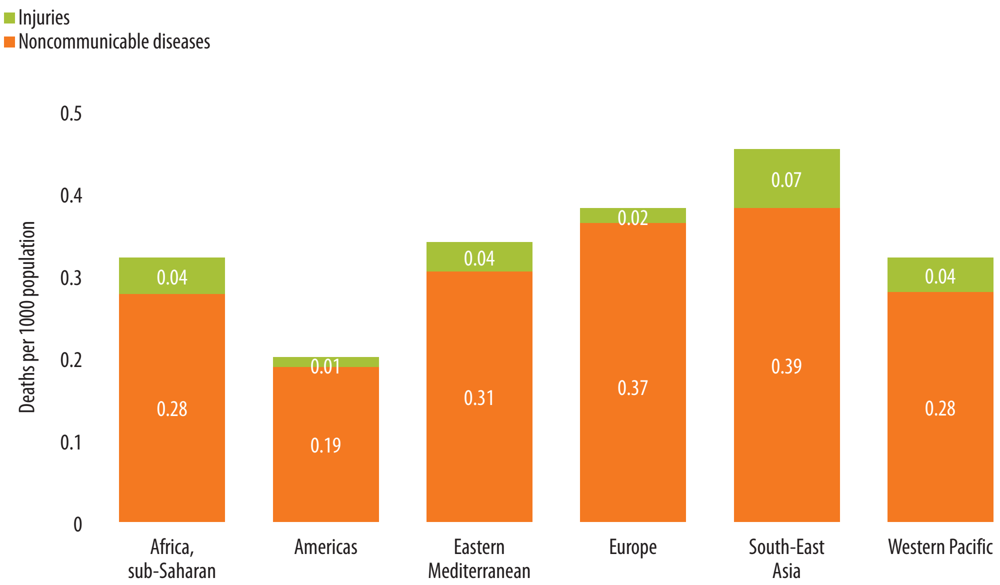


**Figure 6. Total age-standardized deaths attributable to chemicals (without ambient air pollution from combustion sources), by region and disease group**

The noncommunicable diseases are a result of the toxic effects of chemicals and air pollution on the cardiovascular system or that lead to malignant neoplasms; injuries are caused by unintentional poisonings and suicide attempts. Age-standardized measures of deaths and disease are often used to compare countries or regions, as they adjust for differences in population age distributions by applying the age-specific mortality rates for each population to a standard population.




In addition to occupational exposure, inappropriate disposal of building waste can expose the poorest communities to asbestos.

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# REDUCING OR REMOVING EXPOSURE TO CHEMICALS BY SECTOR

## EFFECTIVE INTERVENTIONS BY SECTOR[a]

### AGRICULTURE

Occupational and consumer exposure to chemicals: regulations, personal protective equipment.

- ✓ Banning the most toxic pesticide class in Sri Lanka significantly decreased suicides.

### INDUSTRY/COMMERCE

Air pollution: industrial emission control; improved energy options; indoor tobacco smoke-free legislation.
Occupational exposure to chemicals, air pollutants: workers' personal protection; education on protective behaviour; engineering approaches to reduce exposure, such as ventilation, dust suppression techniques, enclosure of pollution sources etc.; removal from sources of pollutants or other relevant exposures, regulations.
Exposure to industrial chemicals (workers, consumers): legislation, treaties.[b]
Water pollution: industrial emission control.

- ✓ Legislative smoking bans implemented for example in various European countries, Canada and the United States reduced exposure to second-hand smoke both in public and in workplaces and also reduced hospital attendance for childhood asthma, risk of acute coronary events and preterm births and improved cardiac health.
- ✓ Effective control measures in the workplace to reduce exposure to hazardous chemicals and to prevent work-related cancer, pneumoconiosis, chronic obstructive pulmonary disease and asthma include enclosure of pollution sources, local exhaust ventilation, specialized ventilation systems, dust suppression techniques and worker separation.
- ✓ Removing workers with occupational asthma from the relevant exposure reduced asthma symptoms and increased lung function. Eliminating exposure to asthma allergens was also effective for the primary prevention of occupational asthma.
- ✓ Banning the use of all forms of asbestos, phase-out of mercury, harmonized chemicals management, safe handling and disposal of obsolete pesticides and other obsolete chemicals, safe and environmentally sound waste management, legislation on cancer-related chemicals.
- ✓ Coincidental interventions such as a closure of a steel mill (United States) and a nationwide copper smelter strike (United States) decreased air pollution levels and health impacts.

### TRANSPORT

Air pollution: traffic control and improved public transportation schemes; reduction of traffic congestion; replacement of older diesel vehicles, etc.

