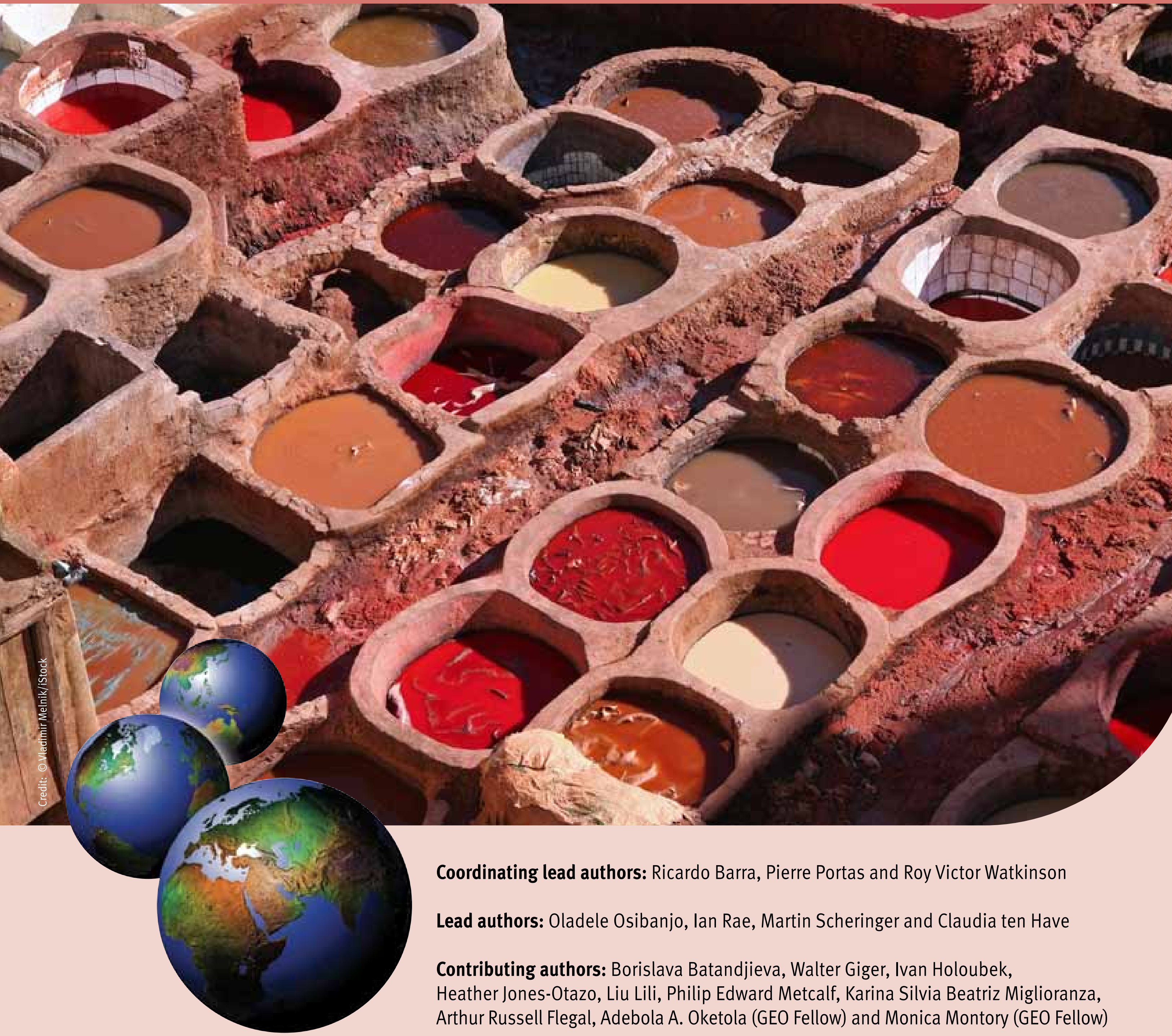
CHAPTER 6

Chemicals and Waste



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Main Messages

There is an extensive but incomplete body of scientific knowledge on the impacts of chemicals and wastes on humans and the environment, with particular information and data gaps on the uses, emissions, exposure pathways and effects of chemicals. Global understanding of the complexity of properties and environmental impact of chemicals and wastes is therefore markedly deficient. The fourth *Global Environment Outlook* (2007) indicated that data were incomplete globally and that, for many regions, it was important to evaluate the magnitude of chemical contamination and its impacts on the environment and human health. But little has occurred since then. The UN Secretary-General, in his May 2011 report on policy options for waste management to the Commission on Sustainable Development, stated that: "the barriers to effective management and minimization include lack of data, information, and knowledge on waste scenarios". And the UN-Habitat report on waste management in cities stated that "waste reduction is desirable but, typically, it is not monitored anywhere" (UN-Habitat 2010).

Over the last decade chemical production has shifted from the countries of the Organization for Economic Co-operation and Development (OECD) to the BRIC countries (Brazil, Russia, India and China) and other developing countries, accompanied by a doubling of sales and the development of many new types of chemical. The OECD's share of world production is now 9 per cent less than in 1970. Much of this shift has been due to major emerging economies. In 2004, China accounted for the largest share of BRIC production at 48 per cent, followed by Brazil and India at 20 per cent each, and Russia at 12 per cent (OECD 2008b). Chemical consumption in developing countries is likewise growing much faster than in the developed world and could account for a third of global consumption by 2020.

Chemicals play an important role in human life, economic development and prosperity, yet they can also have adverse impacts on the environment and human health. The diversity and potential consequences of such impacts, combined with limited capacity in developing countries and economies in transition to manage these impacts, make the sound management of chemicals and waste a key cross-cutting issue. A recent study by the World Health Organization (WHO) (Prüss-Ustün *et al.* 2011) indicated that 4.9 million deaths were attributable to environmental exposure to chemicals in 2004. In many regions, hazardous waste streams are mixed with municipal or solid wastes and then either dumped or burned in the open air (UN-Habitat 2010).

Global chemical pollution is a serious threat to sustainable development and livelihoods. The problem has impacts on both humanity and ecosystems, and includes adverse effects from long-term exposure to low or sub-lethal concentrations of single chemicals or to mixtures of chemicals. Currently, more than 90 per cent of water and fish samples from aquatic environments are contaminated by pesticides. Estimates indicate that about 3 per cent of exposed agricultural workers suffer from an episode of acute pesticide poisoning every year (Thunduyil *et al.* 2008). Pollution with persistent organic pollutants (POPs) is widespread, in particular affecting remote areas such as the Arctic and Antarctic.

Emerging issues requiring better understanding and prompt action to prevent harm to health and

the environment include the sound management of electronic and electrical waste (e-waste), endocrine-disrupting chemicals, plastics in the environment, open burning, and the manufacture and use of nanomaterials. E-waste has become one of the major environmental challenges of the 21st century: it is the fastest-growing waste stream in the world, estimated at 20–50 million tonnes per year (Schwarzer *et al.* 2005). It is of particular interest because it contains not only hazardous substances – such as heavy metals including mercury and lead, and endocrine-disrupting substances such as brominated flame retardants (BFRs) – but also many strategic metals such as gold, palladium and rare earth metals that can be recovered and recycled. Very little is known about whether nanomaterials or nanoparticles are released from products when they are incinerated, buried or degraded over time, so it is possible that they will pose a serious waste disposal challenge. Sound decision making on nanotechnology has provoked much debate among developed country regulators, and increasingly among the regulators of developing countries (Morris *et al.* 2010).

Effective management of these issues requires better information gathering and integrated approaches to chemicals, radioactive materials and waste management, supported where appropriate by improved environmental governance. The process for greater cooperation and coordination between the chemicals and waste conventions (Basel, Rotterdam and Stockholm) provides an opportunity to enhance awareness raising, knowledge transfer, capacity building and national implementation that should be further explored.

INTRODUCTION

More than 248 000 chemical products are commercially available (CAS 2011) and subject to regulatory and inventory systems. Chemicals provide valuable benefits to humanity including in agriculture, medicine, industrial manufacturing, energy extraction and generation, and public health and disease vector control. Chemicals play an important role in achieving developmental and social goals, especially for improving maternal health, reducing child mortality and ensuring food security, and advances in their production and management have increased their safe application. Nonetheless, because of their intrinsic hazardous properties, some pose risks to the environment and human health. Simultaneous exposure to many chemicals – the cocktail or synergistic effect – is likely to exacerbate the impacts.

Chemicals are released at many steps in their life cycle, from the extraction of raw materials, through production chains, transport and consumption, to final waste disposal. They are distributed through indoor environments, food and drinking water, and through soils, rivers and lakes. Certain long-lived chemicals such as persistent organic pollutants (POPs) and heavy metals are transported globally, reaching otherwise pristine environments such as rain forests, deep oceans or polar regions, and can quickly pass along the food chain, bioaccumulating to cause toxic effects in humans and wildlife.

Products derived from chemicals often become hazardous wastes in their end-of-life phase, generating additional pollution risks that can devalue their initial benefits and counteract development advantages. Pollution from dumping and uncontrolled open burning is common (UN-Habitat 2010), and is even increasing in some parts of the world, though some progress has been made in recent decades. The causes of mismanagement often lie in such factors as deficiencies in institutional and regulatory frameworks. Such shortcomings also have an impact on the growing transboundary movement of hazardous wastes from developed to developing countries, where compliance, monitoring and enforcement of regulations tend to be weak, and the financial and technical capacity to implement improved waste management practices is limited. This leads to a risk of rapidly increasing exposure for greater portions of the population and to related, often serious, health problems, in particular for women and children.

Broadly, a two-speed situation exists, with developed countries generally having comprehensive systems for chemical and hazardous waste management, while developing countries generally do not. Developing countries and economies in transition struggle with basic landfill co-disposal of many types of wastes, with little capacity for their separation and sound management.

While many developing countries have ratified the multilateral environmental agreements on chemicals and wastes – such as the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal (Basel Convention 1989) – these are not always transposed into national legislation in a comprehensive manner. In addition, given the cross-sectoral nature of the issue, the regulation and management of chemicals in most developing countries is spread over several ministries – including agriculture, industry, labour, environment and health – and between several agencies within each ministry.

In most countries, it is the poorest members of the population that are at particular risk of exposure. This may be due to occupational exposure, poor living conditions, lack of access to clean water and food, domestic proximity to polluting activities, or a lack of knowledge about the detrimental impacts of chemicals – or a combination of these factors.

Radioactive contamination is another source of potential environmental and health hazards, both from controlled emissions and waste management, and from accidental release. The controlled release of radionuclides to the atmospheric and aquatic environments may occur as authorized effluent discharge, while uncontrolled release may occur as a result of accidents and at legacy sites left by nuclear weapons testing. The management and disposal of radioactive waste from industry, research and medicine, as well as from nuclear power, is relevant to almost all countries, requiring different approaches according to the volume, radioactivity and other properties of the waste.

Initially, governance instruments for chemicals and wastes could be considered to have been reactive, piecemeal and isolated, and with mixed success – the Montreal Protocol on

Waste treatment plant, Los Angeles, United States. *© John Crall/iStock*

Substances that Deplete the Ozone Layer (UNEP 1987), for example, being effective in reducing the impact of ozone-depleting substances, while the Basel Convention (1989) has struggled to reduce the transboundary movement of hazardous waste. There have been significant advances over the past decade, however, and regulatory instruments are now improving with the better and more widespread understanding of the life cycle of chemicals and their association with the generation and processing of wastes. Efforts to bring the work of the Basel, Rotterdam and Stockholm Conventions together constitute a first step towards addressing the entire life cycle of chemicals. This also applies to the establishment of the Strategic Approach to International Chemicals Management (SAICM) and the current negotiation for an international agreement on mercury. Similarly, the Joint Convention on the Safety of Radioactive Waste Management and the Safety of Spent Nuclear Fuel Management is a significant step forward. However, ensuring that these efforts are sustained and fully anchored at the national level requires further investment in better science-based understanding of chemicals and wastes, policy creativity to balance development and sustainability imperatives, public-private partnerships to link technological innovation and societal responsibility, and allocation of funds for comprehensive capacity building.

