# UNEP YEAR BOOK

## EMERGING ISSUES IN OUR GLOBAL ENVIRONMENT

## 2013

UNEP

United Nations Environment Programme

UNEP YEAR BOOK 2013 EMERGING ISSUES IN OUR GLOBAL ENVIRONMENT

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# Preface

The UNEP Year Book 2013 is the 10th edition of UNEP's series that keeps track of major environmental developments and events, as well as highlighting emerging issues in our global environment.

The Arctic may seem a remote place for many people in places like Africa or Latin America, but the environmental changes occurring at accelerating rates there have profound implications for everyone, not least in respect to climate change including rising sea levels.

In 2012, unprecedented change was observed in the Arctic. Summer sea ice cover reached a record low of 3.4 million $km^2$. This was 18 per cent below the previous recorded minimum in 2007 and 50 per cent below the average in the 1980s and 1990s.

Over the past five years, Arctic sea ice has melted more rapidly than had been projected by models and, at one point in 2012, 97 per cent of the Greenland ice sheet surface was melting.

In the short term, important benefits could be gained from action on short-lived climate pollutants under the Climate and Clean Air Coalition (CCAC) for which UNEP hosts the secretariat. The number of CCAC members has expanded from seven to 48 since February 2012.

The Year Book also focuses on the challenge of chemicals. One study shows that out of 95 000 industrial chemicals, only 5 per cent have adequate data on acute aquatic toxicity, the extent to which they build up in the environment (bioconcentration), or how long it takes for them to break down.

In 2002, global leaders agreed that by the year 2020 chemicals should be produced and used in ways that minimize significant adverse impacts on human health and the environment – with less than eight years to go, action on sound chemicals management needs to be urgently stepped up to reach this goal.

A further re-emerging challenge highlighted in the 40th anniversary year of the Convention on International Trade in Endangered Species (CITES) is the increase of poaching of elephants and rhinos and the related illegal trade in ivory and rhino horn. A record 668 rhinos were poached in South Africa in 2012 alone.

Not all trends are negative: The Year Book underlines that there is growing awareness of environmental issues, along with growth in renewable energy. Nevertheless it underlines the urgency of implementing existing agreements and the outcomes of Rio+20 if the world is to deliver *The Future We Want*.

**Achim Steiner**

United Nations Under-Secretary-General and
Executive Director, United Nations Environment Programme

# Acronyms and Abbreviations

| | |
|---|---|
| BPA | bisphenol A |
| BRIICS | Brazil, Russia, India, Indonesia, China and South Africa |
| BRS | Basel, Rotterdam and Stockholm Conventions |
| CBD | Convention on Biological Diversity |
| CBMP | Circumpolar Biodiversity Monitoring Programme |
| CITES | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| CMS | Convention on Migratory Species of Wild Animals |
| $CO_2e$ | carbon dioxide equivalent |
| COP | Conference of the Parties |
| CSD | Commission on Sustainable Development |
| DDT | dichlorodiphenyltrichloroethane |
| DO | dissolved oxygen |
| EEA | European Environment Agency |
| EEZ | Exclusive Economic Zone |
| ELA | Experimental Lakes Area (Canada) |
| ESA | European Space Agency |
| ETIS | Elephant Trade Information System |
| FAO | Food and Agriculture Organization of the United Nations |
| FDES | Framework for the Development of Environment Statistics |
| FSC | Forest Stewardship Council |
| GCO | Global Chemicals Outlook |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |
| GEO-5 | Global Environment Outlook 5 |
| GEOS-5 | Goddard Earth Observing System Model, Version 5 |
| GHG | greenhouse gas |
| GHS | Globally Harmonized System of Classification and Labelling of Chemicals |
| Gt | gigatonne |
| HCFCs | hydrochlorofluorocarbons |
| HDI | Human Development Index |
| HFCs | hydrofluorocarbons |
| ICC | Inuit Circumpolar Council |
| ICCM3 | Third International Conference on Chemicals Management |
| IETC | International Environmental Technology Centre |
| IMO | International Maritime Organization |
| IPCC | Intergovernmental Panel on Climate Change |
| IUCN | International Union for the Conservation of Nature |
| MDG | Millennium Development Goal |
| MEA | Multilateral Environmental Agreement |
| MIKE | Monitoring the Illegal Killing of Elephants |
| NASA | National Aeronautics and Space Administration (United States) |
| NSIDC | National Snow and Ice Data Center (United States) |
| ODP | ozone depletion potential |
| OECD | Organisation for Economic Co-operation and Development |
| OW | open water |
| PBDEs | polybrominated diphenyl ethers |
| PBT | persistent, bioaccumulating and toxic substances |
| PCBs | polychlorinated biphenyls |
| PCE | perchloroethylene |
| PEFC | Programme for Endorsement of Forest Certification |
| $PM_{2.5}$ | particulate matter 2.5 micrometres in diameter |
| POPs | Persistent Organic Pollutants |
| PRTR | Pollutant Release and Transfer Register |
| QSAR | quantitative structure-activity relationship |
| RAIPON | Russian Association for Indigenous Peoples of the North |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemical substances |
| RLI | Red List Index |
| SAICM | Strategic Approach to International Chemicals Management |
| SDG | Sustainable Development Goal |
| TURA | Toxics Use Reduction Act (United States) |
| UNCBD | United Nations Convention on Biological Diversity |
| UNCED | United Nations Conference on Environment and Development |
| UNCLOS | United Nations Convention on the Law of the Sea |
| UNCSD | United Nations Conference on Sustainable Development |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US EPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| WCPA | World Commission on Protected Areas |
| WHO | World Health Organization |
| WMO | World Meteorology Organization |

# Executive Summary

The 10th edition of the UNEP Year Book focuses on rapid change in the Arctic and minimizing chemical risks. It also reports on the spike in rhino and elephant poaching in Africa, growing urban environmental challenges, and the accelerating momentum to tackle short-lived climate pollutants. The UN Conference on Sustainable Development (Rio+20), the biggest environmental event of 2012, resulted in the strengthening of international environmental governance, a process towards developing sustainable development goals, and broad recognition of the role of a green economy in supporting sustainable development and eradicating poverty.

The world is warming, and with it the Arctic. Sea ice extent was at a record low in 2012. In July, 97 per cent of the Greenland ice sheet surface was melting. Climate change is emerging as a major stressor on Arctic biodiversity. The habitats of unique flora and fauna are being reduced – with ice-dependent Arctic marine mammals especially at risk. A widely predicted northward shift of some fish species has now been observed.

The impact of rapid change in the Arctic on the rest of the world extends beyond the contribution of melting ice and snow to global sea level rise. This region plays an important role in the climate system and ocean circulation. It is also significant for millions of migratory birds and mammals. Although much depends on the rate of change, thawing of permafrost soils could release large amounts of greenhouse gases, further amplifying climate change.

Less sea ice will result in new opportunities for shipping and resource exploration. The importance of the Arctic in supplying the world with energy and minerals is expected to expand greatly, triggering construction of roads, ports and new settlements. It is vital to better understand the impacts and potential risks of changes and to enhance the resilience of people in the region as well as ecosystems. To avoid irreversible damage to this fragile environment, a precautionary approach to economic development is warranted. As climate change dominates the current transformation of the Arctic environment, curbing greenhouse gas emissions remains critical.

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. Yet we are falling behind with pre-market testing of new chemicals, and not enough is known about many chemicals already in commerce. A recent study showed that out of 95 000 industrial chemicals, adequate data on aquatic toxicity, bioconcentration and persistence were publicly available for less than 5 per cent. To make optimal decisions on minimizing chemical risks and protecting health and the environment, governments, industry and the public urgently need access to adequate information. New testing and assessment technologies provide promising opportunities in this regard.

Children, women, workers, the elderly and the poor are especially vulnerable to some hazardous chemicals. Once chemicals are in the environment, it can be very difficult to control or remove them. They can be transported through air, water and soil and may have adverse impacts on ecosystems and organisms including bees, fish and amphibians – or their offspring. Emerging challenges to the minimization of chemical risks include chemical mixtures, low-dose exposures, the replacement of hazardous chemicals by others with similar hazards, and nanotechnology.

Costs associated with the risks of chemicals are difficult to assess – but recent studies point out that they can be very high. One way to address inefficiencies that result when chemicals' external costs are not fully borne by those with responsibility for them is to implement cost internalization mechanisms using economic instruments.

To reach the internationally agreed goal to produce and use chemicals in ways that minimize significant adverse impacts on human health and the environment by 2020, increased efforts are needed to strengthen sound chemicals management. Key elements include reducing the production and use of toxic substances, promoting safer alternatives, improving information flow and transparency, building capacity for improved chemicals management, and reducing illegal international traffic in chemicals.

Looking at changes in the global environment based on the annual indicator update in the Year Book, there have been a few success stories. One is the phase-out of production of ozone depleting substances under the Montreal Protocol, which is expected to lead to recovery of the ozone layer in the coming decades. Another is the uptake of renewable energy. Overall, however, the global environment continues to show signs of degradation – from land and water to biodiversity and the atmosphere.

# Year in Review

## Environmental events and developments

The largest United Nations conference in history, the UN Conference on Sustainable Development (UNCSD), was held in Rio de Janeiro in June 2012 – 20 years after the Rio Earth Summit. The year also marked the 25th anniversary of the Montreal Protocol on Substances that Deplete the Ozone Layer, and the end of the first commitment period under the Kyoto Protocol on reducing greenhouse gas emissions. While some progress has been made towards achieving sustainable development in the past two decades, 2012 also witnessed failures to protect the environment, including increased emissions of greenhouse gases and other types of air pollutants, growth in unsustainable consumption and production, and increased biodiversity loss, including a surge in poaching in Africa which threatens some of its most iconic species. Many of the world's ongoing and emerging environmental issues identified during the past decade still persist and must be addressed.

### Working towards sustainable development

Twenty-six years ago the Brundtland report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). A few years later, in 1992, the UN Conference on Environment and Development, better known as the "Earth Summit", took place in Rio de Janeiro, Brazil, where governments agreed on common actions that would lead to sustainable development **(Table 1)**. In 2012, 20 years after the Earth Summit, world leaders reconvened on 13-22 June in Rio de Janeiro for the UN Conference on Sustainable Development (UNCSD), or "Rio+20", to review progress since 1992.

Rio+20 was the largest and most participatory UN conference ever **(Box 1)**. The conference outcome document, *The Future We Want*, outlines crucial next steps towards a sustainable future. One important outcome was agreement to launch a process to develop Sustainable Development Goals (SDGs) built upon the Millennium Development Goals (MDGs). Many of the MDGs are to be achieved by 2015. The conference also reached a consensus on creating a strengthened institutional framework for sustainable development (IISD 2012a, UNCSD 2012a, UNGA 2012).

Poaching of endangered species seriously threatens some of the world's biodiversity. Rhinos like this white rhino in Kruger National Park, South Africa, are endangered species poached for illegal trade in their horns.
*Credit: Laurent Baheux*

Economic development and the expanding world population continue to put pressure on the Earth's resources (OECD 2012, UNEP 2012a). It is necessary to develop and implement ways to

**Box 1:** Rio+20 in figures

- 191 delegations from UN member states and many observers
- 79 Heads of State or Government
- 44 000 official participants
- 500 official side events
- 3 000 unofficial side events
- Over 700 voluntary commitments worth more than US$513 billion, including pledges from the private sector

**Table 1:** Global environmental governance milestones

| Year | Event | Key outcomes |
|---|---|---|
| 1972<br>UNEP | UN Conference on the Human Environment | Stockholm Declaration<br>Stockholm Action Plan<br>UNEP established |
| 1983 | Establishment of World Commission on Environment and Development | 1987 report *Our Common Future* (the Brundtland report) |
| 1992 | UN Conference on Environment and Development | Rio Declaration on Environment and Development<br>Agenda 21<br>Statement of Forest Principles<br>UN Framework Convention on Climate Change<br>Convention on Biological Diversity<br>Convention to Combat Desertification<br>Call for creation of a Commission on Sustainable Development |
| 2002 | World Summit on Sustainable Development | Johannesburg Declaration<br>Johannesburg Plan of Implementation |
| 2012<br>RIO+20 United Nations Conference on Sustainable Development | UN Conference on Sustainable Development | *The Future We Want* |

use resources more efficiently in order to maintain the current level of economic growth. During Rio+20 countries recognized that a green economy is an important way to achieve "the future we want" – a future which will see sustainable development and poverty eradication. A green economy aims at improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low-carbon, resource-efficient and socially inclusive. Growth in income and employment should be driven by public and private investments that reduce carbon dioxide ($CO_2$) and other non-$CO_2$ emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services (UNEP 2011a).

A green economy transformation could generate 15-60 million additional jobs globally in the next two decades and lift tens of millions of people out of poverty (UNEP/ILO/IOE/ITUC 2008). In 2012 the UN Statistical Commission adopted a system of environmental-economic accounting to monitor progress on increasing green investment, creating green jobs, improving energy and resource efficiency, and recycling (UNEP 2012a).

Voluntary commitments during Rio+20 included those by three multinational companies to end deforestation in their supply chains for beef, soy, paper and palm oil by 2020 (Madras et at. 2009). Eight development banks also made commitments to provide US$175 billion in grant and loan funding by 2020 to support sustainable low-carbon transportation. Furthermore, a Partnership for Action on a Green Economy has been launched to support 20 developing countries across relevant sectors such as transport, agriculture and the built environment (UN 2012a).

## Sustaining a growing population

There were some 7.06 billion people in the world by the end of 2012 (US Census Bureau 2013). It is expected that there will be more than 10 billion by 2100 (UN 2011). By comparison, the world population was only 3.85 billion in 1972, the year of the UN Conference on the Human Environment and the establishment of the UN Environment Programme **(Figure 1)**.

Despite the challenges of feeding a growing global population, new figures show that countries are making some progress in responding to malnutrition and hunger. In Latin America, for example, hunger affected 14.6 per cent of the population in 1990-92 compared with 8.3 per cent (49 million people) in 2010-12 (FAO 2013). However, more than 2 billion people who live in


As the President of UNCSD said, Rio+20 was a "global expression of democracy". Among the official participants were representatives of the private sector, NGOs and many other civil society groups including women's organizations, farmers, and members of the scientific and technological community, all of whom were there to draw the attention of world leaders to critical issues such as sustainable food production. *Credit: Conservation International*

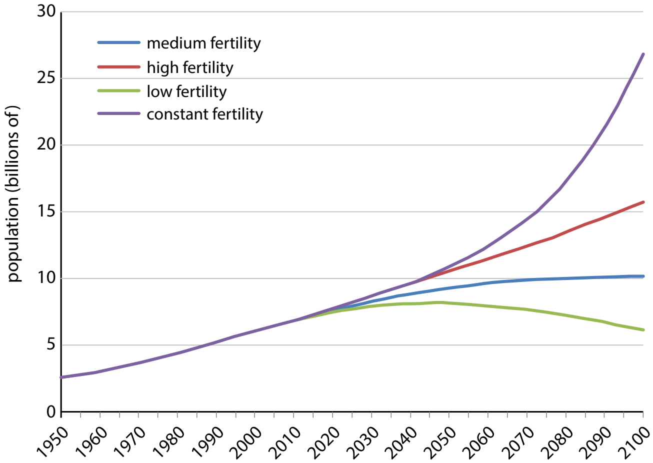


**Figure 1:** Global population by 2100, based on different fertility scenarios. According to the medium fertility scenario, the total population will stabilize at 10 billion around the end of the century. *Source: UN 2011*

the world's dryland countries are threatened by natural resources degradation (UN 2012b), with the number going hungry in dryland regions of Africa and West Asia having increased by 83 million to 275 million since the early 1990s (FAO 2012).

The Earth's capacity to sustain the human population and its increasing demands remains a critical issue (UNEP 2012c). Earth systems are being pushed towards their biophysical limits, and some of these limits may already have been exceeded (UNEP 2012a). With more than 30 per cent of the Earth's surface currently used for agricultural production, some natural habitats have been shrinking by more than 20 per cent since the 1980s (UNEP 2012a). Habitat reduction through conversion to agriculture is a major reason for biodiversity loss. Demand for biofuel feedstock means that with respect to use of both water and arable land, "food versus fuel" has become another critical issue (UNEP 2011c).

Agriculture accounts for more than 90 per cent of the global water footprint, and in many parts of the world agriculture is particularly dependent on groundwater (UNEP 2012a). As a result of climate change and continuing population growth, growing water shortages are anticipated in many regions. Groundwater supplies have continued to deteriorate since 2000, and global groundwater withdrawals have tripled in the last half-century (UNEP 2012a). In 2012 large groundwater reserves were identified in Africa. Although they may help increase water security, scientists caution against large-scale withdrawals (MacDonald et al. 2012).

A shift towards more sustainable consumption and production patterns is increasingly considered a prerequisite for sustainable development that is inclusive and people-centred (UNCSD 2012). For example, worldwide over 30 per cent of all food produced is wasted every year (Gustavsson et al. 2011). At the same time, 40 per cent of children in Africa below five years of age are malnourished (UNDP 2012). During Rio+20, UN Secretary-General Ban Ki-Moon launched the Zero Hunger Challenge, inviting all countries to work for a future where every individual has adequate nutrition and where all food systems are resilient (UNCSD 2012b). The "Think-Eat-Save: Reduce Your Foodprint" global campaign launched by UNEP, FAO and other organizations supports this initiative by focusing on a reduction of food waste.

One concrete outcome of Rio+20 was the adoption of a 10-Year Framework of Programmes on Sustainable Consumption and Production. The purpose of this framework is to enhance international co-operation and innovation in order to accelerate the shift towards sustainable consumption and production in both developed and developing countries (UNEP 2012b). An initial list of areas for action includes consumer information, lifestyles and education, sustainable building and construction, sustainable tourism and sustainable public procurement.

Public procurement represents an average 15 per cent of GDP in OECD countries (OECD 2012). Green public procurement policies are emerging as a key policy instrument to encourage markets and innovation to move in a more sustainable direction. The private sector has a vital role to play in advancing sustainable consumption and production through technology development, innovation, funding, and corporate sustainability reporting.

## Environmental pressures in an urbanizing world

Since 2008, more than half the people in the world live in urban areas. It is projected that this proportion will grow to two-thirds by 2050 (UN-Habitat 2012). Europe, Latin America and North America are already highly urbanized, whereas Africa and Asia have the highest rate of urbanization. Half the population of Asia is expected to live in urban areas by 2020, and Africa is likely to reach this level in 2035. Out of every ten urban residents in the world today, more than seven are in developing countries. Most of the world's population growth is expected to occur in (or result in further migration to) urban areas (UNDESA 2012). It is estimated that over 90 per cent of the increase in total urban population will occur in developing countries (UN-Habitat 2012).

More than half the world's urban residents live in cities and towns with under half a million inhabitants. However, the number of megacities (cities with over 10 million) is expected to increase from 23 in 2012 to 37 by 2025. Intensive human activities and energy consumption in urban areas lead to a concentration of emissions of air pollutants and generation of waste and heat, with multiple adverse impacts on the urban environment, especially air quality (UNDESA 2012). But this concentration of impacts in comparatively small areas can also make it possible to address some environmental problems efficiently in cities.

Of particular concern are the adverse health and environmental impacts of particles less than 2.5 micrometres in diameter ($PM_{2.5}$). These particles are emitted as a result of incomplete combustion of fuel and biomass, for example by diesel vehicles, cooking and heating stoves, and open fires. Outdoor air pollution in urban areas is estimated to cause over 1 million premature deaths annually from exposure to fine particulate matter (WHO 2011). This problem is not confined to urban areas. For example, $PM_{2.5}$ emissions from bush fires may cause the deaths of an estimated 340 000 people per year, with most of the victims in sub-Saharan Africa and South East Asia.

$PM_{2.5}$ is a component of black carbon. Black carbon and ground-level ozone (or tropospheric ozone) are two of the short-lived climate pollutants (SLCPs). Apart from making up a substantial part of the air pollutants that impact human health, SLCPs contribute to climate change. Other pollutants in this group include methane and some hydrofluorocarbons (HFCs). While they are important greenhouse gases, these pollutants remain in the atmosphere for a shorter period than $CO_2$ (UNEP/WMO 2011).

Fast and sustainable action to reduce emissions of SLCPs represents a major opportunity to deliver multiple benefits in terms of public health, food and energy security, and near-term climate protection. Significant reductions of methane and black carbon, if implemented between now and 2030, have the potential to slow down global warming by 0.4°C to 0.5°C by 2050, as well as to prevent more than 2 million premature deaths and crop losses of more than 30 million tonnes per year (UNEP/WMO 2011).

In February 2012, the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) was founded **(Box 2)**. It launched several initiatives for rapid implementation aimed at catalyzing new, accelerated and scaled-up action to address these pollutants, including:

- Reducing black carbon emissions from heavy duty diesel vehicles and engines.
- Mitigating black carbon and other pollutants from brick production.
- Mitigating SLCPs from the municipal solid waste sector.
- Promoting HFC alternative technology and standards.
- Accelerating methane and black carbon reductions from oil and natural gas production.

Controlling long-range air pollution is an international issue. For example, a recent study found that transport of air pollutants from Asia contributes directly to elevated tropospheric ozone levels in the United States (Lin at al. 2012). Transboundary effects need to be taken into account both in regulating local emissions and in negotiating international standards. In May 2012, Parties to the Convention on Long-range Transboundary Air Pollution agreed to revisions to its Gothenburg Protocol which, for the first time, include black carbon in an international agreement on air pollution.

Growing urbanization and industrialization also lead to rapid increases in the volumes and types of solid waste. This is a major concern for local and national governments, especially in developing countries, which are often constrained by limited resources and capacity. Lack of appropriate waste management policies, capacity and financial resources leads to increasing adverse impacts of waste on human health and the environment, most noticeably in cities (Hoornweg and Bhada-Tata 2012).

The composition of waste in many countries is changing, with the share of hazardous electrical and electronic waste (e-waste) expanding rapidly (Hoornweg and Bhada-Tata 2012, UNEP 2012a, Lundgren 2012) (see Chapter 3, Box 2). In Phnom Penh, Cambodia, for example, the amount of e-waste generated has been projected to quadruple within a decade (MoE/UNEP 2009). As the number of healthcare facilities in the world grows, another concern regarding hazardous waste is the increasing volume of healthcare waste and its potential adverse impacts (UNEP 2012d).

Poor waste management can result in contamination of soil and water sources as well as greenhouse gas emissions. In addition, precious materials which could be recovered may be lost. Landfills are estimated to be the third largest source of global anthropogenic emissions of methane, which is a potent greenhouse gas and a precursor of another greenhouse gas, tropospheric ozone (Global Methane Initiatives 2011). In 2012 the International Environmental Technology Centre (IETC) and CCAC partners launched an initiative to support municipal and national governments in reducing emissions of SLCPs across the municipal solid waste sector by capping and closing open dumps, capturing and utilizing landfill gas, and ensuring proper waste handling and organics management.

