UNEP YEAR BOOK

EMERGING ISSUES IN OUR GLOBAL ENVIRONMENT

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Reaching for the 2020 Goal

The need for better information and sound management to minimize chemical risks

The volume of chemicals manufactured and used continues to grow, with a shift in production from highly industrialized countries towards developing countries and countries with economies in transition. Increased international co-operation is needed to eliminate or reduce the use of toxic chemicals, to promote the development and adoption of safer alternatives, and to build capacity for regulation and management at every stage of the lifecycle of chemicals. It is also important that existing national laws and international agreements for sound chemicals management be fully implemented. Public availability of adequate information about chemicals – including their multi-faceted impacts on health and the environment – is essential to support these efforts. Yet we are lagging further behind with testing chemicals before they become available on the market, while too little is known about many of those already in commerce. To meet the internationally agreed goal to produce and use chemicals in ways that minimize significant adverse impacts on human health and the environment by 2020, we urgently need to increase our knowledge of chemicals.

Chemicals and their risks

Among their many other benefits, chemicals can help boost agricultural production, make water safe to drink and treat disease. However, they may also present risks to human health and the environment at every stage of their lifecycle, from production and use to storage, transport and disposal.

Annual sales of products of the chemical industry doubled between 2000 and 2009, with the share manufactured in highly industrialized countries falling from 77 to 63 per cent and the share manufactured in the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) increasing from 13 per cent to 28 per cent (Sigman et al. 2012). Chemical production is expected to continue to grow in all parts of the world (Sigman et al. 2012, UNEP 2012a) **(Figure 1).** As production of bulk chemicals shifts away from highly industrialized countries, there are concerns that the risks of chemicals for human health and the environment will be increased due to lack of regulatory experience in some countries, as well as insufficient infrastructure and resources to address these risks.

A small bottle of mercury used in artisanal and small-scale gold mining. Mercury is of global concern because of its persistence in the environment, its ability to accumulate, and adverse impacts on people and ecosystems. *Credit: Kevin Telmer*

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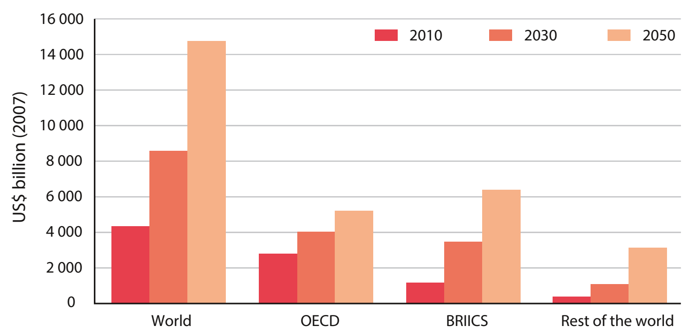


Figure 1: Current and projected chemical production (in sales) for the world, OECD members, BRIICS and other countries in the world, 2010-2050. *Source: Adapted from Sigman et al. (2012)*

Chemicals can be grouped into several (sometimes overlapping) main categories, including industrial chemicals, pesticides and biocides, pharmaceuticals, and chemicals used in consumer products.

Industrial chemicals include a very wide range of substances used in chemical processes and products (such as dyes, solvents and plastics) as well as thousands of everyday chemicals. They are manufactured, stored, transported and used worldwide as gases, liquids, suspensions, or in solid state and may pose a great variety of risks (Dhaniram et al. 2012).

Pesticides and biocides are used to kill, repel or control pests, influence the life processes of organisms and destroy or prevent their growth, and preserve plant products. They can be man-made chemicals or, like rotenone, be derived from nature. The properties of these chemicals' formulations, the amounts applied, application methods and environmental conditions determine their behaviour and fate in the environment. For example, pesticides can move in the air through volatilization and vapour drift and have adverse effects on humans and other non-target organisms, damaging ecosystems and reducing biodiversity (Davie-Martin et al. 2012, Reimer and Prokopy 2012).

Pharmaceuticals are generally used in the diagnosis and treatment of disease in people and animals. This category is very important in terms of its health benefits and global economic value.

Chemicals in consumer products including those commonly used in households often have known or suspected risks for human health and the environment (Massey et al. 2008, UNEP/SAICM 2011, UNEP 2012a). They mainly belong to the large category of industrial chemicals, or are in cosmetics and other personal care products. Chemicals are used in almost all manufactured articles to enhance appearance or performance. Impurities or by-products derived from the manufacturing process may also be present.

Most types of chemicals eventually end up as waste. Chemicals produced during manufacturing and other activities may be disposed of on land, incinerated, or treated by physical or chemical means. Other chemicals end up as waste in discarded products. The harmful health and environmental effects of some chemicals in products have been discovered after the products were already in wide use. Examples include brominated flame retardants, some plastic additives, and perfluorinated compounds. Some chemicals used in products can interfere with hormonal systems and have adverse impacts on human and wildlife, including foetal development (UNEP/SAICM 2011, UNEP 2012a).

Young children are especially vulnerable to some chemicals in consumer products. Exposures that might have little effect in an adult can produce irreversible damage in a foetus, infant or child. *Credit: Grish*

Some hazardous chemicals, including pharmaceuticals and those in personal care products, are released directly to the environment, intentionally or unintentionally (Kierkegaard et al. 2012, Parolini et al. 2012). The presence of such contaminants in drinking water is a source of growing global concern (Piel et al. 2012, Radović et al. 2012). Also of growing concern internationally is electrical and electronic waste (e-waste), due to its rapidly increasing volume and the serious risks for human health and the environment presented by the many different chemicals it contains **(Box 1)**.

When products are used or discarded, the chemicals they contain are released to the environment **(Box 2)**. The ways chemicals enter the human body include inhalation, absorption through the skin and ingestion **(Figure 2)**. Many human health effects are causally associated with environmental exposures to certain

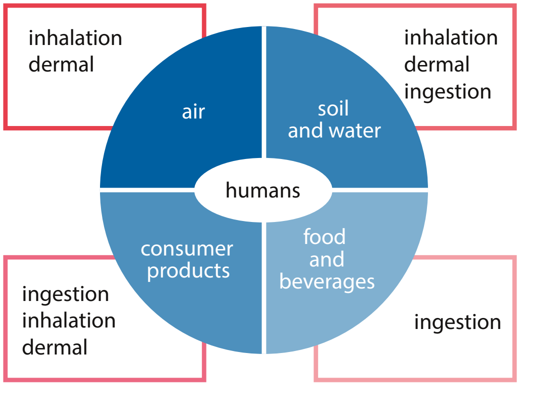


Figure 2: Possible exposure media and ways people come into contact with chemicals. Releases to air, soil and water may occur at any point in a chemical's lifecycle. *Source: Adapted from WHO (2010)*

Box 1: How can e-waste processing be made less dangerous?

E-waste contains valuable and scarce materials that can be reclaimed and recycled, but also hazardous substances that need special handling (Tsydenova and Bengtsson 2011). Dangerous practices such as open burning and acid baths are common in informal e-waste processing (Chan and Wong 2012, Sthiannopkao and Wong 2012). Workers, their communities and the environment are exposed to hazardous chemicals through air and water pollution and contaminated soil (Asante et al. 2012). Larger facilities, with appropriate technology, may meet higher health and safety standards through improved emission control, but there are health and safety risks even at such facilities (Nimpuno and Scruggs 2011).

E-waste processing can be highly profitable. Revenues from global e-waste recovery could reach US$14.6 billion by 2014 (Wolfe and Baddeley 2012). In principle, reuse and recycling can contribute to sustainable development by extending the lifetime of equipment, product parts and material. However, a large share of the e-waste exported from industrialized to developing countries, mainly in West Africa and Asia, is misrepresented as reusable equipment or donations instead of hazardous waste.

Protection of workers largely depends on understanding the chemicals present in production. Electronics stakeholders at different stages of the lifecycle of products need information on the chemicals in these products. Best practices for electric and electronic products include ways to decrease or eliminate use of hazardous chemicals; business standards and practices for tracking, handling and disclosing hazardous chemicals at the manufacturing, use and end-of-life stages; provision of information on potential safer alternatives; and green purchasing initiatives (IISD 2012, Lundgren 2012).

E-waste processing area in Taizhou, China. The volume of e-waste in the world is increasing rapidly, with current production at around 40 million tonnes per year. *Credit: Jiangjie Fu*

chemicals and chemical mixtures, including cancer, respiratory disorders such as asthma, neuropsychiatric and developmental disorders, birth defects, and endocrine diseases and diabetes (Prüss-Ustün et al. 2011, UNEP 2012a) **(Table 1)**.

Susceptibility to chemicals varies from person to person (Forestiero et al. 2012). In addition to genetic diversity, important differences in vulnerability are related to sex, nutrition and stages of life. The developing foetus, infants and children are especially susceptible to toxic chemicals (Landrigan and Goldman 2011). Their rapidly developing organs are immature and, compared to adults, children drink and eat more and breathe more air per unit body weight. People's vulnerability to hazardous chemicals may also vary according to their social roles and gender (UNDP 2011). Workers are particularly at risk, with migrant workers, those in the informal sector, and child labourers bearing a disproportionate burden. Vulnerable groups including children, women, workers, the elderly and the poor can be irrevocably damaged by hazardous chemicals, such as certain metals **(Box 3)** or brominated flame retardants and bisphenol A (BPA), a compound whose hormone-like properties have raised concerns about its suitability in consumer products and food containers (Rudel et al. 2011, Trasande et al. 2011, Channa et al. 2012).

In assessing the risks of the adverse health and environmental impacts of chemicals, the questions that need to be answered include: What are the dangers of these chemicals? How many, and how much, of these chemicals are released to the environment? And who or what (people or the environment) is being exposed? Knowledge of the environmental fate of chemicals, and pathways to human and environmental exposure, includes: releases to the environment; transport; distribution among different environmental compartments (air, water, soil, sediments, biota); transformation; and degradation. Depending on the chemicals' physicochemical properties, associated with persistence, they can be metabolized to other chemicals, bioaccumulated, and biomagnified through the food web.

Table 1: Some major health impacts associated with environmental exposures to chemicals and other environmental stressors. *Source: Adapted from EEA (2005)*

Health impact	Associations with some environmental exposures
Infectious diseases	Water, air and food contamination Climate change-related changes in the lifecycle of pathogens
Cancer	Air pollution Some pesticides Asbestos Natural toxins (aflatoxins) Polycyclic aromatic hydrocarbons Some metals, e.g. arsenic, cadmium, chromium Benzene Dioxins
Cardiovascular diseases	Air pollution Carbon monoxide Lead
Respiratory diseases, including asthma	Sulphur dioxide Nitrogen dioxide Inhalable particles Ground-level ozone Fungal spores Dust mites Pollen
Skin diseases	UV radiation Some metals, e.g. nickel Pentachlorophenol Dioxins
Reproductive dysfunctions	Polychlorinated biphenyls (PCBs) DDT Cadmium Phthalates and other endocrine disruptors Pharmaceuticals
Developmental (foetal and childhood) disorders	Lead Mercury Cadmium Some pesticides Endocrine disruptors
Nervous system disorders	Lead PCBs Methylmercury Manganese Some solvents Organophosphates
Immune response	Some pesticides

Mercury, for example, is transformed by aquatic micro-organisms into methylmercury and bioaccumulates in fish, sometimes reaching tens of thousands of times the concentration originally present in water **(Figure 3)**.

Persistent Organic Pollutants (POPs), controlled under the Stockholm Convention, are a group of chemicals that are particularly persistent and bioaccumulative. They can cause severe damage, including through cancer, eggshell thinning and disruption of organisms' endocrine systems (Fredslund and Bonefeld-Jørgensen 2012). POPs can travel long distances, far from where they were produced and used, thus creating transboundary challenges to their regulation.

Recent findings suggest that cycling of chemicals between environmental compartments is increasingly influenced by the effects of climate change (UNEP-AMAP 2011, Kallenborn et al. 2012). For example, higher temperatures will increase secondary emissions of POPs to the air by shifting partitioning of the POPs between air and soil, and between air and water. Releases from environmental reservoirs such as soil, water and ice will also increase due to increasing temperatures. The impact of temperature on emissions of semi-volatile POPs is probably the most important effect of climate change on the environmental cycling of POPs (UNEP-AMAP 2011).

International chemicals governance

Sound management of chemicals requires co-operation among countries, including sharing of information and experience, adoption of common chemicals control policies, and strengthening capacity. Chemicals are currently addressed in 18 multilateral environmental agreements (MEAs). The Stockholm Convention on POPs, for example, regulates some of the chemicals that present the greatest risks to humans and wildlife. Other MEAs whose purpose is to reduce exposure to hazardous chemicals include the Basel Convention, the Rotterdam Convention, and the Montreal Protocol on Substances that Deplete the Ozone Layer. A new legally binding treaty on mercury (Minamata Treaty) has just been agreed.

Some of these agreements are chemicals based (Montreal, Stockholm, Minamata) while others are lifecycle stage based (Basel, Rotterdam). The Stockholm, Basel and Rotterdam Conventions **(Box 4)** increasingly work together as a chemicals and waste "cluster", enhancing their effectiveness at national, regional and global levels (UNDESA et al. 2011).

Box 2: Chemicals in the environment

Some chemicals, like pesticides, were developed to kill insects, rodents, weeds or other organisms. As the environment is an open system, they may also have adverse impacts on non-target organisms, including bees and insect-eaters (Gil et al. 2012, Tu et al. 2013). After chemicals are released to the environment, they can be transported through air, water and soil. Transport by wind and water currents has led to widespread distribution and transfer of significant amounts of persistent chemicals as far as the Arctic and Antarctic (Scheringer 2009). Persistent chemicals can bioaccumulate and biomagnify through the food web, leading to higher levels of exposure in predator species (Ondarza et al. 2012).

Once chemicals are in the environment, it can be extremely difficult to control or remove them. Persistent, bioaccumulative and toxic (PBT) chemicals have particularly long-term effects on ecosystems that go beyond individual organisms. Endocrine disruptors, for example, can affect organisms' reproduction and have a direct impact on population growth (Blazer et al. 2012).

A large share of man-made chemicals eventually reaches the aquatic environment. Water bodies receive pollutants from diffuse sources such as agricultural runoff, as well as point sources such as sewage treatment plant effluent, and so are contaminated with complex, ill-defined mixtures of chemicals. In some cases, pollution with endocrine-disrupting substances has had dramatic effects on aquatic organisms, such as occurrence of intersex in fish (Sumpter and Jobling 2013). Tributyltin is implicated in the masculinization of female molluscs and fish (McGinnis and Crivello 2011) and oestrogens are thought to be the major cause of feminization in male fish (Baynes et al. 2012, Zhao and Hu 2012). Some effects of chemicals on ecosystems may still be undiscovered. It is not certain which chemicals pose the greatest risks to aquatic organisms, or what factors make some aquatic ecosystems more susceptible than others, for example to bioaccumulation (Sumpter 2009).