INTERNATIONALLY AGREED GOALS

This chapter evaluates progress towards internationally agreed goals relevant to chemicals and wastes. The goals are those identified by the *GEO-5* High-Level Intergovernmental Advisory Panel from key multilateral environmental agreements and related agreements and declarations, as further considered and prioritized in regional consultations. The current lack of data, a key constraint on many aspects of chemical and waste management, has not been seen as a reason to preclude the selection of a goal. The goals evaluated are reflected in Table 6.1.

In the 1970s and 1980s the human health and environmental impacts of chemicals and waste led to the creation of a number of key international agreements. These, along with other related goal-based international agreements and declarations such as those emanating from the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, constitute a framework for organizing and implementing specific goals for the environmentally sound design, production, consumption and recycling or disposal of chemicals and hazardous waste (Box 6.1). These goals are also considered against the background of the Millennium Development Goals (MDGs), specifically MDG 1 for eradicating extreme poverty and hunger, and MDG 7 for ensuring environmental sustainability. MDG 7 includes specific targets for ozone-depleting substances, as well as for improved access to safe drinking water and sanitation facilities.

The broad set of principles pivotal to the development of international agreements comprises prior informed consent for the transboundary movement of hazardous waste and certain hazardous chemicals; transparency through national reporting; the environmentally sound management of chemicals and waste; waste prevention; the precautionary approach; and the polluter-pays principle. These are addressed through specific obligations such as the implementation of control measures, monitoring of the state of the environment, and compliance regimes with supportive delivery mechanisms including capacity building and training, international cooperation, synergies and partnerships.

Goals relevant to the sound management of chemicals and waste aim to protect human health and the environment while improving resource efficiency. They can be grouped into six themes:

- sound management of chemicals throughout their life cycle, including persistent organic pollutants and heavy metals, and of waste;
- control of the transboundary movement of hazardous wastes as well as responsible trade in hazardous chemicals;
- transparent science-based risk assessment and risk management procedures, as well as monitoring systems at the national, regional and global levels;
- support for countries to strengthen their capacity for the sound management of chemicals and waste;
- protection and preservation of the marine environment from all sources of pollution;
- safe radioactive and nuclear waste management.

Box 6.1 Multilateral environmental agreements and the sound management of chemicals

The sound management of chemicals is addressed by 17 different multilateral agreements including the 1998 Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the 2001 Stockholm Convention on Persistent Organic Pollutants (both effective since 2004). In addition, in 2006 the First International Conference on Chemicals Management established the Strategic Approach to International Chemicals Management (SAICM), a multi-stakeholder policy framework for achieving the safe management of chemicals worldwide by 2020 (SAICM 2009). So far, more than 300 activities have been conducted under the SAICM Global Plan of Action. Pollutant release and transfer registers have been promoted and currently just 23 countries have established a functioning national register. The globally harmonized system of classification and labelling of chemicals, containing all criteria necessary for classification of chemicals according to their intrinsic hazardous properties, has been established, as have provisions for hazard communication. However, many challenges remain and the lack of prioritization of sound management of chemicals, the limitations of legislation, the lack of information and the lack of adequate financial resources, including for the funding of activities concerning the remediation of contaminated sites, are still major obstacles to achieving the 2020 goal (CSD 2010).

Table 6.1 Selected internationally agreed goals related to chemicals and waste

Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 23 *(Prioritized during regional consultations in Europe and the Asia and Pacific region)*	Renew the commitment, as advanced in Agenda 21, to sound management of chemicals throughout their life cycle and of hazardous wastes for sustainable development as well as for the protection of human health and the environment, *inter alia*, aiming to achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment, using transparent science-based risk assessment procedures and science-based risk management procedures, taking into account the precautionary approach, as set out in principle 15 of the Rio Declaration on Environment and Development (UNCED 1992a), and support developing countries in strengthening their capacity for the sound management of chemicals and hazardous wastes by providing technical and financial assistance.
Paragraph 22 *(Prioritized during regional consultations in the Asia and Pacific region)*	Prevent and minimize waste and maximize reuse, recycling and use of environmentally friendly alternative materials, with the participation of government authorities and all stakeholders, in order to minimize adverse effects on the environment and improve resource efficiency, with financial, technical and other assistance for developing countries.
Paragraph 23g	Promote reduction of the risks posed by heavy metals that are harmful to human health and the environment, including through a review of relevant studies, such as the United Nations Environment Programme global assessment of mercury and its compounds.
Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention 2001) Article 1	... to protect human health and the environment from persistent organic pollutants.
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (Rotterdam Convention 2001) Article 1	... to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention 1989) Preamble	... to protect, by strict control, human health and the environment against the adverse effects which may result from the generation and management of hazardous waste and other wastes.
International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 (MARPOL 1973/78) Article 17	The Parties to the Convention accept the obligation to promote, in consultation with other international bodies and with assistance from UNEP and coordination with the Executive Director of UNEP, the necessary support for Parties who may require technical assistance in the following areas: a) Training scientific and technical staff; b) obtaining equipment and monitoring installations where needed; c) ease the adoption of additional measures and conditions which seek to prevent or reduce pollution in the marine environment by ships; and d) encourage research; preferably within the concerned countries, in order to promote realization of the aims and objectives of this convention.
International Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter (London Convention 1972) Article 2	Contracting Parties shall individually and collectively protect and preserve the marine environment from all sources of pollution and take effective measures, according to their scientific, technical and economic capabilities, to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter.
Article 12	The Contracting Parties pledge themselves to promote, within the competent specialized agencies and other international bodies, measures to protect the marine environment against pollution caused by: (a) hydrocarbons, including oil and their wastes.
Agenda 21 (UNCED 1992b) Chapter 22 Paragraph 3	The objective of this programme area is to ensure that radioactive wastes are safely managed, transported, stored and disposed of, with a view to protecting human health and the environment, within a wider framework of an interactive and integrated approach to radioactive waste management and safety.
Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA 1997) Article 1	The objectives of this Convention are: (i) to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management [...]; (ii) to ensure that during all stages of spent fuel and radioactive waste management there are effective defenses against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation, now and in the future, in such a way that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations; (iii) to prevent accidents with radiological consequences and to mitigate their consequences should they occur during any stage of spent fuel or radioactive waste management.

STATE AND TRENDS

The fourth *Global Environment Outlook* (2007) indicated that data were incomplete at the global level, making it a challenge for many regions to evaluate the magnitude of chemical contamination and its impacts on the environment and human health. Little has changed in five years and a worldwide effort is needed to fill this gap. The forthcoming UNEP Global Chemicals Outlook report should assist: it aims to provide a framework for assessing and setting priorities to stimulate further international action on sound management of chemicals.

Chemicals and wastes: data and indicators

The lack of data on existing chemicals, and the rapid technological changes that bring new chemicals to the market, have hindered the production of an established set of indicators with time-series data that can be used to identify the state and trends of chemicals and wastes. Several possible indicators to fill this gap are proposed below. In addition, extensive investment in collating the required data and solidifying the knowledge base is required to construct long-term time series.

Underlying data on waste generation, treatment and recycling are difficult to obtain. Some are available on hazardous waste through reports to the Secretariat of the Basel Convention (Figure 6.1), providing information on the quantity, characteristics, destination and mode of treatment or disposal of hazardous waste that is subject to international movement, but even this is incomplete and unverified – as was reported in 2011 to the tenth Conference of the Parties to the Convention (UNEP 2011a). Global data on non-hazardous waste generation and disposal have not been systematically reported and are therefore unsatisfactory. As stated by the UN Secretary-General in his May 2011 report to the Commission on Sustainable Development: "*The barriers to effective management and minimization include lack of data, information, and knowledge on waste scenarios, lack of comprehensive regulations and weak enforcement of existing legislation, weak technical and organizational capacities, poor public awareness and cooperation, and lack of funds.*" (UNCSD 2011)

There is an urgent need to improve the availability and quality of these basic datasets, with a focus on comparability between countries, timeliness and coherence over time, and interpretability. As waste is increasingly seen as a potential resource, waste data and indicators should be more closely linked to economic and social information systems and material flow accounting. The measurability issue is critical to assess waste generation, including municipal, industrial, agricultural, mining, military, radioactive and nuclear.

Box 6.2 Johannesburg Plan of Implementation (JPOI) (WSSD 2002) Paragraph 23

Issue
The sound management of chemicals throughout their life cycle for the protection of human health and the environment

Related goals
To ensure, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment

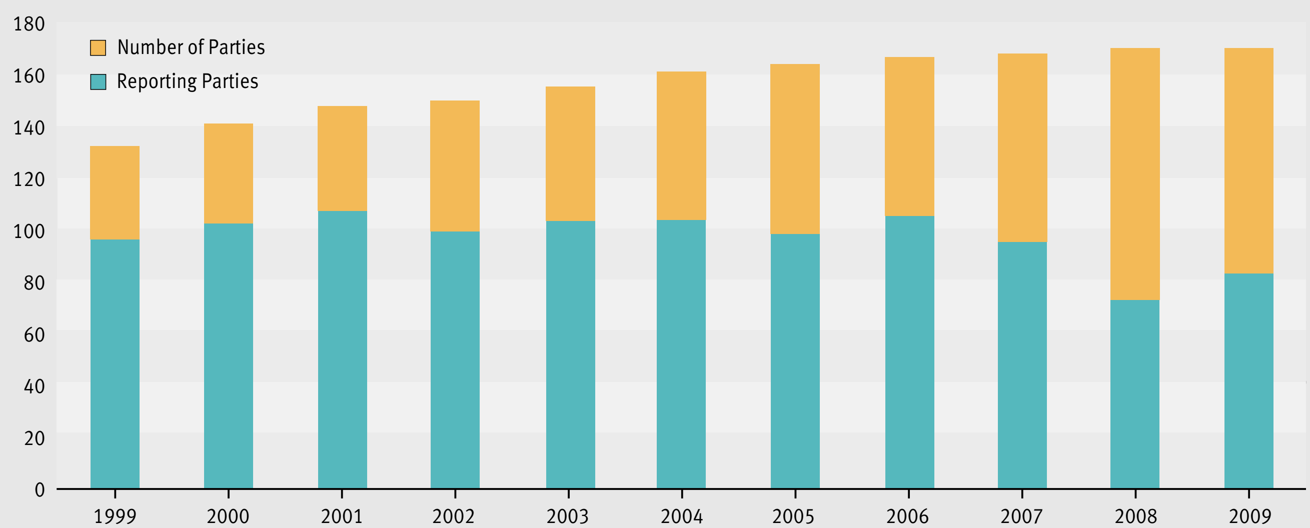
Indicators
Number of signatory countries to the three conventions on chemicals and wastes (Basel, Rotterdam, Stockholm); number of implementation plans being put in place by these countries

Global trends
Some progress

Most vulnerable communities
Labour force, women and children in developing countries, consumers worldwide

Regions of greatest concern
Africa, Latin America and Asia

Figure 6.1 Transmission of national reports by Parties to the Basel Convention, 1999–2009



Source: Basel Convention 2011

Three indicators to help inform governments and municipalities of industry performance and progress are highlighted here. It is imperative that data for these indicators are generated to guide decision making on sound global management of wastes. The key indicators proposed are:

- quantity and types of waste – solid, organic, hazardous and non-hazardous – managed or finally disposed of;
- waste and hazardous waste generation per person; and
- the amount of municipal or household waste, industrial solid waste and hazardous waste that is recycled.