## Box 2: The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC)

The CCAC is a voluntary, collaborative global partnership uniting governments, intergovernmental organizations, representatives of civil society and the private sector committed to taking action on SLCPs. Its primary focus is on black carbon, methane and some hydrofluorocarbons (HFCs).

After the founding in 2012 (by six countries and UNEP) of this first global effort to treat short-lived climate pollutants as a collective challenge, the coalition grew to 48 partners by the end of the year, including 25 countries, the European Commission, and a significant number of international and non-governmental organizations (UNEP 2012f).

The sources of black carbon are plentiful and aerosol processes in the climate system are extremely complex **(Figure 2)**. The CCAC is supported by a Scientific Advisory Panel to keep the Coalition abreast of scientific developments. All the partners recognize that its work is entirely complementary to efforts to reduce carbon dioxide, particularly those under the United Nations Framework Convention on Climate Change (UNFCCC).

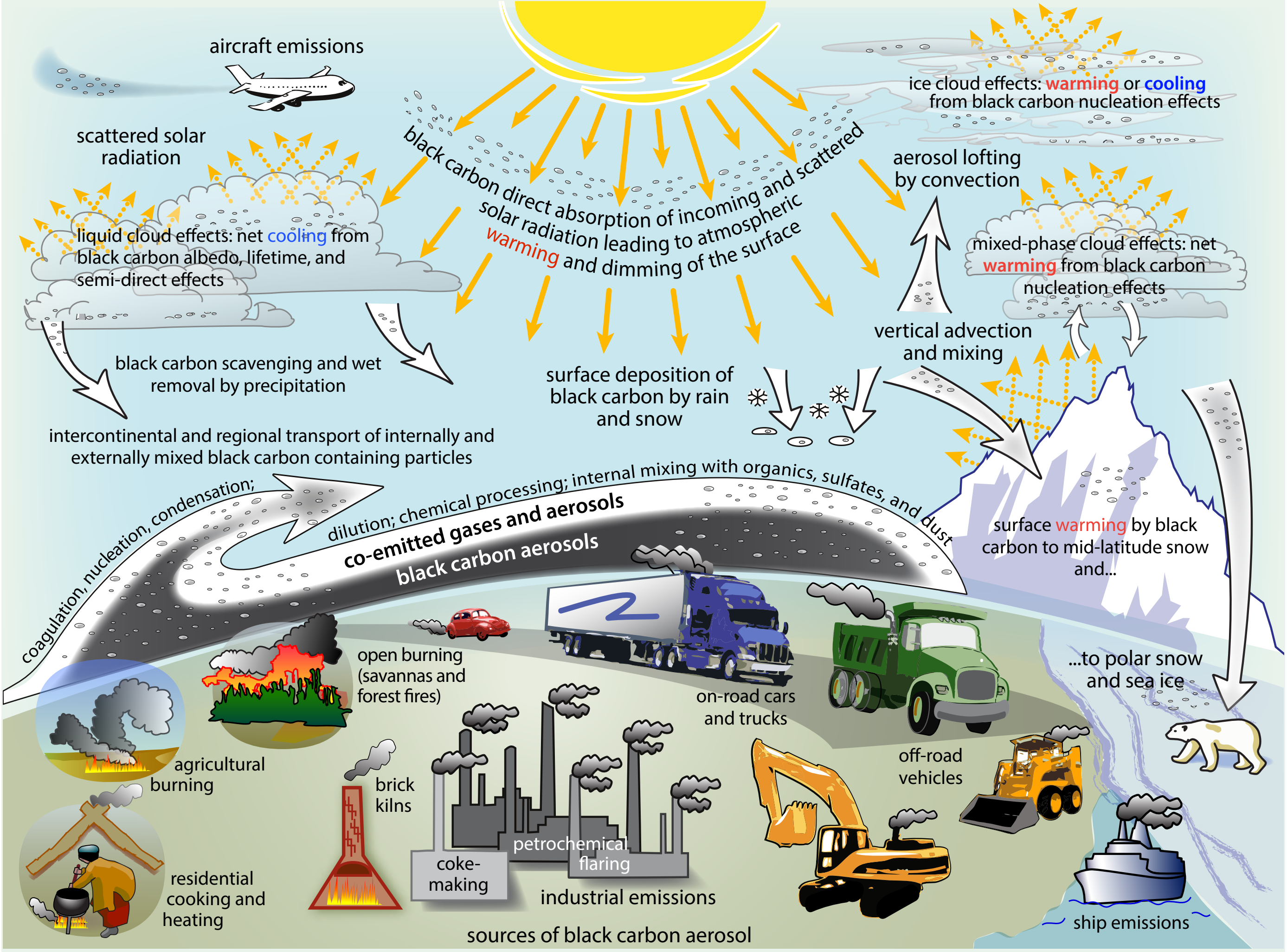


Figure 2: Main sources of black carbon and its co-emitted pollutants, their transport in the environment, and impacts on the global environment and climate. *Source: Bond et al. 2013. Credit: David Fahey*

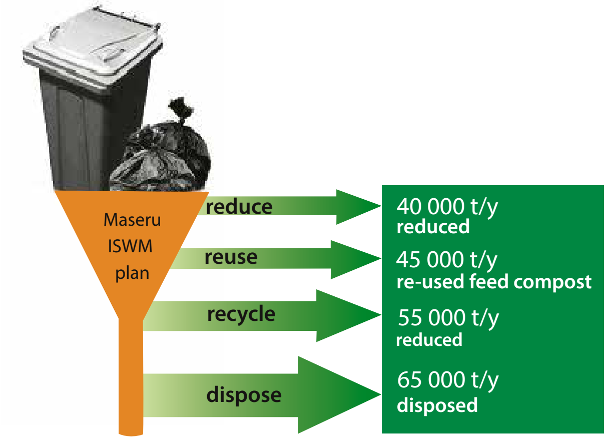


**Figure 3:** In Maseru city, Lesotho, an Integrated Solid Waste Management (ISWM) programme has been developed. Preventing waste generation and sorting different types of waste for recycling, composting and reuse is expected to help reduce the 205 million tonnes of waste generated per year to a total disposal amount of 65 000 tonnes. Diverting waste to capture materials and energy has the potential to raise revenues and mitigate costs by reducing the final waste volume. *Source: UNEP/University of Cape Town/Environmental Consultants Enviro Tech (2008).*

Work has started in ten cities in developing countries that will act as ambassadors in their countries and regions for showcasing best practices and sharing lessons learned.

As the volume of waste increases, more of it has to be disposed of. Thus, the costs of waste management also increase. They are expected to reach US$375 billion in 2025, compared with some US$205 billion in 2010. The relative costs of waste management are projected to rise most sharply in low income countries, which will experience more than five-fold increases (Hoornweg and Bhada-Tata 2012) **(Table 2)**.

Local authorities, especially in low income countries, often lack the resources to expand or improve their waste management systems. Because much waste processing in developing countries is carried out by the informal sector, with limited infrastructure and technology, overall recovery and recycling levels remain low and the major portion of resources are discarded as waste. There is frequently a lack of local capacity to assess, select, adopt and implement efficient technologies (Chalmin 2011). Redesigning conventional waste management systems so they can handle the growing volumes and types of waste effectively and efficiently could contribute to improving public health as well as increasing economic opportunities. Integrated Solid Waste Management (ISWM) is a promising approach that local authorities can use to achieve that objective **(Figure 3)**.

Table 2: Current and estimated solid waste management costs, 2010 and 2025. *Source: Hoornweg and Bhada-Tata 2012*

| Country income group | 2010 (US$ billion) | 2025 (US$ billion) |
|---|---|---|
| Low income countries | 1.5 | 7.7 |
| Lower middle income countries | 20.1 | 84.1 |
| Upper middle income countries | 24.5 | 63.5 |
| High income countries | 159.3 | 220.2 |
| **Total global cost (US$)** | **205.4** | **375.0** |

## Meeting environmental goals

UNEP's fifth *Global Environment Outlook* (GEO-5) shows that progress on meeting environmental goals and objectives to improve the state of the environment has been uneven (UNEP 2012a). Efforts to slow the rate or extent of adverse environmental change, including improvements in resource efficiency and implementation of mitigation measures, have had modest success but have not succeeded in reversing these changes. Out of 90 of the world's most important environmental goals assessed, significant progress has been made on only four: access to improved drinking water supplies, phasing out leaded fuel, boosting research to reduce pollution of the marine environment, and eliminating production and use of ozone-depleting substances **(Box 3)**. Some progress was shown on 40 goals and little or no progress was detected on 24 (UNEP 2012g).

Cleaning up toxic sludge after a major chemical spill in Hungary. Urgent action is required to reach the 2002 Johannesburg Plan of Implementation goal that chemicals should be produced and used in ways that minimize significant adverse impacts on human health and the environment by 2020. *Credit: Márton Bálint*

The world failed to achieve the target of significantly reducing the rate of biodiversity loss by 2010. While a new biodiversity target was agreed by countries at the end of 2010, environmental trends continue to show threats to species and an intensification of natural resource use (see Chapter 4). Half the world's wetlands have been lost during the 20th century (Russi et al. 2012). In 2012 it was reported that the coral in the Great Barrier Reef, one of the world's most biodiverse ecosytems, has been halved in the past 27 years, mainly due to damage from heavy storms, crown-of-thorns starfish and ocean acidification (De'ath et al. 2012). Scientists warn that trends may result in a further halving in the next ten years.

GEO-5 gives examples of policies from all parts of the world that can help speed up achievement of environmental goals and targets. Many national policies are based on commitments under more than 500 international treaties and other agreements related to the environment (323 are regional and 302 date from between 1972 and the early 2000s). Where possible, better co-ordination on related issues can help reduce the burden on countries to fulfil reporting requirements and other obligations under this fragmented international framework.

Environmental crime is on the rise due to increased demand for, for example, wildlife products ranging from ivory to orchids. It has become one of the most profitable forms of criminal activity (Patel 2012). The value of illegal logging is estimated at US$30-100 billion (Nellemann 2012). Illicit trade in hazardous waste, illegal, unregulated and unreported fishing, and illicit trafficking in wildlife are other forms of environmental crime that hinder progress towards sustainable development. This type of crime also threatens areas where good international progress has been made, such as smuggling of ozone-depleting substances.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) operates at the intersection of trade, environment and development. The recent increase in poaching of elephants and rhinos demonstrates that the Convention's contribution to the conservation and sustainable use of biodiversity is as relevant today as when it was adopted in 1973 **(Box 4)**.

## Climate change: time to act

In the Rio+20 outcome document, countries affirmed that climate change is one of the greatest challenges of our time. They expressed alarm over the fact that emissions of greenhouse gases continue to rise globally – adding that they were "deeply concerned that all countries, particularly developing countries, are vulnerable to the adverse impacts of climate change, and are already experiencing increased impacts including persistent drought and extreme weather events, sea level rise, coastal erosion and ocean acidification, further threatening food security and efforts to eradicate poverty and achieve sustainable development" .

**Box 3:** Protecting the ozone layer – 25 years of the Montreal Protocol

In 1974 scientists reported that certain chemicals (chlorofluorocarbons, or CFCs) used, for example, as propellants in sprays were migrating to the upper atmosphere, where they cause destruction of the ozone layer. The Antarctic ozone hole was discovered in the early 1980s and its existence was linked to CFCs and related chemicals. In response, the Montreal Protocol on Substances that Deplete the Ozone Layer was developed in 1987. The Montreal Protocol is one of the most successful international agreements in history. During the Protocol's 25 years of existence, countries have reduced global production and consumption of nearly 100 ozone-damaging chemicals by nearly 100 per cent (Molina and Zaelke 2012). Due to implementation of the Protocol's provisions, the ozone layer should return to pre-1980 levels by 2050 to 2075, thereby avoiding millions of cases of skin cancer and cataracts, among other impacts, and a trillion US dollars in health care.

Because the same chemicals that destroy the ozone layer warm the atmosphere, the Montreal Protocol has also made an important contribution to cutting emissions of greenhouse gases. More can still be done in this regard by phasing out production and use of hydrofluorocarbons (HFCs) and avoiding their build-up in the atmosphere. These gases are substitutes for CFCs. They do not affect the ozone layer, but are strong greenhouse gases that rapidly gained popularity as substitutes used in air conditioning and refrigeration. At the meeting of the parties to the Montreal Protocol in November 2012, it was agreed to undertake a detailed study of alternatives to HFCs.

Sea level rise increased between 1993 and 2011 by approximately 3.2 mm per year. Melting ice in the polar regions was a major contributor (Van den Broeke 2011, Meyssignac et al. 2012, Rahmstorf et al. 2012). Arctic sea ice is disappearing faster in the summer than had been projected by models (see Chapter 2). Ice shelves in West Antarctica are breaking up, allowing the glaciers held back on adjacent land to slide into the sea. The increase in the number of extreme weather events, such as the floods and heat waves experienced in North America, Western Europe, the Russian Federation and elsewhere in recent years, is considered by some scientists to be related to global warming (NOAA 2012). Rising sea levels will raise the launching pad for storm surge, the thick wall of water that the wind can drive ahead of a storm (Schaeffer et al. 2012).

## Box 4: Elephant and rhino poaching in Africa and illegal wildlife trade

Many African countries are experiencing a serious spike in poaching of elephants and rhinos and the related illegal trade in ivory and rhino horn. Data compiled by the CITES programme for "Monitoring the Illegal Killing of Elephants" (MIKE) indicate an ongoing increase in levels of illegal killing of elephants since 2006, with 2011 showing the highest levels of poaching since monitoring began **(Figure 4)**.

Information available from the Elephant Trade Information System (ETIS) confirms that 2011 was the worst year on record for ivory seizures (ETIS 2012) **(Figure 5)**. In Port Kelang, Malaysia, 1 500 pieces of tusks were discovered as they were being secretly transported from Africa to Asia. They had been declared as wooden floor tiles. This was the sixth seizure in the country within 18 months and the second largest ivory seizure on record (Traffic 2013a).

Poaching of large numbers of elephants for their ivory increasingly involves organized criminal groups and, in some cases, well-armed rebel militias (Traffic 2012a). For example, in Bouba N'Djida National Park, in northern Cameroon, up to 450 elephants were killed in early 2012. In response, the government of Cameroon deployed up to 150 soldiers in the National Park to support park rangers in putting an end to the elephant killing. Poached ivory is believed to be exchanged for money, weapons and ammunition to support conflicts in the region.

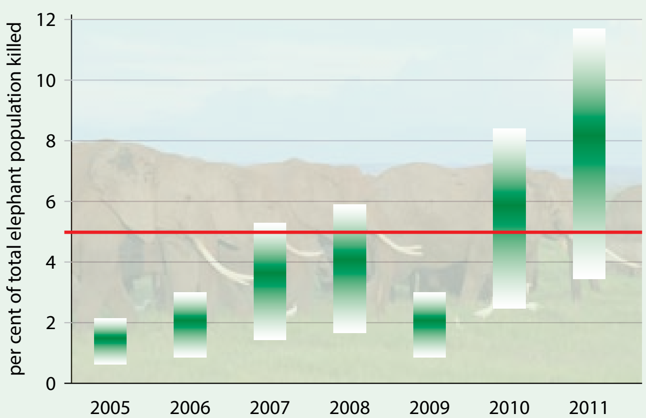


Figure 4: Estimated percentage of the population of African elephants killed at MIKE sites, 2005-11. The red line (around 5 per cent) represents approximately the growth level of healthy populations. Levels of illegal elephant killing above 5-6 per cent of the total population are likely to result in net declines if sustained over a number of years. The situation since 2010, with a significant increase in elephant killings, is well beyond sustainable levels. *Source: CITES MIKE. Credit: Trang Nguyen*

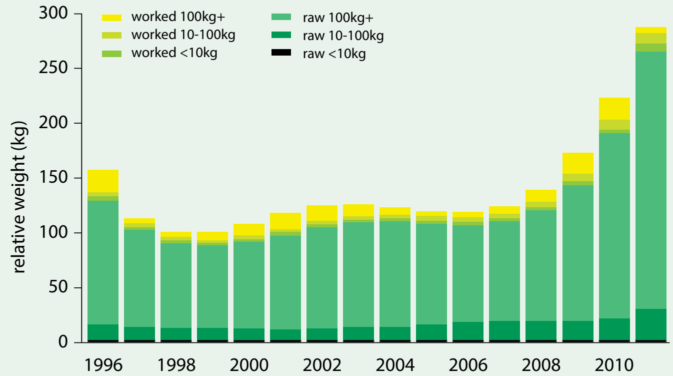


Figure 5: Trends in ivory seizures by ivory type and weight of seizure classes, 1996-2011. Ivory is seized in the form of tusks (raw) and as, for example, carved ornaments (worked). *Source:* ETIS (2012)

Another example of this type of poaching was the killing of 22 elephants in the Garamba National Park, Democratic Republic of the Congo in April 2012. These elephants were shot from a helicopter in a single raid. In January 2013, eleven elephants were gunned down in Tsavo National Park, Kenya.

The number of elephants killed in Africa in 2011 likely ran into the tens of thousands, and early indications suggest that the same happened again in 2012 **(Figure 6)**. A record 668 rhinos were poached in South Africa in that year driving this species further towards extinction **(Figure 7)**. The MIKE programme has identified a relationship between poaching and poverty, governance, law enforcement effectiveness and demand in ivory consuming countries. Mitigating the poaching crisis will require action on these fronts at multiple levels.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a multilateral environmental agreement (MEA) that promotes the conservation and sustainable use of biodiversity. CITES works with elephant and rhino range states to enhance their law enforcement capacity and help combat poaching and illegal trade in these and other species (CITES 2012a, b). To bring more co-ordinated support to national wildlife law enforcement agencies and networks, the Convention works closely with other partners (INTERPOL, the UN Office of Drugs and Crime, the World Customs Organization (WCO) and the World Bank) in the International Consortium on Combating Wildlife Crime. In 2012, the consortium introduced a wildlife and forest crime analytic toolkit to strengthen national enforcement capacities to fight wildlife crime.

## Box 4: Elephant and rhino poaching in Africa and illegal wildlife trade

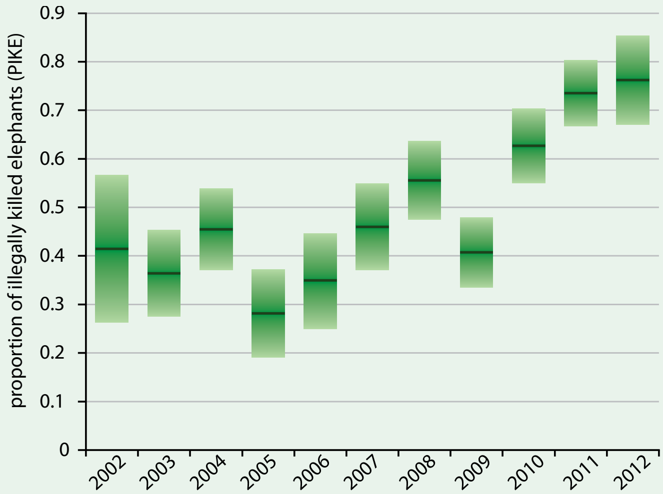


**Figure 6:** The proportion of illegally killed elephants (PIKE) is defined as the number of illegally killed elephants found divided by the total number of dead elephants encountered by patrols or other means. PIKE estimates are given with 95 per cent confidence limits for reporting sites in Africa, 2002-2011. For 2012, only 6 months of data are included. *Source: CITES MIKE*

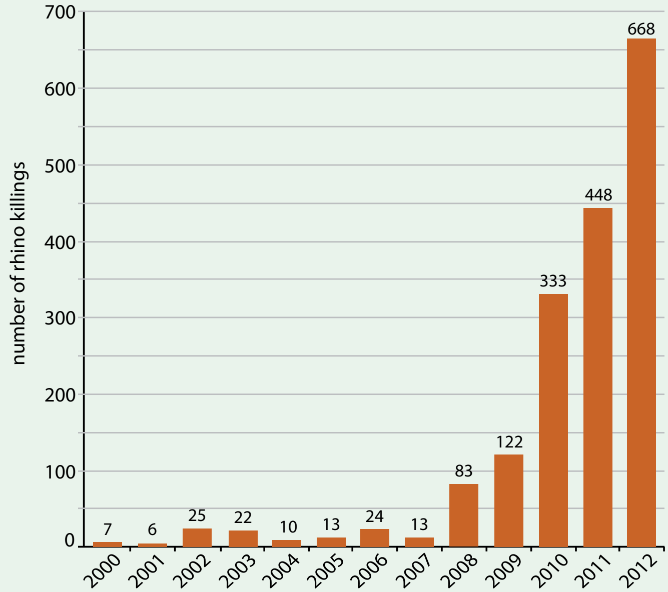


**Figure 7:** The annual number of rhinos poached in South Africa, 2000-2012. There has been a steep increase in the number of rhinos poached for their horns in recent years. *Source: Traffic (2012b)*

A US$3 million GEF project has been developed to support use of modern forensic techniques to tackle poaching of rhinos and trace smuggling of their horns.

Adequate scientific capacity in countries from which wildlife is exported is critical to ensure that international trade takes place within biologically sustainable boundaries. Seventy-one proposals to amend the CITES Appendices, covering hundreds of animal and plant species, were received for consideration at the 16th meeting of the Conference of the Parties to CITES (COP16) in March 2013. Several shark species, the manta ray, the polar bear, the poison dart frog, and many timber species are included. In addition, a draft resolution for the uniform interpretation and application of the Convention to the transport into a country of species taken from the marine environment not under the jurisdiction of any state will be discussed at COP16.

40 CITES 1973-2013

CITES is approaching universal membership. There are currently 177 Parties, of which Maldives is the most recent. COP16 is scheduled to coincide with the 40th anniversary of the adoption of the Convention.

Officials detected and prevented an attempt to smuggle 33 rhinoceros horns into Hong Kong. The horns had been concealed in a container declared to be scrap plastic and were discovered during X-ray screening. *Credit: CITES*

Scientists have projected that if global warming is kept below 2ºC, impacts such as catastrophic sea level rise could be avoided. Even if the global temperature rise can be held within the 2ºC limit, sea levels are expected to continue to rise beyond 2100 since warmth is distributed in the ocean at great depths. Under a 2ºC scenario, sea level rise resulting from climate change is expected to be 75-80 cm compared to the 2000 level (Schaeffer et at. 2012). However, there is a significant gap between the total mitigation pledges of countries in terms of their global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with keeping the increase in global average temperature below 2ºC.

Current global emissions of greenhouse gases are at 50.1 gigatonnes (Gt) of carbon dioxide equivalent ($CO_2$e) per year, already 14 per cent higher than what the emission level in 2020 would need to be for the world to have a likely chance of meeting the 2°C target (UNEP 2012e). This level has been estimated at 44 Gt$CO_2$e. The emissions gap between a business as usual scenario and emission pathways consistent with the 2°C limit is in the range of 8-13 Gt$CO_2$e, much greater than the gap of 5 Gt$CO_2$e estimated in 2010 (UNEP 2010, 2012e). However, there is still a chance to bridge the gap through concrete and immediate actions (UNEP 2012e).