A wide range of uncertainties make environmental protection a challenge. In the case of multiple stressors, chemicals may be a factor affecting the resilience of ecosystems by weakening species' immune systems and making them more prone to, for example, fungal disease, competition from alien species, or changes in the environment. Sound data and information on the potential hazards of chemicals, including their properties and behaviour in the environment, need to be available and accessible in order to assess and manage their risks.

Tributyltin compounds are covered by the Rotterdam Convention, and the use of tributyltin as an antifouling agent on ships is banned by the International Maritime Organization (IMO). However, such measures require time to come into effect and to produce results. Moreover, measures are often taken on a chemical-by-chemical basis, responding to emerging scientific evidence. Chemicals management is therefore not keeping pace with the introduction of chemicals in the environment.

Mink frog with extra limb discovered in Minnesota, United States. Such deformities found in amphibians at various North American locations are possibly associated with the presence of certain chemicals in the environment. *Credit: USGS*

Pesticide spraying in a rice field, Karawang region, Indonesia. Most people in the world who apply pesticides do not use necessary protection. *Credit: Beawiharta/Reuters*

Box 3: Health and environmental hazards of metals

A number of metals pose significant threats to human health and the environment. Some are necessary in small quantities for good health, but can cause acute or chronic toxicity in larger amounts (Phoon et al. 2012). Other metals, such as lead and mercury, cause significant damage even in small quantities. Aquatic organisms show a host of sub-lethal effects at increased metal levels, including changes in tissues, suppression of growth, poor swimming performance, reduced enzyme activity, behavioural changes, and changes in reproduction.

Sources of metal pollution include surface runoff from mining, fossil fuel combustion, domestic wastewater, solid waste incineration, use in products such as fuel and paint, and many industrial activities. Urban stormwater runoff often contains lead and other metals from roadways. Leaded fuel has been phased out in almost all countries. However, ongoing sale of leaded paint in many developing countries remains a serious concern (Weinberg and Clark 2012). Gold ore processing has led to a large number of cases of lead poisoning. In 2010 in Zamfara State, Nigeria, for example, 400 children died due to exposure to lead in gold ore, with 2 000 other children under treatment (Lo et al. 2012).

Mercury, whose emissions will be controlled under the new Minamata Treaty, presents a major health risk worldwide. It is released to the atmosphere from industrial activities such as metal and cement production, manufacture of vinyl chloride monomer, municipal waste incineration, fossil fuel combustion and mining. Some 10-15 million miners around the world are exposed to mercury (UNEP 2013). Mercury is used in a variety of products, including some computer monitors, some batteries, automobile switches, thermostats, medical devices and compact fluorescent light bulbs. When these products are disposed of or broken, the mercury can be released into the environment. Total mercury emissions were estimated at 1 960 tonnes in 2010 (UNEP 2013).

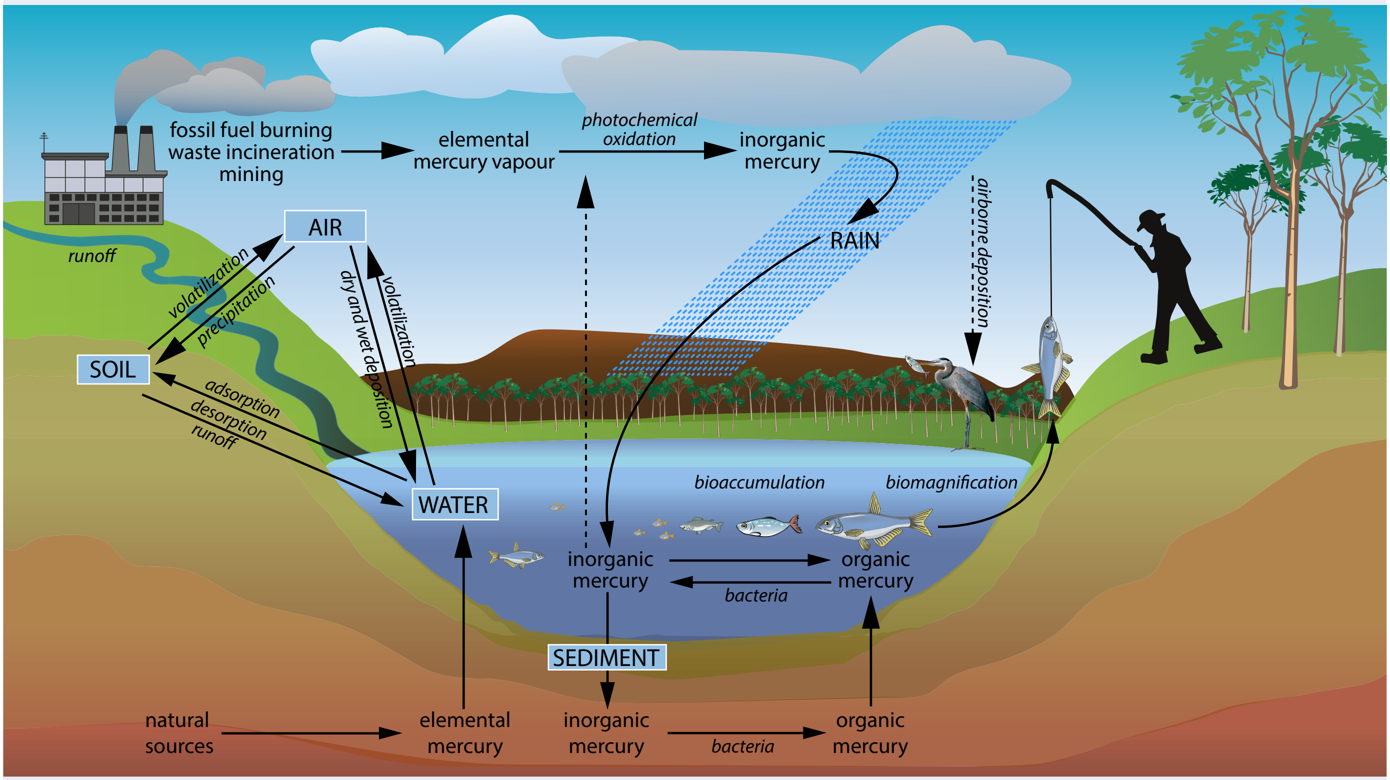


Figure 3: Mercury contamination affects people along several environmental pathways. Highly toxic methylmercury is formed in wet soil, sediments and water, where it bioaccumulates and biomagnifies. Fish consumption is a main route of human exposure. Infants, children and women of child-bearing age are particularly vulnerable to adverse health effects, which include permanent damage to the nervous system. Mercury can be transferred from mothers to unborn children.

Box 4: The Stockholm, Basel and Rotterdam Conventions

The **Stockholm Convention** on the protection of human health and the environment from Persistent Organic Pollutants (POPs) came into force in 2004. It restricts and ultimately aims to eliminate the production and use of listed chemicals. This Convention also promotes the use of both chemical and non-chemical alternatives to POPs. Twelve chemical compounds – "the dirty dozen" – were on the Convention's original list of POPs. They included pesticides such as the insecticide DDT, although its use to fight malaria is still allowed, as are unintended releases to the environment of listed chemicals such as the combustion products dioxins and furans. To date, ten more POPs have been added to this list and others are under review.

The **Basel Convention** on the Control of Transboundary Movements of Hazardous Wastes and their Disposal aims to protect human health and the environment, with strict controls, against the adverse effects which may result from the generation and management of hazardous waste and other wastes. It was adopted in 1989 in response to the discovery in the previous decade of the extent of imported toxic wastes in Africa and other parts of the developing world and came into force in 1992.

The **Rotterdam Convention** on the Prior Informed Consent Procedure for certain hazardous Chemicals and Pesticides in international trade entered into force in 2004. It promotes shared responsibility and co-operative efforts among Parties in the international trade of certain hazardous chemicals, in order to protect human health and the environment from potential harm and contribute to the environmentally sound use of these chemicals by facilitating information exchange about their characteristics, providing for a national decision-making process on their import and export, and disseminating these decisions to Parties.

To make optimal decisions on how to protect human health and the environment, governments, industry and the public need more information than is often available to them. This includes information on the amount and types of chemicals used in products, the way chemicals are released from production processes and products throughout their lifecycles, and data on the physicochemical properties, degradability and toxicity of chemicals. For the vast majority of chemicals, this information has either not been generated or is not accessible by the public. A considerable amount of the information is not publicly available, as it is considered to be sensitive information and the intellectual property of the developers of chemicals or their clients (Abelkop et al. 2012).

While the chemical industry continues to expand, only a small percentage of chemicals on the market have been adequately evaluated for their potential health and environmental effects (Judson et al. 2009, UNEP 2012a). Currently, experimental data on degradation half-lives, bioaccumulation potential and toxicity are publicly available for only a small fraction (less than 5 per cent) of industrial chemicals (Schaafsma et al. 2009, Strempel et al. 2012) **(Figure 4)**.

Lack of information is a serious obstacle to the assessment and management of chemical risks. During the 1992 UN Conference on Environment and Development countries identified "lack of sufficient scientific information for the assessment of risks entailed by the use of a great number of chemicals" as a major problem, especially in developing countries (UNCED 1992). Some hazardous substances incorporated in products present little risk during use, but much greater risks during production and waste management. The current situation could be improved through a combination of actions: disclosure of at least some parts of the information on chemicals use and properties that is currently confidential; substance-flow analyses for chemicals in a variety of products, covering all lifecycle properties, degradation half-lives, and toxicity; and compilation of the information generated in databases such that this information is publicly available in a systematic way.

Some progress has been made towards better information provision at the international level and a number of datasets are publicly available. Of particular importance is the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), first published in 2003 and updated every two years (UN 2011). GHS addresses the classification of chemicals by types of hazard and proposes harmonized hazard communication elements, including labels and safety data sheets. It aims to ensure that information on physical hazards and toxicity of chemicals will be available to enhance protection of health and the environment during handling, transport and use. The GHS also provides a basis for harmonization of rules and regulations on chemicals at national, regional and worldwide levels. However, it does not include the establishment of a publically accessible database for safety data sheets, nor does it address the need for information about chemicals in products.

At the 2002 World Summit on Sustainable Development in Johannesburg, countries agreed that by the year 2020 "chemicals

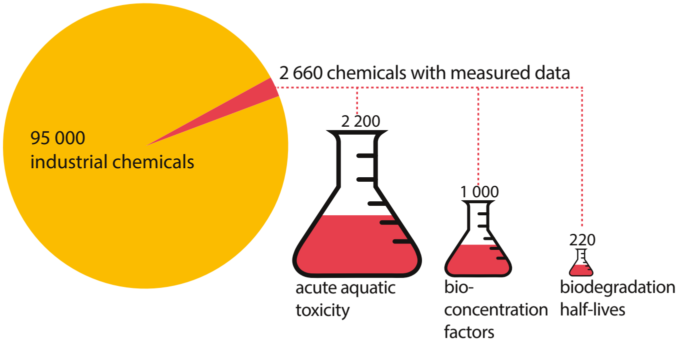


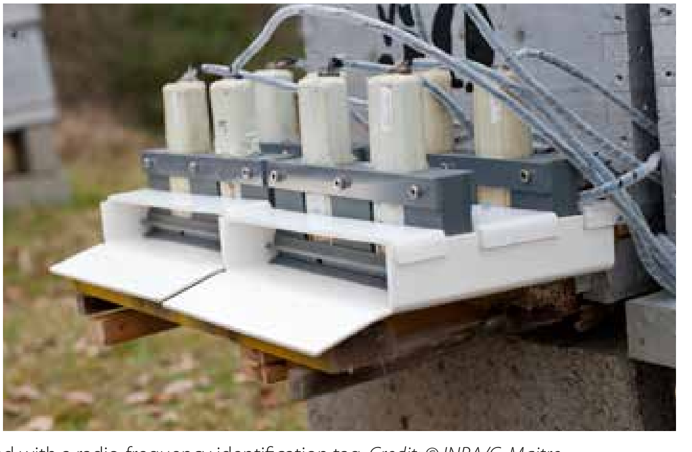
Figure 4: Out of a set of 95 000 industrial chemicals, very few had data on acute aquatic toxicity, the extent to which they build up in the environment (bioconcentration factors), or how long it takes them to break down (biodegradation half-lives). *Source: Adapted from Strempel et al. 2012*

should be produced and used in ways that minimize significant adverse impacts on human health and the environment". So far, progress towards reaching this goal has been limited (UNEP 2012a, b). Lack of adequate information on chemicals, mainly as a result of failure to require generation of the relevant information and disclose it, remains a major problem. The United Nations Conference on Sustainable Development (Rio+20) in 2012 reaffirmed the 2020 goal. It recognized that growing global production and use of chemicals and their prevalence in the environment call for increased international co-operation. It also expressed concern about the lack of capacity for sound chemicals management, particularly in least developed countries (UN 2012).

To achieve the 2020 goal, the Strategic Approach to International Chemicals Management (SAICM) has been developed as a policy framework whose overall purpose is strengthening sound management of chemicals throughout their lifecycle. In 2012, the third International Conference on Chemicals Management (ICCM3) reviewed progress and considered further actions on emerging policy issues including chemicals in products, removal of lead in paints, hazardous substances in electrical and electronic products, and nanotechnology and manufactured nanomaterials. It also considered perfluorinated chemicals and agreed to co-operative actions on endocrine disrupters. Transparency and sharing of data and information will be essential to make real progress in these areas (IISD 2012).

Ongoing and emerging challenges

The number of man-made chemicals in the environment is increasing. Since 1999, the presence of chemicals in the blood and urine of a sample of the population of the United States has been monitored. In 2009, 212 chemicals were reported, including 75 not previously measured (CDC 2009). Findings from the study indicated widespread exposure to some industrial chemicals; 90 to 100 per cent of samples assessed had detectable levels of substances including perchlorate, mercury, BPA, acrylamide, multiple perfluorinated chemicals, and the flame retardant polybrominated diphenyl ether-47. Recently, measurements for 66 of the chemicals were updated and an additional 34 chemicals were found to be present (CDC 2012). These data provide a good indication of the increased presence of chemicals in the environment. They show that despite widespread efforts to improve the knowledge on chemical risks and ways to manage them, we only partially understand the fate and impacts of chemicals in the environment. Because similarly comprehensive biomonitoring programmes are not being carried out in developing countries, these data are an important source of information on the extent to which chemicals may be present in the human body. Such data also point to what could be expected to happen in developing countries as manufacturing and use of chemicals in these countries intensifies.