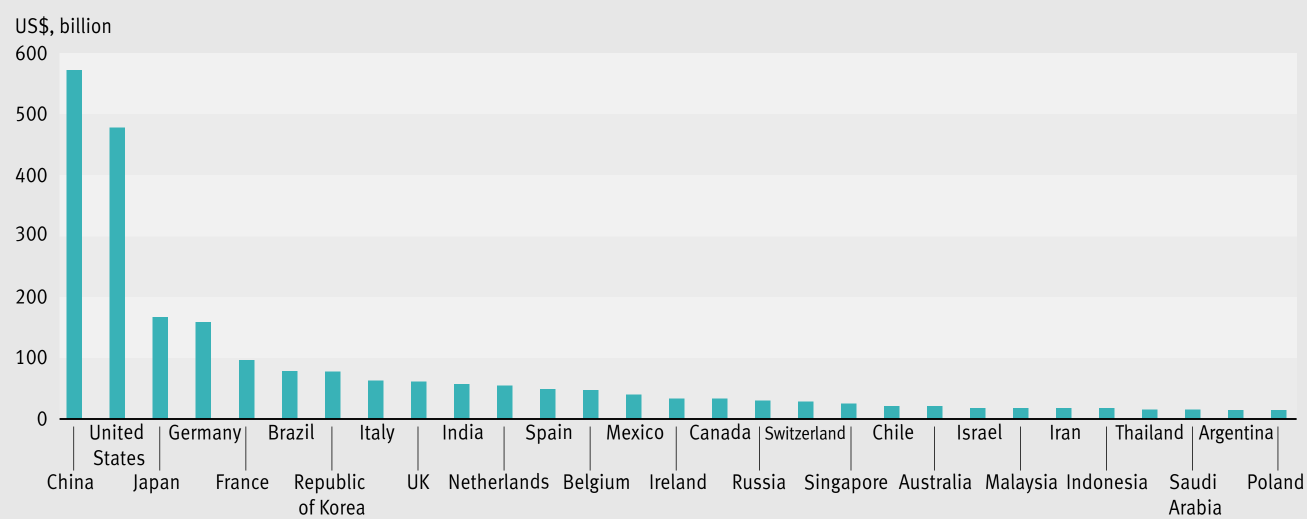
Large-scale chemical plant at night. © *Tetsuo Morita/iStock*

Status and trends of the chemical industry

The chemical industry is a major driver of economic growth and its performance is a leading indicator of economic development. In 2008 the global chemicals industry had an estimated turnover of about US$3.7 trillion (OECD 2010a) and was growing at 3.5 per cent per year. More than 20 million people around the globe are employed by it directly or indirectly, and it is an intensive energy consumer and a ubiquitous generator of emissions.

While companies in the countries of the Organisation for Economic Co-operation and Development (OECD) continue to account for the bulk of world production (74.5 per cent in 2004), the OECD's share is now 9 per cent less than in 1970. Much of this shift has been caused by the major emerging economies, particularly the BRIC countries (Brazil, Russia, India and China). In 2004, China accounted for most BRIC production (48 per cent), followed by Brazil and India (20 per cent each), and Russia (12 per cent) (OECD 2008b). Chemical consumption in developing countries is likewise growing much faster than in developed countries, and could account for a third of global consumption by 2020. At the same time, some data show that developed countries are reducing chemical use. For example, overall use of pesticides in OECD countries declined by 5 per cent during 1990–2002, although trends vary from country to country (OECD 2008a). Total releases and transfers of the 152 pesticides that are common to the United States and Canada dropped by 18 per cent and the production of ozone-depleting substances almost stopped; emissions of acid rain precursors dropped by 48 per cent, ozone precursors by 38 per cent and non-methane volatile organic compounds by 26 per cent. Nonetheless, international cooperation between all governments is needed to build capacity, share information and promote effective chemicals management globally (OECD 2008b). Figure 6.2 shows the sales data of the world's major chemical-producing countries.

Figure 6.2 Chemical sales by country, 2009



Source: OECD 2010b

Waste as an issue of global significance

The growing interdependence of the global economy along with the increasing generation and complexity of waste worldwide can lead countries to unsound waste management and disposal operations, and there may come a point when related costs are such that the economy and public services fail to keep up. Integrated policies are required to support sustainable economic development through recycling, recovery, reuse and other operations aimed at reducing both the use of natural resources and the quantities of waste, as it is inevitable that some resource inputs to industrial production are returned to the environment as waste, and may be hazardous. A critical issue is to reverse current trends in waste generation, which would require a high level of commitment to minimize both quantities and levels of hazard. Furthermore, unsound recycling comes with the risk of pollution and increased human exposure to toxic substances. Recycling can also be misused as a disguise for criminal operations.

Box 6.3 Waste in the OECD

The quantity of municipal waste generated in OECD countries has risen steeply since 1980, exceeding an estimated 650 million tonnes in 2007 (556 kg per person). In most countries for which data are available, increased affluence associated with economic growth and changes in consumption patterns tend to generate higher levels of waste per person. Over the past 20 years, however, waste generation has risen less rapidly than either GDP or expenditure on private consumption, with a slow-down in recent years. The amount and composition of municipal waste going to final disposal depend on national waste management practices. Despite improvements in these practices, only a few countries have succeeded in reducing the quantity of solid waste for disposal (OECD 2010b).

The introduction of many new chemical substances to the market leads to the production of new kinds of wastes. In many regions, hazardous waste streams are mixed with municipal or solid wastes and then either dumped or burned in the open (UN-Habitat 2010). This raises issues of environmental and social justice, as the people most affected by such precarious practices are usually the poor who live and work adjacent to dump sites.

Through globalization, materials may be produced in one country or region, used in another and managed as waste in a third. Electrical and electronic equipment provides a case in point (Schluepa *et al.* 2009; Cui and Forssberg 2003). The treatment of end-of-life electronics, including toxic substances and plastics with associated flame-retardants as well as precious metals, exemplifies the two sides of this business. The original equipment has the potential to contribute to protecting human health, supporting livelihoods and creating jobs, while also promoting a shift from waste to resources that supports economic development, energy efficiency and the conservation of natural resources. However, unsound or inadequate waste management can have profound human health impacts and cause serious harm to the environment. Extending the useful life of electrical and electronic equipment and using less harmful substances in these products is one way to reduce the waste burden and its accompanying hazards.

Municipal waste

The unsound management of waste can lead to mutually reinforcing undesirable effects. It can pollute and contaminate the environment, pose a threat to human health and represent a loss of resources in the form of both materials and energy. The recent UN-Habitat report on solid waste management in cities refers to the escalating challenge of managing it across the globe, and amply demonstrates the complexity and variety of issues faced, including the difficulty of achieving objectives when progress goes unrecorded, stating for example that "waste reduction is desirable but, typically, it is not monitored anywhere" (UN-Habitat 2010).

Municipal waste constitutes a significant percentage of the total waste a country generates (OECD 2008b), with annual figures ranging from 0.4 to 0.8 tonnes per person, and solid waste generation increasing at an estimated rate of about 0.5–0.7 per cent per year. Waste complexity is also increasing with the co-disposal of assorted waste types: biodegradable components currently account for almost 50 per cent of municipal solid waste and electronic waste (e-waste) for 5–15 per cent. The management of waste is further complicated by the range and diversity of waste generators, from mining and a wide variety of manufacturers through agricultural and medical waste to household rubbish. In addition, the sound management of municipal waste constitutes a sizable and continuous part of a municipality's budget.

Many countries do not have the infrastructure to deal with ever more complex waste streams. Nor do many have the regulatory and physical infrastructure to derive some rebate from the recyclable materials that are inevitably part of municipal waste.

Municipal truck with robotic arm collecting residential waste for recycling. *© Paul Vasarhelyi/iStock*

Life-cycle thinking: identifying the range of impacts from chemicals and wastes

What ultimately determines how humans and ecosystems are exposed to toxic chemicals is defined by their life-cycle characteristics. Releases of substances not only occur during chemical production but also during the use of products containing chemicals (Figure 6.3), and finally at their disposal. Life-cycle thinking promotes an integrated approach to the sustainable production and consumption of such substances.

The entire life cycle of resource use, from extraction and production/manufacture through consumption/use to post-consumption disposal, produces undesirable environmental impacts from emissions and wastes. These impacts can include unintended side effects such as endocrine disruption, which directly interferes with growth and development in most animals, and can also affect people (WHO 2002). Life-cycle analysis helps understand such impacts, but, while a useful tool, it can be extremely complex. Too often, when problems are identified, shifts to alternative chemicals that have the same intended properties may result in further unexpected or undesirable outcomes (Muir and Howard 2010).

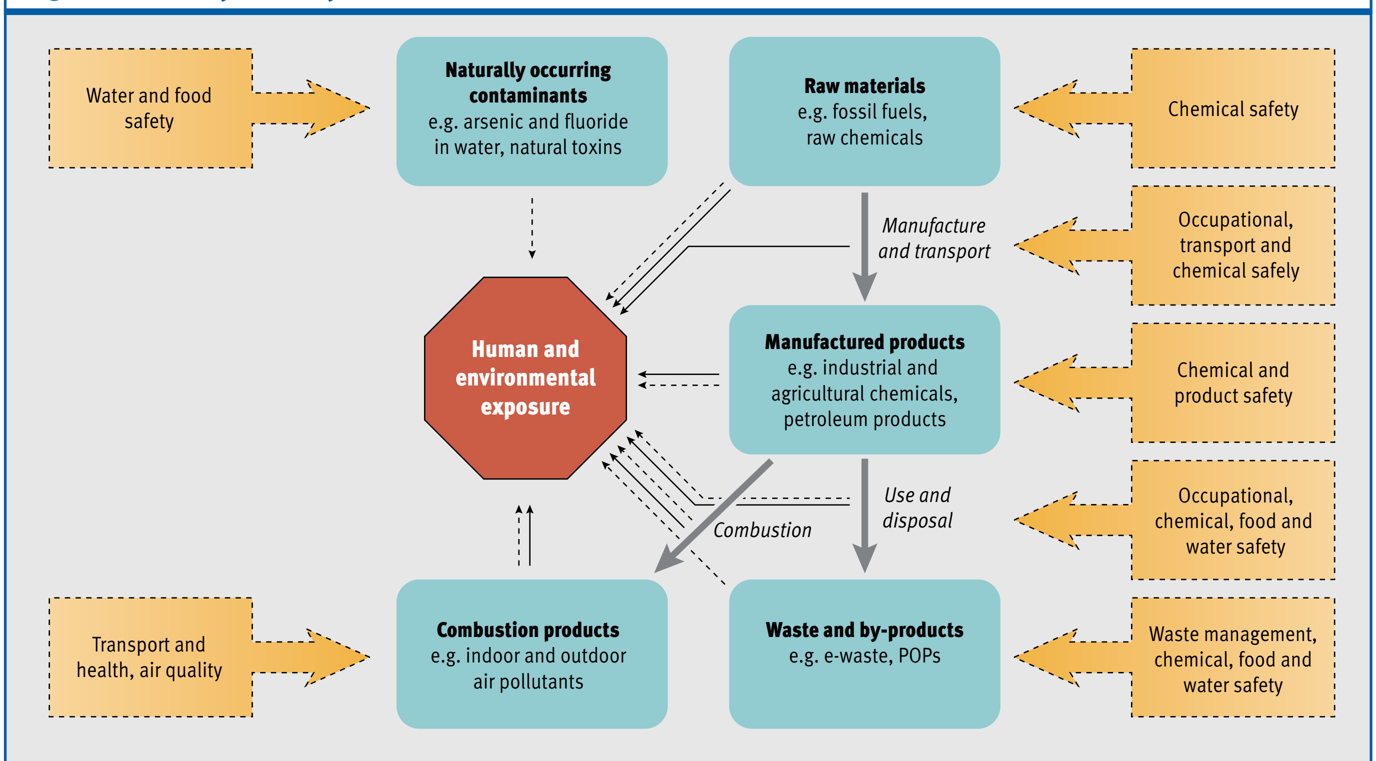
The latest materials to raise concern are those arising from synthetic biology and engineered nanomaterials. With the accelerated pace at which new technologies and chemicals are being deployed (Poliakoff *et al.* 2002), a different approach is needed in which their implications are systematically and comprehensively assessed before they reach production. The use of green chemistry principles in chemical design and the adoption of clean production processes may help to prevent problems at a later stage. While this is happening in some parts of the world through the use of exposure models – for example by the Canadian Centre for Environmental Modelling and Chemistry (CEMC 2012) – for some technologies and chemicals, life-cycle analysis has yet to become a universal systematic approach. This may well require new forms of international governance (Finnveden *et al.* 2009).