Slowing the rate of near-term global warming by reducing SLCPs could help moderate the impacts of climate change on those already affected, reduce biodiversity loss, and avoid crossing critical thresholds. However, long-term climate protection will only be possible if deep and persistent cuts in $CO_2$ emissions are made in the short term. Fast action to reduce SLCPs would be an important contribution. It should not be seen as a substitute for (or an opportunity to delay) urgent mitigation of $CO_2$ emissions, but rather as a complementary action.

At the UNFCCC Conference in Doha, Quatar, in November 2012 governments took an essential next step towards an effective global response to climate change and promoted much-needed concrete and immediate actions. As the first commitment period expired, a new commitment period was launched under the Kyoto Protocol on the reduction of emissions of greenhouse gases. A firm timetable for the adoption of a universal climate agreement by 2015 was also agreed, as well as a path to raise the necessary ambition to respond to climate change (UNFCCC 2012a).

Despite the progress made at Doha, these outcomes may not be sufficient to keep temperature increase under control and below 2ºC by the end of the century. For example, the current Kyoto Protocol commitment for greenhouse gas mitigation does not cover some of the world's largest economies. Furthermore, a number of developed countries withdrew from the Protocol in 2011 and 2012. By the time of the COP18 meeting, the Kyoto Protocol commitment covered only 15 per cent of the world's emissions (IISD 2012b).

Financing for climate change adaptation presents a mixed picture of both opportunities and reasons for concern **(Box 5)**.

**Box 5:** The ability to act – climate financing

A report released in late 2012 estimated that the world's annual climate finance flows reached an average US$364 billion in 2010-11. US$12.3-15.7 billion (approximately 4-5 per cent) was targeted for adaptation purposes. The largest share of the world's recorded adaptation financing for developed and developing countries (US$5.2 billion) comes from national finance institutions. About 60-67 per cent of the total financial flow is funded by the private sector. The public sector's contribution to climate financing is relatively small at around 26 per cent (US$92-99.3 billion), including funds provided by development finance institutions (21 per cent) and from climate funds (1 per cent). The public sector acts as a catalyst to attract further funding from other sources. Climate financing is nevertheless inadequate to achieve sufficient emission reductions to keep the global temperature rise within the 2ºC limit (Buchner et al. 2012).

The Adaptation Fund Board reported at Doha an accumulative amount for the approved adaptation projects and programme of US$167 million – an average of about US$11 million approved per year since 15 years ago (UNFCCC 2012c). Immediate solutions to improve adaptation financing include strengthening the process of monetizing certified emission reductions (CERs), improving accessibility to funding, and meeting by developed countries of their commitments to the long-term financing target of up to US$100 billion per year by 2020 to support adaptation and mitigation actions in developing countries.

The sustainability, adequacy and predictability of the Adaptation Fund are of major concern to countries. The decision in Doha on a "loss and damage" approach has opened a narrow window for advancing support and co-operation (including financing) for climate change adaptation in affected countries, particularly Small Island Developing States (SIDS) and least developed countries.

There is still a gap regarding climate financing to achieve sufficient emission reductions to keep the global temperature rise within the 2°C limit (Buchner et al. 2012). In Copenhagen in 2009, the target for long-term financing to support mitigation and adaptation actions in developing countries was agreed at US$100 billion per year until 2020. Under the Doha Climate Gateway Package, from December 2013 the long-term financing mechanism will be scaled up as a new funding mechanism, the Green Climate Fund (UNFCCC 2012b).

Two decades of negotiations have yielded some results in terms of reducing carbon dioxide ($CO_2$) emissions **(Table 3)**. The advances made through the UNFCCC process are extremely important. They have established, step by step, the basis for international co-operation on solving the global climate issue.

The potentially enormous human, environmental and economic losses that may result from climate change have become increasingly clear as methods for assessing them have been further developed (ADB 2009, Bouwer 2012, EEA 2012). An analysis has found that among 450 urban areas with 1 million or more inhabitants in 2011 (representing 1.4 billion people), 60 per cent or about 890 million people are located in regions exposed to major risk from natural disasters (UNDESA 2012).

With the probability of extreme weather events in the future increasing as a result of climate change (Fischetti 2012, UNEP 2012a), some of those that occurred in 2012 draw attention to the need to prepare for and make efforts to prevent heavy losses. The final costs of Hurricane Sandy, which devastated parts of the Caribbean, Canada and the United States in late October 2012, are difficult to calculate and are likely to continue to be revised upwards (Economist 2012, Mackenzie 2012). MunichRe has reported that Sandy's costs to insurance and reinsurance companies will be US$20-25 billion (Dauer 2013). It damaged billions of dollars' worth of real estate in the New York City area alone (Cowan 2013). The costs of new infrastructure to protect the city in the future, possibly including flood barriers, are estimated at US$20 billion or more (Crooks and Wright 2012).

Mural outside the Qatar Sustainability Expo, which ran concurrently with the UNFCCC's COP18 conference in Doha. The road to a sustainable future requires not only innovative, inspirational ideas but also a transformation of policies, actions, and collaboration. *Credit: CGIAR Climate*

**Table 3:** Milestones in progress on the UNFCCC and its Kyoto Protocol

| Year | Event | Key outcomes |
|---|---|---|
| 1992 | Earth Summit | Adoption of UN Framework Convention on Climate Change (UNFCCC) |
| 1997 | 3rd Conference of the Parties (COP3), Kyoto, Japan | Agreement on Kyoto Protocol: Annex I Parties to reduce their overall emissions of six greenhouse gases (GHGs) by average 5 per cent below 1990 levels between 2008 and 2012 (first commitment period) |
| 2007 | COP13, Bali, Indonesia | Bali Roadmap on long-term issues, Bali Action Plan, and the Reducing Emissions from Deforestation and forest Degradation (REDD) mechanism |
| 2009 | COP15, Copenhagen, Denmark | Copenhagen Accord (as a non-binding political agreement) endorsed by more than 140 countries within 12 months, with 80 countries providing information on their national mitigation targets or actions |
| 2010 | COP16, Cancun, Mexico | Cancun Agreement recognizes need for deep cuts in global emissions to limit global average temperature rise to 2°C by 2100<br>Establishment of Cancun Adaptation Framework and Adaptation Committee, Technology Mechanism, Climate Technology Centre and Network, and Green Climate Fund<br>US$30 billion in commitments for fast-start finance 2010-12 |
| 2011 | COP17, Durban, South Africa | Durban Platform for Enhanced Action. Path to negotiate a new legal and universal emission reduction agreement by 2015 (to come into effect by by 2020) drafted and accepted by the COP. Governments decide that Parties will move into a second Kyoto Protocol commitment period in 2013 |
| 2012 | COP18, Doha, Qatar | Doha Climate Gateway package |

## Looking ahead

There were clear challenges to protecting the global environment in 2012. Concrete agreements were, however, concluded at international level to continue to address climate change. Moreover, the Rio+20 conference reaffirmed countries' commitment to sustainable development and strengthened the environmental pillar of sustainable development, providing a strong foundation for the future.

Meeting the 2°C target for global temperature rise is becoming more challenging, but is still not impossible to reach. United and immediate global actions will be required to curb greenhouse gas emissions. Among a number of needed measures, ensuring the availability of financial resources and improving their accessibility are critical not only for actions to mitigate emissions, but also for actions to build resilience and strengthen the adaptability of communities and ecosystems in developing countries – where the impacts of climate change are being felt widely and often more clearly. Although the climate negotiations in Doha did not signal a significant shift in regard to a new global climate deal, the Doha conference took further steps towards an evolving mechanism to address climate change.

The evidence of climate change impacts, as well as the results of scientific research that continued to emerge in 2012, demonstrate that all countries are connected. The future depends on joint decisions and on implementation of collective actions. Strengthening the science-policy interface will be critical for continued sound and equitable environmental decision-making.

The world has the unique opportunity to meet renewed commitments and take actions to improve human society and the environment. The negotiations of UN Member States during Rio+20 took place against a backdrop of significant political and social tension. Although no binding targets and little new financial support were included in the outcome document, *The Future We Want*, it does reiterate the global commitment to continue to work towards sustainable development and calls on all actors to redouble their efforts. It confirms that sustainable development is the only viable development path and provides a platform for linking actions by citizens all the way up to governments. The challenge remains how to advance economic, social and environmental objectives simultaneously. The outcome of Rio+20 signals a broad understanding that the systems and behaviour that led to the current state of the environment can and must be changed.

Informal settlement in Quito, Ecuador. Over 90 per cent of the future increase in the world's total urban population will take place in developing countries.
*Credit: Marcio Ramalho*

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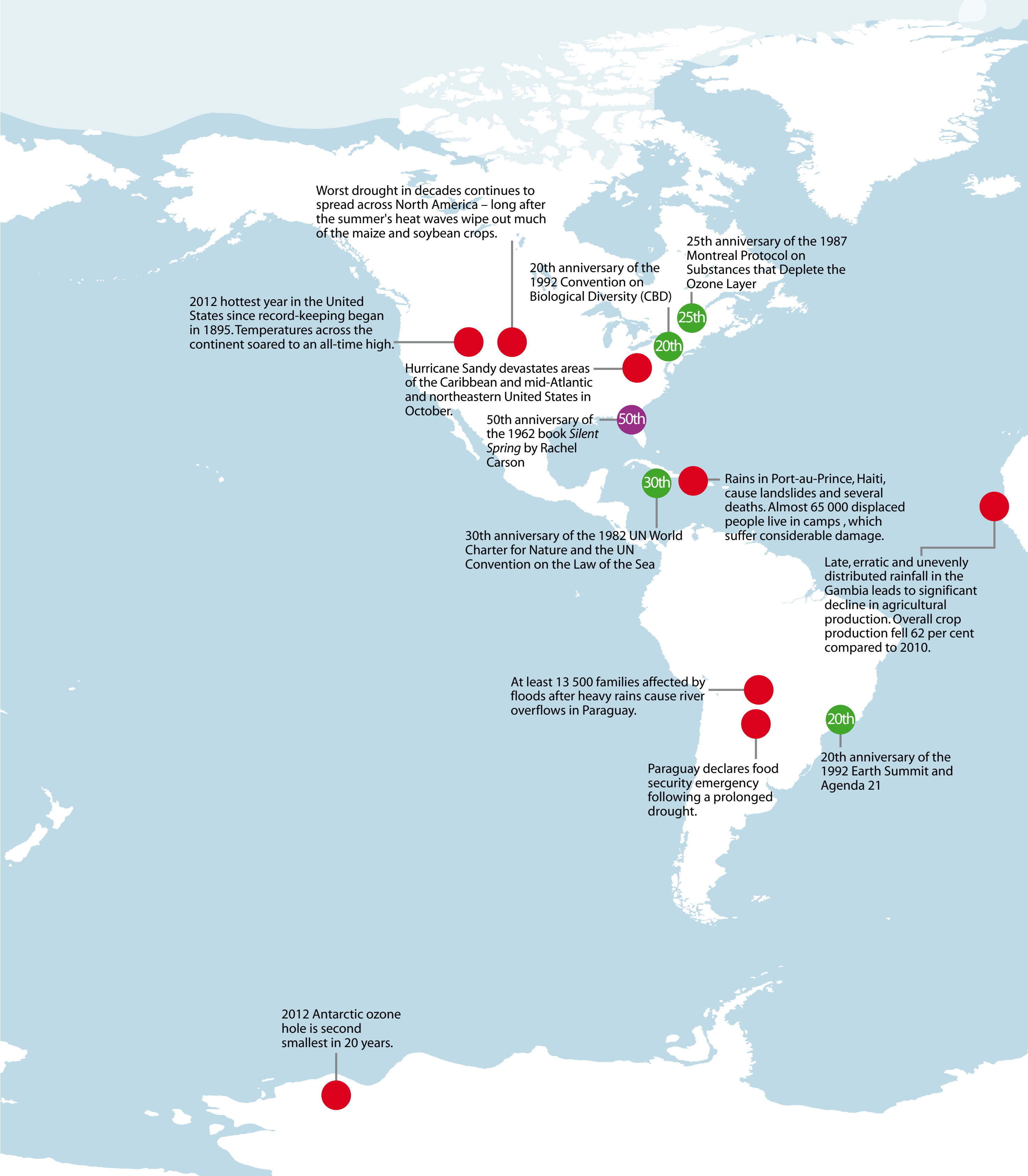
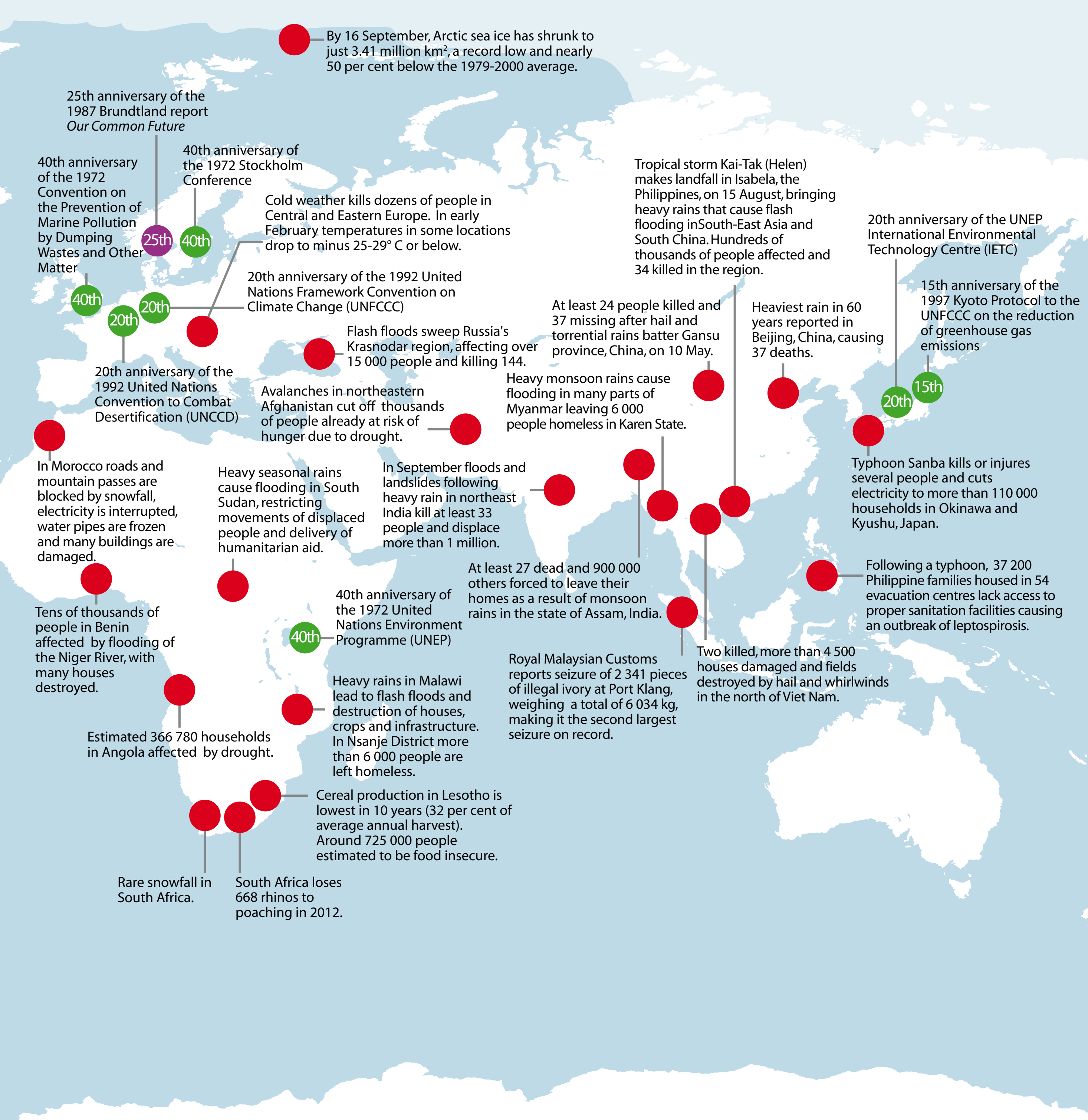

Worst drought in decades continues to spread across North America – long after the summer's heat waves wipe out much of the maize and soybean crops.
2012 hottest year in the United States since record-keeping began in 1895. Temperatures across the continent soared to an all-time high.
20th anniversary of the 1992 Convention on Biological Diversity (CBD)
25th anniversary of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer
25th
20th
Hurricane Sandy devastates areas of the Caribbean and mid-Atlantic and northeastern United States in October.
50th anniversary of the 1962 book *Silent Spring* by Rachel Carson
50th
30th
Rains in Port-au-Prince, Haiti, cause landslides and several deaths. Almost 65 000 displaced people live in camps , which suffer considerable damage.
30th anniversary of the 1982 UN World Charter for Nature and the UN Convention on the Law of the Sea
Late, erratic and unevenly distributed rainfall in the Gambia leads to significant decline in agricultural production. Overall crop production fell 62 per cent compared to 2010.
At least 13 500 families affected by floods after heavy rains cause river overflows in Paraguay.
20th
Paraguay declares food security emergency following a prolonged drought.
20th anniversary of the 1992 Earth Summit and Agenda 21
2012 Antarctic ozone hole is second smallest in 20 years.




Major events in 2012 caused many casualties and billions of dollars in damage across the world (red dots). A large number of environmental bodies, agreements and events also celebrated their anniversary during 2012 (green dots). It was respectively 50 and 20 years ago that two of the most influential books on the environment were published (purple dots).

# 2012

## At a glance

- **January 1** – Start of the 2012 International Year for Sustainable Energy for All
- **January 15** – Cadmium spill contaminates Longjiang river within Guangxi city limits, China, killing 40 000 kg of fish between 15 January and 2 February
- **January 16-19** – Fifth World Future Energy Summit held in Abu Dhabi, United Arab Emirates
- **February 16** – Launch of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants in Washington, DC, United States
- **February 20-22** – 12th Special session of the UNEP Governing Council/Global Ministerial Environment Forum (GCSS12/GMEF), Nairobi, Kenya
- **March 22** – Global Peace Initiative of Women convenes Environmental Conference, Nairobi, Kenya
- **May 10-11** – Global Green Growth Summit 2012, Seoul, Korea
- **June 20-22** – United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil, is held 20 years after the ground-breaking 1992 Earth Summit
- **June 24** – "Lonesome George," thought to be the last remaining Pinta Island tortoise, dies in captivity at an age of 100 years, Galapagos, Ecuador
- **June 27-July 2** – 4th Session of Intergovernmental Negotiating Committee to Prepare a Global Legally-binding Instrument on Mercury, Punta del Este, Uruguay
- **July 27-Aug 12** – 2012 Summer Olympics: the 1st "green Olympics", London, United Kingdom
- **August 6** – US National Aeronautics and Space Administration (NASA) rover "Curiosity" lands on the surface of Mars
- **Sept 4** – Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD) and World Food Programme (WFP) call for action to avert global food crisis, Rome, Italy
- **Sept 6-15** – IUCN World Conservation Congress 2012, Jeju, Korea
- **Sept 14** – Partnership for Action on a Green Economy launched to support 20 developing countries across relevant sectors such as transport, agriculture and the built environment
- **Sept 18** – 67th Session of UN General Assembly (UNGA 67) in New York, United States
- **November 27** – 18th Meeting of the senior officials of the Environmental Management Group agrees to carry out work on several areas in support of the Rio+20 outcomes

- **March 11** – Pan-African Forum on E-Waste underlines green economy opportunities in e-waste sector, Nairobi, Kenya
- **March 26-29** – Planet Under Pressure Conference – largest gathering of global change scientists prior to Rio+20 discusses sustainable development, London, United Kingdom
- **April 22-27** – International Polar Year 2012 Conference, Montréal, Canada
- **May 12 - Aug 12** – International Exposition "The Living Ocean and Coast", Yeosu, Korea
- **June 5-6** – World Environment Day celebrated and 5th Global Environment Outlook (GEO-5) launched, Rio de Janeiro, Brazil
- **June 17-20** – World Congress on Justice, Governance and Law for Environmental Sustainability brings together over 250 top judges, legislators and auditors general, Rio de Janeiro, Brazil
- **July 4** – Existence of the Higgs boson proven, a fundamental building block of the universe, Geneva, Switzerland
- **August 23-25** – First meeting of the Board of the Green Climate Fund, Geneva, Switzerland
- **Sept 11** – List of world's 100 most threatened animal, plant and fungi species released by Zoological Society of London and International Union for Conservation of Nature in London, United Kingdom
- **October 1** – World Habitat Day
- **October 8-19** – More than 180 countries agree to double funding to protect biodiversity in developing countries by 2015 at the UN Convention on Biological Diversity meeting in Hyderabad, India
- **November 5-6** – Global Partnership on Waste Management (GPWM) holds its first biennium conference in Osaka, Japan
- **November 26 - December 7** – Doha Climate Change Conference - COP18/CMP8 of UNFCCC
- **December 4-6** – International conference on indicators for inclusive green economy, "Measuring the Future We Want," Geneva, Switzerland
- **December 7** – The UN General Assembly adopts a number of draft resolutions to strengthen the environment pillar in the context of sustainable development

# Calendar of events 2013

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|---|---|---|
| January | January 13-18 | 5th Session of Intergovernmental Negotiating Committee to prepare a Global Legally-binding Instrument on Mercury, Geneva, Switzerland |
| | January 13-14 | 3rd International Renewable Energy Agency General Assembly, Abu Dhabi, United Arab Emirates (UAE) |
| | January 15-17 | World Future Energy Summit 2013, Abu Dhabi, UAE |
| | January 21-26 | 1st Plenary meeting of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany |
| | January 23-27 | World Economic Forum Annual Meeting 2013, Davos, Switzerland |
| February | January 31-February 2 | Delhi Sustainable Development Summit: Global challenge of resource efficiency, growth and development, New Delhi, India |
| | February 2 | World Wetlands Day |
| | February 5-6 | Africa Adaptation Knowledge Network Workshop, Nairobi, Kenya |
| | February 10-12 | 3rd International Conference on Solid Waste Management in Developing Countries – WasteSafe 2013, Khulna, Bangladesh |
| | February 18-22 | 27th Session of the UNEP Governing Council/Global Ministerial Environment Forum (GC27/GMEF), Nairobi, Kenya (universal) |
| March | March 3-14 | 16th meeting of Conference of the Parties of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Bangkok, Thailand |
| | March 4-8 | Eye on Earth Global Network of Networks Conference, Dublin, Ireland |
| | March 12-13 | Arctic Summit: A New Vista for Trade, Energy and the Environment, Oslo, Norway |
| | March 14 | Asian Regional Partners Forum on Combating Environmental Crime Meeting, Bangkok, Thailand |
| | March 22 | Declaration of International Year of Water Cooperation |
| | March 25-27 | Latin American Carbon Forum 2013, Rio de Janeiro, Brazil |
| | March 26 | 3rd Asia-Pacific Climate Change Adaptation Forum, Incheon, Korea |
| April | April 8-19 | 10th Session of UN Forum on Forests, Istanbul, Turkey |
| | April 22 | Earth Day |
| | April 26 | Clean Energy Financing Forum for Central America and the Caribbean |
| | April 25-26 | 1st Arab Conference on Environment and Sustainable Development, Beirut, Lebanon |
| | April 29-May 2 | Arctic Observing Summit, Vancouver, Canada |
| May | Apr 28 - May 10 | Meetings of the Conferences of the Parties to the BRS Conventions, Geneva, Switzerland |
| | May 11-13 | World Migratory Bird Day |
| | May 15 | Arctic Council Ministerial Meeting, Kiruna, Sweden |
| | May 19-23 | 4th Session of the Global Platform for Disaster Risk Reduction, Geneva, Switzerland |
| | May 22 | International Biodiversity Day |
| | May 28-31 | International Forum for Waste Management, Recycling, Environmental Technologies and Renewable Energy, Moscow, Russia |
| June | June 5 | World Environment Day |
| | June 17 | World Day to Combat Desertification |
| | June 18-20 | 44th Meeting of the GEF Council, Washington, DC, United States |
| July | July 11 | World Population Day |
| | July 22-August 2 | 11th International Conference on Mercury as a Global Pollutant, Edinburgh, Scotland |
| August | August 9 | International Day of the World's Indigenous Peoples |
| | August 12 | International Youth Day |
| September | Sept 5-7 | 13th International Conference on Environmental Science and Technology, Athens, Greece |
| | Sept 16 | International Day for the Protection of the Ozone Layer |
| | Sept 23-27 | World Maritime Day Parallel Event, Peru |
| | Sept 29-2 Oct | 15th Session of the Joint Committee for Environment and Development in the Arab Region, Cairo, Egypt |
| October | Oct 2-4 | 2nd Global Conference on Land-Ocean Connections, Montego Bay, Jamaica |
| | Oct 6-11 | 5th World Conference on Ecological Restoration, Madison, United States |
| | Oct 7-11 | Minamata Convention on Mercury open for signature at Diplomatic Conference, Minamata, Japan |
| | Oct 16 | World Food Day |
| | Oct 21-27 | 3rd International Marine Protected Area Congress, Marseille and Corsica, France |
| | Oct 30-Nov 2 | World Conference on Sport and Environment, Sochi, Russia |
| November | Nov 6 | International Day for Preventing the Exploitation of the Environment in War and Armed Conflict |
| | Nov 11-22 | 19th Conference of the Parties to the United Nations Framework Convention on Climate Change, Warsaw, Poland |
| December | Week 2 (TBC) | 2nd Plenary meeting of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany |
| | Dec 19-20 | 25th Session of the Council of Arab Ministers Responsible for the Environment, Cairo, Egypt |

# The View from the Top

## Searching for responses to a rapidly changing Arctic

In the fragile Arctic region the extent of sea ice was at a record low in September 2012. Land ice is also retreating, while snow is disappearing and permafrost is thawing. Rapid environmental change in the Arctic, as a result of climate change, is providing new development opportunities including easier access to oil and gas, minerals and fisheries. It is also threatening ecosystems – with ice-associated animals especially at risk. Changes in the Arctic will have consequences far beyond this region, including a global rise in sea levels and probably more extreme weather across much of the northern hemisphere. These current and future consequences of climate change require urgent responses. Arctic and non-Arctic countries share responsibility for protecting this region, in particular by limiting their greenhouse gas emissions.