- ✓ Ambient air pollution legislative interventions such as the reduction of fuel sulfur content (Hong Kong SAR, China), stronger regulations during Olympic Games (United States and China), congestion charging schemes (London and Stockholm) decreased different air pollutants and measurable adverse health impacts (mainly reduced cardiovascular and respiratory morbidity and mortality).
- ✓ Phasing out of leaded petrol was paralleled by a steady decline in the population's mean blood lead levels in most countries globally.

**HOUSING/COMMUNITY**

Household air pollution: use of clean fuels; strategies to reduce exposure to smoke from solid fuels – implementation of WHO Indoor Air Quality Guidelines.

Exposure to chemicals: safe management of chemicals in the home and community.

- ✓ Interventions reducing exposure to household solid fuel smoke through modern energy sources and cooking technologies reduced acute lower respiratory infections, lung function decline, respiratory symptoms and diastolic blood pressure.
- ✓ Home safety interventions conducted in many countries including the United States, Canada, Australia, South Africa and various European countries were effective in increasing the proportion of families storing medicines (53% increase) and cleaning products (55% increase) out of reach, and having the poison centre numbers accessible (330% increase).

**WATER**

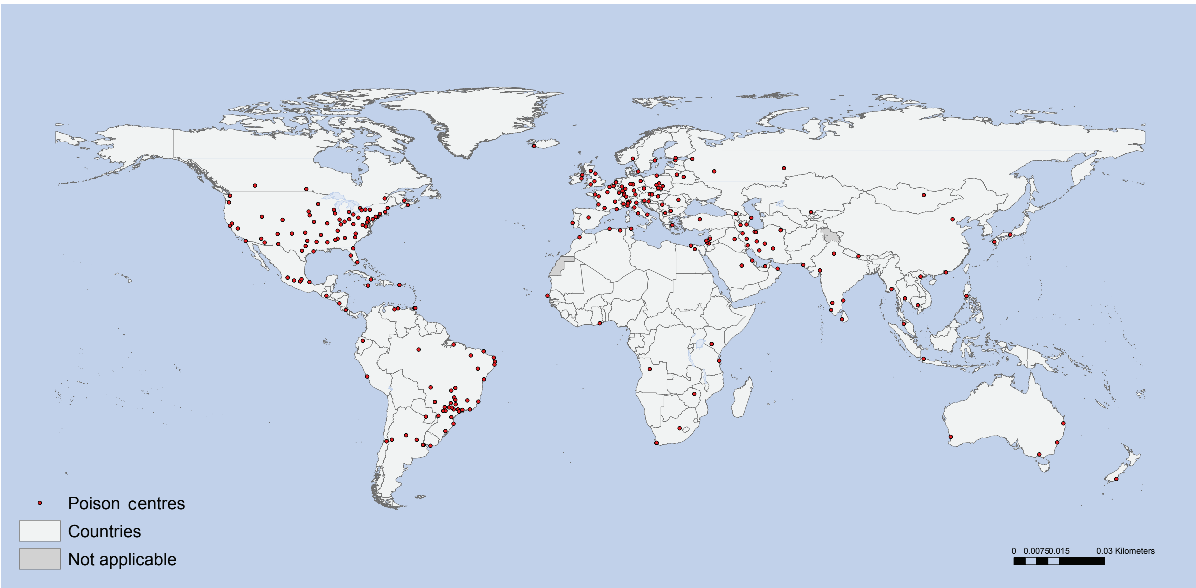
Exposure to arsenic and other chemicals in drinking-water: implementation of WHO Drinking-water Quality Guidelines; strategies to reduce exposure to arsenic and other chemicals in drinking-water.

- ✓ Provide drinking-water with arsenic below 10 µg/l in areas where level is high via:
  - Collecting rainwater (caveat: prevent microbial contamination and mosquito breeding);
  - Water testing for arsenic levels;
  - Centralized or domestic arsenic removal systems; and
  - Discriminating between high- and low-arsenic water sources.

Note: [a] Summary from the compilation developed in the framework of the WHO report (see Prüss-Ustün et al (2016)[1] for references); arsenic interventions are from http://www.who.int/ipcs/features/arsenic.pdf; [b] Examples: Minamata Convention on Mercury, Stockholm Convention on Persistent Organic Pollutants, Strategic Approach to International Chemicals Management, Basel Convention, International Programme on Chemical Safety, WHO Framework Convention on Tobacco Control, EU Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals.

**Figure 7. Poison centres (June 2015)**

A poison centre is a specialized unit that advises on, and assists with, the prevention, diagnosis and management of poisoning. Only 47% of countries have a poison centre, with particular gaps in the African and Eastern Mediterranean regions and in the small island states in the Western Pacific Region.




