6. Chemicals

During the past decade, growth of the European Union chemical industry has been higher than that of EU gross domestic product and than that of the chemical industry in either the United States or Japan. The chemical sector in central and eastern Europe, the Caucasus and central Asia experienced significant downturns during the early 1990s.

Emissions of many heavy metals and persistent organic pollutants in Europe have fallen during the past decade mainly as a result of the introduction of stricter national and regional regulatory frameworks, the use of improved pollution abatement systems by industry and the development of cleaner technologies.

There is a need for further global initiatives on mercury. High concentrations continue to be found in the Arctic environment despite cuts in European emissions. The neurological development of children in several native Arctic populations may be suffering damage as a result of dietary exposure to this toxic element.

Although there is much 'good news' about the effectiveness of policies leading to decreasing concentrations of several chemicals in the environment, there remain a number of instances where target levels are exceeded and which, for example, necessitate food recommendations for pregnant women. Dioxins and mercury in fish are two examples.

Monitoring and reporting of chemicals in Europe is uncoordinated with an imbalance between different substances. Pharmaceuticals and their metabolites are monitored occasionally. A relatively few selected heavy metals, persistent organic pollutants and pesticides seem to be the only groups of substances that are frequently monitored in most environmental areas, food, consumer products and human tissues. Integrated monitoring and exposure assessment should ideally consider all relevant sources during the life cycle of a product, emphasise the complete sequence of direct and indirect routes of exposure, and especially consider the exposure of sensitive groups. Most of these data are currently lacking.

Despite more than 25 years of regulation of chemicals in Europe, there remains a general lack of information and knowledge about the end uses and hazardous properties of most of the circa 30 000 existing substances currently on the EU market. With regard to existing chemicals, i.e. chemicals that were identified on the European market in 1981, current EU legislation only requires primary chemical producers and importers to provide limited information. Downstream users, e.g. industrial users, formulators and product manufacturers, do not have to provide any data. Information on the uses of specific substances is therefore difficult to obtain, and knowledge about subsequent environmental and human exposures from use of downstream products is scarce.

Current policy approaches to chemicals do not adequately address a number of issues that are of public concern e.g. combined exposures to multi-pollutants, and the impacts of some pollutants, e.g. endocrine disruptors and certain flame retardant chemicals present at low concentrations. Recognising the inadequacy of current procedures for chemical risk management, two recent and contrasting initiatives (the Stockholm convention on persistent organic pollutants and the EU chemicals policy White Paper) both incorporate precautionary-based approaches to risk prevention. The EU White Paper also places the burden of providing hazard information on the producer — a change in the development of European policy on chemicals.

6.1. Introduction

The chemical industry supplies a vast range of chemicals to virtually all sectors of the economy although the exact number of substances marketed within Europe is not known. The European inventory of existing chemical substances (EINECS) compiled by industry in 1981 identified 100 195 chemicals that year (although it is uncertain how many were actually marketed) and approximately 3 000 'new' substances have been brought onto the European market since that time (European Commission, 2001). A large proportion (about 30 %) of manufactured chemical products are consumed or further processed within the chemical industry itself. Basic chemicals undergo further treatment to be converted into chemical additives suitable for a variety of industrial, agricultural and consumer products. These include high value-added products such as medicines, adhesives, paints, dyes, plastics, fertilisers, pharmaceuticals, cosmetics and household products.

However, lack of access to information on chemical production, especially for hazardous chemicals, continues to impede policy-making in this field across Europe. The European coverage of monitoring data for halogenated organics in general and persistent organic pollutants (POP) in particular is rather patchy. Information on degradations, transformations, by-products and exposures to mixtures is also poor.

There is also increasing concern over the rising concentrations of a number of newly identified pollutants in the environment, such as alkoxy phenols, chlorinated paraffins and polybrominated flame retardants. Controls on the use and emissions of these substances may be required to prevent further wildlife and human exposure occurring.

This chapter reviews some of the key issues concerning the release of hazardous chemicals into the European environment. Trends in chemical production within the European region are discussed together with information on the key uses and routes leading to environmental releases. The state and impacts of chemical pollution within the environment are illustrated with selected examples that show the effectiveness of previous policy responses to these impacts. A number of areas are identified where better quality information is required (see Box 6.1.), and an assessment is made of the current main challenges to the reduction of risks resulting from environmental exposure to hazardous chemicals.