### Accelerated summer meltdown

Arctic sea ice extent is rapidly diminishing. The minimum sea ice cover in 2012, at 3.4 million km$^2$, was 18 per cent below the previous recorded minimum in 2007 and 50 per cent below the average in the 1980s and 1990s **(Figure 1)**. Every year from 2007 the minimum has been lower than in any year before 2007 (NASA 2012a, NSIDC 2012). Floating ice has covered much of the Arctic Ocean for most of the past three million years (Polyak et al. 2010). But how much longer will this be the case?

The retreat of sea ice has been much more rapid than projected in the Intergovernmental Panel on Climate Change's latest report (IPCC 2007, Polyak et al. 2010, Stroeve et al. 2012) **(Figure 2)**. More recent modelling studies have come closer, but none has yet reproduced the observed trend (Stroeve et al. 2012). Nor have these studies been able to project precisely when ice-free conditions will first be observed during the Arctic summer. The IPCC report warned that this could happen around 2100 (IPCC 2007). One extrapolation of recent trends suggested that September could be ice-free before the end of this decade (Wadhams 2012). However, the most common prediction is that this will take place around 2035 (Wang and Overland 2012).

Figure 1: Every summer the Arctic sea ice melts down to its minimum in mid-September, before colder weather rebuilds the ice cover. The figure shows the 2012 minimum (recorded on 16 September), compared with the average minimum extent between 1979 and 2010 (yellow line). *Source: NASA (2012a), NSIDC (2012)*

Sea ice is frozen seawater that floats on the ocean surface. It forms in the winter and partly retreats in the summer. The extent and thickness of sea ice covering the Arctic Ocean is significantly decreasing. *Credit: Peter Prokosch*

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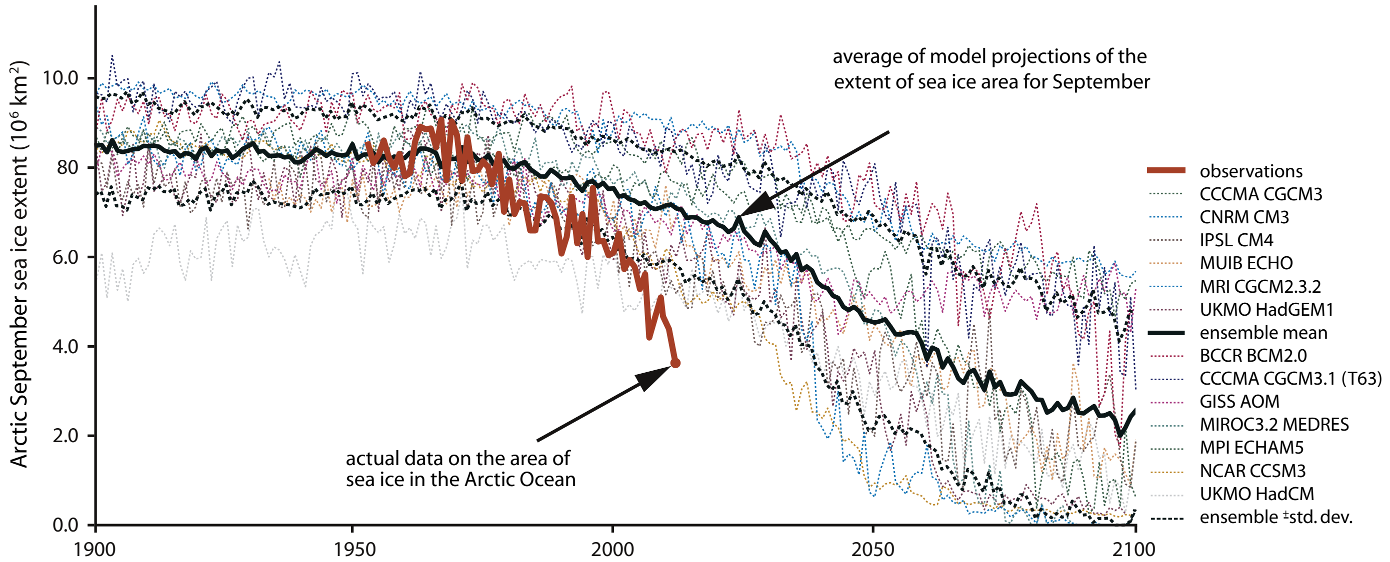



**Figure 2:** Plots of September sea ice extent, based on observations (red) and model runs (black/dotted), show that melting is taking place more rapidly than projected by any models. *Source: Stroeve et al. (2012)*

Every winter the Arctic sea ice reforms. While this will probably continue to happen, the amount of thick, old ice surviving from one year to the next is diminishing (Maslanik et al. 2011). The multi-year ice is at its maximum extent in March. However, it made up only 45 per cent of the total in 2010 compared to 75 per cent in 1988 **(Figure 3)**. The Arctic's thinned winter ice is thus primed for destruction in summer (Lenton 2012, Livina et al. 2012).

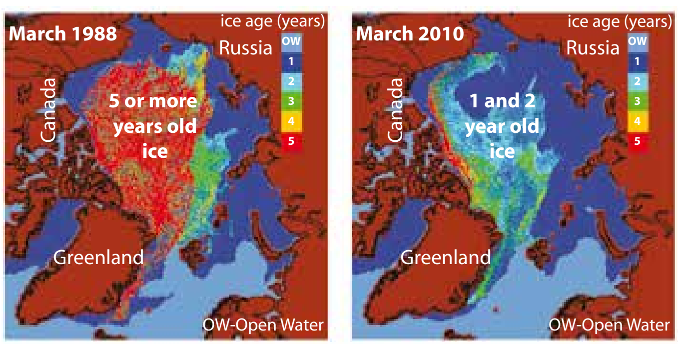



**Figure 3:** Each winter new sea ice forms and covers the Arctic Ocean. The amount of old ice that survives from year to year is diminishing, as shown by the ice age distribution in March 1988 and March 2010. Because of a continuous counterclockwise rotation the older multi-year sea ice is extruded into the North Atlantic and replaced during the winter by new sea ice, which is much younger. Historically, these processes were slower and less ice was extruded, hence remaining in the Arctic for longer periods of time. *Source: Maslanik et al. (2011)*

Loss of sea ice has been accompanied by melting of the Greenland ice cap, thawing of permafrost on the tundra (the region where tree growth is hindered by low temperatures and short growing seasons), less snow on land due to earlier snow melt, and melting of some snow cover on glaciers (Philip 2005, AMAP 2011a, Gardner et al. 2011, Jacob et al. 2012, NOAA 2012). The average snow cover remaining in the northern hemisphere in June – virtually all of which is within the Arctic – has declined by more than 50 per cent in the past three decades, to less than 4 million km$^2$. The five lowest values were all recorded since 2007 (Derksen and Brown 2012).

## A changing energy balance

The world is warming, and with it the Arctic **(Figure 4).** However, the Arctic has been warming at least twice as fast as the global average (ACIA 2005, Arndt et al. 2012). One reason is that more heat is brought into the Arctic through the atmosphere and with ocean currents. Several local factors are also increasing warming by changing the region's energy balance.

The greatest local amplification is due to the melting itself, which reduces the reflection of incoming sunlight. White ice and snow act as a mirror, reflecting about 85 per cent of solar radiation back to the sky. Dark ice-free areas of the ocean reflect only about 10 per cent and absorb the rest, while bare tundra reflects about 20 per cent (Climate Data Information 2012). As ice and snow melt, the exposed ocean and land absorb about 80 per cent of incoming radiation from the sun, increasing local surface warming. Heat in the ice-free ocean also directly warms the air above it.

Black carbon (or soot), a short-lived climate pollutant, darkens snow and ice and may also contribute to warming in the Arctic (AMAP 2011b) **(Box 1)**. Dust and volcanic ash contribute to cooling while in the atmosphere, but have the same effect as black carbon when they fall on snow or ice. Furthermore, shrubs and trees moving into the tundra increases absorption of sunlight by making the land surface darker (Chapin et al. 2005).

Other accelerators of atmospheric warming involve water vapour (Callaghan et al. 2011a). With more open sea in the Arctic, more water will evaporate, increasing the amount of water vapour in the air. Water vapour is a powerful, locally acting greenhouse gas. It traps heat, further escalating warming. On the other hand, more water vapour may increase cloud cover, which generally has a cooling effect during daylight hours. The overall balance of these different feedbacks has not been established, but strong warming suggests that positive feedbacks dominate (AMAP 2011a).

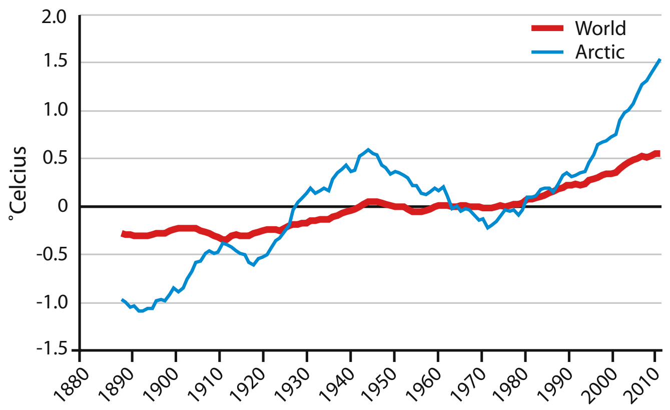



**Figure 4:** The combined sea-surface and air temperatures, globally (red) and in the Arctic (blue), show temperature anomalies for the period 1880-2011 compared to a 1951-1980 baseline. The Arctic strongly amplifies global signals of cooling and warming. As global temperatures increase or decrease, so do temperatures in the Arctic, but multiplied by a factor two or three. *Source: NASA/GISS 2012*

## Box 1: The role of black carbon (soot)

Carbon dioxide ($CO_2$) is the main anthropogenic greenhouse gas responsible for warming the atmosphere. However, short-lived climate pollutants in the Arctic, such as organic carbon, methane and ozone, also increase warming. Soot, which scientists often refer to as black carbon, is produced by burning many things from diesel to dung. In the air, black carbon absorbs solar radiation and radiates it out again as heat, warming the surrounding air. But the tiny particles only stay aloft for a few days before falling to the ground (Ramanathan and Carmichael 2008).

In most places that is effectively the end of black carbon's climatic impact. In the Arctic, however, where particles may fall onto white snow and ice, its warming effect continues. As the particles accumulate, they darken the snow and ice, increasing heat absorption, warming the air and accelerating snow melt (Flanner et al. 2007, Doherty et al. 2010, AMAP 2011b).

Typical levels of black carbon in Arctic ice and snow are around 5-10 parts per billion. This “dirtying of the mirror” increases the amount of heat absorbed by an estimated 1-4 per cent, raising local temperatures and melting snow and ice (Flanner et al. 2007, AMAP 2011b). As a result, the black carbon’s warming effect remains greater in the Arctic than in most of the rest of the world (AMAP 2011b). The fallout of black carbon in the Arctic is at its maximum in late winter. Modelling studies suggest that this fallout may be increasing spring snow melt rates by between 20 and 30 per cent (Flanner et al. 2007, AMAP 2011a). There is, however, uncertainty related to the models used for calculating how strong the effect is (AMAP 2011b). Models need to be verified with data collected in the Arctic.

Although some black carbon is generated within the Arctic and adjacent areas – from diesel-powered electric generators and ship engines, flaring during oil and gas exploration, agricultural burning, forest fires, and use of wood stoves – much originates outside the region (Sharma et al. 2006). Better controls on air pollution in northern countries outside the Arctic have recently reduced black carbon fallout (AMAP 2011b). As the Arctic is opened to increased shipping and industrial activity, that trend could be reversed. One modelling study has suggested a possible five-fold increase in black carbon emissions from Arctic shipping by 2030 (Corbett et al. 2010). Whether this will happen greatly depends on future emission controls.

Global controls on black carbon could slow global warming by about a decade, according to some estimates, while saving the lives of up to 2 million people in the world killed annually as a result of inhaling indoor smoke from cooking stoves (Streets 2006, Kandlikar et al. 2010, UNEP/WMO 2011). A number of concrete measures have been identified that could produce this slowdown of the warming in the Arctic (UNEP/WMO 2011) (Chapter 1, Box 2). Reducing black carbon emissions is therefore important, but clearly is not a substitute for reducing emissions of $CO_2$ and other greenhouse gases.

Warming of the Arctic could unleash other contributions to warming with global consequences. Of particular concern is the thawing of frozen tundra soils and continental shelf seabed (Abnizova et al. 2012, Schaefer et al. 2012, UNEP 2013). Permafrost soils often contain large volumes of organic carbon – the remains of plants accumulated over thousands of years (Tarnocai et al. 2009). If the soils thaw, the release of some of this carbon as $CO_2$ or methane will be irreversible.

Methane is stored in permafrost and in frozen marine sediments in the coastal seabed as gas hydrates. It is released at temperatures above the freezing point. Methane is a more powerful greenhouse gas than $CO_2$ although it does not last as long in the atmosphere, most of it eventually turning into $CO_2$. Along the East Siberian Arctic shelf of Russia and elsewhere throughout the Arctic, extensive methane venting to the atmosphere has been reported (Anisimov 2007, UNEP 2013). These releases may account for 5 per cent of world methane emissions (Walter et al. 2007).

Permafrost has retreated northwards in many places (AMAP 2011a, Callaghan et al. 2011b). Up to 50 gigatonnes (Gt) of predicted amount of hydrate storage could be released, increasing the methane content of the planet's atmosphere by a factor twelve (Shakhova et al. 2008). There is, however, considerable uncertainty about how big a threat such emissions may prove to future climate. Much will depend on the speed of their release (IPCC 2007). According to one recent modelling study, significant releases are likely by the end of the 21st century, raising global temperatures by a further 0.8°C (MacDougall et al. 2012). This temperature increase could be still greater in the Arctic (AMAP 2011a).

Ponds in the Siberian Lena Delta, Russia, formed by melting permafrost. Permafrost is likely to be an important source of atmospheric methane in the future, though the timing and volume of methane releases remains unclear. *Credit: Peter Prokosch*

## Global impacts

Melting of ice and snow on land in the Arctic adds to the amount of water in the ocean, raising global sea levels possibly even more than models used by IPCC have predicted (Rhamstorf et al. 2012). The biggest long-term concern in the Arctic is Greenland, which is covered by ice up to 3 km thick – enough to raise global sea levels by an eventual 7 metres if it melted (Dahl-Jensen et al. 2011). Such a catastrophe is not imminent, as it would take several hundred years at current and projected rates of warming, but Greenland is increasingly surrounded by open water and experiences air temperatures reaching 11°C in summer, when large shallow lakes form on the ice pack. Recently melting has extended, particularly in southern Greenland. It now lasts up to five months (Tedesco et al. 2011). The United States National

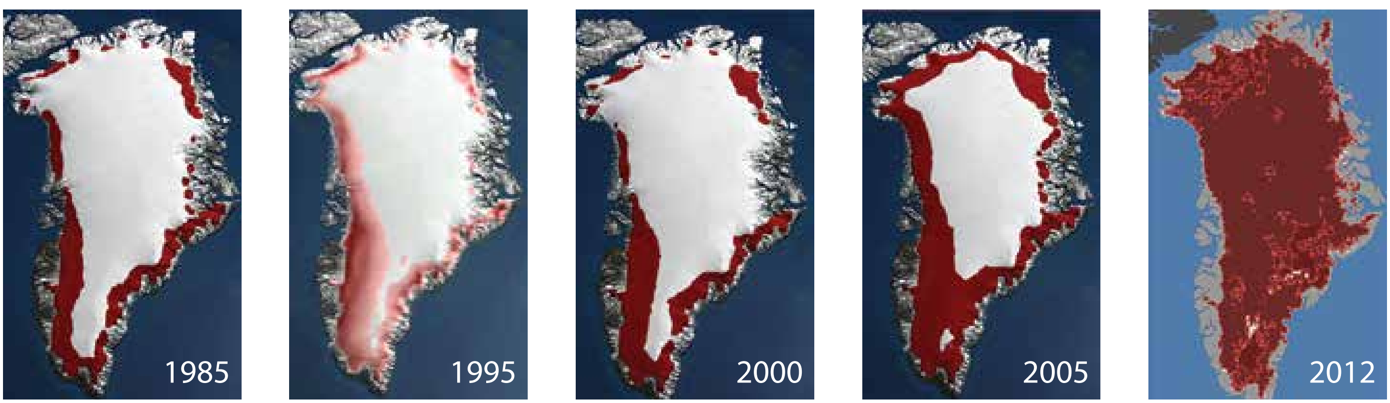



**Figure 5:** Areas of the Greenland ice sheet where melting occurred on more than three days between 1 May and 30 September in the years shown (red). Areas with higher annual accumulated days of melt are shown in darker red than those with fewer days of melt. Areas where melting only occurred on three days or less during the year are white. *Source: NASA (2012b)*

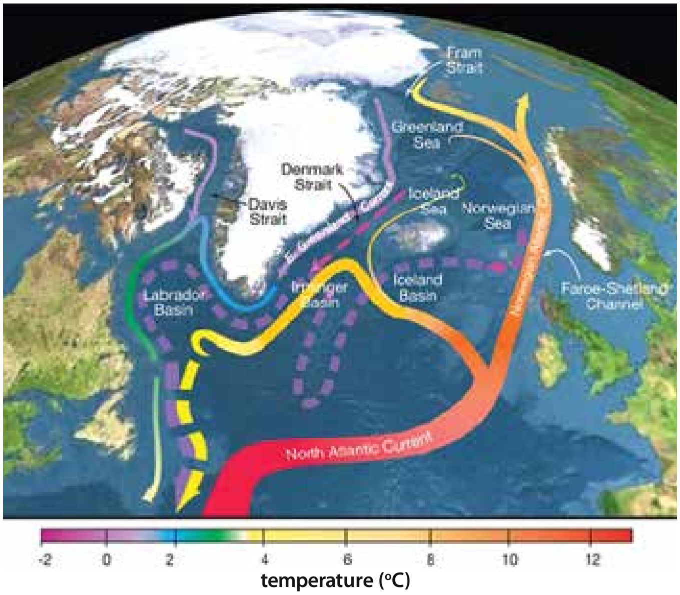



Figure 6: Climate change at high latitudes has the potential to alter circulation patterns in the global ocean through the process known as the thermohaline circulation. Water becomes heavier as it gets saltier and colder. Both warming and freshening of surface water may lead to a reduction of the density of surface water, thus inhibiting or at least slowing the formation of deep, dense water that sinks down and drives global ocean circulation. Such a breakdown of the thermohaline circulation has the potential to further amplify global climate change. Surface currents on the map are shown as solid pathways; deep currents are dashed, and colour indicates the water temperature. *Credit: Woods Hole Oceanographic Institution*

Aeronautics and Space Administration (NASA) reports rapid melting of ice in Greenland during the past two decades **(Figure 5)**. By mid-July 2012, the melting area covered an estimated 97 per cent of total surface area (NASA 2012b). These trends suggest that current predictions of Greenland's future snow and ice cover are conservative (Wang and Overland 2012).

The loss of ice in Greenland and the shrinking of glaciers in other parts of the Arctic currently contribute up to 40 per cent of the average 3 mm of global sea level rise per year (AMAP 2011a). Ice caps decline through melting, evaporation or collapsing into the sea, but scientists do not understand these mechanisms well enough to predict the fate of Arctic land ice with any accuracy. A number of studies suggest Greenland could be a major contributor to a potential rise in sea levels of 0.5 to 1 metre by the end of the century (Kopp et al. 2009).