The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization
Map Production: Health Statistics and Information Systems (HSI)
World Health Organization

World Health Organization

## ECONOMIC EVALUATIONS BY SECTOR[a]

### AGRICULTURE

- Estimated annual illness costs of acute poisonings in Nepalese farmers due to pesticide use was nearly one third of total annual health-care costs.
- In Paraná, Brazil, for each dollar spent on pesticides, approximately US$ 1.28 may be spent on health care and sick leave due to occupational poisoning.

### INDUSTRY/COMMERCE

- In Hong Kong SAR, China, annual direct costs of medical care, long-term care and productivity loss from second-hand smoke were estimated at US$ 156 million.
- In the United States, the yearly treatment costs for ischemic heart disease from second-hand smoke were estimated between US$ 1.8–6.0 billion.
- Introducing smoke-free legislation in all United States workplaces would result in an estimated US$ 49 million savings in direct medical costs.
- Implementing smoke-free workplaces was estimated to be about nine times more cost-effective per new non-smoker than free nicotine replacement therapy programmes.
- Cleaning-up polluted industrial sites and hazardous waste dumps to prevent health effects in the Campania region in Italy was judged as cost-beneficial.
- Occupational cancer deaths in Italy were estimated to cost around €360 million in indirect economic loss and €456 million for health care. Occupational lung and bladder cancer cost the Spanish national health system €88 million. In France occupational respiratory cancers were also shown to be a considerable economic burden.
- Total costs of occupational asthma in the United Kingdom were estimated at between £95–135 million.

### TRANSPORT

- In Taiyuan, China, the total health damage from air pollution (particulate matter) was estimated to amount to 2.4–4.9% of the city's GDP.
- For Mumbai, India, the total costs of health impacts were estimated at US$ 113 million for a 50-mg/m$^3$ increase in $PM_{10}$, and US$ 218 million for a similar increase in $NO_2$.
- For Barcelona, Spain, reducing $PM_{10}$ exposure from 50 mg/m$^3$ to 20 mg/m$^3$ was estimated to lead to 3 500 fewer deaths, 1 800 fewer hospitalizations for cardio-respiratory diseases, 5 100 fewer cases of chronic bronchitis among adults, 31 100 fewer cases of acute bronchitis among children, and 54 000 fewer asthma attacks among children and adults and related savings of €6 400 million per year.
- For Denmark, the potential health-care system savings from reducing ambient air pollution ($PM_{2.5}$) and the resulting cost reductions for coronary heart disease, stroke, chronic obstructive pulmonary disease and lung cancer were estimated at €0.1–2.6 million per 100 000 people. The productivity costs from leaving the labour market due to those four diseases from exposure to $PM_{2.5}$ were estimated at €1.8 million per 100 000 people aged 50–70.
- Annual childhood asthma-related costs attributable to air pollution in two United States communities were estimated at US$ 18 million and were mainly borne by the children's families. Exposure to $PM_{2.5}$ was furthermore positively associated with increased costs of childhood asthma hospitalizations.
- The economic cost of premature deaths from ambient and household air pollution was estimated to amount to US$ 1.5 trillion in the European Union.

### HOUSING/COMMUNITY

- Lead-safe window replacements in all pre-1960 homes in the United States would yield a net benefit of at least US$ 67 billion; additional benefits would include, for example, avoided attention deficit hyperactivity disorder, reduced crime and delinquency, and associated long-term costs of climate change.
- Lead paint hazard control in homes to prevent children's exposure would yield a net saving of US$ 181–269 billion in the United States if considering costs of health care, lifetime earnings, tax revenue, special education, attention deficit hyperactivity disorder and direct costs of crime associated with elevated lead exposure. Investing in such control measures, especially targeted at early intervention of lead poisoning in communities most likely at risk, would be very cost-effective.
- Various interventions replacing solid fuels for cooking and heating or investing in cleaner cookstoves were evaluated as cost-effective.
- Regulations on residential wood burning in California, United States, were estimated to save between US$ 200–400 million mean annual mortality costs and between US$ 6–27 million morbidity costs from cardiovascular and respiratory diseases per metropolitan area.

Note: [a] Summary from the compilation developed in the framework of the WHO report (see Prüss-Ustün et al (2016)[1] for references).

**Figure 8. International Health Regulations core capacities implementation status (2014) (160 reporting countries)**

Parties to the International Health Regulations (2005) are required to have or to develop minimum core public health capacities to detect, assess and report public health events, including chemical accidents and emergencies. In 2014, capacities on chemicals were assessed by states as the lowest among the core public health capacities.