6.2. Production and uses of chemicals

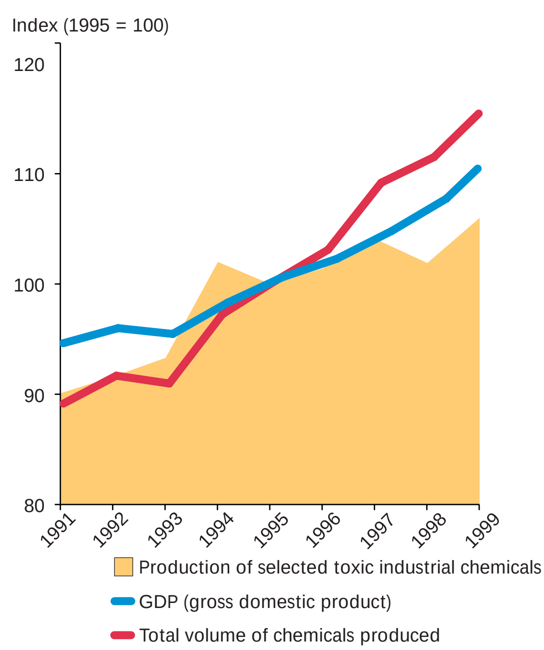
The EU is the largest chemical producing area in the world, accounting for 32 % of an estimated global turnover for chemical production of EUR 1 632 billion in 2001 (CEFIC, 2002). During much of the 1990s, the EU chemical industry grew faster than GDP (Figure 6.1), with total chemical production growing more strongly than other EU industry sectors over the past 10 years (3.2 % per year), and faster than the chemical sectors of the US (2.4 % per year) and Japan (1.4 % per year) (CEFIC, 2002). The drivers behind this growth are the stimulation of consumer demand for products based on new uses of chemicals, and the availability of many feedstocks (ethylene, benzene, propylene etc.) that are produced by the petrochemical industry (EEA, 1998).

In contrast to most western European (WE) countries, many countries in central and eastern Europe (CEE) experienced large falls in chemical production during the early 1990s in line with significant decreases in GDP that occurred during that time. Most CEE countries have since seen a recovery in chemical production although annual growth is generally lower than that in the WE countries. The chemical industry in eastern Europe, the Caucasus and central Asia (EECCA) has stabilised due to growth of exports (Breiter, 1997), but its competitiveness remains comparatively low with exports largely comprising raw materials rather than high value-added products.

The use and disposal of products containing hazardous chemicals has been linked to a range of potential impacts on the environment and human health. Concern is greatest for highly persistent chemicals which may remain in the environment for many years, and particularly those that can bioaccumulate in wildlife and humans. Table 6.1 provides some examples of environmentally persistent chemicals and their main uses.

Despite these concerns and the availability of some key data within the chemical industry, there is still very little robust and detailed information on pan-European production and import/export volumes of 'hazardous'

Figure 6.1. **Production volumes of chemicals relative to GDP for EU Member States 1991–1999**



Sources: EU toxic CMR (carcinogenic, teratogenic, mutagenic and reprotoxic chemicals) production data: Eurostat, 2001a; total EU chemical production volumes: CEFIC, 2000; GDP: Eurostat, 2001b

Main sources and uses of some environmentally persistent chemicals Table 6.1.

Source: Based on Swedish EPA, 1993

Abbreviation	Type of chemical	Applications/sources
ACB	Alkylated chlorobiphenyls	PCB substitutes
CP	Chlorinated paraffins	C_{10}-C_{30} alkanes with 30–70 % chlorine, plasticisers for use in polymer manufacture, metal working fluids, flame retardants, paint additives
Cyclodienes	Aldrin, endrin, dieldrin, endosulfan, chlordane, heptachlor	Pesticides
DDE	4, 4-dichloro-diphenyl-dichloroethene	Degradation product of DDT
DDT	4, 4-dichloro-diphenyl-trichloroethane	Insecticide (still used in tropical developing countries)
HAC	Halogenated aliphatic compounds	Volatile halogenated solvents such as tri- and tetrachloroethylene and ethylene dichloride tar
HCB	Hexachlorobenzene	Formerly used as a fungicide; also a combustion by-product
HCH	Hexachlorohexanes	Used as insecticide. Several persistent isomers including lindane (gamma isomer)
HMs	Heavy metals	Large numbers of potential sources e.g. combustion by-products, industrial processes, water treatment sludges, batteries, paints, anti-fouling coatings, zinc and cadmium from car tyres, mercury in dental amalgam, nickel from diesel, cadmium from phosphate fertilisers, arsenic, copper and chromium from wood preservatives
NPN	Nonylphenol	Stable degradation intermediate of nonylphenol ethoxylates used as detergents and additives in latex and plastic goods
Oms	Organo-metallic compounds	Mainly mercury, lead and tin compounds; mercury in paints; seed disinfectants; anti-sliming agents; lead in petrol; tin in marine anti-fouling agents
PAC	Polycyclic aromatic compounds	Heterocyclic aromatic compounds, derivatives of PAHs (such as nitro-, chloro- and bromo-PAHs)
PAE paint	Phthalatic acid esters (phthalates)	Plasticisers (e.g. in PVC — polyvinyl chloride); additives, varnishes; cosmetics; lubricants
PAH	Polycyclic aromatic hydrocarbons	Crude oil; by-products of incomplete combustion by-products of fuel and wood; creosote wood preservative; coal tar
PBB/PBDE	Polybrominated biphenyls/diphenyl ethers	Intermediates for chemical industry; brominated flame retardants
PCB	Polychlorinated biphenyls (and their degradation products)	More than 200 substances (but not all congeners are found in technical product or in the environment); insulating fluid in transformers; cables; plasticisers; oil and paint additives; hydraulic fluids; combustion by-products
PCC	Polychlorinated camphenes	Pesticides e.g. toxaphene, campechlor
PCDD/F	Polychlorinated dibenzo-p-dioxins/dibenzofurans, collectively referred to here for simplicity as 'dioxins'	More than 200 substances; mainly by-products from combustion and other chemical processes, such as incineration; paper pulp bleaching and metal refining; as contaminants impurities in PCBs, PCP, transformer oils; and chlorinated phenolic herbicides; contaminants; incinerators; paper pulp bleaching
PCDE	Polychlorinated diphenyl ethers	By-products of PCP manufacture; PCB substitutes; pesticide additives
PCN	Polychlorinated napthalenes	Insulating fluids in capacitors; flame retardants; oil additives; wood preservatives, pesticides; combustion by-products
PCP	Pentachlorophenol	Fungicides; bactericides; wood preservatives
PCS	Polychlorinated styrenes	By-products of chemical processes
PCT	Polychlorinated terphenyls	PCB substitutes