The Arctic's influence on the rest of the world extends beyond its contribution to rising sea levels. Lost Greenland ice, along with runoff to the ocean from thawing of permafrost and melting of smaller glaciers, contributes to changes in the global ocean's circulation system, with potentially major consequences for weather systems globally (Dmitrenko et al. 2011, Rignot et al. 2011) **(Figure 6)**.

There is increasing evidence that rapid Arctic warming may already be responsible for a shift in weather patterns and changes in the frequency and intensity of extreme weather events at lower latitudes (AMAP 2011a, Francis and Vavrus 2012). Because the Arctic is warming faster than regions further south, temperature differences between the Arctic and mid-latitudes are becoming smaller. This appears to have been responsible for a slowing down of the jet stream (the strong wind in the upper atmosphere that steers weather systems from west to east around the northern hemisphere) by about 14 per cent since 1980 (Francis and Vavrus 2012, Overland et al. 2012). The slower jet stream causes weather systems to linger, creating "blocking" formations that produce more intense and longer periods of rainfall and drought, summer heat waves, and cold snaps in winter (Francis and Vavrus 2012, Hanna et al. 2012). This may explain some recent unusual weather phenomena, including Russia's record heat wave in 2010, prolonged cold spells in Europe in 2012, heavy snow in the United States and Canada in 2011, and droughts in North America in 2011 and 2012 (Francis 2012, Francis and Vavrus 2012, Inoue et al. 2012).

## Changes in the Arctic biosphere

Climate change is emerging as a major stressor on Arctic biodiversity (CAFF 2010). Habitat fragmentation, pollution, industrial development and overharvesting of wildlife are also having impacts. As a result, unique habitats for flora and fauna such as tundra, ponds and lakes, and permafrost peatlands have been disappearing in recent decades (CAFF 2010, AMAP 2011a). This threatens wildlife, including many birds and mammals that migrate annually from as far as Africa, Latin America and South-East Asia to the Arctic to breed **(Figure 7)**.

The lifecycles of many Arctic species are synchronized with the onset of spring and summer to take advantage of peaks in food availability. Earlier melting of snow and ice, or flowering of plants, can cause a mismatch between the timing of reproduction and the supply of food. At the same time, warming may allow non-Arctic species to expand their range northwards, displacing and outcompeting native Arctic species. For example, the red fox is replacing the Arctic fox in parts of the European Arctic (Fuglei and Ims 2008, Angerbjörn et al. 2012). There has been a northward shift in the distribution of some fish species and their prey due to warming sea temperatures (Meier et al. 2011). Such changes may, in turn, have caused breeding failures in some sea birds, and subsequent population decline, as fish species that used to be a major food source for seabirds move out and are replaced by other, unsuitable ones (CAFF 2010, Harris et al. 2007).

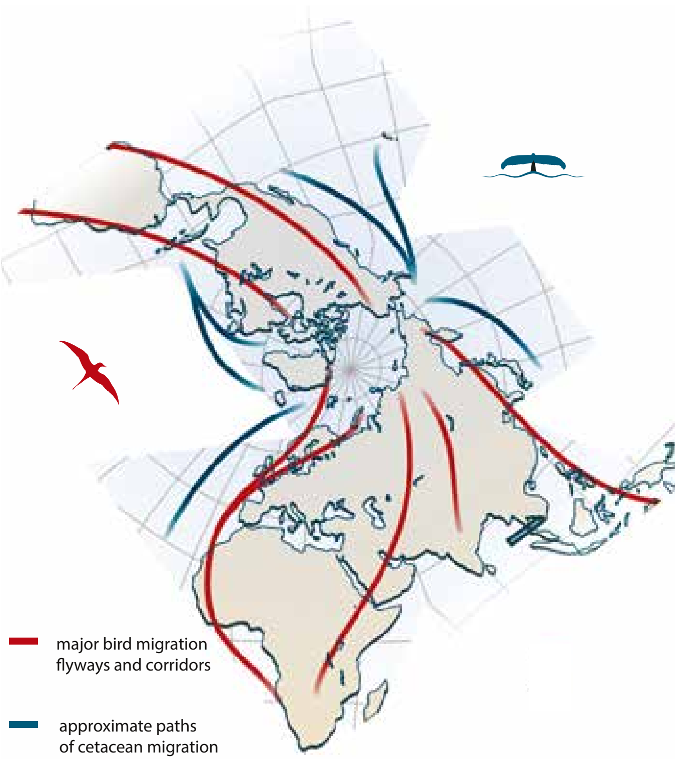



Figure 7: Many species, particularly birds (red) and marine mammals (blue), migrate to the Arctic annually from all parts of the world to breed. Migratory birds evolved over millennia to fly long distances to make use of many different habitats and seasonally abundant resources across a range of climatic zones. *Source: ATMP (2009), ACS (2013), Wetlands International (2013)*

Arctic marine mammals are particularly vulnerable to the loss of summer sea ice. Polar bears, walruses and some seals spend all or part of the year under, on top of, or on the edges of sea ice. These ice-edge zones are rich in food and serve as vantage points and resting places during hunting. Pacific walruses, for example, rest on ice when feeding. As the ice recedes, they are forced ashore to rest. Increasing numbers are congregating at a handful of locations on land. There have been ten-fold increases in the number of walruses at some sites along the coast of the Chukchi Sea in the past decade, with an estimated 97 000 at one location in Russia in 2010 (Kochnev 2010). Packed together, often far from their feeding grounds, the walruses go hungry and lose weight while the young may be crushed to death (Garlich-Miller 2012, MacCracken 2012).

Polar bears use sea ice as a base for hunting seals. Drastic reductions in their range and population are projected by the end of the century as sea ice continues to disappear at an accelerated rate in summer (Hunter et al. 2010). This brings into question the management of populations and other wildlife management decisions affecting their resilience **(Box 2)**.

The narwhal, one of three whale species that live in the Arctic year round, is also vulnerable. The majority of the world's narwhals winter in Baffin Bay, where they dive for Greenland halibut in areas with heavy pack ice, but shrinking ice cover is reducing their feeding areas (Laidre and Heide-Jorgensen 2011). Narwhals are also at increased risk from killer whales, which are becoming more common as the ice disappears.

Warmer springs and longer ice-free periods mean longer growing seasons for vegetation on land and in the sea (Vincent et al. 2011). Algae production, the basis of the marine food web, has increased by about 20 per cent since 1998 (Arrigo and van Dijken 2011). Algal blooms provide a moving feast at the edge of retreating ice that is critical for the reproduction of tiny floating creatures such as copepods, which are in turn eaten by fish, birds and marine mammals (Hunt et al. 2011, Leu et al. 2011). This may sound like good news, but many creatures dependent on algae are vulnerable to changes in the timing, quality and location of these blooms **(Figure 8)**. For example, thick-billed murres at some nesting colonies in Canada used to feed on Arctic cod that gorge on copepods at the ice edge. But because the ice melts earlier, the cod are no longer concentrated near the murres' nesting area when the birds need food for their chicks. The murres have partly adjusted, laying eggs five days earlier than they did 20 years ago. However, the ice is melting on average 17 days earlier. The birds have turned to new food sources and have found it more difficult to feed their chicks, which are growing more slowly as a result (Gaston et al. 2009, Meier et al. 2011).

Thousands of Pacific walruses on the beaches at Cape Kojevnikova, Chukotka, Russia. Walruses rest on ice when feeding. As the Arctic sea ice recedes, they are forced ashore to rest. Increasing numbers are congregating on "haul-out sites" as shown here. *Credit: Varvara Semenova, MMC*

## Box 2: Quandry over polar bears

Polar bears are perceived as an iconic species threatened by climate change (Ford 2011, Wenzel 2011). They are frequently shown clinging to remnants of ice, giving the impression that they are on the brink of extinction (Festa-Bianchet 2010).

While this is not yet true, there is cause for concern. Polar bears use ice to travel and to find the seals on which they feed. If there is no ice, the polar bears fast. Reduced populations, poorer body condition, and changes in distribution and behaviour have all been recorded, especially among populations at the southerly extent of their range (Stirling and Derocher 2012).

Polar bears undoubtedly also risk a drastic reduction of their range as population declines (Amstrup et al. 2010, Derocher 2010). So far, though, only a few populations are actually known to be in decline (Vongraven and Richardson 2011). Currently numbering between 20 000 and 25 000, polar bear populations may have increased overall in recent decades due to improved management of hunting. Thus, any suggestion that polar bear hunting should be banned remains controversial (Freeman and Foote 2009, Wenzel 2011).

There is growing tension between several of the Inuit communities, for whom polar bear hunting is central to their culture as well as an economic resource, and some outsiders who favour full protection (Meek 2011, Wenzel 2011). In the view of local wildlife managers, some polar bear populations could continue to support limited hunting (Ferguson 2010). However, climate change and loss of habitat make such management decisions more complex (Peacock et al. 2011, Rode et al. 2012). Approaches to minimizing these conflicts may require less rigid conservation regimes that involve local people and make use of their knowledge in reaching decisions that affect their well-being (Chapin 2010, Meek 2011).

Marine species with limited distributions or specialized feeding habits are particularly vulnerable (Laidre et al. 2008). As the ice disappears, major changes will take place in pelagic species and in ice-associated plankton. The marine ecosystem is also affected by changing water temperatures and ocean acidification **(Box 3)**. Moreover, climate change may alter the fate of Persistent Organic Pollutants (POPs) such as some pesticides, and of mercury, which accumulate in Arctic species, especially those at the top of the food chain (Kallenborn et al. 2012). Melting may also cause the release of "old" pollutants immobilized and stored in snow and ice over the years (Ma et al. 2011).

Along with the increase in ocean algae, there has been a 20 per cent increase in production of green plants on land since 1982 (Epstein et al. 2012). While there are more shrubs, there has been a loss of lichen, an important food source for caribou and reindeer (Myers-Smith et al. 2011). Additionally, lichens suffer with the thawing of the frozen peatlands on which they grow (Vincent et al. 2011). There are also concerns that thawing permafrost, by adding cold underground water to rivers, is changing their flow, temperature and chemistry. This type of change could have major implications for freshwater ecosystems and fisheries depending on them (Frey and McClelland 2009).

Although the overall biological productivity of the Arctic is increasing, changing conditions mean there is often less food at critical periods for many species. It is likely that the rate and extent of change will outstrip the adaptive capacity of many species to respond (Gilg et al. 2012).

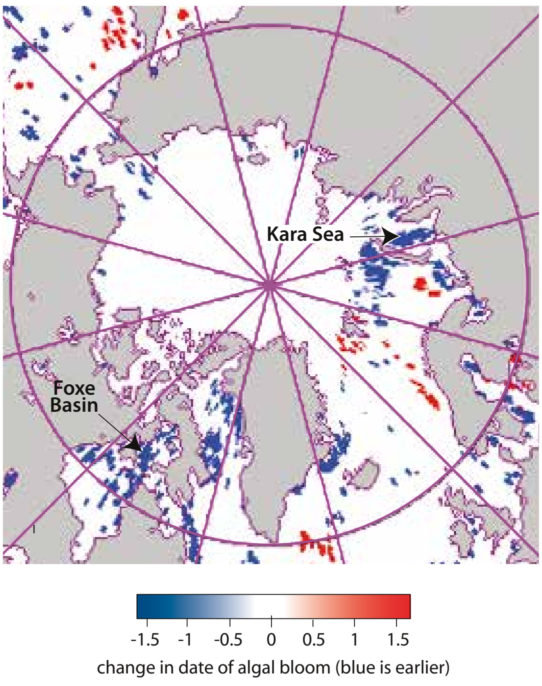



**Figure 8:** Trends in peak algal blooms in the Arctic Ocean, 1979-2009. Algal blooms are occurring earlier in about 11 per cent of the Arctic Ocean. The change is in areas where ice is melting in early summer, creating gaps that make these earlier blooms possible. The rate of change is very rapid at some locations. For example, peak algal bloom occurred in early September in Foxe Basin and in the Kara Sea in the mid-1990s but had shifted to mid-July by 2009, a change of about 50 days. *Source: Kahru et al. (2011).*

**Box 3:** Ocean acidification in the Arctic

The ocean has become 30 per cent more acidic in the past two centuries (UNEP 2009). This is largely because some of the $CO_2$ emitted to the atmosphere by human activity dissolves in ocean waters, forming carbonic acid. However, changes in freshwater balance, heat budgets and land-ocean exchange may also play a locally significant role. Modelling studies suggest that even if the atmosphere recovers its former chemistry, acidification will take thousands of years to reverse.

Polar regions are particularly prone to acidification because colder water can hold more $CO_2$ than warmer water. In addition, changes in ocean chemistry due to melting sea ice lead to calcium carbonate being less available to animals that need it to build shells and external skeletons (Carmack et al. 2012). This has potentially serious implications for molluscs, corals and crustaceans.

In parts of the Canadian Arctic and the East Bering Sea, researchers have reported seasonal shifts in seawater chemistry, from conditions that enable molluscs to form shells to conditions in which shells dissolve (Yamamoto-Kawai et al. 2009, Mathis et al. 2011). Pteropods, tiny sea snails that are important in the Arctic marine food web, may be particularly vulnerable. The common pteropod *Limacina helicina* could become extinct by the end of the century (Comeau et al. 2012). This would have major ecological and economic impacts, including on North Pacific pink salmon fisheries. Only urgent global action to reduce $CO_2$ emissions can prevent such impacts (Turley and Gattuso 2012).

The pteropod, or "sea butterfly", is about the size of a small pea and a major food source for animals ranging from krill to whales. When placed in seawater with an acidity and carbonate concentration at levels projected for the year 2100 the shell slowly dissolves. *Credit: Russel Hopcroft*

## The rush for Arctic resources

Resource exploitation is not new in the Arctic. Major longstanding developments include oil drilling on the North Slope of Alaska, natural gas or methane extraction on Russia's Yamal peninsula, and mining of metals around Norilsk, Russia, the world's largest source of nickel and palladium. But as ice and snow recede, making access and transport easier, the Arctic is expected to play a greatly expanded role in world energy and minerals supplies.

The United States Geological Survey (USGS) estimates that 30 per cent of the world's undiscovered natural gas is in the Arctic, mostly on the continental shelves beneath the Arctic Ocean. More than 70 per cent of the undiscovered oil resources are estimated to occur in northern Alaska, the Amerasian Basin, the eastern side of Greenland, the eastern Barents Sea region, and the Davis Strait of Greenland and Canada. An estimated 84 per cent of the undiscovered oil and gas in the Arctic occurs offshore. The largest gas resources are likely to be off the coast of western Siberia in the Kara Sea region (USGS 2008).

One insurance company expects up to US$100 billion in Arctic investment in the coming decade, largely in the minerals sector (Emmerson and Lahn 2012). Exploration and mining are already accelerating, triggering construction of roads, ports and new settlements. In 2012 Shell constructed a new oil rig offshore of Alaska's Arctic National Wildlife Refuge (McClatchy 2013) and the Canadian government gave the green light for a giant iron-ore mine at the Mary River, which will be linked to a port on Baffin Island by the world's most northerly railway (North of 56 2012). Another target for early economic development will be the southwest coast of Greenland, which may have the world's largest deposits of rare earths (GME 2012).

While foreign companies are keen to exploit Arctic reserves, indigenous and local communities hope that some of the profits will benefit their development and employment opportunities. In 2012 the Inuit-owned Nunavut Resources Corporation began raising money on Wall Street to prospect for gold and other minerals in the Kitikmeot region (MacDonald 2012).

Public funding is often essential to such enterprises. Russia reportedly spent US$19.3 billion subsidizing its oil and gas industries in 2010 (Gerasimchuk 2012). Even so, not all schemes are realized. In August 2012 Statoil decided to pull

out of the US$15 billion Shtokman gas project in the Barents Sea due to rising costs and falling global gas prices (Macalister 2012). The start of this project in one of the world's largest gas fields is now delayed until at least 2017.

## Shipping

Receding sea ice is opening the Northern Sea Route and Northwest Passage for shipping. In 2011 the Northern Sea Route was open for five months. More than 30 ships passed through, including Russian gas tankers and Nordic iron ore carriers (Helmholtz Association 2012, Macalister 2012). In September 2012 the icebreaker *Xue Long*, or *Snow Dragon*, became the first Chinese vessel to complete the route (NZweek 2012). The Northern Sea Route is a substantially shorter passage (35-60 per cent savings in distance) for shipping between northern European ports and those of the Far East and Alaska than routes through the Suez or Panama Canals **(Figure 9)**. The implications for global trade could be considerable, as some 17 000 ships per year pass currently through the Suez Canal.

In 2011 the then Prime Minister of Russia, Vladimir Putin, announced that Russia intends to turn the Northern Sea Route into a shipping highway "of global importance" with a 40-fold increase in shipping by 2020. In June 2012 a new Russian federal law regulating commercial shipping in the Northern Sea Route was signed. There will be a new hydrographic survey to improve seabed mapping, and ten search and rescue centres along the Arctic coast (Marinelink 2012). Another major development will be the opening of a route away from the coast through deeper waters north of the New Siberian Islands.

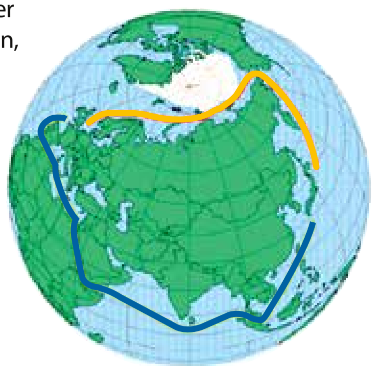


Figure 9: The Northern Sea Route (orange) will provide a shorter passage from the North Atlantic to the Pacific than the current shipping route through the Suez Canal (blue). *Credit: Danish Institute for International Studies*

The Northwest Passage through the Canadian Arctic was open in 2011, but partially blocked by ice throughout 2012. It, too, may soon be sufficiently free of ice to allow ships to pass during part of the year. Meanwhile, the Arctic is set to become a growing tourist destination, particularly for cruise ships (PAME 2009). More shipping will, however, increase the likelihood of accidents and of environmental damage.

## The challenges of development

Approximately 4 million people live in the Arctic region, about half in Russia (SDWG 2004) **(Figure 10)**. One-tenth are indigenous peoples, a high proportion of whom (including almost all Inuit communities) live along the coasts, where loss of sea ice increases opportunities for fishing but also increases climate-related risks (Forbes 2011).

Historically, coastal populations have been protected from winter storms by ice. The shorter period of ice cover today exposes coasts to storms that erode the shoreline, typically by 1-2 metres a year but up to 30 metres in certain locations (Forbes 2011). Some villages, such as Shishmaref in Alaska, have made plans to move inland as a result (CAKE 2010).

Elsewhere, thawing permafrost buckles roads and destroys pipelines, and ice roads sometimes unexpectedly become impassable. On rivers, changes in ice cover damage hydropower infrastructure and bridges (Prowse and Brown 2010). In Alaska, the costs for upkeep of public infrastructure could add US$3-6.1 billion to normal maintenance costs from 2008 to 2030 (Schaefer et al. 2012).

Resilience – the long-term capacity to deal with change and continue to develop and adapt within critical thresholds – is vital (Arctic Council 2012). Indigenous communities, in particular, have developed subsistence lifestyles based on hunting, herding, fishing and gathering that are adapted to the Arctic's climatic extremes and variability. Changes to the Arctic may threaten their way of life.

Protection against severe erosion of the coastline in Shishmaref, Alaska, United States. The reduced period in which there is sea ice has made sandy sediments more vulnerable to erosion. *Credit: Lawrence Hislop*

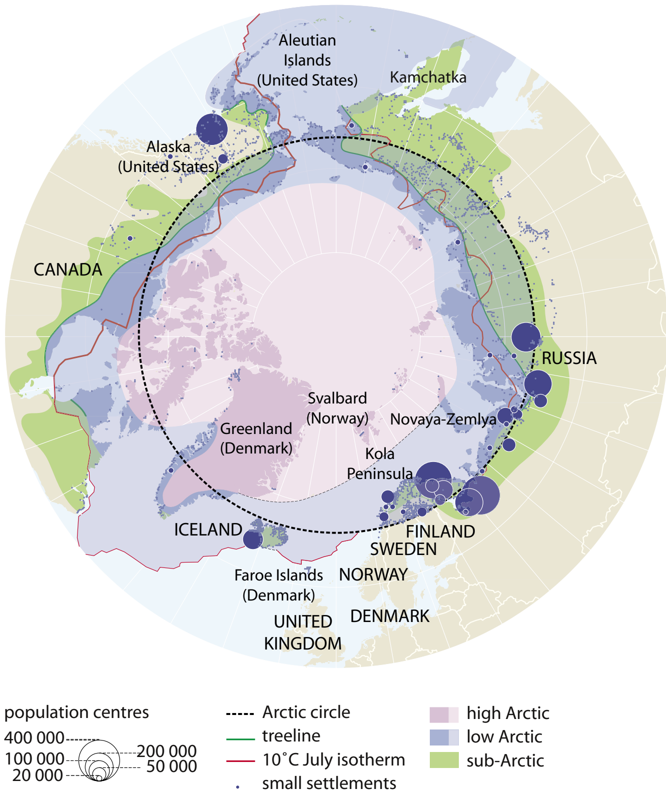



Figure 10: The Arctic can be divided into the low Arctic and high Arctic according to various environmental and biological characteristics. Tundras are most common in the low Arctic and polar barrens are dominant in the high Arctic. The circumpolar Arctic covers 14.8 million km$^2$ of land and 13 million km$^2$ of ocean. Seven of the ten largest remaining wilderness areas on Earth are located in the Arctic region. The Arctic is also home to diverse and unique societies, including indigenous cultures depending on and maintaining close ties to the land and ocean. *Credit: Adapted from Vital Arctic Graphics, GRID-Arendal*

For nomadic peoples their resilience depends on unfettered access to land and water, allowing them and migrating wildlife to move with the seasons. Changes in access to resources can pose real threats. Even minimal development of infrastructure in terms of surface areas, such as roads and pipelines, can be extremely disruptive **(Box 4)**. The footprint of new economic development in the Arctic remains small. Yet by fragmenting the landscape, economic development can interrupt hydrology, endanger ecosystems, and prevent the passage of migrating caribou and reindeer in search of grazing spots and calving areas.

Industrial and infrastructure developments may bring short-term economic benefits for some indigenous communities. On

## Box 4: The Nenets – a test of resilience in the face of industrial development

The nomadic Nenets are reindeer herders living on the Yamal peninsula in Western Siberia, Russia. They have faced rapid development of gas fields on their grazing grounds since the end of the 1980s. The peninsula has recently been producing 17 per cent of the world's natural gas.

The Yamal peninsula is largely flat, but is crossed by strips of higher terrain traditionally used by the Nenets as camp sites and migration routes for their herds. Industrial development has often targeted the same elevated terrain. While the physical footprint of the gas fields remains small, pipelines and other facilities have blocked two of the four main Nenets migration routes, obliterating grazing areas and closing access to 18 traditional camping grounds (EALÁT 2011).

So far, the Nenets have been able to reorganize their lives and survive. But expansion of infrastructure **(Figure 11)**, combined with degradation of terrestrial and freshwater ecosystems, rapid climate change and a massive influx of industrial workers, will test their resilience (Forbes et al. 2009).