Simulated nicotinoid pesticide exposure of a free-ranging forager honey bee labelled with a radio-frequency identification tag. *Credit: © INRA/C. Maitre*

Mixtures

People and ecosystems are exposed to mixtures of tens or hundreds of chemicals from a wide range of sources. Some chemicals are more harmful in combination with other chemicals than they are individually, even when the levels of individual chemicals are considered safe. Due to practical limits on measuring ecotoxicological effects, it is difficult to study interactions between more than two or three chemicals. Mixture effects have therefore become a major challenge for scientists and policy makers (EU 2012, Sarigiannis and Hansen 2012).

Empirical evidence provided by human toxicology and ecotoxicology has repeatedly demonstrated mixture effects. It strongly supports the need to take these combined effects into consideration in estimating acceptable human and environmental exposures. New approaches to toxicological testing, such as examining chemical interactions with a focus on the molecular and cellular level, are expected to provide a deeper understanding of toxicity and its health impacts (NIEHS 2011, Kavlock et al. 2012, Rider et al. 2012).

Low-dose exposures

An increasing body of scientific evidence indicates that many chemicals have biological effects at doses previously considered negligible (Vandenberg et al. 2012). For most chemicals, acute effects were originally noted at high doses. It is increasingly evident that more subtle deleterious effects can occur due to longer-term exposure to relatively low doses of chemicals, individually or in mixtures (Birnbaum 2012). The risks created by exposure to a low dose of an individual chemical from multiple pathways are referred to as "aggregate" risks. Cumulative risk assessment (studying risks created by aggregate exposure to multiple pollutants) is a developing approach to addressing low-dose exposures (Meek et al. 2011, Alexeeff et al. 2012).

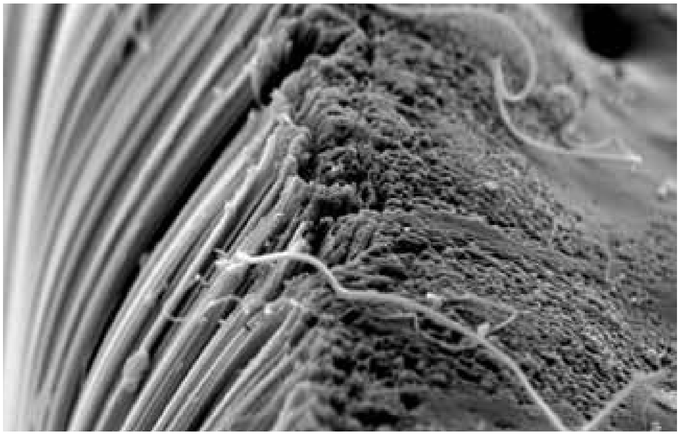
New concerns have recently been raised about the impact of pesticides on non-target organisms including insects, especially bees, and amphibians (Brühl et al. 2013). Studies suggest that low doses of neonicotinoids, a group of neurotoxic chemicals widely used in many countries as insecticides, could have sub-lethal effects on honey bees (Henry et al. 2012) and bumble bees (Whitehorn et al. 2012) with serious consequences for wild populations of these crucially important pollinators and therefore for agriculture and the environment (UNEP 2010, Rozen 2012). It has also been suggested that detailed investigation of the effect of neonicotinoids on mammalian brain function, especially brain development, is needed to protect human health, especially that of children (Kimura-Kuroda et al. 2012).

Replacing hazardous chemicals by similar ones

When efforts are made to eliminate a highly hazardous chemical in products, manufacturers frequently substitute another hazardous chemical in its place (DiGangi et al. 2010, Covaci et al. 2011). Often, these replacements create relatively unstudied health and environmental concerns that may differ little from those of the chemicals they replace. A "lock-in" problem exists when one chemical from a group of structurally similar chemicals is removed from the market and replaced by other chemicals from the same group, so that no true replacement takes place (Strempel et al. 2012). For example, polybrominated diphenyl ethers (PBDEs) are replaced by other brominated flame retardants, polychlorinated biphenyls (PCBs) replaced by short-chain chlorinated paraffins, and less-studied and unregulated halogenated solvents adopted in place of ones that have been extensively studied (OSHA 1999, Stockholm Convention 2012).

Nanotechnology

Nanosizing materials can give them different inherent chemical and physical properties. This challenges existing hazard identification approaches, which assume that the intrinsic property of a chemical can be discovered through studies of the bulk material. For example, from a chemical perspective carbon nanotubes are simply carbon, but in their nanotube form they present significant new hazards because of their shape and size (Maynard et al. 2011). Studies have shown evident toxicity of some nanoparticles to living organisms and ecosystems (Love et al. 2012). However, lack of available data and the inadequacy of current experimental protocols and risk assessment procedures make comprehensive risk assessments difficult to perform (Gajewicz et al. 2012, EEA 2013).



Scanning electronic microscope image of carbon nanotubes, which may present new risks due to their shape and extremely small size. *Credit: Anastasios John Hart, University of Michigan, United States*

New opportunities for testing and assessment

Since the 1960s, the steep rise in production of man-made chemicals has coincided with the development of increasingly sensitive analytical equipment and growing concerns about health and environmental effects, starting in 1962 when Rachel Carson's book *Silent Spring* was published (Ohandja et al. 2012). Today we know much more about chemicals, including their toxicity, pathways and environmental fate, than a few decades ago. With new technology, increasingly small amounts of chemicals can be detected in the environment. This allows earlier detection and better risk management. However, advances in technology also show our knowledge is far from complete, as additional contamination issues emerge with advancing analytical methods.

Monitoring chemicals in the human body and in the environment can help identify and track human and environmental exposure to chemicals and hence the results of chemical management. Particularly useful in early detection of adverse impacts in people and organisms, before overt damage has occurred, is the use of biological markers of exposure, effect and susceptibility. Monitoring in ecological systems is useful to determine how chemicals migrate in the environment, accumulate in animals and plants, and settle in sediments and soils. The importance of continuous, long-term measurement series for future generations cannot be overestimated. The Experimental Lakes Area (ELA) in Canada is a unique example of a "field laboratory" where long-term, ecosystem scale monitoring and experimentation have been carried out since 1968 (Blanchfield et al. 2009).

Models help to estimate exposure throughout an area of impact, and to determine where to place monitors optimally to assess whether chemical releases exceed allowable levels. Contaminant fate models are often used to predict levels of chemicals in air or water resulting from expected or unwanted chemical releases. These models are effective tools in various contexts, from plant siting and emergency response planning to chemical exposure assessment, but they need to be validated using actual measurements (MacLeod et al. 2010).

Advances in computational methods applied to toxicology promise to increase predictability while minimizing the need for costly or time-consuming animal assays (tests exposing organisms to, for example, naturally contaminated water, discharged effluents or sediment samples). Knowledge of quantitative structure-activity relationships (QSARs) can often, but not always, predict toxicity (OECD 2012). New assays based upon advances in molecular biology permit a fuller understanding of the effects of chemical perturbations in biological systems (Kavlock et al. 2012) **(Box 5)**.

Aquatic biomonitors use fish and their breathing patterns to detect the presence of potentially toxic substances in water. *Credit: United States Army Center for Environmental Health Research*

Identifying chemical sources, and using models and assessments to understand their impact, is important to underpin the work of international Conventions and Protocols. Improved measurement and analytical techniques allow chemicals to be identified and quantified more rapidly and accurately than in the past. They also reduce the costs of implementing and carrying out measurements. Assessments provide the basis for understanding the relative contributions of different sources and ranking actions that address the most important environmental releases.

Box 5: Predictive toxicology

Predictive toxicology aims at understanding the relation between the structure of a chemical and its effects, and at detecting the potential for risks before the chemical is produced or released. It includes tests for chemical and physical characteristics, such as flammability, and tests that point to the likelihood that the chemical produces mutations, reproductive or developmental effects, or readily enters the food chain. A new programme combines the insights of molecular toxicology with high throughput technology derived from the pharmaceutical industry to improve the prediction of the toxicity of large numbers of chemicals (Martin 2012). Validation of this new approach is in progress (Kavlock et al. 2012). If successful, this programme will provide better tools for the chemical industry and for regulators to disclose unwanted consequences of new or existing chemicals.

The costs of inaction

The production, use, storage, transport and disposal of chemicals and products containing chemicals result in a variety of external costs that are generally not (or not fully) borne by the companies that carry out these activities (UNEP 2012a). Examples include: maintenance of emergency response infrastructure; clean-up of contaminated sites; emergency and long-term care for individuals harmed by chemical exposures; home or institutional care and special education services for people with developmental problems; loss of value of contaminated real estate; loss of fishing, hunting, and farming opportunities; loss of safe water supplies; and water treatment and purification to remove chemical contaminants.

Costs associated with the risks of chemicals are difficult to assess. Nevertheless, the findings of studies that have estimated health and environmental costs support the urgency of risk minimization (Prüss-Ustün et al. 2011, Hutchings et al. 2012, UNEP 2012a). Chokshi and Farley (2012) reported that the cost-benefit ratio of environmental intervention in disease prevention is three times higher than clinical and non-clinical person-directed measures. They also noted the paucity of studies on the cost-effectiveness of environmental interventions.

Trasande and Liu (2011) found that the costs of lead poisoning, prenatal methylmercury exposure, childhood cancer, asthma, intellectual disability, autism and attention deficit disorder in the United States were US$ 76.6 billion in 2008. They estimated that pre-market testing of new chemicals, toxicity testing of chemicals already in use, reduction of lead-based paint hazards, and curbing mercury emissions from coal-fired power plants could prevent further increases in such costs. Another study estimates that preventing exposure to the neurotoxin methylmercury in children would yield an economic benefit of €8 000 to 9 000 million (about US$11-12 000 million) per year in the European Union (Bellanger et al. 2013). Mercury exposure in humans affects brain development, resulting in a lower IQ and, consequently, lower earning potential. The long-term cost to society can be calculated as lifetime earning loss per person.

Depending on the country, some costs may be covered directly by those responsible for them. For example, chemical manufacturers are sometimes taxed to provide funds for the clean-up of contaminated sites (US EPA 2012). In many countries employers provide funds for worker compensation. However, most costs associated with the risks of chemicals are not paid by industry. Therefore, these costs may not be taken into account when companies make decisions about which chemicals to produce and use, and how to manage them. One way to remedy the inefficiencies that result from excluding health and environmental costs is to implement cost internalization mechanisms using certain economic instruments, including fiscal measures or other economic incentives **(Box 6)**.

Box 6: Use of economic instruments

Economic instruments can be used to internalize the costs of chemical management and create financial incentives to improve chemical safety. If these instruments are well conceived, they may also generate public revenues and provide resources needed to fund agency programmes. For instance, in Sweden the costs of the Swedish Chemicals Agency (KemI) are largely borne by the pesticide and other chemical industries through chemical fees. These cover the costs of activities such as inspections and assessments of applications for approval of pesticides (KemI 1998). In 2010, about 57 per cent of KemI's costs were covered by these fees (about 29 per cent from pesticide fees and approximately 28 per cent from general chemical fees). These fees are calculated based on the number of chemical products and the volumes of these products. Firms are required to report to the Swedish Products Register.

In the United States, the Massachusetts Toxics Use Reduction Act (TURA) requires facilities that use more than a specified amount of a toxic chemical to pay an annual fee, which is used to fund chemicals management activities including enforcement, training, research and technical assistance (Massey 2011). California levies a fee on the sale of perchloroethylene (PCE), a garment care solvent, to provide grants and training to help garment cleaners make the transition to safer processes (California Air Resources Board 2012).

Gabon charges a 10 per cent tax on exported waste that it receives, while China charges a fee on industrial pollution that exceeds a base level and invests a portion of that revenue in pollution abatement programmes.

Towards better chemical risk management

Many different types of instruments exist worldwide to reduce chemical risks. Some are anticipatory and aim to avoid the production or sale of chemicals known to be harmful. Others are more concerned with the introduction of changes during the lifecycle of chemicals to protect people and the environment. Chemical disasters have led to the development of preventive approaches and response measures. In addition, specific regulations have been developed concerning toxic chemicals in consumer products. Examples are EU regulations on chemicals in cosmetics and the EU Toy Safety Directives.

Since 2007, the European Registration, Evaluation, Authorisation and Restriction of Chemical Substances (REACH) regulation has aimed to improve protection of human health and the environment and make the use of chemicals safer through better and earlier identification of their intrinsic properties **(Box 7)**. Under REACH, companies that place chemicals on the market are responsible for providing reliable, comprehensive information on the health and environmental hazards of these chemicals. REACH also calls for substitution of the most dangerous chemicals.

Some countries are making information about chemicals and chemical releases more easily available to interested parties and to the public than in the past. For example, the European Chemicals Agency is building a publicly accessible database with information about chemicals. Pollutant Release and Transfer Registers (PRTRs) are another important source of information. PRTRs are national inventories providing data to the public on releases and transfers of potentially dangerous chemicals and other pollutants. Some jurisdictions require companies to report on their use of certain chemicals. In the United States, the states of Massachusetts and New Jersey require annual reporting of toxic chemical use in manufacturing and other industrial facilities (Massey 2011). This approach increases the information available to government agencies and the public, ensures that company managers know what chemicals are being used in large quantities in their facilities, and facilitates identification of potential occupational and other hazards.

Box 7: The European REACH system

The European Registration, Evaluation, Authorisation and Restriction of Chemical Substances (REACH) system regulates industrial chemicals. It does not cover pesticides, biocides or pharmaceuticals, as these are dealt with under other European regulations. Under REACH, businesses that place chemicals on the market in the EU above 1 tonne per year must provide adequate documentation on properties, uses, and safe ways of handling them. Although REACH is still in its early stages and its implementation is challenged by data quality issues (Gilbert 2011), this general approach may serve as a useful model in other parts of the world. Registration of chemicals under REACH takes place between 2010 and 2018. To date, 140 000 chemicals have been pre-registered and full registrations have been completed for some 5 000. A recent assessment by the German Federal Environment Agency and the Federation of German Consumer Organizations found that REACH has had a positive impact during its first five years, but that there are also important areas for improvement. For example, concern was expressed that data submitted by industry did not always fulfil the requirements of the regulation (Flasbarth 2012). These findings highlight the importance of capacity building for adequate implementation and enforcement of requirements.