The high number and diversity of chemicals and the complexity of their life cycles inevitably lead to a situation where the scientific understanding of the impacts of chemicals, and the regulatory schemes used to manage them, lag behind technological and economic developments.

Poverty and exposure to chemicals: vulnerable groups

The overwhelming majority of impacts from unsafe chemical use and unsound waste disposal – including death, impairment of health and ecosystem degradation – occur in situations of poverty (Sexton *et al.* 2011). Increased risks of exposure to toxic and hazardous chemicals and wastes predominantly affect the poor, who routinely face such risks because of their occupation, poor living standards and lack of knowledge about the detrimental impacts of exposure to these chemicals and wastes. Many of the poor enter the informal sector of the

Figure 6.3 Life-cycle analysis of chemicals



Note: Dashed lines are management options; solid lines correspond to the life cycle.

Source: Adapted from Prüss-Ustün *et al.* 2011

Shacks along a polluted waterway in Manila, Philippines.

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economy where they may encounter new kinds of toxic hazards such as electronic and electrical waste (e-waste). Risk is not only related to the dose they receive from such exposure, but also to important factors such as age, nutritional status and co-exposure to other chemicals. Children are particularly susceptible to the negative health impacts of chemicals due to their rapid growth and development and greater exposure relative to body weight (Sheffield and Landrigan 2011).

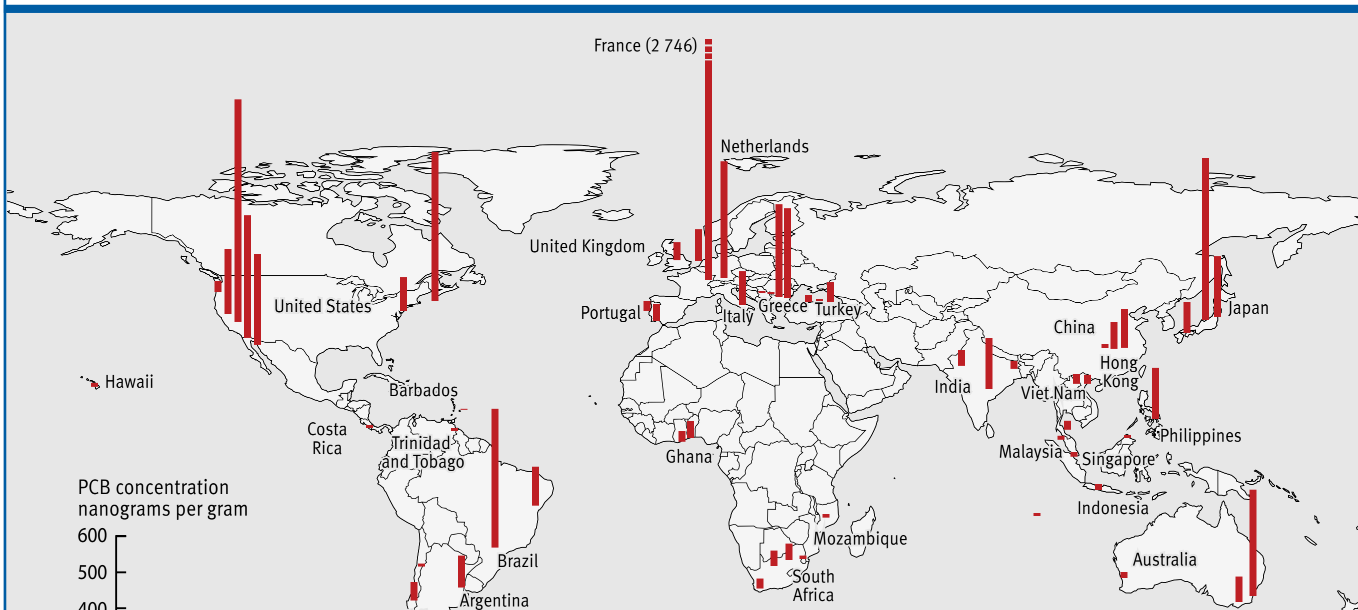
A recent study by the World Health Organization (WHO) (Prüss-Ustün *et al.* 2011) indicated that 4.9 million deaths were attributable to environmental exposure to chemicals in 2004. Indoor smoke from the use of solid fuels, outdoor air pollution and second-hand smoke are among the most critical causes. The study concluded that the known burden of chemicals, while considerable, is an underestimate because data on many chemicals are scarce.

Changes in the global production, trade and use of chemicals and the concomitant production of hazardous wastes are not always accompanied by corresponding control measures, thus increasing the risk of releasing hazardous chemicals into the environment. It is estimated that there are 2 million contaminated sites in Europe, the United States and the Russian Federation alone. Data for developing countries and economies in transition are more difficult to obtain, but indications are worrying. The Global Inventory Project – which involves the Blacksmith Institute together with the United Nations Industrial Development Organization (UNIDO), the Green Cross and the European Commission – is currently assessing the state of contaminated areas in 80 countries worldwide, with trace metal and pesticide pollution among the ten most problematic types of contamination (Blacksmith Institute 2011). This is the first such attempt to give governments, international organizations and affected communities aggregated data for decision making.

Marine pollution

The oceans cover 71 per cent of the Earth's surface and are polluted to varying degrees, threatening marine life, fisheries, mangroves, coral reefs, and estuarine and coastal zones, with

Figure 6.4 PCBs in beached plastics



Samples of polyethylene pellets were collected at 56 beaches in 29 countries and analysed for concentrations of organochlorine compounds. PCB concentrations – shown here as nanograms per gram – were highest in pellets collected in the United States, Western Europe and Japan. They were lowest in samples collected in tropical Asia and Africa. This spatial pattern reflects regional differences in the use of PCBs.

Source: UNEP 2011b

Box 6.4 Waste generated on board ship

The world fleet comprises more than 80 000 vessels of which around 50 000 merchant ships carry out 90 per cent of international trade. Every ship generates waste during its operation or when transporting cargo, including sludge, oily tank washings known as slops, rubbish from the crew, and cargo residues. Depending on its size, a ship can generate a few hundred tonnes of slops during a voyage. With 50 000 ships of more than 500GT (gross tonnage) in the world fleet, and assuming an average of ten port calls per ship, half a million port calls take place annually (Mikelis 2010). Port states are required by the International Convention for the Prevention of Pollution from Ships 1973, as modified by its 1978 Protocol (MARPOL 73/78), to provide adequate port reception facilities to collect waste generated on board ships. Illicit discharges of slops represent a major source of marine pollution. For instance, according to the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), there are more than 2 500 illicit discharges of ship waste in the Mediterranean Sea annually. The 1972 London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, along with its 1996 Protocol, is one of the first global conventions to protect the marine environment from the effects of human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.

some 80 per cent of the pollution coming from land-based sources (UNEP 2011b). Common man-made pollutants include pesticides, chemical fertilizers, heavy metals, detergents, oil, sewage, plastics and other solids (UNEP 2011b). Many of these pollutants accumulate in the deep oceans and sediments (Jacobsen *et al.* 2010; Zarfl and Matthies 2010; Wania and Daly 2002), where they are consumed by small marine organisms and may be reintroduced to the global food chain. Some 20 per cent of marine pollution originates from direct disposal into the oceans: regular discharges of oily wastes from ships, accidental oil spills and untreated sewage disposal in enclosed areas such as the Mediterranean are threats to marine ecosystems (UNEP 2011b). Figure 6.4 shows the occurrence of PCB in beached plastics around the globe. Some of the most harmful pollutants also come from diffuse sources such as air pollution.

Persistent organic pollutants

Persistent organic pollutants (POPs) are a group of chemicals with common features including persistence, bioaccumulation and long-range transport. Combined with their toxicity, these characteristics have significant adverse effects both on wildlife, including marine mammals, and on human populations, in particular such vulnerable groups as nursing mothers and infants. The health effects of exposure to POPs include neuro-developmental disorders, endocrine disruption and carcinogenicity (Diamanti-Kandarakis *et al.* 2009).

The Stockholm Convention on POPs was adopted in 2001 in response to an urgent need for global action, and entered into force in 2004. It currently has 177 Parties and calls for documentation of the amounts of POPs that are still present in different countries and for global monitoring of these substances in human tissue (blood and milk). This is one of two indicators proposed for monitoring and assessing the status and trends of POPs in the environment and their impact on human health. The Stockholm Convention established a Global Monitoring Plan as a source of globally consistent and reliable data. Collection of data is at an early stage and more will become available in the coming years, but individual studies already provide historical and regional trends for some substances. An example is DDT, for which Ritter *et al.* (2011) report global time series of concentrations in human tissue from many individual measurements (Figure 6.5). In general, DDT body burdens have fallen over recent decades, but are still considerably higher in tropical than northern regions. Where DDT is used for malaria control, concentrations are still very high and the decrease is less pronounced than elsewhere.

The other indicator for POPs is trends of selected atmospheric POPs in both urban/industrialized and remote regions. Concentrations of these substances in the air follow changes in emissions more closely than concentrations in food and human tissue, and reflect the effect of atmospheric long-range transport. Hung *et al.* (2010) provide a summary of long-term time trends of various POPs measured at Arctic monitoring stations. In general, concentrations of most substances in Arctic air show a falling trend, but

Box 6.5 Human health, the environment and persistent organic pollutants

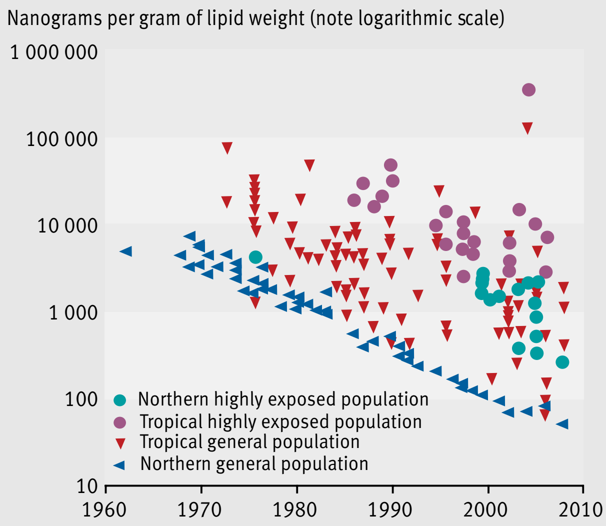
Related goals
To protect human health and the environment from POPs

Indicators
Trends in levels of selected POPs in human tissue;
trends in atmospheric levels of selected POPs such as PCBs (conventional POPs, regulated for many years) and endosulfan (emerging POPs, added to the list in the Stockholm Convention in 2010)

Global trends
Some progress; it is too early to use the above indicators for evaluation

Most vulnerable communities and areas of greatest concern
Arctic communities, in particular children; communities in areas with indoor residual spraying of dichlorodiphenyltrichloroethane (DDT); children of the world exposed to POPs