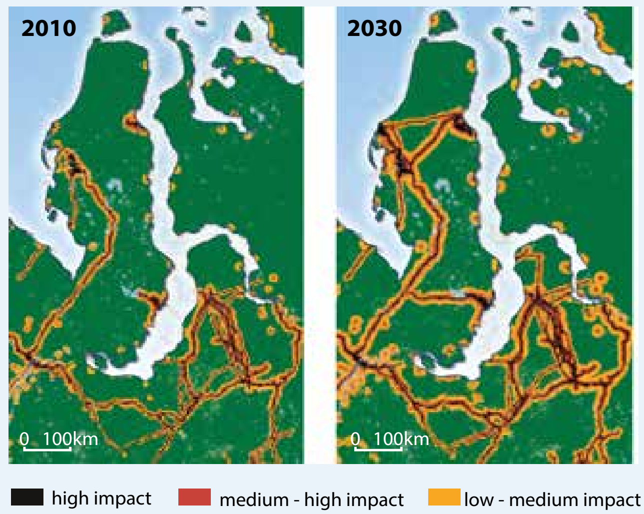



Figure 11: Current industrial development (2010) and expansion of infrastructure projected for 2030 in the Yamal region. *Source: Magga et al. (2011)*

the Alaskan North Slope, for example, some Inuit welcome the oil industry because it brings jobs and civil amenities (AMAP 2010). But for many indigenous peoples, protection of access to their lands is the top priority and fundamental to the survival of their traditional livelihoods. The challenge is how to respect the traditional way of life of local and indigenous communities while

making economic development environmentally safe. Meeting this challenge is associated with rights to land and natural resources, as reflected in international agreements such as the 2007 United Nations Declaration on the Rights of Indigenous Peoples.

## Environmental governance

The Arctic has been called a bellwether for global climate change (Post et al. 2009). Due to its rapid warming, impacts often show up here first. The combination of rapid environmental transformation and the rush for resources in a previously remote region raises important geopolitical issues that are likely to have ramifications far beyond the Arctic (Conley 2012). It can therefore also be considered a bellwether for tackling environmental governance challenges.

Central to any discussion of Arctic governance is the role of the Arctic Council, established in 1996 based on the 1991 Arctic Environmental Protection Strategy (Stokke 2011, Kao et al. 2012). The eight Arctic countries forming the core of this high-level forum are Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States (Arctic Council 2013). A number of indigenous peoples' organizations, including the Inuit Circumpolar Council (ICC) and Russian Association for Indigenous Peoples of the North (RAIPON), became permanent participants. Several non-Arctic countries, as well as international organizations, have observer status. A number of other countries and organizations are seeking to become observers to the Arctic Council.

The Council leadership rotates every two years. In 2013 it passes from Sweden to Canada. The Council has considered sustainable development of the Arctic through reports on pollution, climate change impacts, snow, water, ice and permafrost, shipping, human development and biodiversity. The Arctic Council countries have also taken steps recently to strengthen governance, including through the adoption of a first agreement on Cooperation in Aeronautical and Maritime Search and Rescue in the Arctic (Kao et al. 2012).

Thousands of indigenous peoples living in the Yamal peninsula, Russia, practise traditional reindeer herding. Since the 1980s, rapid development of gas fields has occurred on these nomadic herders' historic grazing lands. *Credit: Anna Degteva*

### Resource exploitation and shipping

Under the United Nations Convention on the Law of the Sea (UNCLOS), coastal states have the right to establish a 200 nautical mile Exclusive Economic Zone (EEZ) where they have sovereign rights and jurisdiction over the continental shelf unless there is a need for maritime delimitation with another coastal state **(Box 5)**. States that have a continental shelf that stretches at least 200 nautical miles have to document its outer limits. According to UNCLOS Article 77 "the coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources".

**Box 5:** Legal questions

In 2010 Norway and Russia ended 42 years of negotiations on their disputed maritime delimitation line in the Barents Sea and the Arctic Ocean, opening up parts of the continental shelf to natural resource development. This is one of a series of Arctic geopolitical issues being resolved.

Outstanding issues include border disagreements between Denmark/Greenland and Canada; issues concerning the Northwest Passage; and a difference in opinion in regard to the interpretation of the Treaty concerning Spitsbergen. The Svalbard archipelago, situated midway between Norway's mainland and the North Pole, is under Norwegian sovereignty, but particular provisions of the Treaty accord certain rights to nationals and companies of its Parties, and there are different views on the geographical scope of application of these provisions.

The largest territorial question over a maritime delimitation line may be between Canada and the United States in the Beaufort Sea, an area expected to be rich in petroleum resources. Another contentious issue will be where to draw the border on the seabed between Denmark/Greenland, Russia and Canada on the Lomonosov ridge, a section that stretches over the North Pole from Russia to Greenland and Canada. The five countries bordering the Arctic Ocean (Canada, Denmark/Greenland, Norway, Russia and the United States) have confirmed their commitment to UNCLOS as the legal framework to orderly settlement of any overlapping claims in the Arctic Ocean (Ilulissat Declaration 2008, Kullerud et al. 2013).

Rapid changes in the Arctic environment and increased opportunities for exploitation of the region's resources create challenges for the region, for co-operative bodies such as the Arctic Council, and for the wider world. The international community is keen – at different times – both to exploit those resources and economic opportunities and to protect the region's fragile environment. For example, British parliamentarians have called for a halt to oil and gas drilling in the Arctic Ocean until a pan-Arctic response system has been established to handle large spills (House of Commons 2012).

Exploitation of natural resources such as minerals and hydrocarbons remains largely a national issue, but it is one in which the global community is taking an interest. With the opening of new shipping routes and the exploration of oil, gas and mineral deposits in the Arctic, non-Arctic countries are eager to gain a foothold in the region. China opened its first Arctic scientific research station in Ny-Ålesund, Svalbard, in 2004. Singapore, which has an extensive ship-building industry, has also expressed an interest in the region.

Increasing ship traffic will require attention to shipping lanes and pollution risks. UNCLOS sets out a legal framework for rights of passage and navigation on shipping. Other related issues include responsibilities for ensuring the structural safety of ships operating in the Arctic, search and rescue, security, crew training, hydrographic surveys, charting, and pollution prevention. The International Maritime Organization (IMO) is currently developing international requirements for the safety of ships navigating ice-filled water, known as the Polar Code.

**Box 6:** A fisheries boom?

The Arctic is already the base for large commercial fisheries, including salmon and walleye pollock in the Bering Sea and cod and haddock in the Barents Sea. Future decades may see a boom thanks to warmer waters nurturing growing stocks, as well as more open ocean in which to catch fish. One modelling study projects that, by 2055, fish catches at high latitudes, including in the Arctic, could increase by 30-70 per cent, while those in the tropics decrease by 40 per cent (Cheung et al. 2010).

A widely predicted northward shift in subarctic fish species, including Atlantic and Pacific cod, is now being detected (Meier et al. 2011). Six species have recently extended their ranges through the Bering Strait into the Beaufort Sea (Sigler et al. 2011). The number of voyages by fishing vessels in the Canadian Arctic increased seven-fold between 2005 and 2010.

Not all the effects will be beneficial for fishing. In the Bering Sea longer warm periods with less ice cover are expected to reduce walleye pollock stocks, while higher sea temperatures may increase winter mortality of juvenile sockeye salmon (Farley et al. 2011, Hunt et al. 2011).

Meanwhile, these movements can create international tensions. The northward migration of North Atlantic mackerel has caused disputes between Iceland and other countries. The movement of fish stocks can also be bad news for local fisheries. The village of Narsaq in southern Greenland once prospered due to catching and processing of local shrimps. But as local waters warmed, the shrimps headed north, the fleet of eight vessels was reduced to one, the shrimp factory closed, and the village's population was halved (Hamilton et al. 2000).

Fish stocks are moving towards polar regions due to the effects of climate change. This, coupled with the increased accessibility of Arctic areas due to melting sea ice, will further raise interest in future large-scale fisheries in the region. *Credit: Corey Arnold*

Some northern communities, dependent on subsistence fisheries, could be crowded out by the arrival of commercial vessels. The currently fragmented fisheries management in the Arctic is not up to the task of either managing such issues or protecting stocks. As ecosystems change and economic opportunities are pursued, there is an urgent need to reassess fisheries management in the Arctic.

### Management of fisheries and ecosystems

The management of Arctic fisheries is currently based on a patchwork of regional conventions, agreements and regimes. This is unsatisfactory now that melting ice is allowing passage, particularly as there is considerable uncertainty about how fish will respond to the ecosystem changes under way **(Box 6)**. The United States has reacted to this uncertainty by placing a moratorium on all fishing in its Arctic Ocean waters until research is completed (Stram and Evans 2009, Pew Environment Group 2012). The Canadian government and the Inuvialuit, the Inuit of the Canadian Western Arctic, signed a formal agreement in 2011 to freeze expansion of fishing in the Canadian Beaufort Sea.

As ecosystems change, current approaches to the management of wildlife and conservation of habitats within countries will no longer be adequate. The risks to ecosystems are great because many changes may be sudden and unforeseen. The development of the Arctic Marine Biodiversity Monitoring Plan 2011 is a welcome step (Gill et al. 2011). However, in many cases monitoring systems are not in place to detect changes at an early stage (Chapin et al. 2010, Vincent et al. 2011, Young 2012). Bringing together science and the traditional knowledge of indigenous and local communities to better monitor and understand ecosystem changes is vital (Huntington 2011). At the same time, monitoring and understanding are of little use without the ability to respond. Marine spatial planning is emerging as an important ecosystem management tool **(Box 7)**. As many species migrate to the Arctic from other parts of the world, there may also need to be changes in the management of such species outside of the Arctic (Boere and Stroud 2006).


The *Xue Long* or *Snow Dragon*, an icebreaker, became the first Chinese vessel to cross from the Pacific to the Atlantic via the Arctic. Less sea ice may open new trade routes and near-term opportunities for exploration of oil, gas and mineral deposits in the Arctic. *Credit: Yong Wang, State Ocean Adminstration of China*

**Box 7:** Ecosystem-based management of the marine environment

The importance of addressing multiple stressors to the marine environment in an integrated way has long been recognized. Ecosystem-based management is an approach that considers the health, productivity and resilience of the entire ecosystem. The Arctic Council follows this approach in several of its intiatives, including the Circumpolar Biodiversity Monitoring Programme (CBMP).

Marine spatial planning is an important tool to implement ecosystem-based management. Key features include consideration of multiple scales; a long-term perspective; recognition that humans are an integral part of ecosystems; an adaptive management perspective; and concern for sustaining ecosystem goods and services.

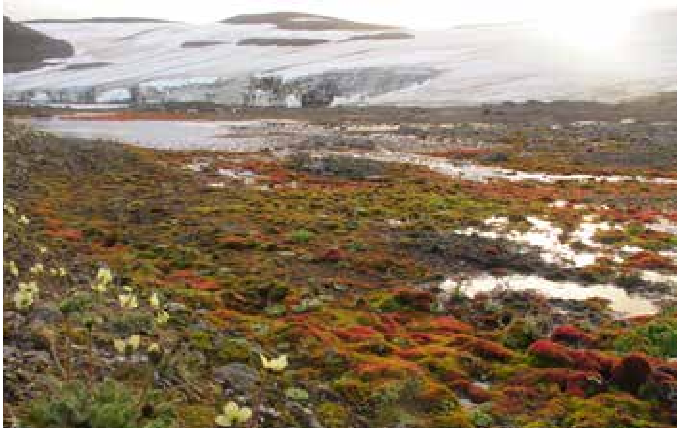
A successful example is the Barents Sea Management Plan, which provides a framework for managing the oil and gas industry, fishing and shipping (Olsen et al. 2007). The plan requires strict regulation of activities in ecologically valuable areas. To reduce conflict between fisheries and shipping, Norway has applied to move shipping lanes outside Norwegian territorial waters. Some areas may be restricted or closed to oil and gas exploration and exploitation in order to avoid future conflict. There are also plans to extend marine protected areas and seasonally close areas to protect fish reproduction.

## The way forward

The Arctic is no longer a world apart. It has resources of global interest far beyond its wildlife. But its fragile environment is one compelling reason why non-Arctic countries are becoming involved in discussing just how much and what form of global governance is needed in this region.

There are a series of urgent issues to be addressed, both to reduce the pace of change in the Arctic and to increase its resilience to that change. Some emerging issues are national and some can be addressed by the region collectively, while still others will require global input and sometimes global action.

Reducing greenhouse gas emissions remains the most important measure, as climate change dominates the current transformation of the Arctic environment. While action within the United



In 2009 Russia turned the Franz Josef Land archipelago into the Russian Arctic National Park. There are plans to introduce ecotourism. *Credit: Peter Prokosch*

Nations climate process is essential, there may be scope for agreements on curbing regional emissions of fast-acting but short-lived climate pollutants such as black carbon to complement global action to reduce emissions of $CO_2$ and other greenhouse gases.

The transformations occurring in the Arctic require the people who live there to find ways to adapt to inevitable climate change. Finding these ways will involve both national governments and local institutions. Adaptation and coping strategies could build on the 2010 Cancun Adaptation Framework on climate change. However, as in other parts of the world, the contribution of local and traditional knowledge is essential. Those living and working in the Arctic know the region's environment best, and so are eminently placed to observe changes and respond accordingly.

It is also vital that no steps are taken to "exploit" the new environmental state of the Arctic without first assessing how exploitation would, intentionally or unintentionally, affect ecosystems, the peoples of the North and the rest of the world. In view of the potential for major environmental damage, a precautionary approach to economic development needs to be carefully considered. Such an approach requires measures such as development moratoriums until full assessments have established risks to the environment and human systems, and until adequate management frameworks have been put in place. The moratoriums imposed by Canada and the United States on expansion of commercial fishing in the Beaufort Sea, pending assessment of sustainability and ecological and economic costs and benefits, could serve as models.

The challenges posed by climate change and, in turn, by social and economic development in the Arctic require a long-term vision and innovative policy responses. There is a need to assess options in areas such as maritime trade and shipping, tourism, commercial fisheries, and oil, gas and minerals development. Such assessments should explicitly include indigenous peoples and other stakeholders of the Arctic, as well as non-Arctic countries.

Arctic climate change will have major and irreversible impacts on the livelihoods and well-being of indigenous peoples and other Arctic communities. It will also have impacts on the rest of the planet. Policy dialogues could consider the need for new international policy regimes, using the precautionary approach adopted in, for example, the proposed Polar Code for ship operations.

The rapid pace of physical, chemical and biological change in the Arctic means that strengthened systems for monitoring and providing early warnings of the unexpected are essential. Additional environmental research is urgently needed in the following critical areas:

- The present and future climate impact in the Arctic of short-lived climate pollutants such as black carbon and methane, and the possibilities for taking immediate measures to curb their emissions in the Arctic and beyond.
- The mechanisms of changes to snow and ice, such as melting of the Greenland ice cap and loss of Arctic sea ice, and their implications for global sea level rise, regional shipping, coastal development and international trade.
- Present and future changes in the biosphere, and their consequences for fisheries, food webs, habitats and Arctic cultures.
- The use of traditional knowledge and direct observations by indigenous peoples to inform policy and management actions.

Effective governance is the key to sustainable development of the Arctic. The fate of its ice and snow, frozen land and open waters, along with its wildlife and peoples, crucially depends on how the world addresses climate change and the resulting changes in human activities. Building upon existing institutions and scientific expertise in the region, the Arctic could set an example of environmental governance for the rest of the world. While Arctic countries need to take the lead, inputs from non-Arctic countries are vital, as the rest of the world stands to lose – or gain – from Arctic change.

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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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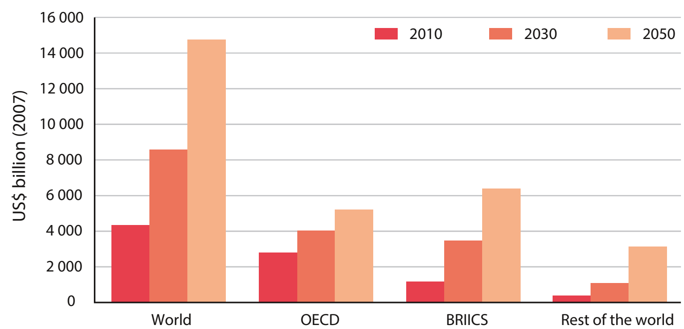



**Figure 1:** Current and projected chemical production (in sales) for the world, OECD members, BRIICS and other countries in the world, 2010-2050. *Source: Adapted from Sigman et al. (2012)*

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

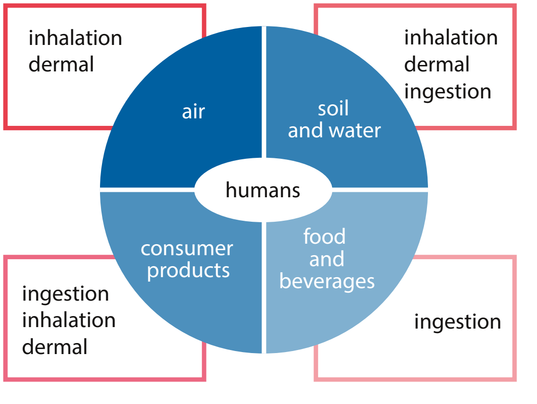



**Figure 2:** Possible exposure media and ways people come into contact with chemicals. Releases to air, soil and water may occur at any point in a chemical's lifecycle. *Source: Adapted from WHO (2010)*

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

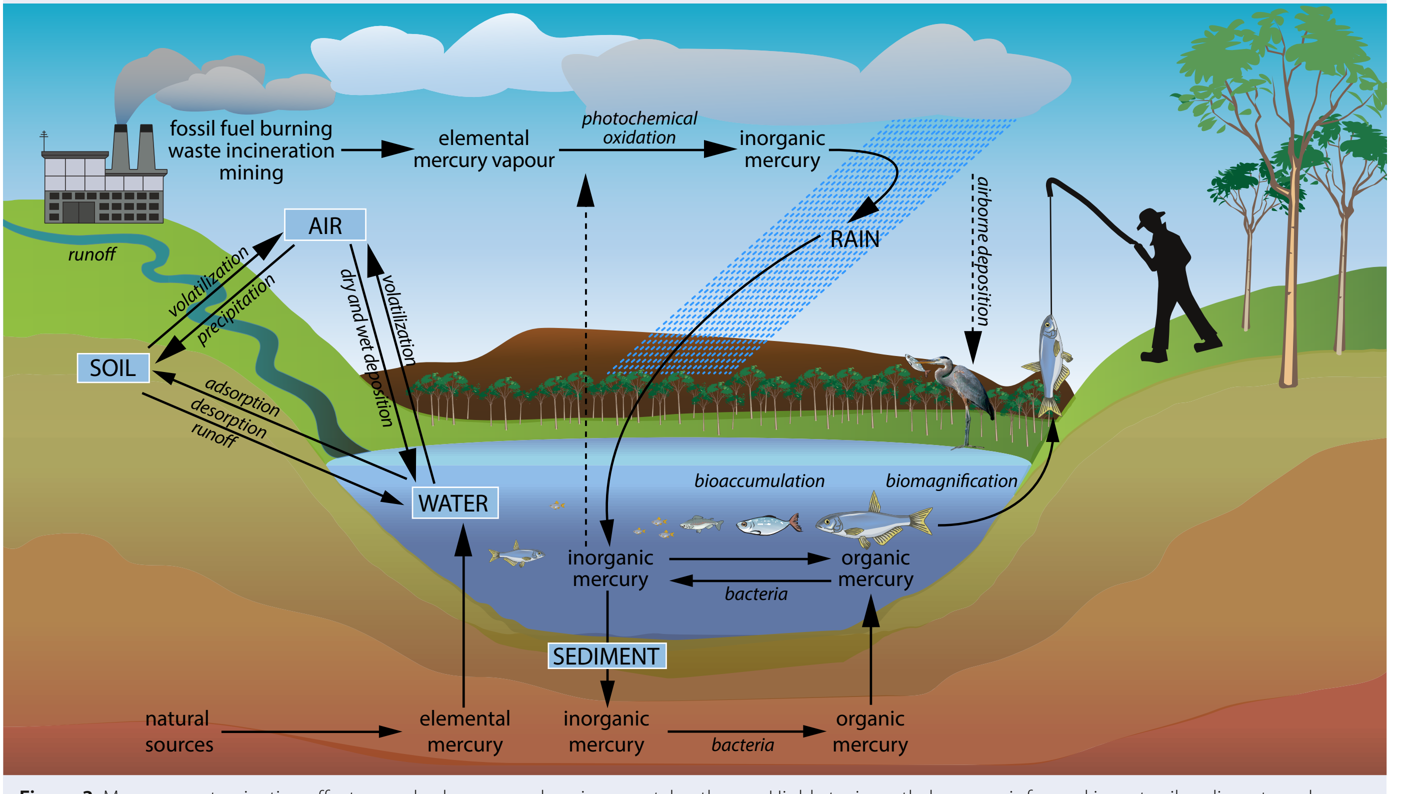



**Figure 3:** Mercury contamination affects people along several environmental pathways. Highly toxic methylmercury is formed in wet soil, sediments and water, where it bioaccumulates and biomagnifies. Fish consumption is a main route of human exposure. Infants, children and women of child-bearing age 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

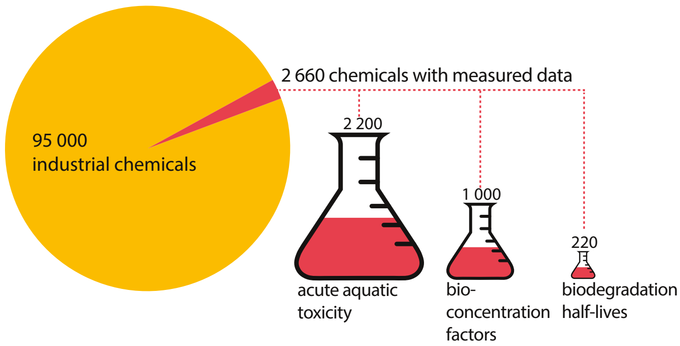


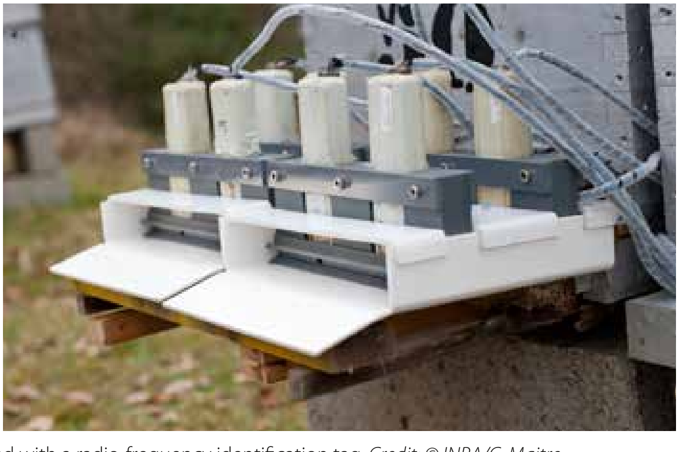

Figure 4: Out of a set of 95 000 industrial chemicals, very few had data on acute aquatic toxicity, the extent to which they build up in the environment (bioconcentration factors), or how long it takes them to break down (biodegradation half-lives). *Source: Adapted from Strempel et al. 2012*

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).