Measures to strengthen sound chemicals management range from improved government capacity for chemical regulation to increased support for businesses in selecting safer alternatives in product design. A key element is use of an anticipatory approach, whereby chemical risks are identified and prevented up front rather than addressed after damage has occurred (UNEP 2012c). Evolving approaches to protect people and the environment against the unwanted effects of chemicals occur at different levels:

- Prevention of production and use of harmful chemicals through multilateral environmental agreements (MEAs).
- Capacity building to support development of regulatory and other chemicals management infrastructure in developing countries and countries with economies in transition.
- Development of guidelines and systems to ensure transparency about chemical use in industry and in consumer products.
- (Re)design of products and processes in ways that minimize the use and generation of harmful substances, through approaches such as green chemistry, alternatives assessment, and toxics use reduction.
- Process engineering, aiming to prevent releases of chemicals during manufacture, distribution, use and waste treatment.
- Use of monitoring systems to detect chemicals released to environmental media.
- Identification of the health and environmental effects of chemicals through evaluating biological markers of exposure and effects in ecosystems and humans.

The way forward to minimize risks

Sound management of chemicals urgently needs strengthening to avert ongoing damage to human health and the environment and reach the 2020 goal. Reducing the production and use of toxic substances, promoting the development and adoption of safer alternatives, improving information flow and transparency, building capacity for improved chemicals governance, and reducing illegal international traffic in chemicals are key elements of sound chemicals management – with important roles for government, industry, researchers, and civil society organizations **(Box 8)**.

One of the most critical elements of sound chemical management is ensuring that chemicals are tested for their health and environmental effects prior to being placed on the market and incorporated into products. Thus far, chemicals governance activities have largely been reactive. With current trends in mind, a strengthened and more proactive governance approach is required based on science, best practices and lessons learned. Methods used to predict and detect the adverse effects of chemicals are critical to support sound chemicals management. They provide tools for generating essential data and information that can facilitate science-based decision-making.

To minimize the risks of chemicals, more attention should be paid to the earliest stages in their lifecycle, when chemicals are developed and synthesized before they find their way to the market – and when modern tools can be used to test and estimate *a priori* the properties, fate and impact of new chemicals. The value of results and measurements from research organizations, universities, government agencies and industry around the world would increase if they were collected and accessible in a formalized, open-access database. In particular, more effort is needed to obtain data and information on the impacts of chemical mixtures, low-dose exposures, nanomaterials and the impact, migration and transformation of chemicals in natural systems.

To minimize risks from exposure to chemicals and prevent unwanted chemicals entering the environment, more formalized monitoring, labelling and communication are needed. A broadened REACH system covering the full range of chemicals in commerce could be a model for a global system, to be accompanied by capacity-building programmes.

Information on safe use of chemicals (particularly pesticides, certain metals, and chemicals in e-waste) should be easily accessible and disseminated more thoroughly to related occupational groups, especially in developing countries. Safety and hazard preparedness training programmes are also required. Production and transboundary transfers of all chemicals need to be preceded by the compilation and submission of a dossier, by the producer or importer, containing the required data. To make this possible, procedures need to be implemented at the national level, taking into account the international framework for chemicals governance and building on existing procedures and regulations to improve chemicals risk management.

The presence of hazardous chemicals is not always obvious. Pesticides remaining on the human body after spraying can be made visible under special light. *Credit: Richard Fenske*

The outlook for chemicals governance, however, goes beyond technical and regulatory approaches. It begins by asking if there is a need for hazardous chemicals in the first place. In some cases, safer, non-chemical alternatives and approaches are available that are both proven and effective. Examples include integrated pest management, adoption of non-chemical substitutes for POPs, water-based processes for industrial cleaning, and adoption of safer substitutes for toxic flame retardants. Support for the assessment of such alternatives and approaches, and for prioritizing research and development in these areas, will be part of the way forward to better manage chemical risks.

To keep pace with rapid developments and new challenges, chemicals governance needs to benefit from the latest science and speed up testing and registration of chemicals. It also needs to be recognized that impacts occur "from cradle to grave", that production is frequently not located in one place, that both chemical products and environmental residues may be widely distributed, and that impacts vary due to the differing vulnerability of both human populations and ecosystems.

Box 8: Roles of stakeholders in minimizing chemical risks

Governments: Establish clear and consistent guidelines requiring disclosure of information about the hazards and uses of chemicals, estimate the costs of inaction against the risks from chemicals, and build capacity to strengthen sound chemicals management.

Industry: Disclose information about the hazards and uses of chemicals, and consider alternatives when developing chemicals to reduce chemical risks.

Scientists: Compile existing information in publicly accessible databases, and provide coherent interpretations in existing knowledge, identifying inconsistencies and gaps.

Civil society organizations: Gather and organize chemical information, promote the adoption of relevant regulations, help build capacity, and monitor implementation of policy measures.

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Key Environmental Indicators

Tracking progress towards environmental sustainability

The United Nations Conference on Sustainable Development (Rio+20) in June 2012 was the largest UN conference ever held and a further step towards achieving a sustainable future. The fifth edition of the UNEP *Global Environment Outlook* report (GEO-5) – launched on the eve of Rio+20 – demonstrates that the world continues to speed along an unsustainable path, despite hundreds of internationally agreed goals and objectives for sustainable development. GEO-5 also shows that clear targets and indictors are needed if progress towards sustainable development is to be measured and improved.

The Rio+20 outcome document, *The Future We Want*, calls for a wide range of actions, including launching a process to establish sustainable development goals (SDGs). The SDGs should address – and incorporate in a balanced way – the three dimensions of sustainable development (social, economic and environmental) and their interlinkages. They should build on the ongoing Millennium Development Goals (MDGs) process and be accompanied by targets and indicators for tracking progress towards their achievement (UN 2012a).

Clear goals, concrete numerical targets, and solid data for use in tracking progress are critical to the success of international agreements (UNEP 2012a). So far, the field of environment has remained markedly weak in terms of specific goals, quantified targets, and detailed data with which to monitor and assess changes. For a considerable number of environmental issues, however, it is possible to use one or more indicators to show at least the direction in which changes are taking place at global, regional or local levels. Together, these key indicators provide a general, snapshot picture of the global environment and of progress towards environmental sustainability – or of further environmental deterioration.

The Mau Forest, Kenya. Aerial surveys and other observation techniques provide important information on state and trends in the environment.
Credit: Christian Lambrechts

Indicators are measures that can be used to illustrate and communicate complex phenomena in a simple way, including trends and progress over time.

The set of key environmental indicators presented in this chapter can serve as a basis for elaborating sustainable development goals and targets and further indicators for tracking progress toward environmental sustainability. However, for several environmental issues even the most basic data are not available in most parts of the world to depict consistent, long-term trends, such as for the use of chemicals, waste collection and treatment, air quality, land degradation, and biodiversity loss. A roadmap showing the way towards sustainable development needs to include more attention to environmental data collection and processing on the part of the international community.

The set of key indicators in the following sections corresponds to major global environmental issues: climate change, ozone depletion, chemicals and waste, natural resource use (air, land, water, biodiversity) and environmental governance. Indicators which coincide with those used in the MDG process are marked.

Climate change and energy

Global CO_2 emissions from fossil fuel combustion have continued to increase in recent years, despite countries' existing commitments and economic crises in various parts of the world. They reached 32.1 billion tonnes in 2009 **(Figure 1)**. This increase is occurring to a large extent in the Asia and the Pacific region, where per capita emissions are approaching the world average although they are still below those in Europe, West Asia, and particularly North America **(Figure 2)**. Growth in emissions

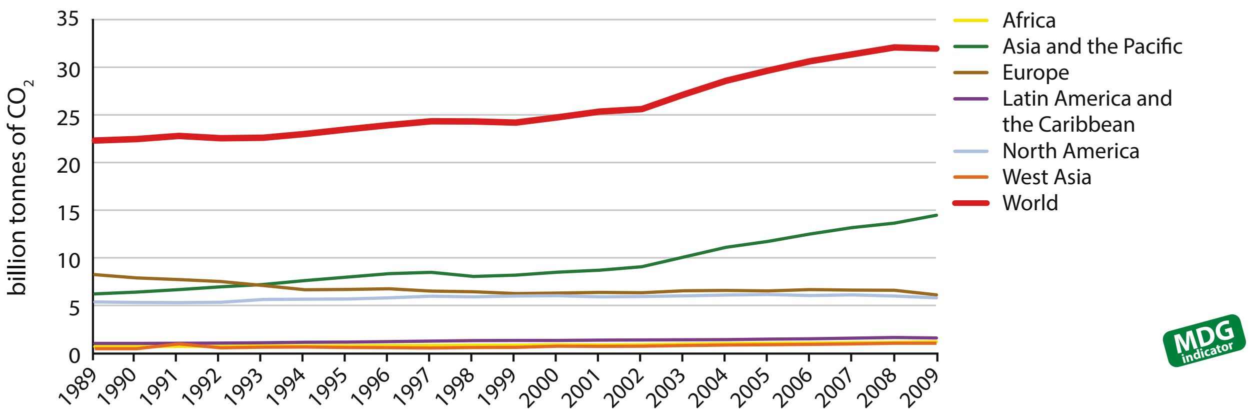


Figure 1: Carbon dioxide emissions from fossil fuels and cement production, expressed in billions of tonnes of CO_2, 1989-2009. Global CO_2 emissions have increased in recent years, mainly in the Asia and the Pacific region. *Source: UNEP EDE, compiled from Boden et al. (2012)*

causes higher CO_2 concentrations in the atmosphere and rising global temperatures. 2012 was one of the ten warmest years on record, as well as the 36th year in a row in which temperatures exceeded the long-term average (NOAA 2013).

The continued increase in CO_2 emissions indicates widening divergence from a trajectory that would make it possible to limit global warming to the 2˚C needed to stay within safe planetary limits. Keeping global temperature rise below 2ºC has become the basic goal of international climate change negotiations. This was acknowledged in recent sessions of the Conference of the Parties to the UNFCCC. In view of the gap between targeted emission reductions and actual trends, in November 2012 the 18th session of the Conference of the Parties to the UNFCCC in Doha, Qatar, agreed to scale up efforts before 2020 (beyond countries' existing pledges to curb emissions) in order to stay below 2˚C warming.

Greenhouse gas emissions are largely produced by the combustion of fossil fuels for industrial production, heating and transport, in addition to deforestation and other land use changes. Fossil fuels continue to dominate global energy supply **(Figure 3)**. Significant investments in more sustainable forms of energy, notably solar and wind, have resulted in impressive growth of renewable energy use **(Figure 4)**, but the overall share of renewables is still modest compared to that of fossil fuels at 12.9 per cent of overall energy supply (in 2010).

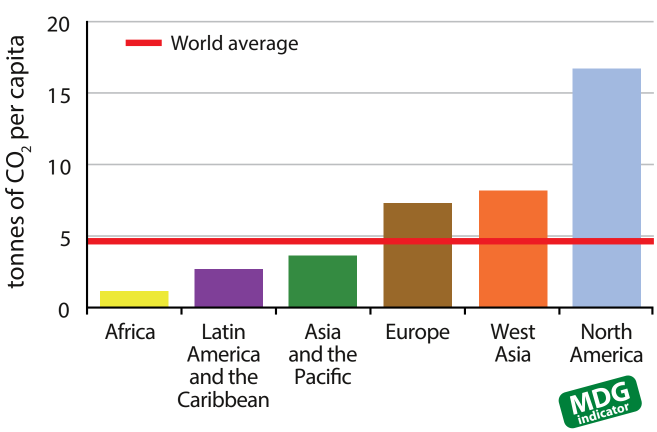


Figure 2: Carbon dioxide emissions per capita, 2009. Per capita emissions of CO_2 are well above the global average in Europe, West Asia and particularly North America. *Source: UNEP EDE, compiled from Boden et al. (2012)*

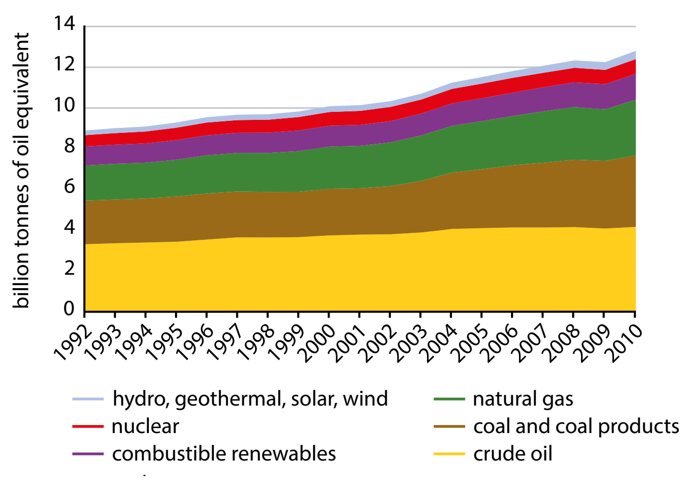


Figure 3: Primary energy supply, 1992-2010. Use of fossil fuels has increased steadily in the past two decades. A small dip occurred around 2009. Renewable resources represent a modest but rising share. *Source: UNEP EDE, compiled from IEA (2012a)*

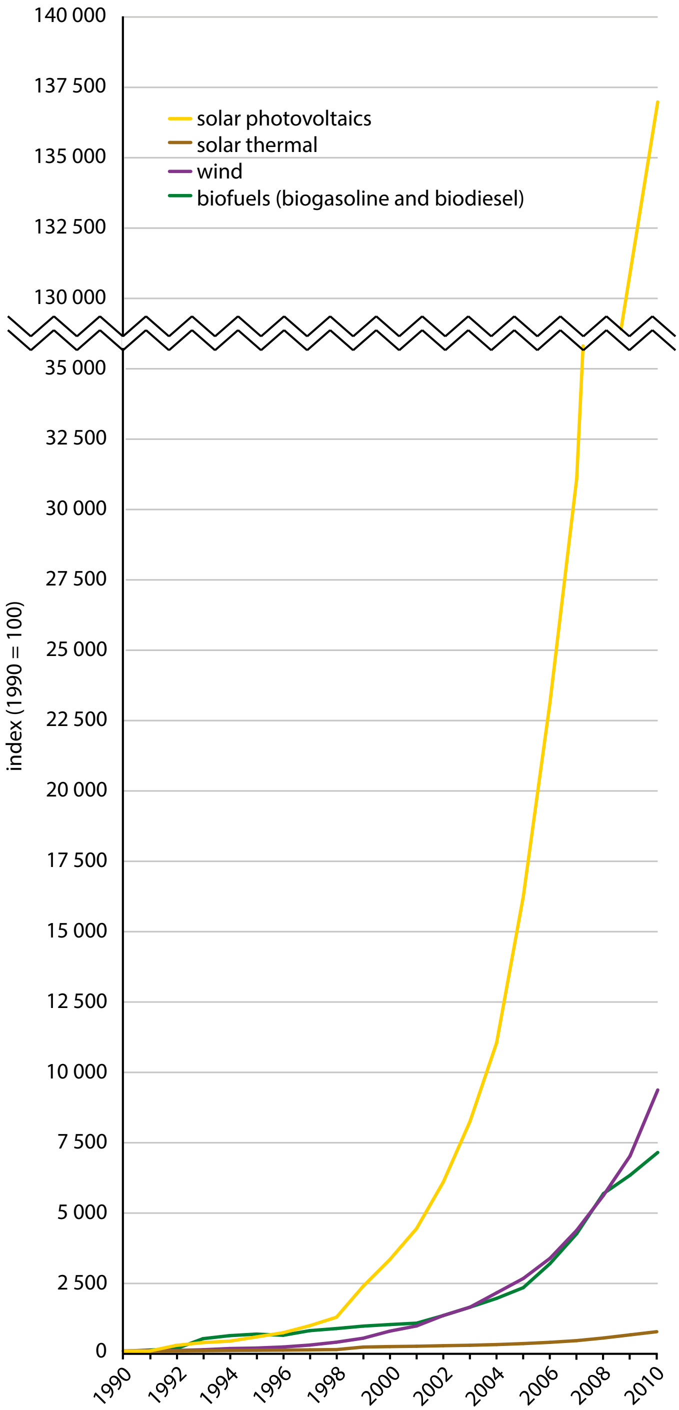


Figure 4: Renewable energy supply index, 1990-2010 (1990=100). Use of solar energy is skyrocketing, followed by wind and biofuels. *Source: UNEP EDE, compiled from IEA (2012b)*