Figure 6.5 DDT levels in humans, 1960–2008



Source: Ritter *et al.* 2011

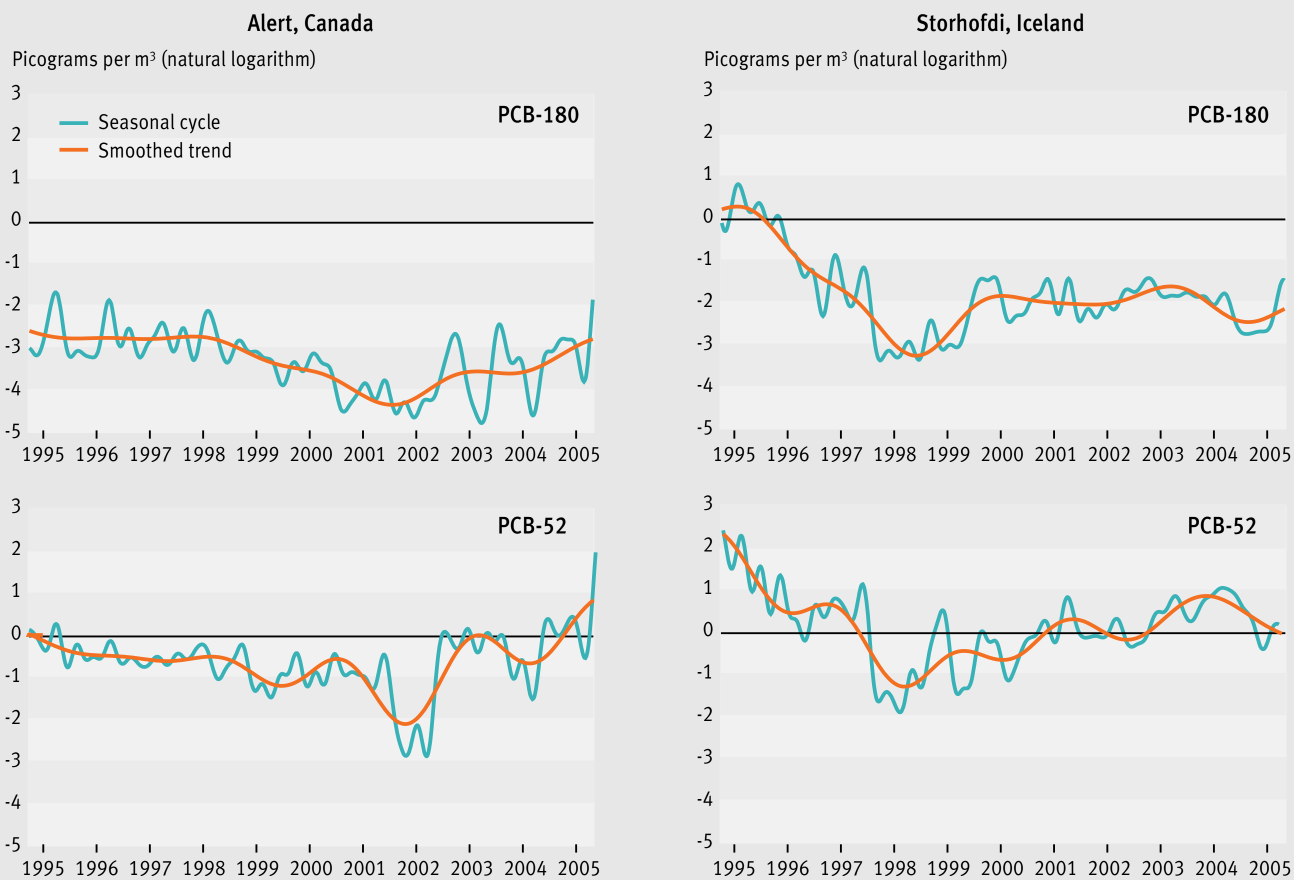
half-lives are often long – five to ten years and sometimes even longer. In recent years the decrease has come to a halt for several compounds, and some concentrations have been observed to be on the rise, for example polychlorinated biphenyls (PCBs), chlordane and DDT. Long-term trends for two PCBs are shown in Figure 6.6.

The environmental behaviour of POPs is strongly affected by temperature and other climate-related factors (UNEP/AMAP 2010; Macleod *et al.* 2005), including precipitation patterns, wind fields and extreme weather events. In general, climate change is expected to cause greater mobilization of POPs from primary and secondary sources as well as increased airborne transport (Lamon *et al.* 2009). It is unclear to what extent higher temperatures will accelerate the degradation of POPs, but the melting of ice in which they have been held for decades contributes to rising amounts of POPs and other pollutants in the environment (Bogdal *et al.* 2010).

Pesticides including POPs

Pesticides are compounds designed to kill specific pests but often reach non-target organisms as well. In one study, more than 90 per cent of sampled water and fish were found to be contaminated by several pesticides and estimates indicated that

Figure 6.6 Trends in two PCBs from air monitoring data at two sites in the northern hemisphere, 1995–2005



Source: Adapted from Hung *et al.* 2010

A farmer, wearing no protective equipment, sprays his vines with pesticide. *© Alistair Scott/iStock*

about 3 per cent of exposed agricultural workers suffer from an episode of acute pesticide poisoning every year (Thunduyil *et al.* 2008). It is therefore imperative to know the nature of exposure and causes of contamination, and to identify action that can be taken to reduce pesticide levels in terrestrial and aquatic ecosystems. Long-term pesticide sales data constitute the main global and regional indicators of pesticide use (Brodesser *et al.* 2006). The last 25 years have seen a reduction in insecticide sales due to mammalian toxicity concerns, although general pesticide sales increased from US$5.4 billion in 2004 to US$7.5 billion by 2009 in the Latin American region, with 2,4-D, paraquat, methamidophos, methomyl, endosulfan and chlorpyrifos accounting for a high proportion of these sales (Brodesser *et al.* 2006).

Globally, the main 15 pesticides found in streams and groundwater include the herbicides atrazine and di-ethylatrazine, metolachlor, cyanazine and alachlor, and the insecticide diazinon. However, regarding fish, riverbed sediments and soils, the main pesticides still include persistent insecticides, heavily used in the 1960s and currently banned in most developed countries, such as DDT, dieldrin and chlordane. Moreover, endosulfan sulphate, the metabolite of endosulfan still in use in many countries, is a very common contaminant of surface and groundwater (Ondarza *et al.* 2011). Although the use of most organochlorine insecticides came to an end 10–25 years ago, they remain in the environment at levels of concern (Gonzalez *et al.* 2010; Ondarza *et al.* 2010).

More than 70 per cent of the populations of low-income countries live in rural areas, and 97 per cent of rural populations are engaged in agriculture. While developing countries account for just one-third of global pesticide use, the vast majority of pesticide poisonings occur in these countries (Brodesser *et al.* 2006).

The extent of human exposure and the health effects of pesticides under future climate change conditions will depend on the adoption of less toxic practices that take account of changes in factors such as temperature and precipitation (Boxall *et al.* 2009).

Obsolete pesticides

Pesticides become obsolete when they can no longer be used for their intended purpose. There are four major international agreements for their regulation: the Stockholm, Rotterdam and Basel Conventions and the 1998 Protocol on POPs to the 1979 Geneva Convention on Long-Range Transboundary Air Pollution (UNECE Geneva Convention 1979/98). It is difficult to estimate exact quantities of obsolete pesticides because many are very old and documentation is scarce. Parties to the Stockholm Convention are in the process of collecting information on nine POPs that were added to the convention's annex in 2009, including hexachlorocyclohexane (HCH), and a good deal is known about dump sites of the latter even though some smaller sites may be missed. However, amounts of obsolete pesticides that do not fall under the Stockholm Convention remain vague and can only be roughly calculated. On the basis of experience in Africa and the Middle East, UNEP estimates that on average POP pesticides make up only around 30 per cent of all existing obsolete pesticides (UNEP 2000).

Country-by-country assessments carried out by the International HCH and Pesticide Association (IHPA 2009) suggest that obsolete pesticides could amount to between 256 000 and 263 000 tonnes in the countries of the former Soviet Union, the Southern Balkans and new Member States of the European Union (defined as EU-12, EU accession countries, the countries of the European Neighbourhood Policy (ENP), the Russian Federation and Central Asia together), costing approximately US$780 million to dispose of, while some estimates for Africa by UNEP Chemicals suggested

Table 6.2 Quantities of obsolete pesticides

Region	Estimated quantities (tonnes)	Estimated disposal costs at US$3 000–5 000 per tonne (US$ million)
Africa	27 395	82.2–137.0
Asia	6 463	19.4–32.3
Eastern Europe	240 998	722.9–1 204.9
Latin America and the Caribbean	11 284	33.9–56.4
Near East	4 528	13.6–22.6
Total	**290 668**	**872–1 453**

Note: The latest updates given by FAO vary from 1994 to 2006.

Source: FAO 2012

that there may be as much as 120 000 tonnes remaining (UNEP 2002), costing some US$200–250 million to dispose of, applying UN Food and Agriculture Organization cost estimates (FAO 2002). These assessments alone identify 376 000–383 000 tonnes for disposal at a cost of US$968–1 040 million. The most recent FAO figures, shown in Table 6.2, indicate that there are some 290 000 tonnes of pesticide stockpiles with estimated disposal costs of US$3 000–5 000 per tonne (FAO 2012).

The Africa Stockpiles Programme (ASP), launched in 2005, aimed to clear all obsolete pesticides and contaminated waste in Africa within 10–15 years and to promote prevention measures and capacity building. It is very likely that the costs of inaction by far exceed the costs of cleaning up. As underlined by the European Environment Agency (EEA), downplaying the costs of inaction is a frequent phenomenon (Koppe and Keys 2001) and analysis suggests that the costs of inaction are high (OECD 2008c).

Metals, metalloids and heavy metals

Inorganic pollutants, including metals and metalloids, also adversely impact human populations on a global scale (Blacksmith Institute 2011). Unlike organic chemicals, metallic elements do not degrade and may accumulate in the environment and become increasingly bio-available over time. Their impacts are often most severe in the developing countries where they are mined, processed, used and recycled with limited environmental control and regulation. Populations in more developed countries also suffer from historic and on-going industrial emissions of pollutants, as well as from associated releases of other pollutants such as sulphur oxides, which cause acid rain, and acid mine drainage (Carn *et al.* 2007). Contamination even extends to Antarctica, as industrial pollutant emissions are carried there by long-range atmospheric transport from other continents (Caroli *et al.* 2001). Pollutants can also be re-released after decades as glaciers melt (Geisz *et al.* 2008).

Poisoning by naturally occurring arsenic is a global problem (Ravenscroft *et al.* 2009). More than a decade ago it was estimated that 130 million people around the world have been exposed to toxic levels of arsenic in drinking water, above the WHO recommended limit of 10 parts per billion (Smith and Lingus 2000), but there is mounting evidence that arsenic toxicity occurs at levels below that standard (Wasserman *et al.* 2004). There are also many unexplored sources of arsenic and the total number of people affected may be higher (Huang *et al.* 2011). Associated toxicities include diabetes and skin, kidney, lung, neurological and vascular diseases – most notably blackfoot disease which leads to gangrene – and bladder cancer. These diseases are most prevalent in vulnerable populations living on subsistence diets of arsenic-contaminated foods and with limited access to clean water, minerals and nutrients, which partially counteract that toxicity. Arsenic pollution in Bangladesh, which resulted from drilling wells to protect the population from surface waters contaminated with pathogens (Lokuge *et al.* 2004), has been described as "the largest poisoning of a population in history" (Smith and Lingus 2000). Populations in both developed and developing countries may be exposed to arsenic at contaminated sites left behind by the formerly widespread use of arsenic as a pesticide.