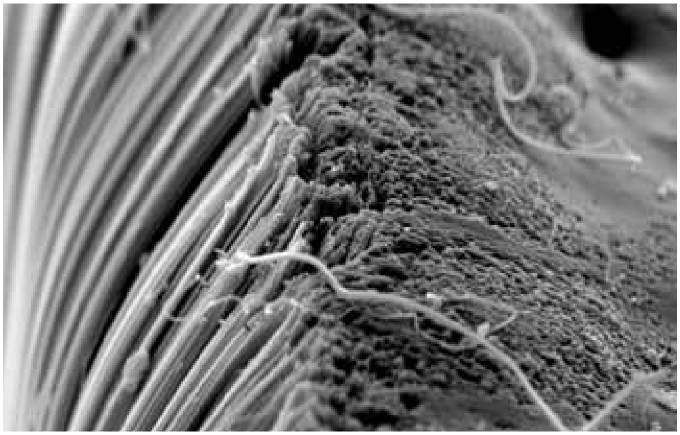
New concerns have recently been raised about the impact of pesticides on non-target organisms including insects, especially bees, and amphibians (Brühl et al. 2013). Studies suggest that low doses of neonicotinoids, a group of neurotoxic chemicals widely used in many countries as insecticides, could 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

**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.

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.

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

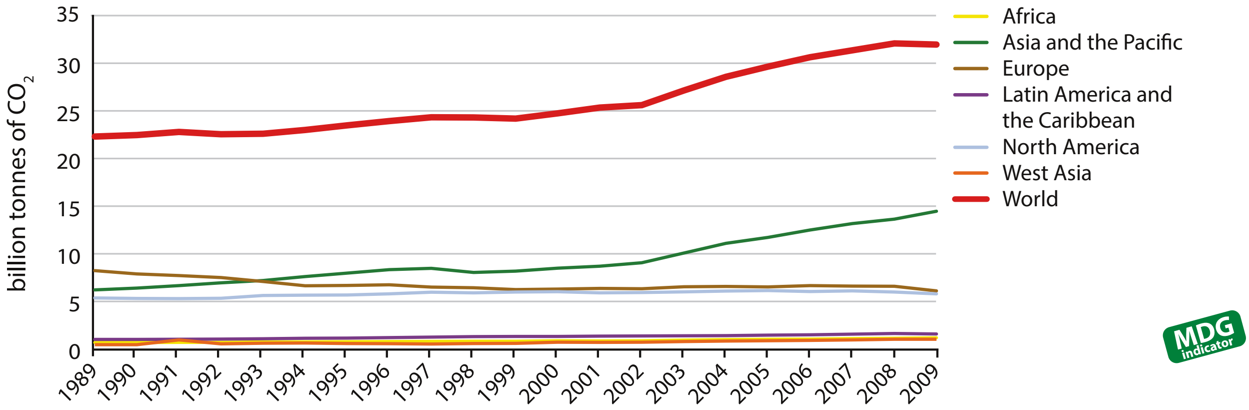



**Figure 1:** Carbon dioxide emissions from fossil fuels and cement production, expressed in billions of tonnes of $CO_2$, 1989-2009. Global $CO_2$ emissions have increased in recent years, mainly in the Asia and the Pacific region. *Source: UNEP EDE, compiled from Boden et al. (2012)*

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 36$^{th}$ 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 18$^{th}$ 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).

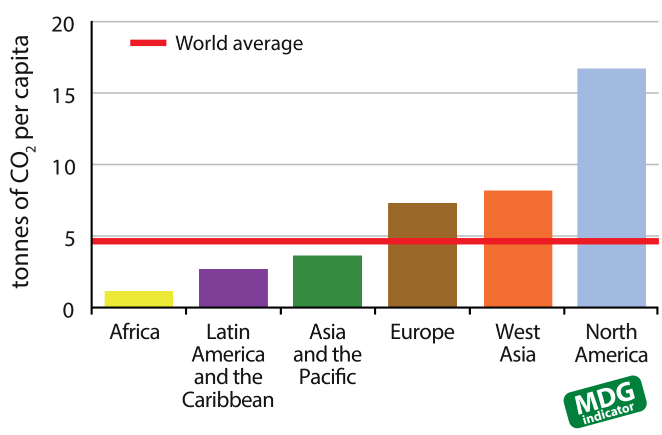



**Figure 2:** Carbon dioxide emissions per capita, 2009. Per capita emissions of $CO_2$ are well above the global average in Europe, West Asia and particularly North America. *Source: UNEP EDE, compiled from Boden et al. (2012)*

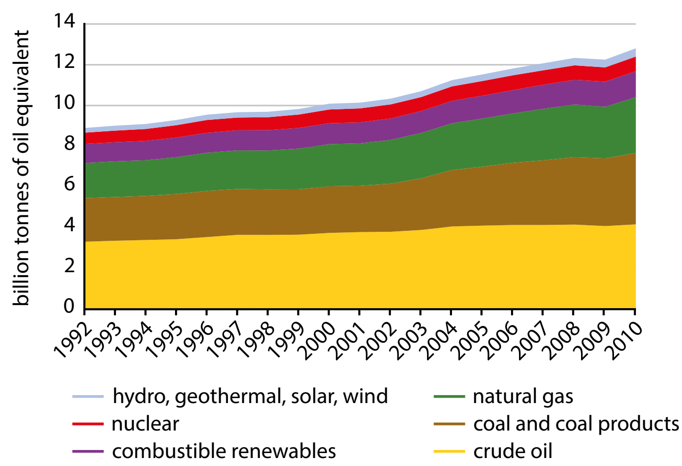



**Figure 3:** Primary energy supply, 1992-2010. Use of fossil fuels has increased steadily in the past two decades. A small dip occurred around 2009. Renewable resources represent a modest but rising share. *Source: UNEP EDE, compiled from IEA (2012a)*

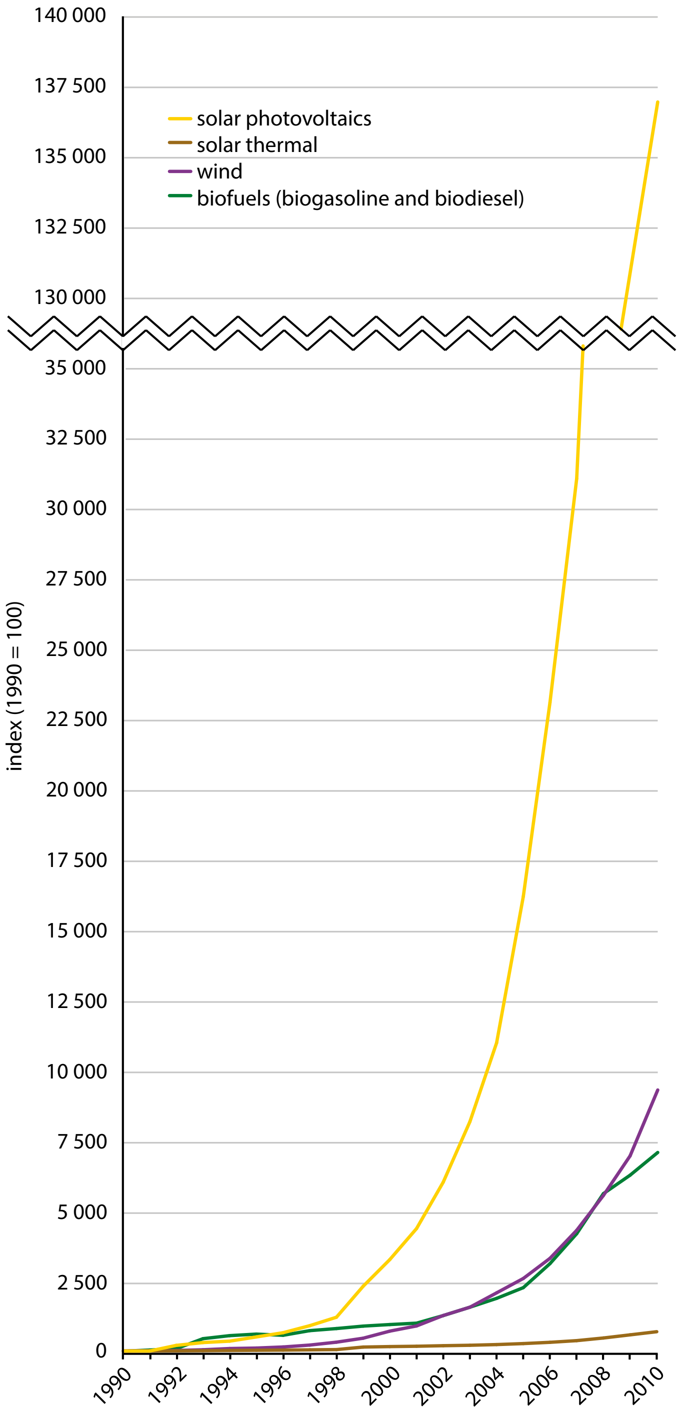



Figure 4: Renewable energy supply index, 1990-2010 (1990=100). Use of solar energy is skyrocketing, followed by wind and biofuels. *Source: UNEP EDE, compiled from IEA (2012b)*

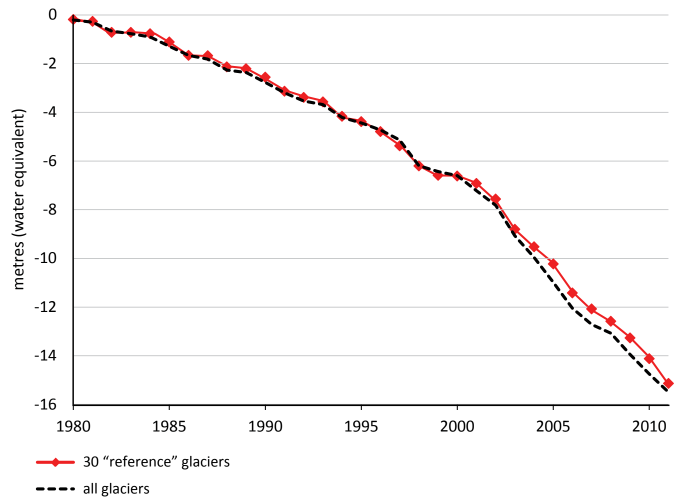



Figure 5: Mountain glacier mass balance, 1980-2011. Glaciers have continued to melt at unprecedented rates, with increasingly severe impacts on the environment, natural resources and human well-being. *Source: WGMS 2013*

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

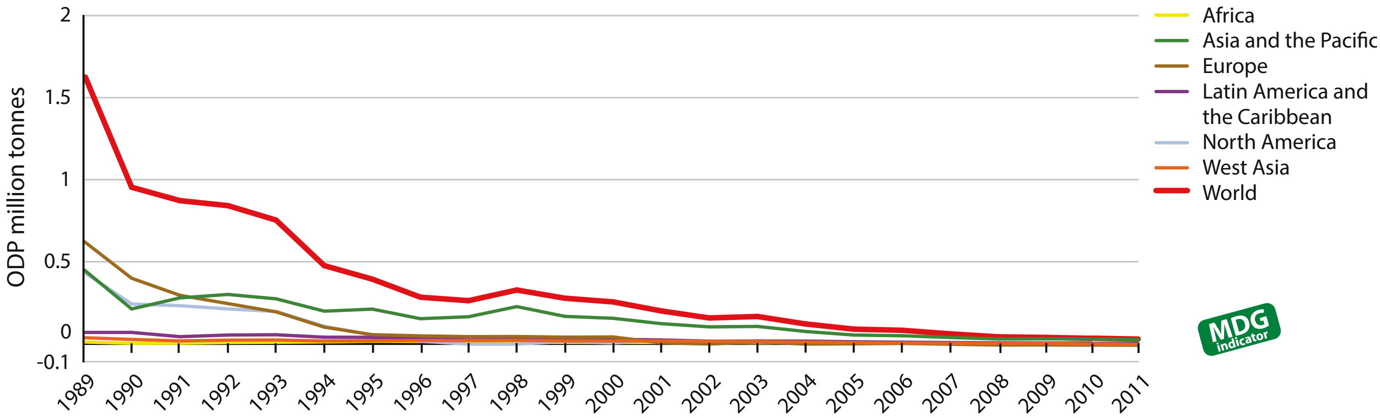
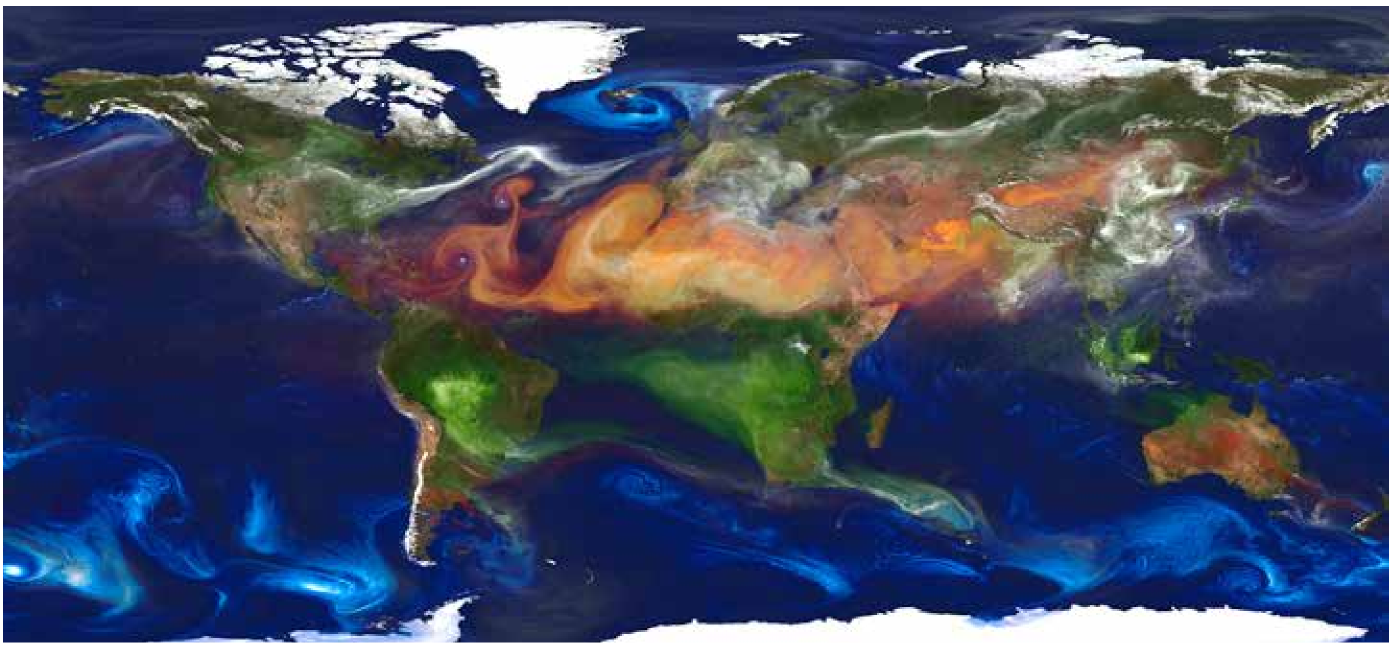



**Figure 6:** Consumption of ozone-depleting substances expressed as million tonnes of ozone depletion potential (ODP), 1989-2011. Challenges remain, but the consumption of ozone-depleting substances has declined tremendously through implementation of the Montreal Protocol to the Vienna Convention for 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*

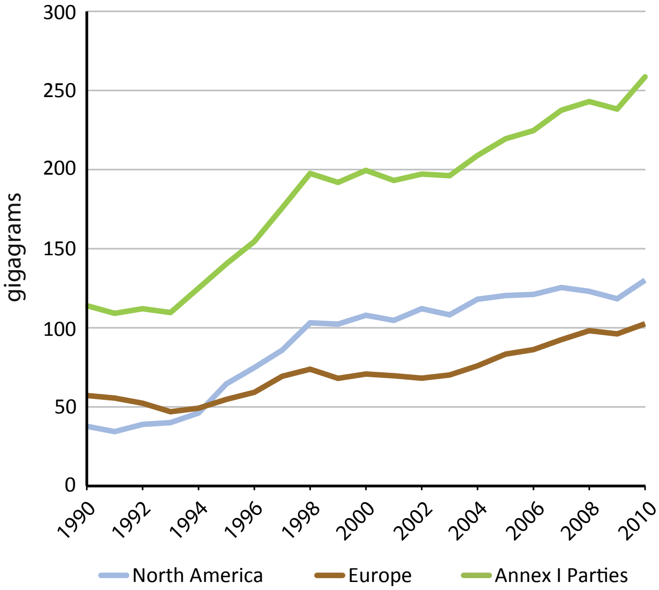



Figure 7: Consumption of hydrofluorocarbons (HFCs) in gigagrams, 1990-2010. Even when considered as suitable replacements from the point of view of protecting the ozone layer, some substitutes for ozone-depleting substances, such as HFCs, have a high warming potential and can have a significant impact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

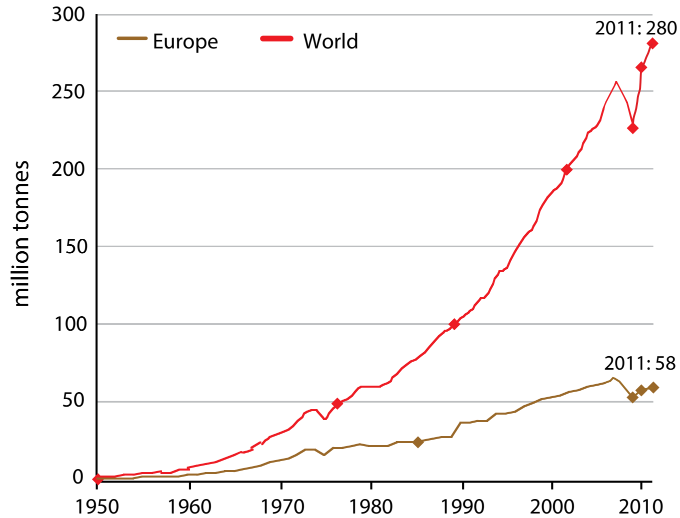



Figure 8: Plastics production in million tonnes, 1950-2011. After a dip around 2008-2009, world production reached a new record of 280 million tonnes in 2011. Plastic debris in the ocean is an issue of growing concern in recent years. *Source: PlasticsEurope (2012)*

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.

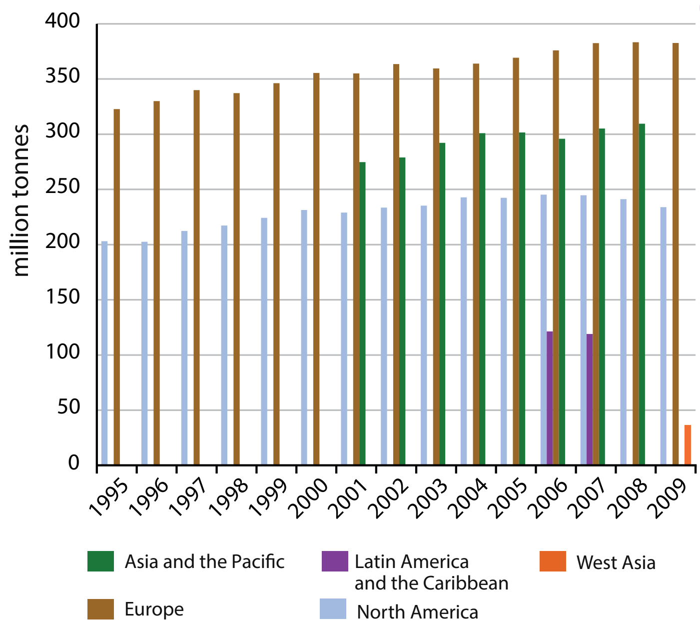



Figure 9: Municipal waste collection in different regions, 1995-2009. Data are sparse, and for Africa no regional data are available. *Source: UNEP EDE, compiled from UNSD (2012).*

## 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).

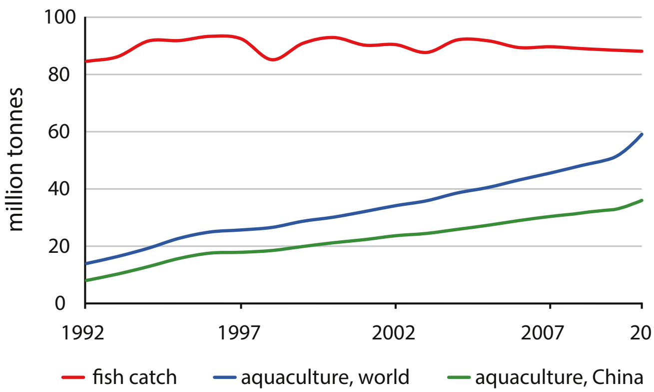



**Figure 10:** Fish catch and aquaculture production, 1992-2010. The global fish catch has stabilized at around 90 million tonnes per year. Aquaculture has been increasing significantly, particularly in China and other parts of Asia. *Source: UNEP EDE, compiled from FAO (2012b)*

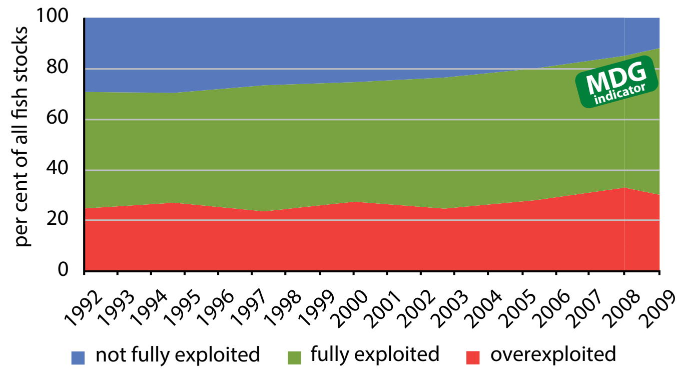



**Figure 11:** Fish stocks exploitation, 1992-2009. The percentage of fish stocks fully exploited or overexploited was 85 per cent in 2009. *Source: UNEP EDE, compiled from FAO (2012c)*