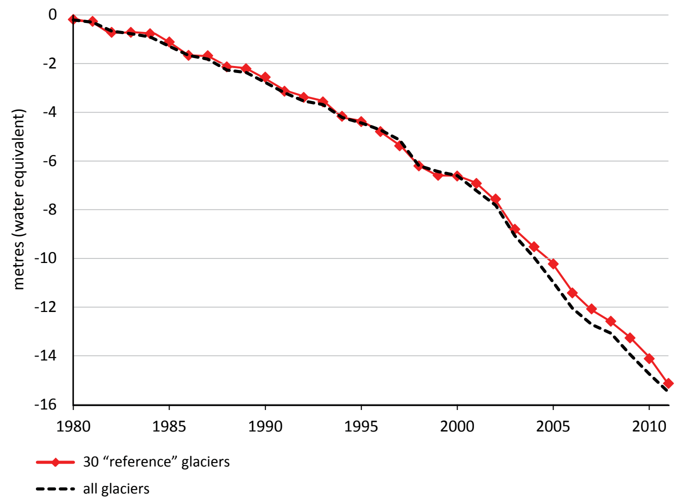


Figure 5: Mountain glacier mass balance, 1980-2011. Glaciers have continued to melt at unprecedented rates, with increasingly severe impacts on the environment, natural resources and human well-being. *Source: WGMS 2013*

Consistent trends in changes in glaciers are a key indicator of ongoing climate change. Glacier measurements dating to the late 19th century point to dramatic ice loss, even when temporal and regional variability is taken into account. Melting has accelerated in recent years **(Figure 5)**, with significant impacts on the environment and human activities, including by contributing to landslides, changes in water and energy supply, and global sea level rise. Major glaciers shrank 1.05 metre on average in 2011, the latest year for which there are recorded data (WGMS 2013). Arctic summer sea ice is melting rapidly, while land ice is retreating and permafrost is thawing. Figure 1 in Chapter 2 shows the significant reduction of Arctic sea ice cover.

Depletion of the ozone layer

In the last 20 years, through implementation of the Montreal Protocol, consumption of ozone-depleting substances has been reduced by over 98 per cent – a major success story **(Figure 6).** Since most of these substances are potent greenhouse gases, a significant contribution has also been made to protecting the global climate system (UN 2012b). Reductions achieved to date leave hydrochlorofluorocarbons (HCFCs) as the largest group of substances remaining to be phased out under the Protocol.

Governments are considering an amendment to the Protocol to address hydrofluorcarbons (HFCs), a class of chemicals with global warming potential often used as substitutes for certain ozone-depleting substances **(Figure 7)**. The phase-out period for the other main categories of ozone-depleting substances is

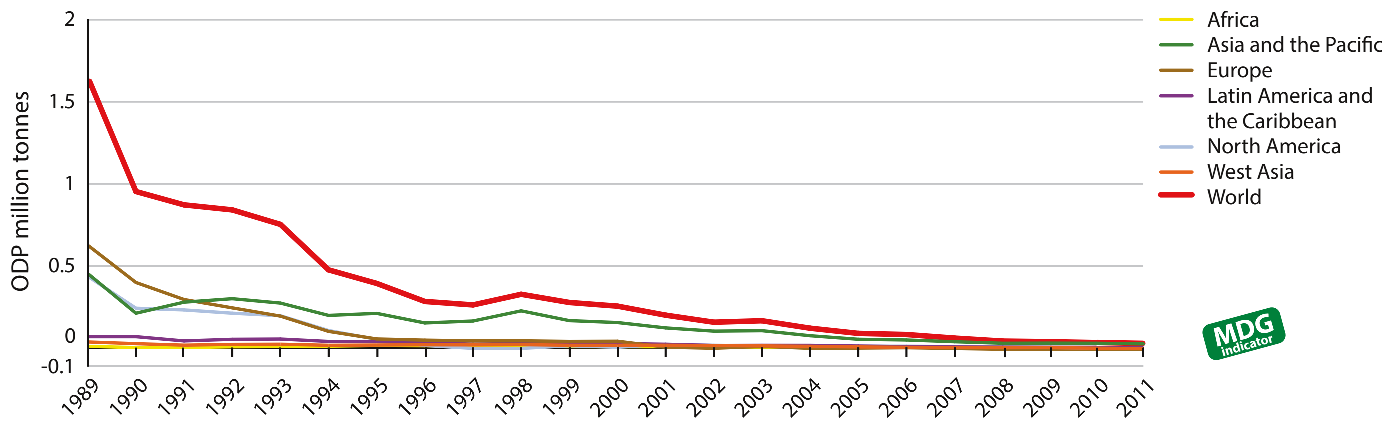
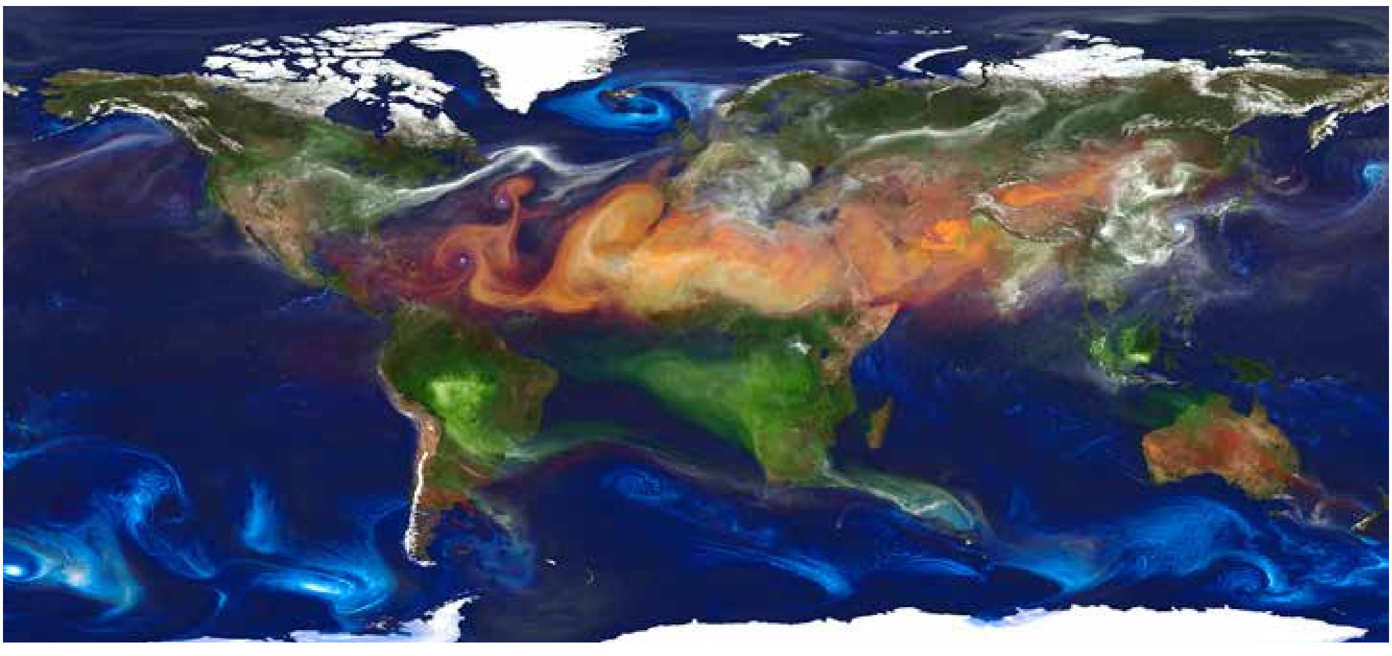


Figure 6: Consumption of ozone-depleting substances expressed as million tonnes of ozone depletion potential (ODP), 1989-2011. Challenges remain, but the consumption of ozone-depleting substances has declined tremendously through implementation of the Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer. *Source: UNEP EDE, compiled from UNEP (2012c)*

coming to an end. Closer attention is currently being paid to several small classes of exempted uses of these substances (through better tracking or reporting), as well as to environmentally safe management and the destruction of existing ozone-depleting substances, such as those in obsolete stockpiles and in equipment like air conditioning and refrigerators (UN 2012b).

Chemicals and waste

In response to rising demand for chemicals in products and processes, the international chemical industry has grown dramatically since the 1970s. Global chemical output increased by a factor of 25 between 1970 and 2010, from an estimated US$171 billion to US$4120 billion (UNEP 2012b). Countries, manufacturers and the international community have made



This representation of global aerosols was produced by a simulation of the Goddard Earth Observing System Model, Version 5 (GEOS-5) at a 10-kilometre resolution. Dust (red) is lifted from the surface, sea salt (blue) swirls inside cyclones, smoke (green) rises from fires, and sulphate particles (white) stream from volcanoes and fossil fuel emissions. *Credit: William Putman, NASA/Goddard*

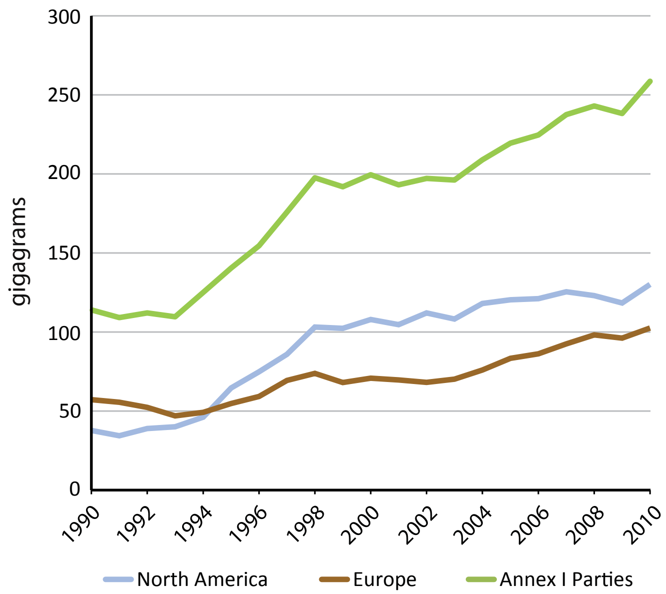


Figure 7: Consumption of hydrofluorocarbons (HFCs) in gigagrams, 1990-2010. Even when considered as suitable replacements from the point of view of protecting the ozone layer, some substitutes for ozone-depleting substances, such as HFCs, have a high warming potential and can have a significant impact on climate change. *Source: UNFCCC (2012)*

some progress in reducing chemical risks over the past four decades using norms, rules and regulations. But greater efforts are needed to achieve the Johannesburg 2020 goal to use and produce chemicals in ways that do not lead to significant adverse impacts on human health and the environment (UN 2002).

An issue of particular concern is the increasing amounts of marine litter and plastic debris that end up in waterways and the ocean, and their potential impact on human health and the environment (UNEP 2011a). The volume of plastics produced in the world has risen sharply in the past decades, reaching 280 million tonnes in 2011 **(Figure 8)**. Approximately 100 kg of plastic materials per person per year is used in North America and Europe (2005). This is expected to increase to 140 kg by 2015. The average is much lower in rapidly developing countries such as those in Asia, but is increasing from 20 kg per person in 2005 to an expected 36 kg by 2015 (UNEP 2011a).

Solutions to health and environmental problems associated with waste are being sought through greater waste reduction and improved waste management (reduction, reuse and recycling). There have been encouraging developments in several parts of the world, including international efforts to control generation and movement of hazardous waste. Lack of comprehensive and comparable data makes it impossible to obtain a clear picture of global resource use and the extent of waste-related problems. One indicator that can be

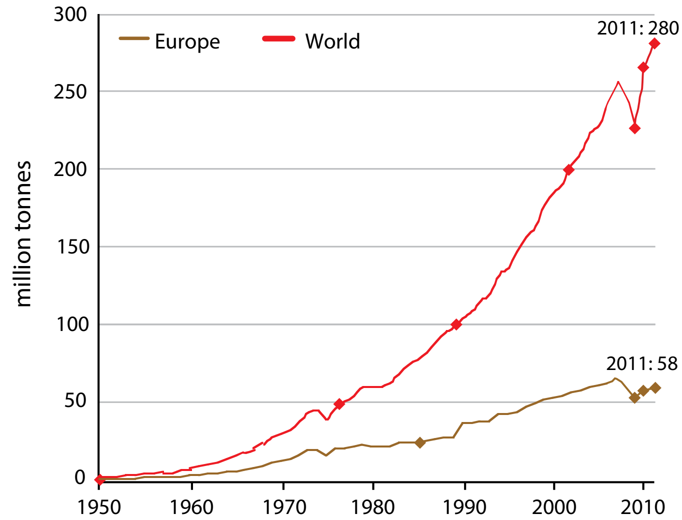


Figure 8: Plastics production in million tonnes, 1950-2011. After a dip around 2008-2009, world production reached a new record of 280 million tonnes in 2011. Plastic debris in the ocean is an issue of growing concern in recent years. *Source: PlasticsEurope (2012)*

used, however, is municipal waste collection. While data are sparse, they are available for recent years in most regions. **Figure 9** shows that Europe stands out in this respect, followed by Asia and the Pacific, North America, Latin America and the Caribbean, and West Asia. For Africa no regional data can be provided.