Lead is among the most prominent of the global contaminants (Rauch and Pacyna 2009), with several activities being responsible for acute lead poisoning. There are on-going human health problems at previous mining and smelting sites, including in Kabwe, Nigeria (Nweke and Sanders 2009) and the Rudnaya River Valley, Russia (von Braun *et al.* 2002), where high lead levels in children persisted after the smelters in both areas were closed, and in La Oroya, Peru, where 99.7 per cent of the children living nearest the smelter were found to have dangerously high levels of lead in their systems (Fraser 2009). On a global scale, some 85 per cent of lead-acid batteries are recycled, but there are recycling sites such as in Dakar,

The Lavender red copper open pit mine in Bisbee, Arizona, United States.

© Claude Dagenais/iStock

Senegal (Haefliger *et al.* 2009), where the average blood-lead concentration of children was at 130 micrograms per decilitre, enough to cause acute toxicity or even death (ATSDR 2007). Children may also be exposed to lead in paints, which has been phased out in developed countries but persists in some developing ones (Lanphear *et al.* 1998). Electronic waste recycling can also involve exposure to lead in solder, and there are sites such as Guiyu, China (Huo *et al.* 2007), where 82 per cent of the children tested in the village had blood-lead concentrations above the US Centers for Disease Control action level of 10 micrograms per decilitre (ATSDR 2007). Although that level is two orders above the estimated natural lead level, there is no established lower threshold for lead toxicity in humans (Flegal and Smith 1992).

Most coals contain tiny proportions of mercury, so industrial mercury fluxes to the biosphere are projected to increase with greater fossil fuel combustion (Soerensen *et al.* 2010). While large amounts of mercury are thus released into the environment from numerous industrial activities, reports of acute neurotoxicity from mercury poisoning are now primarily associated with its use to amalgamate gold in artisanal mining, which is practised in more than 50 countries (Bose-O'Reilly *et al.* 2008). In Indonesia and Zimbabwe, all of the children tested in two mining areas were found to have elevated mercury levels and corresponding signs of mercury intoxication, whether they were directly involved in mining or not (Bose-O'Reilly *et al.* 2008). This poisoning of children is of special concern because mercury, even at sub-lethal levels, is a neurotoxin that can permanently impair development and – like some other toxins – foster auto-immune resistance, making children and adults more vulnerable to infection and disease, as has been found with artisanal gold miners in Brazil (Feingold *et al.* 2010). Currently, UNEP is convening an intergovernmental negotiating committee to prepare a global legally binding instrument on mercury: more than 100 countries are participating and a global treaty text is expected to be ready for adoption in late 2013 (Selin and Selin 2006).

A number of other metals such as zinc, copper and manganese could have harmful human and environmental impacts at certain levels. Cadmium, which was once used in pigments and for electroplating, is the most toxic, and contaminated sites may remain. Its main uses now are in rechargeable nickel-cadmium batteries, and collection and recycling of these items must be efficient if it is not to be released to the environment. Cadmium is also released into the environment by some fossil fuel combustion, and is in addition a natural contaminant in phosphate deposits, so may be transferred in fertilizers and taken up by root vegetables (Jarup and Akesson 2009).

Radioactive material

Radioactive material has been in use since the 1890s, increasing significantly with the advent of nuclear energy in the 1940s and its exploitation in weapons, with a concomitant increase in the generation of radioactive waste and contaminated sites. In addition, the use of radioactive materials in industry, research and medicine continues and increases, as do the mining and processing of minerals containing elevated concentrations of naturally occurring radionuclides. Some contaminated sites have been remediated at significant cost, while others remain to be addressed. The rising cost and reduced availability of fossil fuels have from time to time favoured the adoption of nuclear power, as have recent concerns over greenhouse gas emissions. However, social attitudes to nuclear accidents such as those at Three Mile Island and Chernobyl – which are rare but can have a very high impact – have exerted a restraining influence. It was predicted in 2008 that the use of nuclear energy would increase by 15–45 per cent by 2020 and by 25–95 per cent by 2030 (IAEA 2008a), but future activity is likely to be affected by responses to the more recent Fukushima disaster.

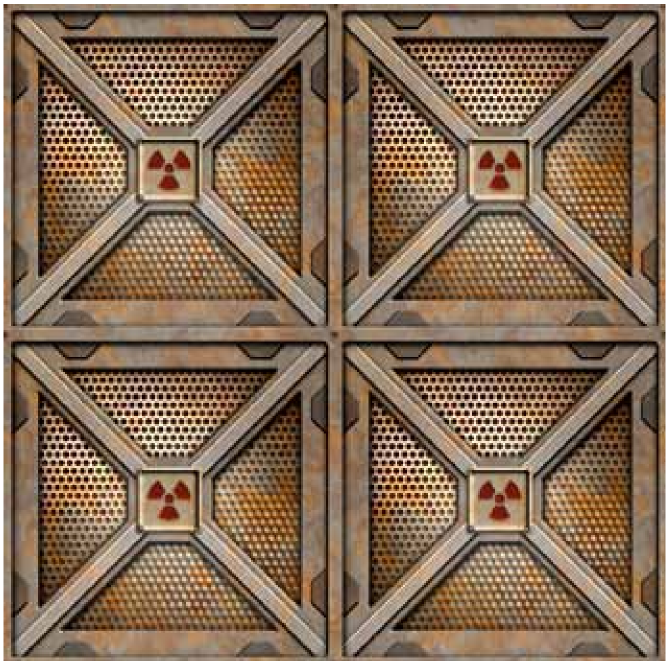
Radioactive waste takes many physical and chemical forms and has differing radioactive properties. The international system of classification (IAEA 2009a) links waste classes (exempt, very short lived, very low level, low level, intermediate level, high level) to options for management and disposal. Disposal is the final

Table 6.3 Global inventory of radioactive waste, 2004

Waste source	Low- and intermediate-level waste		Spent fuel		High-level waste		Mining	
	Volume (million m³)	Activity (million TBq)	Mass (million MTHM)	Activity (million TBq)	Volume (million m³)	Activity (million TBq)	Volume (million m³)	Activity (TBq million)
Nuclear power	2	1.2	0.17	28 000	0.034	42	1 600	0.028
Industrial or medical use	2	1.2						
Weapons	4	0.7			0.8	31	250	0.0046
Total	**8**	**3.1**	**0.17**	**28 000**	**0.8**	**73**	**1 850**	**0.033**

Note: MTHM – metric tonne of heavy metal; TBq – Tera-Becquerel.

Source: IAEA 2008b



Crates for storing radioactive material. *© Clearviewimages/iStock*

step in the management of radioactive waste, generally in near-surface or deep land-based facilities. Apart from high-level and some intermediate-level waste, the majority has been disposed of in such facilities. Table 6.3 presents an estimate of the global inventory of radioactive waste (IAEA 2008b).

About a hundred near-surface facilities exist, and others for disposal of waste of various levels are under development in a number of countries, although the process of selecting and designing a site is often contentious. Many nuclear reactors are ageing and will need to be decommissioned in the near future, resulting in radioactive waste and signalling the need for disposal facilities and trained professionals to operate them. As of 2 February 2012, 435 nuclear power reactors with a combined capacity of about 368 gigawatts are in operation in 30 countries, of which around 75 per cent are more than 20 years old, and 63 plants with a combined capacity of 61 gigawatts are under construction in 14 countries (European Nuclear Society 2012).

Contracting Parties to the Joint Convention on Radioactive Waste and Spent Fuel increased steadily after its establishment in 1997 to number 58 in April 2011, and are committed to ensuring a high level of safety in radioactive waste management. At the 2009 triennial review meeting, the reports of 45 Contracting Parties were reviewed with the conclusion that there is a commitment to improve safety, make progress in building, maintaining and implementing legal/regulatory frameworks, and observe good practices in national radioactive waste management strategies and policies (IAEA 2009b). Despite progress since the 2006 review meeting, however, the 2009 meeting concluded that much still needed to be done to meet the following challenges:

- implementation of national policies for the long-term management of spent fuel, including disposal;
- siting, construction and operation of spent fuel and radioactive waste disposal facilities;
- management of legacy wastes;
- monitoring of disused sealed sources and recovery of orphan sources;
- knowledge management and human resources development; and
- provision of financial resources for liabilities.

There has been a growing trend for disposal facilities to undergo international peer-reviewed safety demonstration (IAEA 2006). In addition, the 2010 General Conference of the International Atomic Energy Agency (IAEA) created an International Working Forum on Regulatory Supervision of Legacy Sites (IAEA 2010), aimed at enhancing regulatory regimes, the professional development of regulators and the application of safety and environmental assessment.

EMERGING ISSUES

Policy making and regulatory processes are naturally prone to lag behind rapid changes taking place in the global production and distribution of chemicals and wastes. The challenge is to protect human health and the environment from the undesirable effects of chemicals and wastes even when there are inadequate quantitative data and the potential life-cycle hazards of both old and new materials are incompletely understood.

Nanomaterial and nanoparticles

Many new materials are produced as minute particles of a nanometre – or one-billionth of a metre – in size, and they exhibit chemical and biological properties that are quite different from those of the corresponding bulk materials. Commercial applications of nanomaterials include, for example, food packaging, personal care products, cosmetics and pharmaceuticals. Their unique properties make nanomaterials useful in cancer therapies, the neutralization of pollution or improvement of energy efficiency. However, safety testing is in its infancy and governments have been slow to adapt existing regulations to these new materials, even though they are widely marketed and some potential for human exposure has been identified (Morris *et al.* 2010). More research is needed for a better understanding of workplace and consumer exposure and related impacts on human health, especially as some of these materials are known to pass through the skin and are small enough to penetrate cell membranes and cause toxic effects at cellular and sub-cellular scales. Furthermore, very little is known about whether nanomaterials or nanoparticles are released from products when they are incinerated, buried or degrade over time, so it is possible that they will pose a serious waste disposal challenge. Sound decision making on nanotechnology has provoked much debate among developed-country regulators, and is increasingly doing so among the regulators of developing countries (Morris *et al.* 2010).

Plastics in the environment

Plastics are ubiquitous in the environment. They are widely used in many products and have many formulations. The simple plastic bag is a prime example of how a utilitarian object can become an environmental hazard. More than 500 billion plastic bags are used every year but many are improperly disposed of, ending up as marine litter. This significant problem was highlighted in the *UNEP Yearbook 2011* (UNEP 2011b), showing that discarded plastic debris forms a major component of marine litter, degrading into micro-pollutants in ocean gyres, fouling beaches in coastal waters, and entering the food chain where it is consumed by marine fauna such as turtles and sea birds, weakening or killing them by affecting their digestion, respiration and reproduction. There is concern that these plastics also act as transport vectors of persistent organic pollutants such as PCBs and similar compounds, with chronic effects on wildlife. The solution is sound management, preventing the escape or discharge of this material, yet rates of plastic recycling and reuse vary greatly, from more than 80 per cent in some EU countries to only a small percentage in many developing ones. The Global Programme of Action (GPA) for the protection of the Marine Environment from Land-based Activities and other local and regional initiatives are seeking to address this issue (Astudillo *et al.* 2009; Young *et al.* 2009).

Electronic waste

The high turnover of equipment in the information and communication technology industry has caused an increase in obsolete electrical and electronic products, which in turn has generated almost uncontrollable volumes of end-of-life products driving a global trade in e-waste. As the fastest growing waste stream in the world, estimated at 20-50 million tonnes per year, e-waste has become one of the major environmental challenges of the 21st century (Schwarzer *et al.* 2005). Generated by a wide range of electrical products, it is of particular interest because it contains not only hazardous substances including heavy metals such as mercury and lead, and endocrine-disrupting substances such as brominated flame retardants (BFRs), but also many strategic metals such as gold, palladium and rare earth metals that can be recovered and recycled. E-waste can thereby serve as a valuable source of secondary raw materials, reducing pressure on scarce natural resources and the environmental footprint of the mining industry.