### 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).

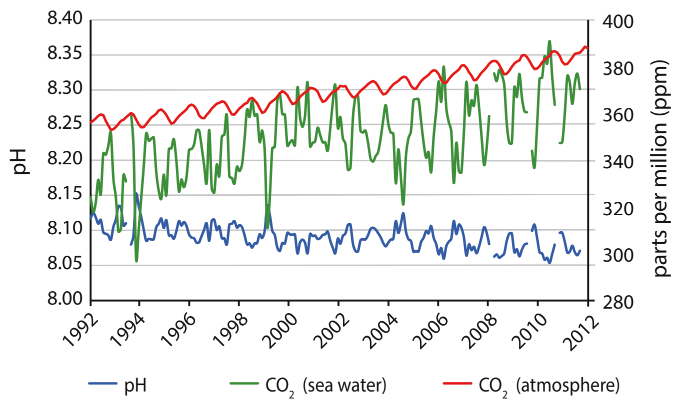



**Figure 12:** Atmospheric $CO_2$ concentrations and ocean acidification, indicated by increased partial pressure of $CO_2$ and lower pH of global mean surface water, 1992-2012. *Source: Caldeira and Wickett (2003), Feely et al. (2009), Tans and Keeling (2011)*

### 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

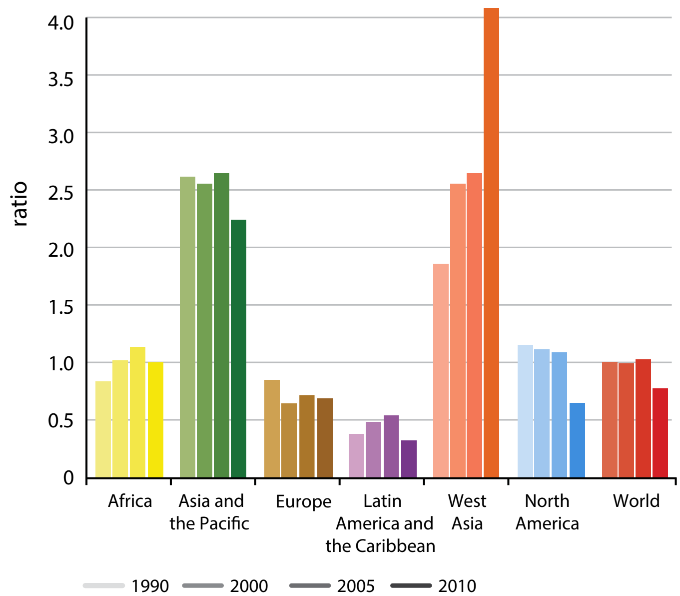



Figure 13: Forest harvest rates expressed as the ratio of roundwood production to growing stock in forests, 1990-2010. After decades of increases, harvesting of roundwood appears to have levelled off in recent years, except in West Asia. *Source: UNEP EDE, compiled from FAO (2005) for 1990, 2000 and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

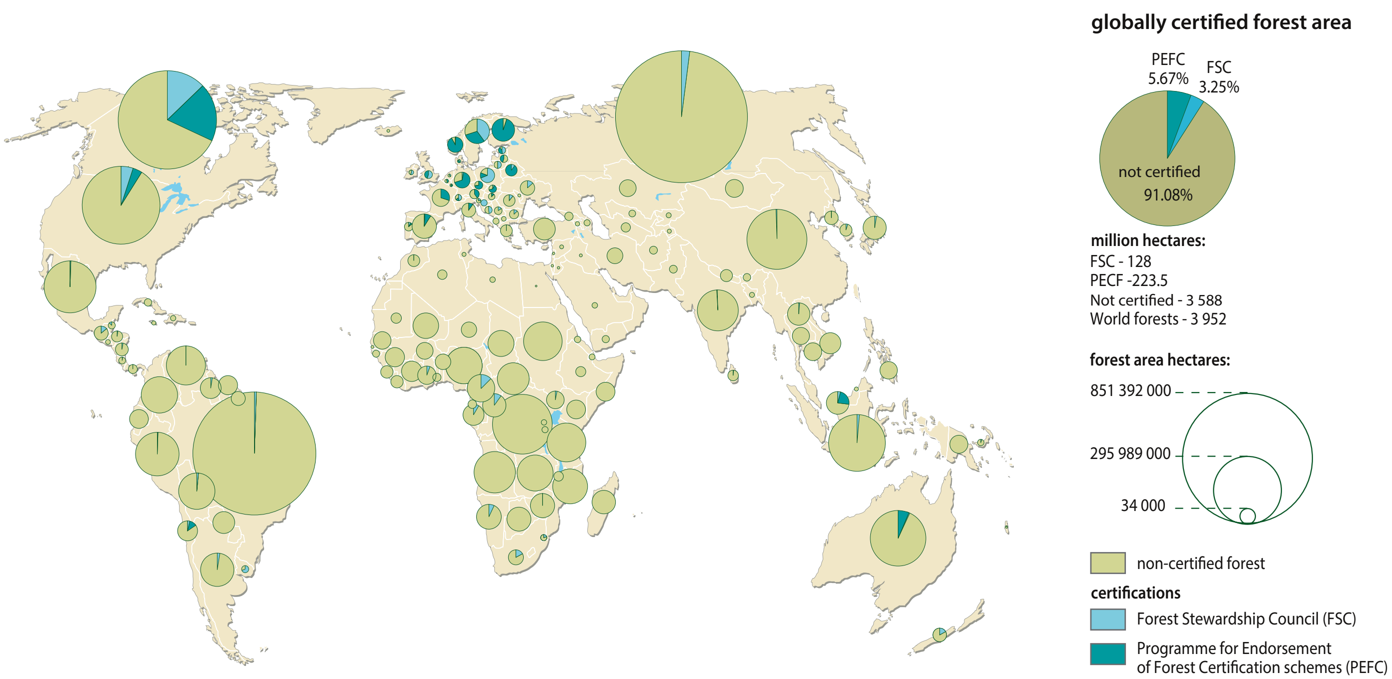



Figure 14: Forest certification by the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification schemes (PEFC) in 2011. There has been an impressive increase in forest certification, largely in Europe and North America. *Source: FSC (2012), PEFC (2012)*

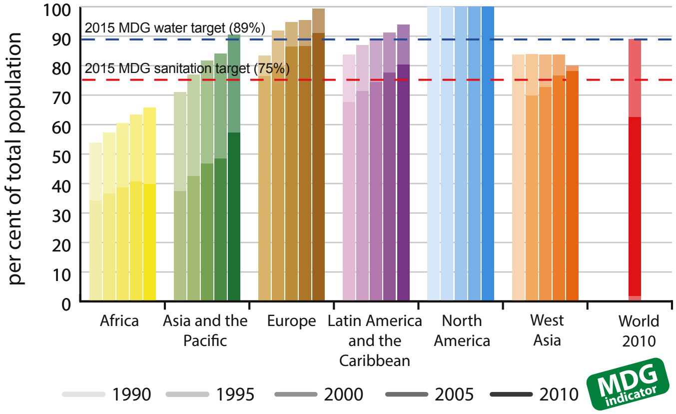



Figure 15: Proportion of the population with sustainable access to an improved water source (back rows) and to basic sanitation (front rows), 1990-2010. The global MDG target for safe drinking water has already been reached, unlike the target for basic sanitation. *Source: UNEP EDE, compiled from WHO/UNICEF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

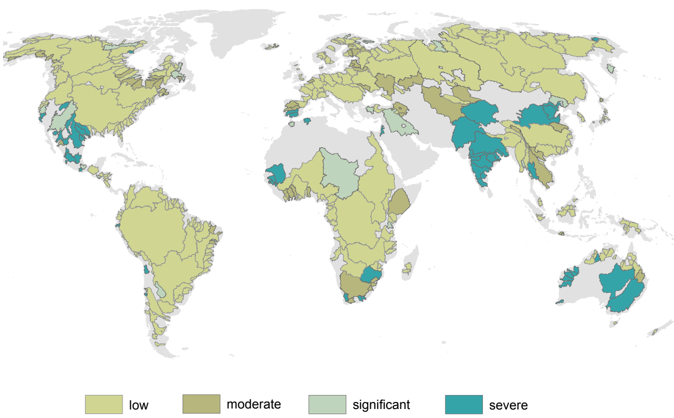



Figure 16: Annual average water scarcity in major river basins, 1996-2005. There is significant or severe blue water scarcity in 82 out of 405 river basins, affecting approximately 520 million people. *Source: Mekonnen* and *Hoekstra (2011)*

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)**.

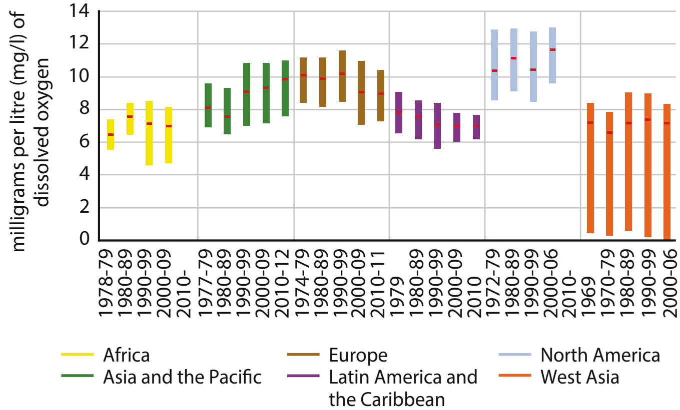



Figure 17: Levels of dissolved oxygen in surface waters, 1969-2010/11. The average is shown as red points, with surrounding uncertainty ranges in the colour of the region. Available data indicate that concentrations of dissolved oxygen are generally within the widely accepted limits of between 6 mg/l 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.

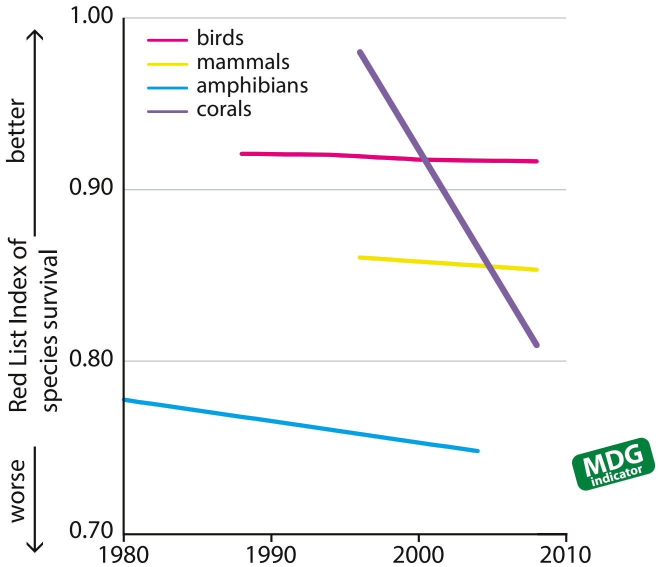



Figure 18: The IUCN Red List Index of Threatened Species, 1980-2010. The RLI measures the risk of extinction of species in seven classes, ranging from Least Concern to Extinct. A value of 1.0 indicates that species are not expected to become extinct in the near future, while 0 means a species is extinct. 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

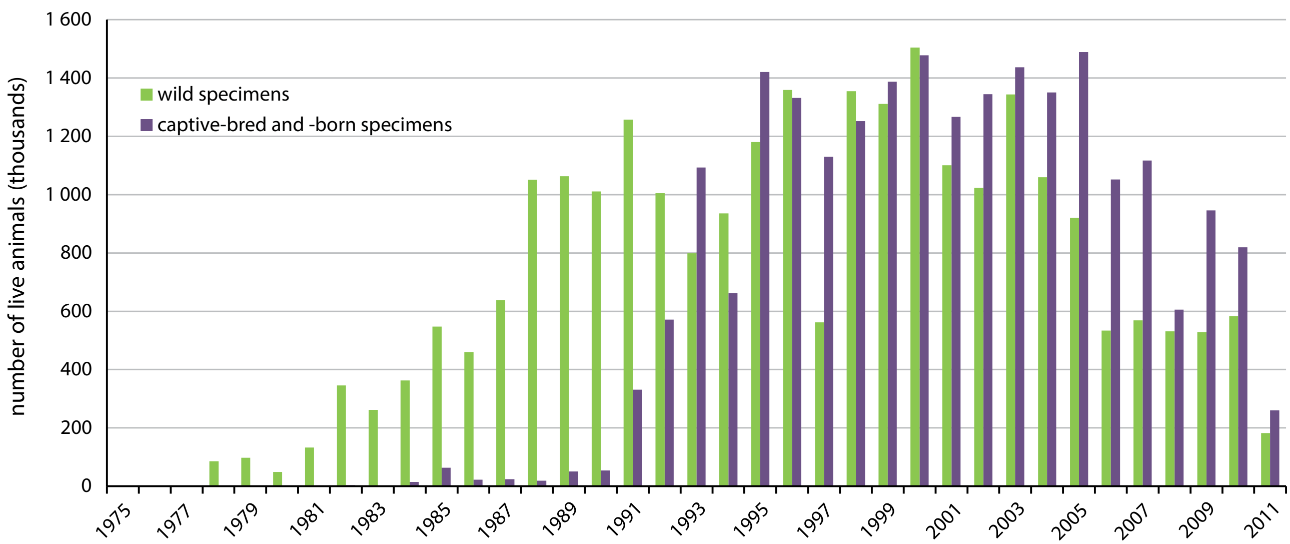



Figure 19: Trade in captive-bred and -born specimens compared with that in wild specimens, 1975-2011. *Source: CITES (2012)*

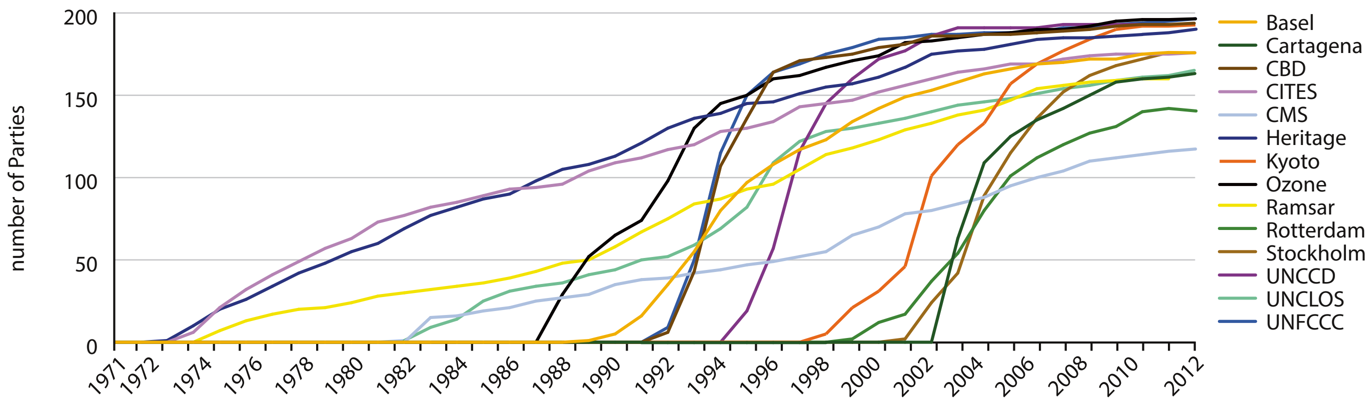



**Figure 20:** Number of Parties to Multilateral Environmental Agreements (MEAs), 1971-2012. Many MEAs and Conventions are reaching the maximum number of countries as signatories (Parties). Taking all 14 MEAs depicted here together, the number of Parties reached 90 per cent in 2012. Establishing and 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).

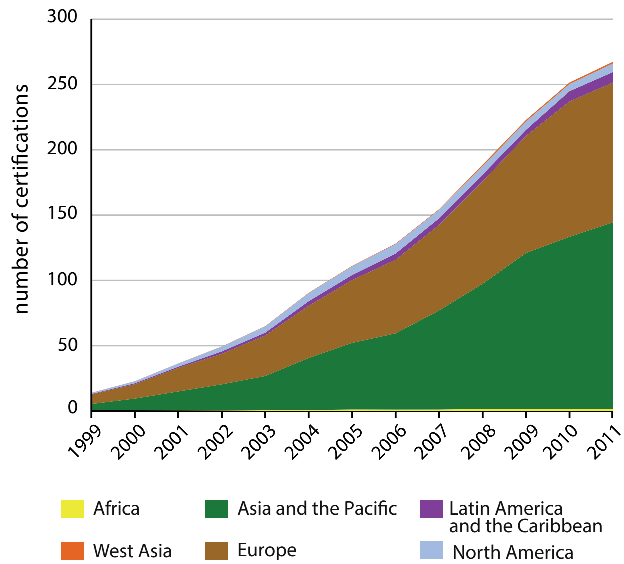



**Figure 21:** Number of ISO 14001 environmental management certifications, 1999-2011. ISO 14001 certification indicates that companies and other organizations are committed to adopt environmental management systems in terms of conforming to their own stated policies. Total certifications surpassed 250 000 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 |
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## 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#
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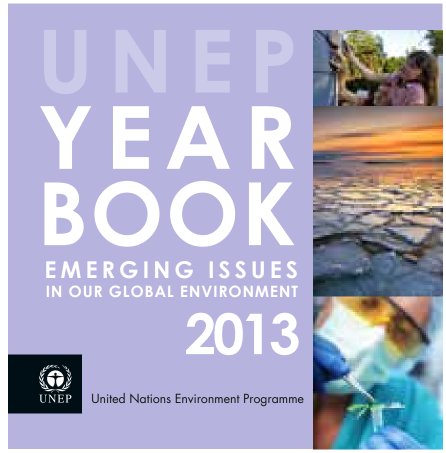


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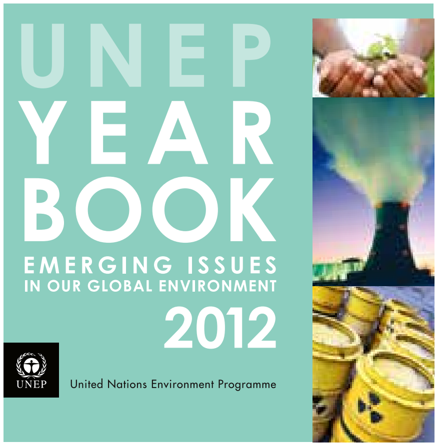


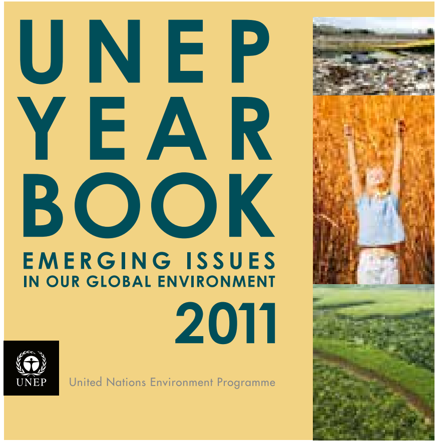


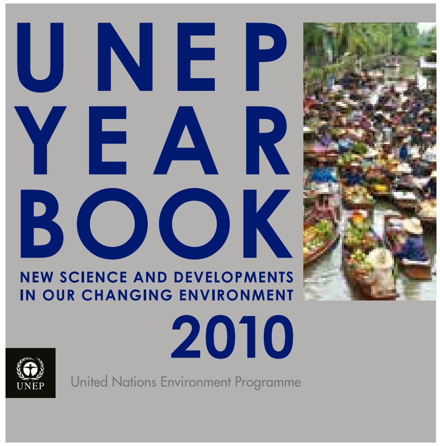


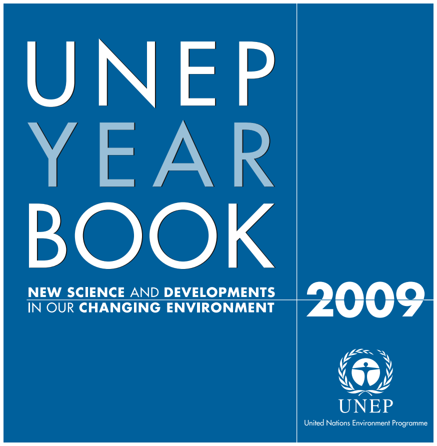


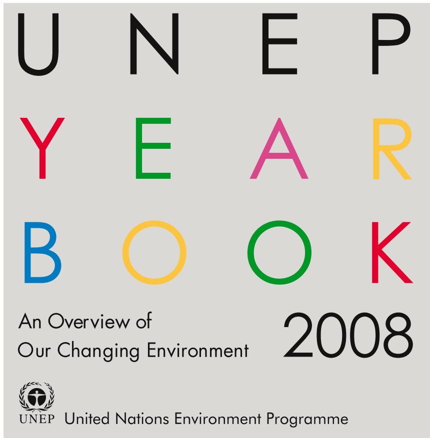


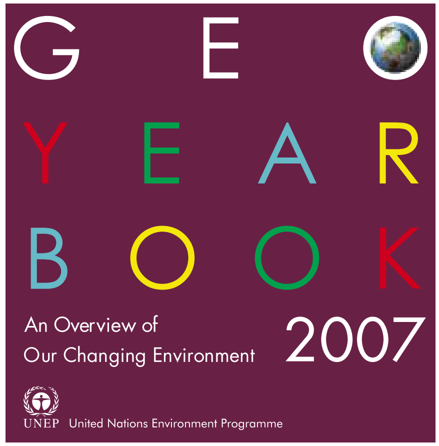


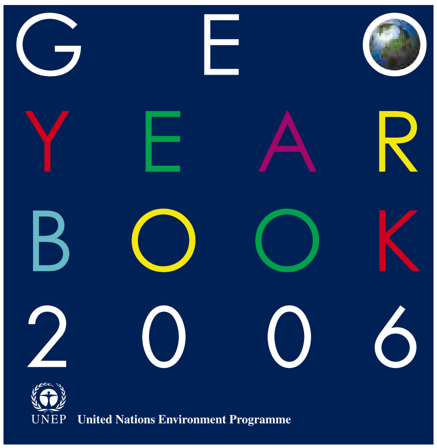


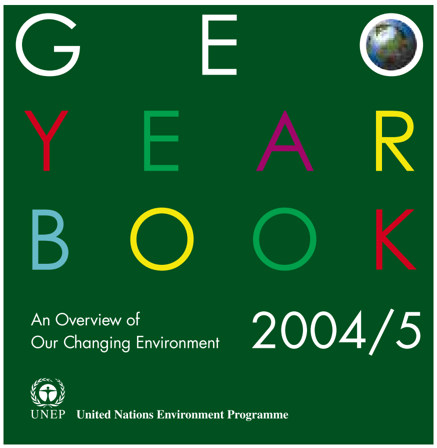


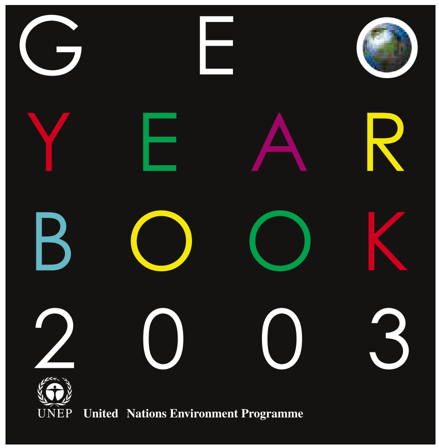


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# Rapid change in the Arctic

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**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.**

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# Minimizing chemical risks

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