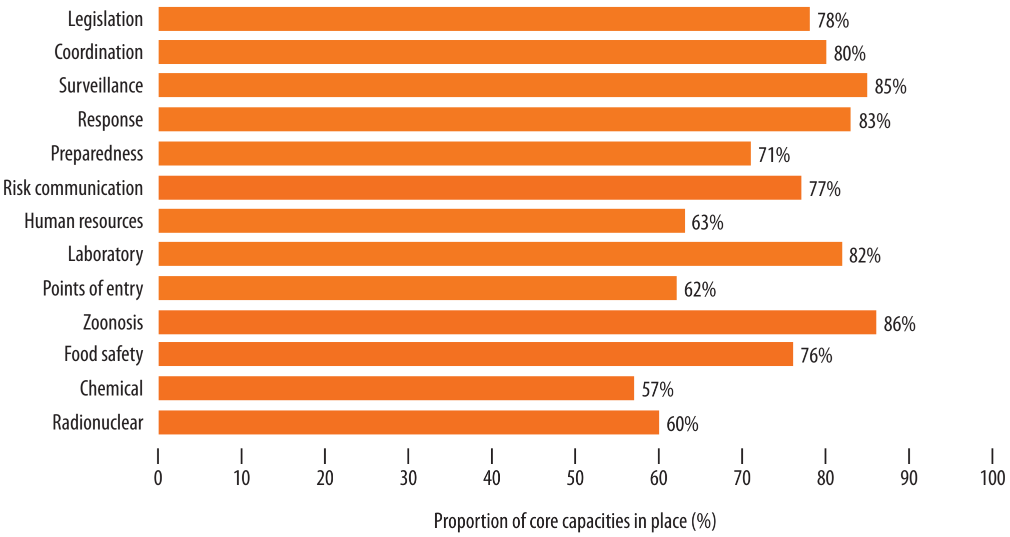
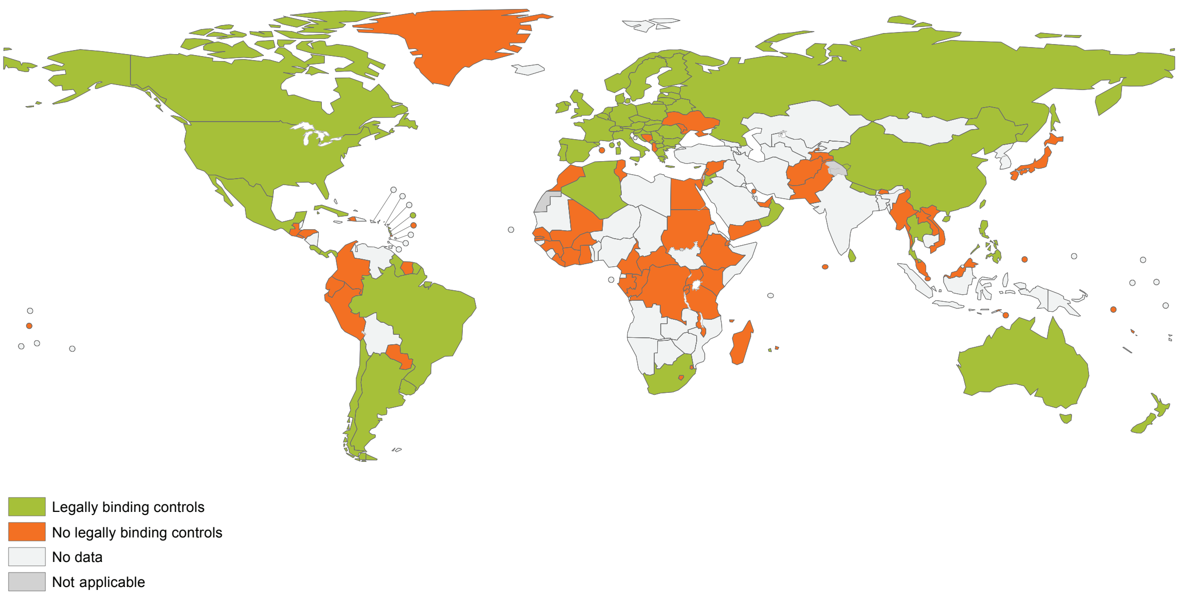



**Figure 9. Countries with legally binding controls on lead paint, based on information from governments, March 2016**



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WHO/FWC/PHE/EPE/16.01

**CONTACT**
DEPARTMENT OF PUBLIC HEALTH, ENVIRONMENTAL
AND SOCIAL DETERMINANTS OF HEALTH
INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY
WORLD HEALTH ORGANIZATION
AVENUE APPIA 20
1211 GENEVA 27
SWITZERLAND
www.who.int/ipcs/en/
email: ipcsmail@who.int