Discarded computer circuit boards. *© roccomontoya/iStock*

Developing countries nonetheless remain the destination of most of the e-waste exported from developed countries as second-hand or used equipment. Yet these countries often lack the infrastructure, capacity and resources for its sound management (UNEP 2009), with the informal sector and vulnerable groups employing crude processing methods such as open-air burning or acid leaching to recover valuable metals like copper and gold. In the process, toxic substances in the waste may be released into the environment, posing a high risk to ecological and human health. Recent studies have revealed that by 2016, developing countries will generate twice as much e-waste as developed countries (Zoeteman *et al.* 2010), but while electronic equipment has positive impacts on development and progress, it can have negative impacts on both human health and environmental integrity as end-of-life e-waste. This is a growing environmental and public health issue that threatens attainment of the Millennium Development Goals (MDGs) in developing countries and economies in transition.

Endocrine disruptors

Endocrine disruption is the term given to the alteration of hormonal signals in living systems when they are exposed to chemical substances. A considerable number of chemicals have been shown to be endocrine disruptors, affecting the growth and reproductive and neurological development of many species, including humans (Waye and Trudeau 2011; Gore and Patisaul 2010; Toppari *et al.* 1996; Colborn *et al.* 1993). In addition, the numerous chemical substances, both natural and anthropogenic, that are present in the environment in low concentrations come together to exacerbate exposure of both humans and wildlife. Many investigations have been conducted since publication of the *Global Assessment of the State-of-the-Science of Endocrine Disruptors* (WHO 2002), and it is clear that both inorganic and organic substances can affect hormonal signalling. UNEP has proposed listing this as an emerging policy issue for listing under the Strategic Approach to International Chemicals Management (SAICM).

Open burning

In open burning, the pollutants produced by combustion are released directly to the air and so enter the environment in uncontrolled ways. Open burning can include forest wildfires, planned combustion activities such as burning stubble in preparation for a subsequent grain crop, irresponsible burning of waste such as domestic rubbish and e-waste, arson-initiated combustion of scrap tyres, and even public detonation of fireworks (Lemieux *et al.* 2004). Polycyclic aromatic hydrocarbons (PAHs) are always released in these processes, and (in the case of fireworks) heavy metals such as lead and copper are also released. PAHs are widespread in the environment in both developed and developing countries (Barra *et al.* 2007), and concern about their carcinogenic properties has led to their classification as primary pollutants by agencies such as the US Environmental Protection Agency.

Gaps in the understanding of chemical toxicity

Since humans are continually exposed to a multitude of manufactured chemicals, there is a need to understand the behaviour of these chemicals and their interaction with human health and the environment. Previously unsuspected properties of widely used chemicals present legacy problems that raise concern in the scientific community and among the public. For example, of the many chemicals that have been found to have endocrine-disrupting properties, bisphenol-A is present in many plastic baby bottles and food can liners, and phthalate esters in various flexible plastics including some children's toys (Hengstler *et al.* 2011). Consumer vigilance is not enough to prevent exposure in such cases because the presence of these chemicals is usually not evident to the non-expert. This places a heavy responsibility on public authorities to inform people about potential risks associated with manufactured chemicals, and on manufacturers to exercise the extended or individual producer responsibility approach and to search for alternatives.

Most existing chemical regulations worldwide address the effects of individual substances. Managing single chemicals is difficult enough, but there is also concern about gaps in understanding human exposure to mixtures of chemicals (Rajapakse *et al.* 2002; Silva *et al.* 2002). As mentioned, little has been done to study the toxicology of mixtures. There is an urgent need for further risk assessment of the combined exposure of multiple chemicals – the chemical cocktail or synergistic effects – to human health and the environment. Integrated environmental risk assessments based on state-of-the-art dynamic pollutant modelling and toxicological experiments on chemical cocktails will help quantify planetary boundaries for chemical pollution (Handoh and Kawai 2011; Rockström *et al.* 2009).

GAPS AND OUTLOOK

Chemical properties, patterns of use and the environment

There is a lack of information about the health and environmental effects of many chemical substances and about the products in which different types of chemicals are used (OECD 2008b). Huge gaps in the assessment of chemicals arise from two causes. First, many were introduced and became established items of commerce before systematic assessments began. Where there is mounting evidence of harm or potential harm, action can lead to regional controls and eventual listing under global conventions, but most industrial chemicals remain unassessed. Second, concerns have arisen over hitherto unsuspected properties such as the endocrine activity of phthalates and bisphenol A, for example, or long-range transport coupled with bioaccumulation. Furthermore, academic assessment suggests the potential for further industrial chemicals and pesticides to qualify as POPs (Muir and Howard 2010, 2006). It should also be noted that wastes are often mixed, which makes it extremely difficult to assess the risks of any chemicals present. In addition, residues arising from the recycling of hazardous waste may contain a higher concentration of toxic materials than the recyclable materials themselves.

Long-term monitoring programmes for POPs in the environment as well as in human tissue need to be maintained and expanded, in particular in the southern hemisphere. They are essential for a better understanding of trends in global chemical pollution and for the Stockholm Convention's evaluation of effectiveness.

More extensive work on chemical toxicity inventories is aiming to fill a significant gap. An example is the European legislation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). This has extended the number of chemicals covered by regulations, notably those that were on the market before 1981 and previously exempt (Chapter 11).

Limited information on chemicals in products makes it difficult to document the extent of the risk posed to human health and the environment. Initiatives such as the ongoing UNEP Global Chemicals Outlook and the Cost of Inaction (UNEP Mainstreaming of Chemicals) will help to fill some important knowledge gaps.

In addition to scientific knowledge gaps, sound chemicals and waste management is also hampered by a lack of resources, capacity and compliance monitoring. A lack of education and training also limits appropriate management of chemicals and wastes in many developing countries. Increased trade resulting from free trade agreements can complicate this picture (Vogel 1997), as such agreements may well exert even more pressure on emerging economies with respect to regulating or restricting chemical use.

Chemicals, wastes and drinking water

At the global level, about 1.1 billion people do not have access to a safe water supply and 2.6 billion people do not have access to adequate sanitation facilities. The associated health impacts are alarming: 1.7 million deaths per year, of which 90 per cent are children under five years of age (WHO/UNICEF 2005). The costs of water pollution may represent between 0.3 and 1.9 per cent of rural gross domestic product (GDP) (WHO/UNICEF 2005). Industrial sectors with the potential for significant water pollution include the chemicals sector, food and beverage sector, textile and mining industry and pulp and paper sector. The policy framework for regulating the industrial point sources of water pollution is well developed in most OECD countries, although some pollutants such as heavy metals and chlorinated solvents remain a concern. Increasing attention is being paid to non-point sources, such as agricultural run-off, which are more difficult to regulate but can lead to nitrate pollution of water bodies. In addition to efforts to reduce the run-off of organic pollutants from fertilizers and manure, organophosphates from pesticides are also a concern. Studies reviewed by the OECD (2008a, 2008b) suggest that national measures to reduce agricultural run-off and manage storm water, including targeted measures to reduce a variety of different pollutants such as arsenic and nitrates, could yield health benefits in excess of US$100 million in large OECD economies (Hammer *et al.* 2011). In non-OECD countries, the cost of inaction with respect to unsafe water supply and sanitation is particularly acute.

Box 6.6 Funding: an ongoing challenge

Much effort at the intergovernmental level goes into identifying the funding and support needs of capacity building, technical assistance and institutional strengthening for the sound management of chemicals and waste in developing countries and economies in transition. This is reflected in the decisions of the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions, especially for national implementation plans. International funding for implementation of the chemicals and wastes agenda is currently managed and channelled through the World Bank, Global Environment Facility (GEF), United Nations Development Programme (UNDP), UNEP, the United Nations Industrial Development Organization (UNIDO), the United Nations Institute for Training and Research (UNITAR), FAO, WHO and the Quick Start Programme of SAICM, as well as the OECD and regional development banks. Some funding is also available through private-sector bodies. In addition, SAICM, the Inter-Organization Programme for the Sound Management of Chemicals (IOMC), Intergovernmental Forum on Chemical Safety (IFCS), and Organisation for the Prohibition of Chemical Weapons (OPCW) play supportive and coordinating roles.

The existing approach is hampered by fragmentation, disconnections and insufficient coordination, and adequate funding remains a fundamental challenge. For example, lack of agreement on funding has played a significant part in delaying establishment of a compliance mechanism for the Stockholm Convention. As a result, in 2009 the Executive Director of UNEP launched the Consultative Process on Financing Options for Chemicals and Wastes to look at overall funding needs and possibilities. Between 2009 and 2011 participants discussed four tracks:

- mainstreaming of sound management of chemicals and hazardous wastes;
- industry involvement, including private-public partnerships and the use of economic instruments at the national and international levels;
- a new trust fund similar to the Multilateral Fund; and
- introducing safe chemicals and waste management as a new GEF focal area, expanding the existing POPs focal area under GEF or establishing a new trust fund under the GEF.

The final meeting of the Consultative Process in October 2011 resulted in a document outlining an integrated approach to financing the sound management of chemicals and wastes (UNEP 2012). This formed the basis of a report by the UNEP Executive Director to the UNEP Governing Council Special Session in February 2012, which in turn resulted in governments requesting the Executive Director for a fully-fledged proposal on an integrated approach ensuring optimal funding for the chemicals and wastes sector. A decision on this is expected at the third SAICM International Conference on Chemicals Management in September 2012 and the UNEP Governing Council in 2013.

The follow-up to the Consultative Process is an important opportunity to raise the profile of financing for sound management of chemicals and wastes and links to human health and development, the environment and carbon. It is an intrinsic component of development and a necessary objective to bring lasting social, environmental and economic benefits. Without adequate infrastructure in the key sectors of health, water, sanitation, energy, transport, information and communication technology, and disaster management, there is little hope of protecting people from the risks of exposure to harmful chemicals, hazardous or radioactive waste and other waste streams contaminating the environment.

Reinforcing a global response

The Basel, Rotterdam and Stockholm Conventions and other instruments that address chemicals and wastes – including the Montreal Protocol on Ozone-Depleting Substances, MARPOL, the London Convention, and regional treaties like the Bamako, Waigani or Mediterranean Conventions, as well as the future Minamata Convention on Mercury – represent the foundation on which to build and consolidate a global response to protect human health and the environment from the adverse effects of chemicals and waste. Discussions conducted under the auspices of these global instruments enable emerging problems to be foreseen and facilitate the formulation of ways to manage issues soundly and collectively on a sustainable basis. All these global legally binding instruments, as well as regional agreements such as those agreed by the OECD and the European Commission, share the universal principle of an environmentally sound management of chemicals and waste. A key feature of this global architecture is transparency in the collection and dissemination of information. The EU chemicals legislation, REACH, is exemplary of such efforts (Hartung and Rovida, 2009). But large gaps remain, both in addressing the number of chemicals and nanomaterials present in the market, and in the fact that many countries are unable to manage hazardous chemicals and waste in an environmentally sound way.

With the Basel, Rotterdam and Stockholm Conventions sharing the common objective of protecting human health and the environment from hazardous chemicals and wastes, the Parties to these agreements have embarked on rationalizing their operations to improve assistance to countries in managing chemicals at different stages of their life cycle. This has been exemplified by the establishment of the International Panel on Chemical Pollution (IPCP) in 2008, enhanced cooperation and coordination between the three conventions during their respective Conferences of the Parties in 2008 and 2009, and their simultaneous extraordinary meetings in Bali, Indonesia, in February 2010. Since early 2011, the convention secretariats have been working under a joint Executive Secretary, opening up the possibility of a more holistic approach to the sound management of chemicals and waste (Basel Convention 2012).

Outlook

Table 6.4 summarizes the main goals into key themes and uses the indicators described in this chapter to illustrate progress towards their achievement. It also makes recommendations for consideration alongside those from other chapters in Part 1 when developing policy options and responses as outlined in Parts 2 and 3.