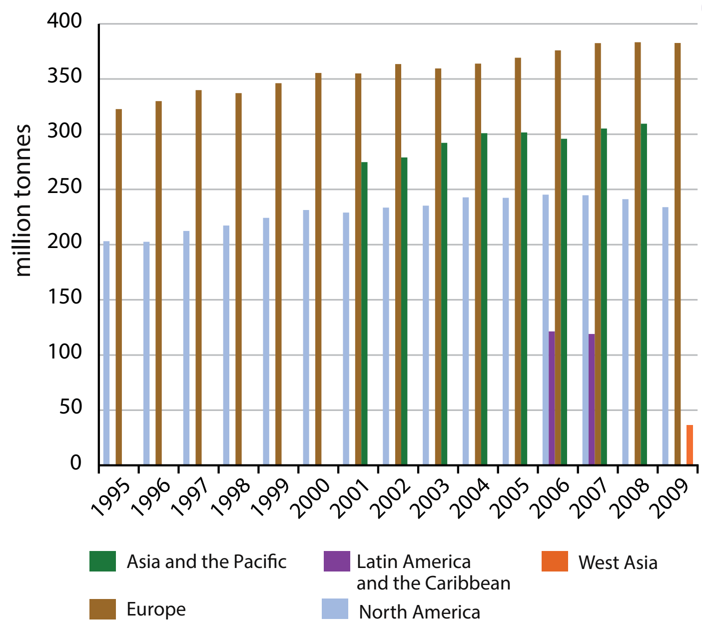


Figure 9: Municipal waste collection in different regions, 1995-2009. Data are sparse, and for Africa no regional data are available. *Source: UNEP EDE, compiled from UNSD (2012).*

Natural resource use

Natural resources are essential to meet basic needs. However, their exploitation has begun to exceed the Earth's capacity. The scale of human activities is "eating into" the planet's reserves. As an analogy, it is said that today we use the equivalent of 1.5 Earths to provide the resources we use and to absorb waste, and by the 2030s we may need the equivalent of two Earths to maintain our current lifestyles (GFN 2012).

Fisheries

An outstanding example of resource depletion is the condition of global fish stocks. Marine fish catch rose steadily to approximately 93 million tonnes per year in the mid-1990s, but has been levelling off since or even decreasing **(Figure 10)**. Only the Asia and the Pacific region continues to show an upward trend. At the same time, the percentage of overexploited fish stocks has risen and the proportion of species not being fully exploited has fallen **(Figure 11).** Overexploitation not only has adverse environmental impacts, but reduces fishery production, with negative social and economic consequences. Despite the worrisome global situation for marine capture fisheries, some regions have made progress in reducing exploitation rates and restoring overexploited fish stocks and marine ecosystems through effective management (FAO 2012c).

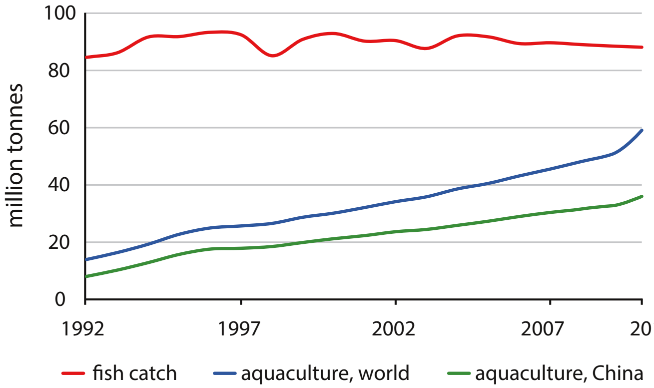


Figure 10: Fish catch and aquaculture production, 1992-2010. The global fish catch has stabilized at around 90 million tonnes per year. Aquaculture has been increasing significantly, particularly in China and other parts of Asia. *Source: UNEP EDE, compiled from FAO (2012b)*

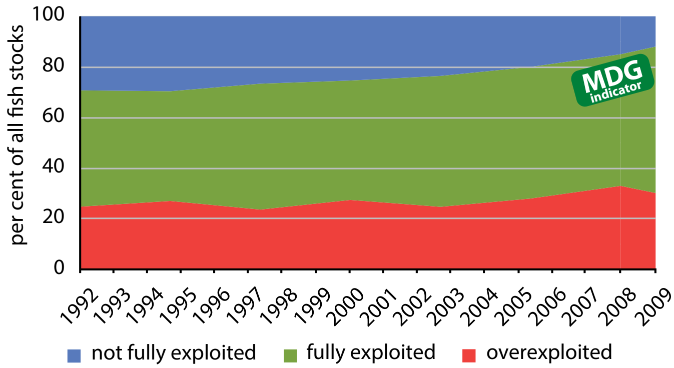


Figure 11: Fish stocks exploitation, 1992-2009. The percentage of fish stocks fully exploited or overexploited was 85 per cent in 2009. *Source: UNEP EDE, compiled from FAO (2012c)*

Ocean

Because of increasing CO_2 levels in the atmosphere, the ocean and coastal areas are becoming more acidic, as shown by gradually decreasing pH values **(Figure 12)**. Absorption of CO_2 in marine waters alters the chemistry of the ocean, with harmful consequences for shell-forming marine life. This, in turn, can disrupt ecosystems and impact fishing, tourism and other human activities that rely on the sea. Ocean acidification is rapidly becoming a critical issue, with the potential to affect many species and their ecosystems and considerably influence the marine-based diets of billions of people (UNEP 2010).

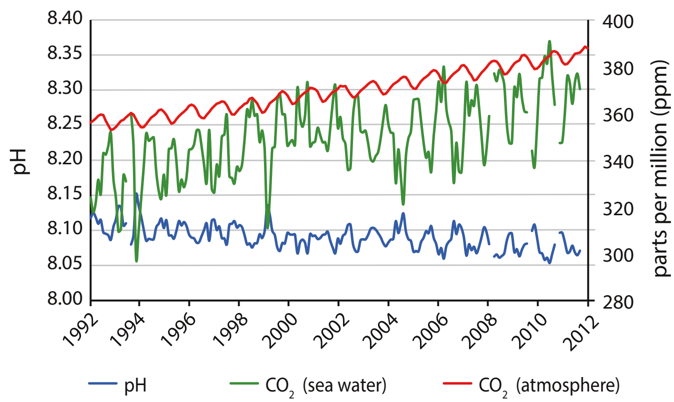


Figure 12: Atmospheric CO_2 concentrations and ocean acidification, indicated by increased partial pressure of CO_2 and lower pH of global mean surface water, 1992-2012. *Source: Caldeira and Wickett (2003), Feely et al. (2009), Tans and Keeling (2011)*

Forests

Trees and other plants have provided fuel and building material for human societies since prehistoric times. As human populations have grown, forests have changed and evolved differently in different regions (FAO 2012b). Following decades of heavy deforestation in many parts of the world, the rate is slowing and forested area in some regions is increasing. Harvesting of roundwood appears to have levelled off in recent years in most regions. In West Asia the forest harvest rate has been increasing, notably in 2010 **(Figure 13)**. Sustainable forest management is the key to reversing depletion and literally "greening the world". Certification of wood and other forest products is one indicator of better forest management. Total

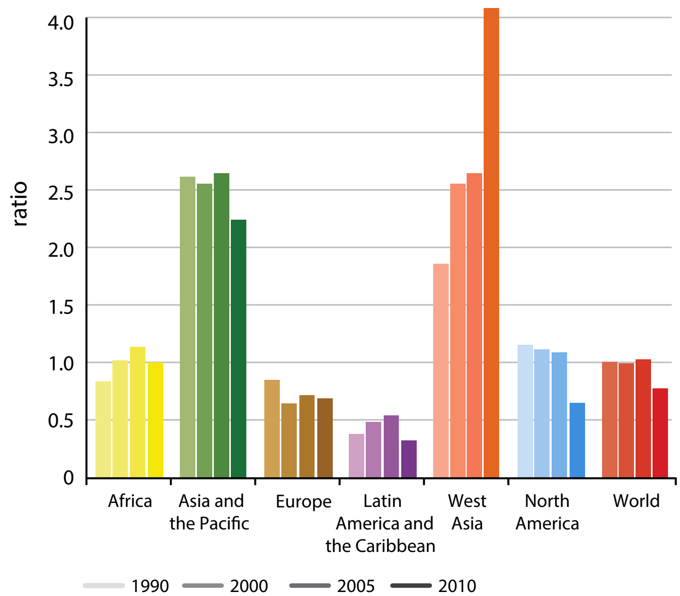


Figure 13: Forest harvest rates expressed as the ratio of roundwood production to growing stock in forests, 1990-2010. After decades of increases, harvesting of roundwood appears to have levelled off in recent years, except in West Asia. *Source: UNEP EDE, compiled from FAO (2005) for 1990, 2000 and 2005, and FAO (2010) for 2010*

certified forest area managed under the two main certification bodies – the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification (PEFC) – is still modest, but an 8 per cent increase since 2002 is impressive. The highest proportions of certified forest are in Europe and North America **(Figure 14)**.

Water

In 2010, 89 per cent of the world population had access to improved drinking water sources, up from 76 per cent in 1990 **(Figure 15)**. This means the global MDG target of halving the proportion of people without sustainable access to safe drinking water was met five years ahead of the 2015 target, with the caveat that more progress was made in urban areas compared to rural areas. Some 11 per cent of the global population (about 783 million people) still does not have access to improved drinking water sources. Coverage remains very low in Oceania and sub-Saharan Africa, which are not on track to meet the MDG drinking water target by 2015 (UN 2012b). The target of halving the proportion of people without sustainable access to basic sanitation continues to be a challenge, particularly in rural areas in developing regions.

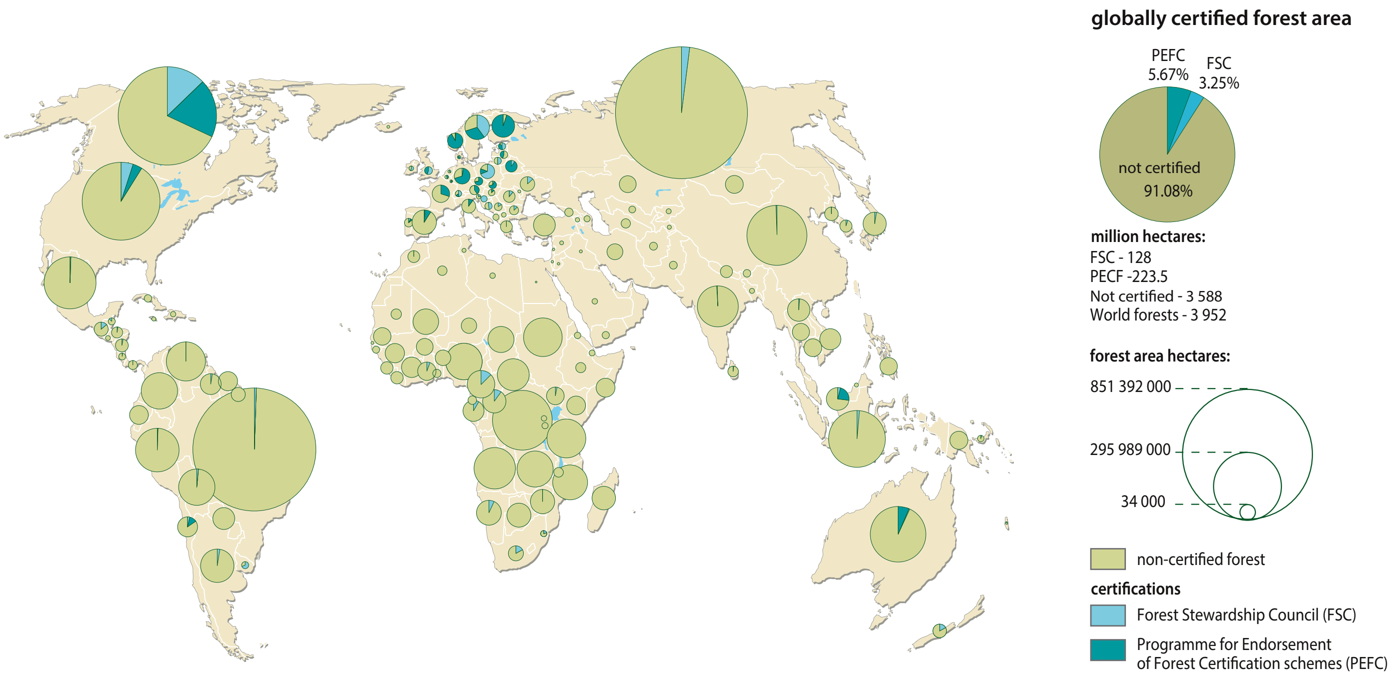


Figure 14: Forest certification by the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification schemes (PEFC) in 2011. There has been an impressive increase in forest certification, largely in Europe and North America. *Source: FSC (2012), PEFC (2012)*

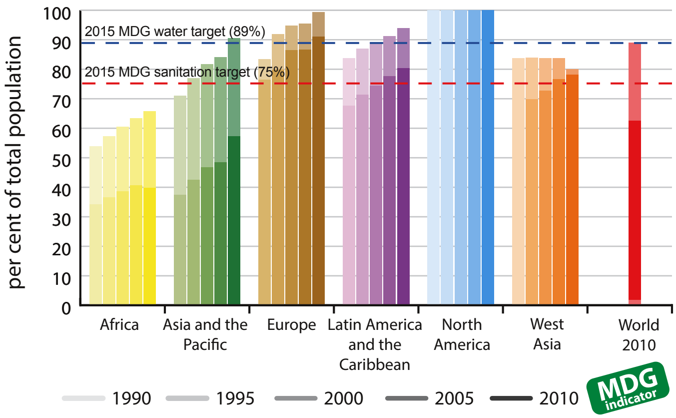


Figure 15: Proportion of the population with sustainable access to an improved water source (back rows) and to basic sanitation (front rows), 1990-2010. The global MDG target for safe drinking water has already been reached, unlike the target for basic sanitation. *Source: UNEP EDE, compiled from WHO/UNICEF (2011)*

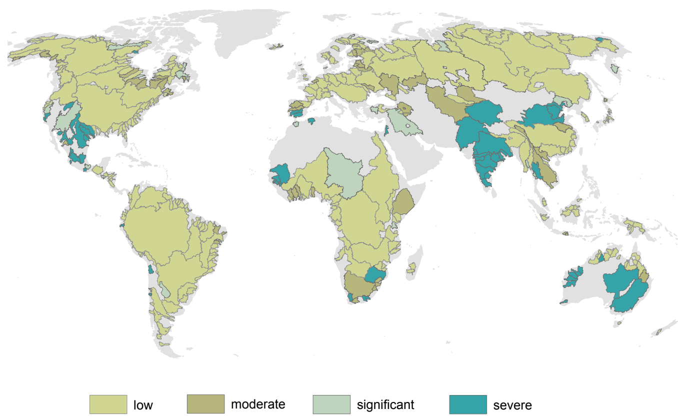


Figure 16: Annual average water scarcity in major river basins, 1996-2005. There is significant or severe blue water scarcity in 82 out of 405 river basins, affecting approximately 520 million people. *Source: Mekonnen* and *Hoekstra (2011)*

Water scarcity remains a significant problem in many parts of the world, as measured by the blue water scarcity indicator showing the proportion of groundwater and surface water consumed relative to sustainable water available for human use (after accounting for environmental flows) (Mekonenn and Hoekstra 2011) **(Figure 16)**. On average, out of 405 river basins studied, 264 basins with a total of 2.05 billion people are facing *low* water scarcity (<100%). However 0.38 billion people in 55 basins face *moderate* (100-150%), 0.15 billion in 27 basins face *significant* (150-200%) and 1.37 billion in 59 basins (particularly in India, Pakistan and China) face *severe* water scarcity (>200%).