Table 6.4 Progress towards goals (see Table 6.1)

A: Significant progress B: Some progress	C: Very little to no progress D: Deteriorating	X: Too soon to assess progress ?: Insufficient data

Key issues and goals		State and trends	Outlook	Gaps
1. Provide sound management of chemicals throughout their life cycle and of waste				
Sound management of chemicals	B	17 multilateral agreements are in place and over 300 activities have been conducted under the SAICM Global Plan of Action; 23 countries have a functioning national chemical register; a globally harmonized system of classification and labelling of chemicals has been established	The number of developing countries implementing sound chemicals management is increasing	Strengthening of the life-cycle approach; a more integrated global framework for risk assessment and risk management of chemicals; plans for the implementation of sound management of chemicals, most notably for developing countries heavily involved in the production, trade and use of chemicals, particularly in Asia and the Pacific and Latin America
Sound management of waste	B	Objective standards of environmentally sound waste management are not optimal; practices vary widely according to local norms and conditions; cities face increasing problems with management of municipal waste, poor monitoring and open burning, and illegal traffic in waste	Waste production will increase according to current trends in consumption and trade	Data on waste
Improve resource efficiency	C	Efficient ways of transforming waste into energy, applicable in developing countries, are lacking	Environmentally sound energy recovery will benefit some situations if balanced with emphasis on waste recovery for reuse and recycling rather than competing with energy solutions	Technology transfer and capacity building for the long term to ensure the performance of any facility is maintained
Prevent and minimize waste by maximizing reuse, recycling and environmentally friendly alternative materials	?	Many initiatives and some regional and national programmes exist, including Reduce, Reuse, Recycle; EU Producer Responsibility Directives; Basel Mobile Phone Partnership; and Basel Partnership Action on Computer Equipment	Potential to raise many of these efforts to a global level	Global measurement methodology and data on waste minimization; reliable data and trend information
Strict control of the generation and management of hazardous and other waste	?	Data from national reporting to the Basel Convention Secretariat is sparse and difficult to interpret; reporting by Parties is declining	Trend may continue if Parties are not supported in improving compliance and changing direction	Additional effort on awareness raising and capacity building
2. Protect human health and the environment from POPs				
Eliminate or restrict the production, use, import and export of POPs	B/B/B	B: Some progress, but it is still too early to evaluate headway on the basis of the indicators; B: long-term records show a decrease in atmospheric POP concentrations during the 1980s and 1990s, but trends have levelled off since 2000; B: in urban regions of Western industrialized countries PCB emissions are ongoing and of the order of 0.1–1.0 gram per person per year	Continuing exposure to POPs in all parts of the world is likely; climate change may increase exposure due to greater mobilization of POPs	Support to developing countries for their national implementation plans under the Stockholm Convention; greater attention to DDT exposure from malaria control, and exposure to polybrominated diphenyl ethers (among other chemicals) from handling e-waste
3. Reduction of the risks posed by heavy metals				
Restrict production and use of heavy metals	B	Progress in developed countries has resulted in a less frequent occurrence of acute toxicity, but exposure still occurs at industrial and legacy sites, and there is increasing concern regarding possible subtle developmental effects of chronic, low-level exposure; significant problems remain in developing countries, where heavy metals are often mined, processed, used and recycled with limited control, and where most cases of acute toxicity occur, particularly for lead, mercury and arsenic	Ongoing global negotiations on mercury are positive, and further efforts are required to include heavy metals (lead, cadmium, arsenic) in international agreements	Additional research into alternative, more benign chemicals for use in consumer goods to help reduce the heavy metal burden to the environment; more stringent occupational, human health and environmental standards

Table 6.4 Progress towards goals (see Table 6.1) *continued*

3. Reduction of the risks posed by heavy metals *continued*				
Restrict import and export of heavy metals, and waste containing heavy metals	B	The rapid turnover of e-products and high cost of eliminating the hazardous substances within them have led to growth in the trade and movement of e-waste to developing countries where labour costs and health and environmental standards are lower	EU directive on the restriction of certain hazardous substances in e-waste is a positive step; global initiatives are also required	Global initiatives such as that on mercury would be beneficial
Improve waste disposal techniques for waste containing heavy metals	?	Much controlled disposal takes place in developed countries, but work is still needed in many developing countries to improve disposal following mining, smelting, battery and e-waste recycling	Internationally agreed goals for lead, mercury and possibly other heavy metals exist or are in development; further efforts are required	More stringent occupational, human health and environmental standards, as well as more stringent regulations surrounding disposal
4. Promote shared responsibility and cooperative efforts between Parties in the international trade of certain hazardous chemicals				
Develop national decision-making processes for the import and export of hazardous chemicals	C	Many developing countries lack policies on sound management, with weak institutional and regulatory frameworks and poor enforcement of existing laws; there is no coherent approach for national decision-making, with a multiplicity of government agencies having mandates for the import and export of hazardous chemicals, causing jurisdictional conflict and weakening decision-making	Foreseeable improvement if the rate of notifications under the Rotterdam Convention continues or is enhanced	Improvement of mechanisms, governance and a regulatory framework for effective decision making at regional and national levels, including promoting synergy in the implementation of international chemical and waste agreements
Facilitate information exchange about chemical characteristics	?	There is a lack of datasets and effective mechanisms available to national, regional and international stakeholders for the retrieval and dissemination of information about chemicals' characteristics; poor information exchange between government agencies at the national level is hindering informed decision making		Development and implementation of functional international, regional and national networks for the exchange of information on the characteristics of hazardous chemicals and wastes
5. Use transparent science-based risk assessment and risk management procedures				
Sound management of chemicals throughout their life cycle	?	Risk assessment is being used at the international level (Stockholm Convention), but is constrained in developing countries by the lack of data on exposure and effects caused by chemicals and wastes, and also by capacity constraints Under the Montreal Protocol, training has been provided for ozone officers to detect illegal shipments; the Globally Harmonized System (GHS) for labelling of chemicals in the workplace is hazard-based and can be used as input to risk assessment There is uncertainty about both the hazardousness of certain chemicals and the risk they pose; chemicals in products are often not identified, sometimes for reasons of commercial confidentiality	The situation may improve through the activities of the convention review committees, the intergovernmental process on mercury, EU REACH and national reassessments of chemicals	Data on children's vulnerability to chemical risk (average risk assessment only uses adult data); training in chemicals identification and risk management under the auspices of SAICM; disclosure of product composition
Encourage research in order to prevent, eliminate and reduce pollution of the marine environment	A	Historically, investment in marine pollution research has been more active in the northern hemisphere; more recently, important efforts are being made in the developing world to protect marine resources – often an important food source – from pollution		Scientifically sound data on contamination
6. Develop adequate monitoring systems (national, regional and global)				
Develop sound science-based monitoring programmes	?	For POPs, the Global Monitoring Plan is in place; for a wide range of additional chemicals, biomonitoring programmes are inadequate in most countries and human exposure is incompletely documented; hazardous waste reporting systems are available for Parties to the Basel Convention but are not fully taken up or reported; the impacts of waste due to unsound disposal are difficult to quantify	Global monitoring programmes involving chemicals are being developed and harmonization and global coverage are expected to be reached in the coming years	Comprehensive regional and global monitoring programmes for building spatial and temporal trends of key chemicals and wastes, as well as datasets and indicators to enable monitoring of change; biomarkers and bioindicators to assist the assessment of chemical exposure and effects; training and appropriate laboratory facilities in developing countries, and support to build capacity for monitoring hazardous residues imported from developed countries (storage, disposal or reprocessing)

Table 6.4 Progress towards goals (see Table 6.1) *continued*

7. Capacity development				
Sound management of chemicals and hazardous wastes	C	In spite of efforts by international agencies, capacity development for sound management in developing countries is still lacking; Basel and Stockholm Convention Regional Centres have been established to enhance the capacity of governments and stakeholders in developing countries, but adequate financing mechanisms are not yet in place	Situation likely to improve if Stockholm and Basel Conventions, SAICM and the GHS can be supported through innovative financing mechanisms	An adequate financing mechanism, as well as information and knowledge sharing between north and south
Improve resource efficiency	B	Waste disposal rather than integrated waste management is practised without resource and materials recovery, and national waste policy and legislations on integrated waste management as well as infrastructure for collection are inadequate; crude and resource-inefficient recycling exists in the informal economy	Environmentally sound management of waste instead of indiscriminate disposal and uncontrolled open burning	Promotion of regional and national initiatives on waste-to-energy and waste-to-organic-fertilizers, along with waste recycling and materials recovery through pilot/demonstration projects
Control of transboundary movements of hazardous waste	?	The control system available via the Basel Convention's prior informed consent notification process can work very well when fully utilized, though the process is vulnerable to circumvention and illegal traffic	Full national implementation of the Basel Convention and measures under SAICM, along with further stimulus, would improve the rate of progress	Improved capacity building and funding mechanisms to sustain implementation and compliance of the Basel Convention; elaboration of synergistic convention initiatives at the regional and national levels; improved cooperation between international, regional and national networks for controlling the transboundary movement of hazardous waste Greater cooperation, for example through the European IMPEL and global INECE networks, to improve compliance and enforcement, together with Interpol Pollution Crimes Working Group initiatives; better reporting as well as active collaboration and cooperation with Basel Convention focal points in developing countries
8. Protect and preserve the marine environment from all sources of pollution				
Pollution from ships	B	Progress has been made under the MARPOL Convention – 150 countries have ratified although many are yet to comply; control of greenhouse gas emissions from international shipping, and a draft of the reduction mechanisms themselves are under further consideration by the International Maritime Organization's Marine Environment Protection Committee (MEPC)	Likely to improve with the development of new mechanisms under MEPC	Development and implementation of functional international networks for the control of ships' wastes, including disposal facilities in ports
Protect the marine environment	X	Protection of the marine environment has not always been given priority by institutional arrangements or by environmental regulations in developing countries; UNEP's regional seas conventions have not all been transposed into law or implemented; many countries have not ratified or implemented MARPOL; the level of coastal and marine pollution continues to increase, with a lack of control of land-based sources of pollution at the regional and national levels; unsustainable exploitation of marine resources and the marine environment is widespread	Mixed	International action to promote the ratification, transposition into national law and implementation of MARPOL, the regional seas conventions and the London Convention at the regional and national levels, as well as to develop multilateral agreements on chemicals and waste
9. Radioactive waste management and safety				
Ensure that radioactive wastes are safely managed, transported, stored and disposed of	B	Radioactive waste from the operation of nuclear facilities and uses of radioactive material in medicine, industry and research are generally controlled according to international standards and reported at meetings of the Joint Convention on Spent Fuel and Radioactive Waste; some legacy sites remain from nuclear weapons production and testing; some uranium mining legacy sites remain in Africa and Central Asia	Radioactive waste will continue to be generated by the nuclear industry, medical and industrial uses and mining and mineral exploitation, with elevated levels of naturally occurring radionuclides; management and disposal facilities will be needed in the foreseeable future	A closer link between the Joint Convention (already an important global instrument for safe management of radioactive waste) and other international instruments on hazardous materials to develop beneficial synergies; support for international efforts to assist with remediation of uranium mining legacy sites
Prevent accidents with radiological consequences and mitigate consequences of accidental releases	B	The Fukushima accident illustrates that nuclear accidents can still occur despite improvements since Chernobyl, and the Convention on Nuclear Safety (sister convention to the Joint Convention) is intended to ensure countries maintain a high level of safety	A number of countries have decided to phase out their nuclear programmes following the Fukushima accident while others continue to develop their programmes; it is too early to say what the overall impact will be	More emphasis to ensure that the objectives of the Convention on Nuclear Safety and the Joint Convention are achieved

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