Comprehensive data on water quality are very poor and only a few indicators can be provided. Levels of dissolved oxygen (DO) in surface waters illustrate the conditions of life in water bodies **(Figure 17)**.

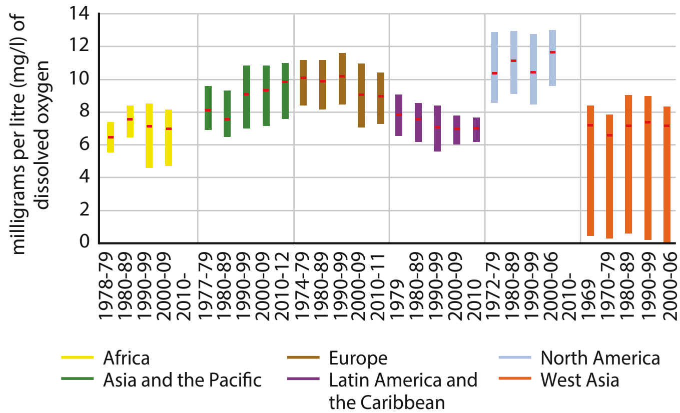


Figure 17: Levels of dissolved oxygen in surface waters, 1969-2010/11. The average is shown as red points, with surrounding uncertainty ranges in the colour of the region. Available data indicate that concentrations of dissolved oxygen are generally within the widely accepted limits of between 6 mg/l in warm water and 9.5 mg/l in cold water, as established for example in Australia, Brazil and Canada. These data are not representative of all waters in the regions, or of each decade, shown here. *Source: UNEP-GEMS/Water (2012)*

Biodiversity

The world's biodiversity continues to decline at alarming rates. Measured by the Red List Index (RLI), the status of all species groups with known trends is deteriorating in regard to their extinction threat, expressed in seven classes ranging from Least Concern to Extinct **(Figure 18)**. This threat is most severe for corals, due to increased bleaching, ocean acidification, and other effects linked to climate change, followed by amphibians (mainly threatened by the fungal disease *chytridiomycosis*), birds and mammals. The status of mammals has deteriorated most dramatically in South-East Asia, while birds are most threatened in Oceania, largely because of invasive species introduced by humans (UNEP-WCMC 2010). There are large gaps in systematic monitoring of biodiversity worldwide, but increasingly co-ordinated efforts are being made to address these gaps (Pereira et al. 2013)

Conservation and regulation have been effective in a number of cases. In the absence of conservation measures, the RLI shows a substantially steeper decline of at least 18 per cent for both birds and mammals. Globally, protected areas continue to increase and now cover nearly 13 per cent of land surface area, 7.2 per cent of coastal and marine areas (up to 12 nautical miles from land) and 1.6 per cent of the ocean (UN 2012b). The international community has set targets for 2020 of 17 per cent for terrestrial and 10 per cent for coastal and marine protected areas (CBD 2010). The need for protected areas to be managed effectively and equitably, as well as the need for proper data and indicators to monitor progress towards meeting these targets, is being emphasized.

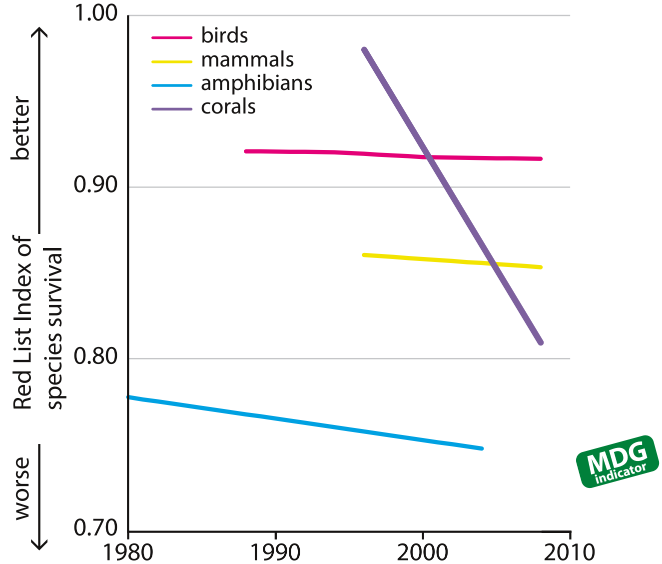


Figure 18: The IUCN Red List Index of Threatened Species, 1980-2010. The RLI measures the risk of extinction of species in seven classes, ranging from Least Concern to Extinct. A value of 1.0 indicates that species are not expected to become extinct in the near future, while 0 means a species is extinct. A small change in the level of threat can have significant impacts on species decline. *Source: IUCN (2012)*

Through the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Trade Database and Dashboards, data on trade in CITES-listed species are being made available. Analysis of these data indicates an increase in reporting of trade by Parties to CITES. After many years of increases, the reported trade in wild and captive animals has decreased recently, with trade in captive animals becoming relatively more significant than trade in those taken from the wild **(Figure 19)**.

Environmental governance

If the world's response to environmental challenges was measured solely by the number of Conventions and other international environmental agreements that have been adopted, the situation would look promising. More than 500 of these agreements have been concluded since 1972, the year of the United Nations Conference on the Human Environment in Stockholm and of the creation of the United Nations Environment Programme (UNEP). They include landmark agreements on climate change, biological diversity, hazardous waste, trade in endangered species, and desertification. Collectively, they represent an extraordinary effort to co-ordinate countries' policies in order to achieve sustainable development. The number of MEAs has grown along with the number of countries (Parties) which are signatories. **Figure 20** shows that 90 per cent of United Nations Member States were signatories to the total set of 14 major MEAs in 2012.

A key indicator for environmental management activities by companies and other organizations is the number of certifications for the ISO 14001 environmental management standard. There were 267 500 such certifications in 2011, with large differences among regions **(Figure 21)**. Certification does not automatically imply that environmental performance is improved, but indicates

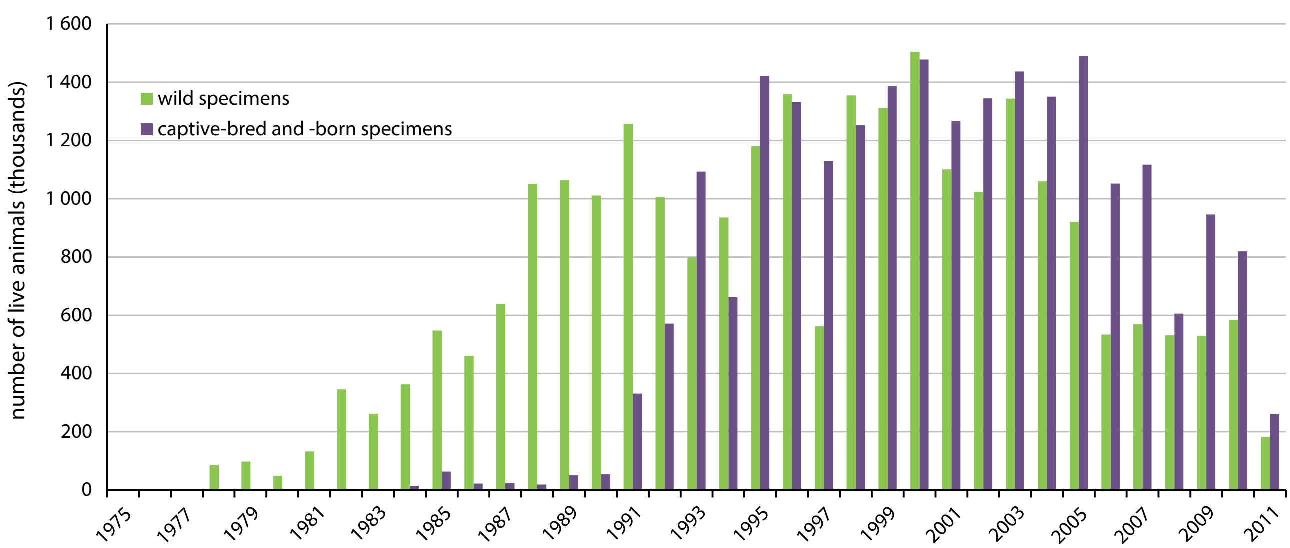


Figure 19: Trade in captive-bred and -born specimens compared with that in wild specimens, 1975-2011. *Source: CITES (2012)*

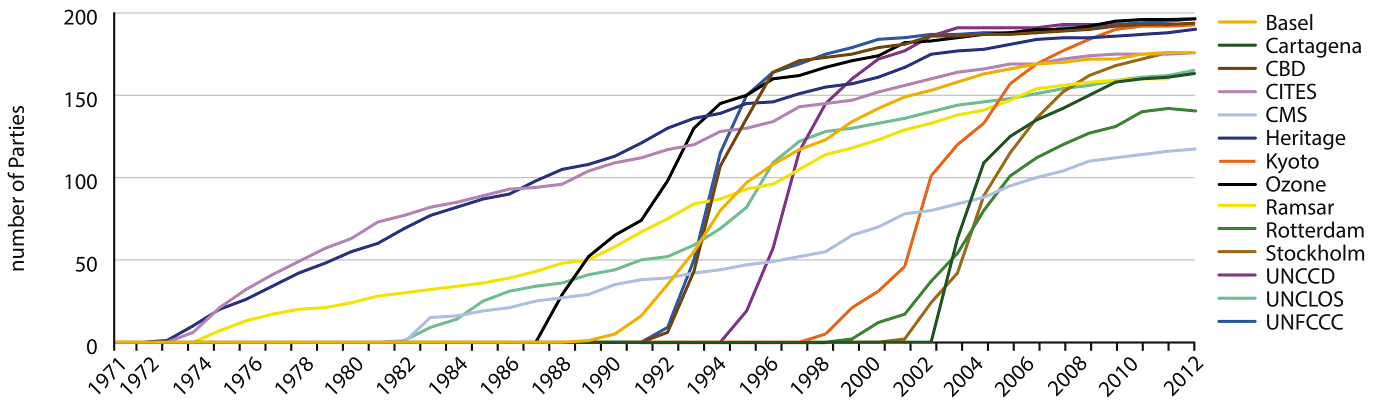


Figure 20: Number of Parties to Multilateral Environmental Agreements (MEAs), 1971-2012. Many MEAs and Conventions are reaching the maximum number of countries as signatories (Parties). Taking all 14 MEAs depicted here together, the number of Parties reached 90 per cent in 2012. Establishing and signing such agreements is a first important step, but does not mean the environmental problems addressed will be solved right away. *Source: UNEP EDE, compiled from various MEA secretariats* **(Table 1)**.

growing awareness by companies and organizations of the need to adopt environmental management systems. Despite an increasing number of legal texts and certifications, greater awareness and many expressions of good intentions, real progress in meeting environmental challenges has been much less comprehensive. There are a number of positive trends and some success stories, but the global environment continues to deteriorate in almost every respect (UNEP 2012a, 2012b).

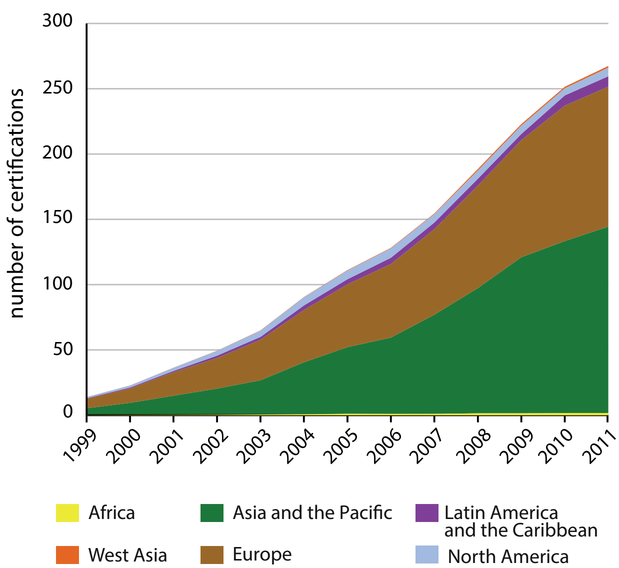


Figure 21: Number of ISO 14001 environmental management certifications, 1999-2011. ISO 14001 certification indicates that companies and other organizations are committed to adopt environmental management systems in terms of conforming to their own stated policies. Total certifications surpassed 250 000 in 2010, with the highest shares in Asia and the Pacific and Europe. *Source: ISO (2012)*

Looking ahead

There are few unequivocal success stories in the field of environment so far. One is the phase-out of the production of substances responsible for ozone depletion under the Montreal Protocol, which is expected to lead to recovery of the ozone layer in the coming decades. Another is meeting the MDG target to halve the proportion of people without sustainable access to safe drinking water source by 2015. Between 1990 and 2010, over 2 billion people gained access to improved drinking water sources, such as piped supplies and protected wells. However, international efforts continue to be required since millions of people still do not have sustainable access to safe drinking water, and the goal of halving the proportion of those without sustainable access to basic sanitation has not been met by far.

Growing awareness of environmental issues, along with political will and commitment to address these issues through international agreements and Conventions are positive signs and are necessary if policy action is to bring about structural changes in consumption and production patterns. Use of renewable energy sources is one encouraging development. Nevertheless, the global environment continues to deteriorate and all its components – from water and air to land and biodiversity – show signs of degradation.

What is not measured cannot be managed. Persistent data gaps and lack of proper environmental monitoring are among the challenges ahead. Internationally comparable data are the basis for tracking global environmental change, as well as for tracking progress towards the achievement of goals and objectives. Data gaps affect our ability to identify consistent, up-to-date trends in global environmental areas including chemicals and waste, land degradation, water quality, and biodiversity. Despite rapid advances in most countries with respect to internet access, remote sensing, social media and other tools and information technologies that can assist in monitoring and data collection, serious data gaps remain.

In addition to more and better data on changes in the environment, clear and measurable targets are needed in order to properly address issues of concern and increase the chances of success. Compared with the economic and social dimensions of sustainable development, the environmental domain is weak in terms of specific, quantified goals and targets. Apart from a few targets such as those related to climate change (for example, staying within the 2°C global warming limit) and biodiversity (for example, increasing protected areas by 2020), many goals and targets included in MEAs are set out in general terms and mainly demonstrate the signatories' good intentions. The most successful international environmental agreements are those that address well-defined issues with specific goals and quantified targets, which can be measured with sound and comprehensive data. Examples are the agreement on protected areas established in 1961 by the World Commission on Protected Areas (WCPA) and the 1987 Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer (UNEP 2011b).

Although there is a lack of specific goals, targets and metrics for achieving and tracking environmental sustainability and sustainable development in general, a number of frameworks and sets of indicators and indices have been proposed since 1992. In 1995 a set of 134 national indicators of sustainable development was formulated, largely following Agenda 21 (the action plan for sustainable development which was a product of the UN Conference on Environment and Development in Rio de Janeiro in 1992). Revised in 2001 and 2006, this UN Commission on Sustainable Development (UNCSD) set comprises 96 indicators, of which 50 are considered part of a core set (UN 2007). Frameworks for the collection of statistical data and for economic-environmental accounting have also been developed to assist countries in developing, organizing and applying environmental and related socio-economic information, notably the Framework for the Development of Environment Statistics (FDES) and the System for Environmental-Economic Accounting. Several composite indices have been developed to measure different aspects of sustainable development, such as the well-known Human Development Index (HDI) and the Ecological Footprint, and the more recent Inclusive Wealth Index, which attempts to measure wealth and growth beyond gross domestic product (GDP) metrics and better reflect the depletion of natural resources. Various proposals are being made to measure progress towards green growth and a green economy, focusing on indicators for economic transformation, resource efficiency, and well-being, and providing guidance on policy reforms and investments aimed at achieving a green transformation of key economic sectors as a means of advancing towards sustainable development. Rio+20 considered a green economy one important way of achieving sustainable development and providing options for policymaking, but without being a rigid set of rules.

One of the main outcomes of Rio+20 was the agreement by countries to launch a process to develop a set of Sustainable Development Goals, which will build upon the Millennium Development Goals and converge with the post 2015 development agenda. The SDGs should consist of concrete goals and targets, which are one of the main strengths of the MDG framework, but be reorganized along four key dimensions of a more holistic approach: inclusive social development; inclusive economic development; environmental sustainability; and peace and security (UN 2012c). They should apply to all countries, and be based on the fundamental principles of human rights, equality and sustainability – building on the principles of the year 2000 Millennium Declaration and the three pillars of sustainable development. A process has begun to establish an "inclusive and transparent intergovernmental process open to all stakeholders, with a view to developing global sustainable development goals to be agreed by the General Assembly" (UN 2012d). Lessons learned from the development of environmental indicators for MDG goal 7 on environmental sustainability, and from other experience, could be invaluable to further guide on this process.

The European Space Agency (ESA) Envisat satellite is the largest Earth observation craft ever built and has been continuously observing and monitoring land, atmosphere, ocean and ice caps since 2002. After ten years of service, ESA formally announced the end of Envisat's mission in May 2012. *Credit: ESA*

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Table 1: Key environmental indicators data (latest update 2012)

Key environmental indicator	Latest year on record	World	Africa	Asia and the Pacific	Europe	Latin America and the Caribbean	North America	West Asia	Unit of measurement
Consumption of ozone-depleting substances	2011	41 053	2 067	28 891	-26	4 836	1 686	3 598	ODP tonnes
Carbon dioxide emissions	2009	32.07	1.20	14.52	6.14	1.60	5.81	1.05	billion tonnes of CO_2
Carbon dioxide emissions per capita	2009	4.7	1.2	3.7	7.4	2.7	16.7	8.1	tonnes of CO_2 per caita
Forest harvest rates	2011	0.8	1.0	2.2	0.7	0.3	0.7	4.1	ratio
Total fish catch	2010	88.1							million tonnes
Area protected to maintain biological diversity relative to total surface area	2010	12.0	10.1	9.9	10.2	19.3	9.5	17.1	per cent of total territorial area
Municipal waste collection	2009			310 (2008)	383	119 (2007)	234	32	million tonnes
Access to safe drinking water	2010	89	65.7	90.5	99.0	94.2	99.1	80.0	per cent of total population
Access to basic sanitation	2010	63	39.9	57.4	90.9	80.1	100.0	78.3	per cent of total population
Number of certifications of the ISO 14001 standard	2011	267.5	1.7	143	107	7.9	6.6	1.3	number of certifications (thousands)

CITES Species Trade (2011) number of wild animals (thousand)	
Captive-bred and -born animals	259 813
Wild animals	182 772

Renewable energy 2010 index (1990 = 100)	
Solar photovoltaics	137 150
Solar thermal	765
Wind	8 799
Biofuels - biogasoline and biodiesel	2 356

Primary energy supply 2010 oil equivalent (thousand million tonnes)	
Crude oil and feedstocks	4.16
Coal and coal products	3.51
Gas	2.73
Combustible renewables and waste	1.28
Nuclear	0.72
Hydro	0.30
Geothermal	0.06
Solar/wind/other	0.05
Total supply (TPES):Million tonnes oil eq.	12.76

MEAs 2012 number of Parties	
Basel	176
Cartagena	164
CBD	193
CITES	177
CMS	118
Heritage	190
Kyoto	192
Ozone	197
Ramsar	163
Rotterdam	147
Stockholm	178
UNCCD	194
UNCLOS	164
UNFCCC	195

MEAs data 2012

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/1290/Default.aspx
Cartagena Protocol on Biosafety to the Convention on Biological Diversity http://bch.cbd.int/protocol/
CBD http://www.biodiv.org/world/parties.asp
CITES http://www.cites.org/eng/disc/parties/
CMS http://www.cms.int/about/part_lst.htm
Heritage Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage). http://whc.unesco.org/en/statesparties/
Kyoto Protocol to the UNFCCC. http://unfccc.int/essential_background/kyoto_protocol/status_of_ratification/items/2613.php
Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat.
http://www.ramsar.org/cda/en/ramsar-about-partiescontracting-parties-in-20715/main/ramsar/1-36-23%5E20715_4000_0__
Rotterdam Convention on the Prior Informed Consent Procedure for Certain hazardous Chemicals and Pesticides in international trade (PIC)
http://www.pic.int/Countries/Parties/tabid/1072/language/enS/Default.aspx
Ozone Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol on Substances that Deplete the Ozone Layer
http://ozone.unep.org/new_site/en/vienna_convention.php
Stockholm Convention on Persistent Organic Pollutants (POPs) http://www.pops.int/documents/signature/signstatus.htm
UNCCD http://www.unccd.int/convention/ratif/doeif.php
UNCLOS (2013) http://www.un.org/Depts/los/reference_files/chronological_lists_of_ratifications.htm#
UNFCCC http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php

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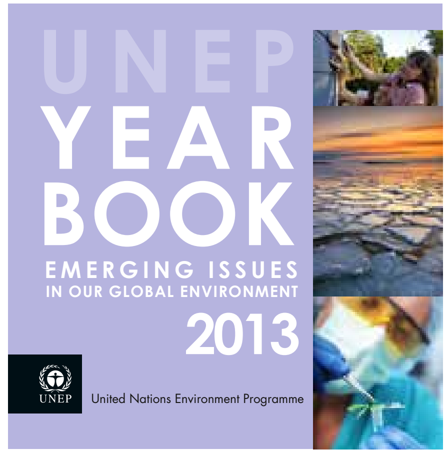

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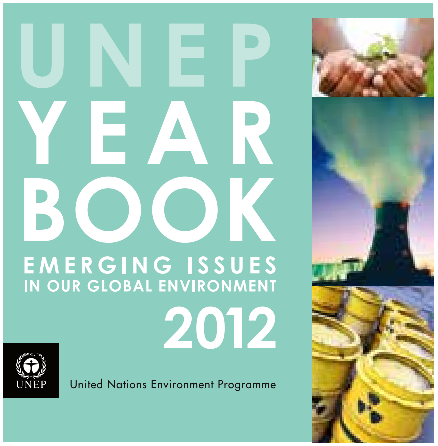
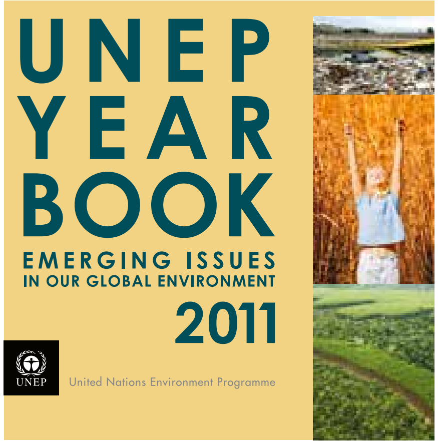
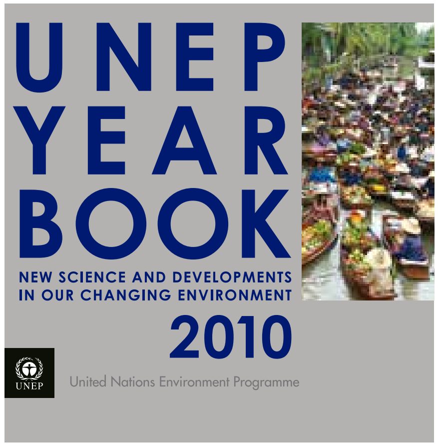
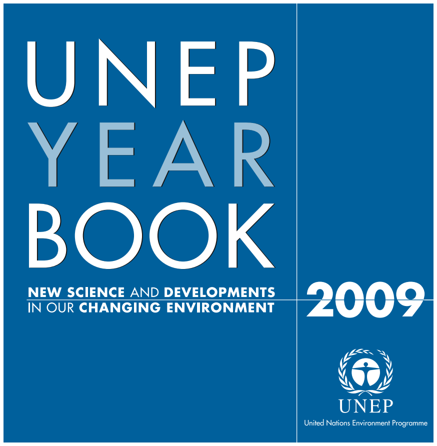
Emergence or re-emergence of infectious diseases
Potential climate change impact on ocean circulation

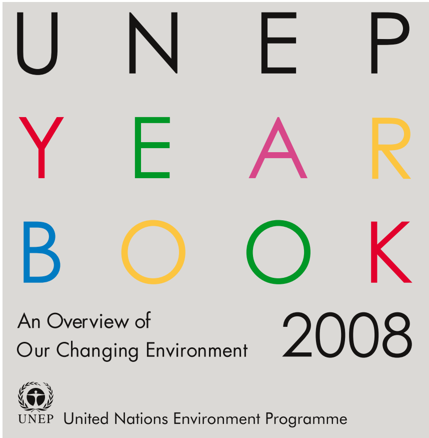
GEO Year Book 2003
Water and the Millennium Development Goals
The nitrogen cascade (hypoxia)
Overfishing

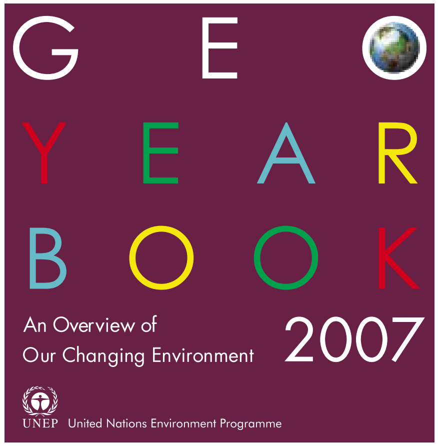


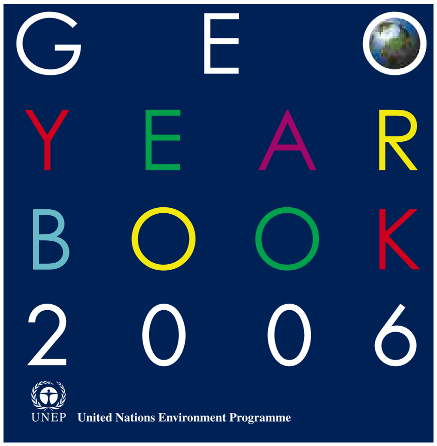


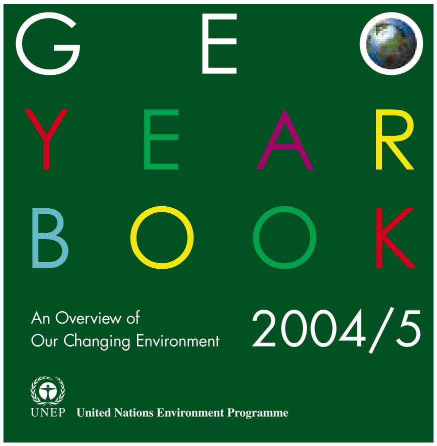


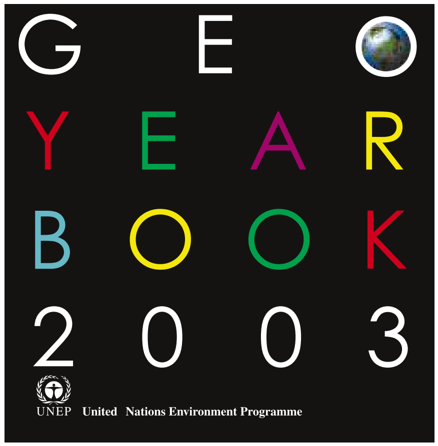












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Rapid change in the Arctic

The extent of Arctic sea ice was at a record low in September 2012. Rapid change in the Arctic resulting from global warming is threatening ecosystems and providing new development opportunities – including easier access to oil, gas and minerals. The UNEP Year Book 2013 shows that changes in the Arctic will have consequences far beyond this fragile region and require an urgent international response.

The volume of chemicals in the world continues to grow, with a shift in production from developed to developing countries. To meet the goal of producing and using chemicals in ways that minimize significant impacts on health and the environment by 2020, we need to step up efforts to reduce the use of highly toxic chemicals, promote safer alternatives and build capacity for sound chemicals management. Adequate information for minimizing chemical risks is essential to support these efforts.

The UNEP Year Book series examines emerging environmental issues and policy-relevant developments. It also presents the latest trends using key environmental indicators.

Minimizing chemical risks

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