chemicals accessible to policy-makers and the public. However, EU production volumes of selected toxic chemicals (i.e. those classified as carcinogenic, teratogenic, mutagenic and reprotoxic, CMR substances, according to EU Directive 67/548/EEC) increased during the 1990s, together with total chemical production as shown in Figure 6.1.

It should be noted that production volume alone is not necessarily an indicator of potential human exposure or environmental risk. In particular, as toxic chemicals will be used in various economic activities, emissions may take place during any stage of the chemical life cycle, from production and use through to waste treatment and disposal. Emissions may therefore vary on a case-by-case basis. Knowledge of both the production processes and subsequent emissions is therefore necessary in order to support activities aimed at reducing exposures. New mechanisms to inform consumers on the exposure to chemicals from product use have been proposed in the EU chemicals policy White Paper (European Commission, 2001).

> ☹ Chemical production within the EU is increasing faster than GDP, illustrating an increasing 'chemical intensity' of EU GDP. The volume of selected hazardous chemicals produced is also increasing, albeit at a slower rate than the production of all chemicals.

6.3. Chemicals in the environment: emissions and concentrations of selected chemicals

Table 6.1 shows that environmentally persistent chemicals have a range of diverse uses, and hence the potential to be released into the environment (together with their degradation products) during production or product life cycles i.e. from raw material acquisition to final waste treatment and disposal. Actual emissions, concentrations and exposures of ecosystems, wildlife and humans will, however, vary between chemicals.

6.3.1. Emissions — heavy metals

Of the many heavy metals released from various products and processes, cadmium, lead and mercury are of great concern to human health because of their toxicity and their potential to cause harmful effects at low concentrations and to bioaccumulate.

Significant progress has been made in reducing emissions to air of these metals in the European region with 1995 emissions being about 50 % of 1990 levels and decreasing further to 40 % by 1999. Lead emissions in 1999 were down to about 17 000 tonnes/year and mercury and cadmium to 200 and 400 tonnes/year, respectively (EMEP, 2002).

All three groups of countries in the European region achieved absolute decreases of emissions (on a tonnage basis) for the three heavy metals over the period 1990–99. Figure 6.2. presents the data for the country groupings weighted by GDP. On this basis, WE released significantly lower amounts of the pollutants in 1999 than either CEE or EECCA. WE also exhibited the greatest percentage reduction in emissions for the period 1990-99.

Although controlling diffuse emissions of cadmium and mercury remains problematic (e.g. batteries), point source emissions of these metals have declined as a result of improvements in sectors such as wastewater treatment, incinerators and the metals sector. Factors contributing to this include large decreases of lead emissions from the transport sector following the introduction of unleaded petrol in the early 1990s (see Chapter 2.6.); continuing moves away from the use of lignite in the eastern European energy sector; and the introduction of improved pollution abatement technologies across a range of industrial and waste treatment sectors.

> ☺ Emissions of the toxic metals cadmium, lead and mercury decreased during the1990s, with emissions in 1999 being 40 % of those in 1990.

A number of recent policy initiatives has been introduced at the international level to address concerns raised by heavy metal emissions. The United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLTRAP) 1998 Aarhus protocol on heavy metals targets cadmium, lead and mercury and requires countries to reduce their emissions of these three metals to below their 1990 levels (or an alternative year between 1985 and 1995).

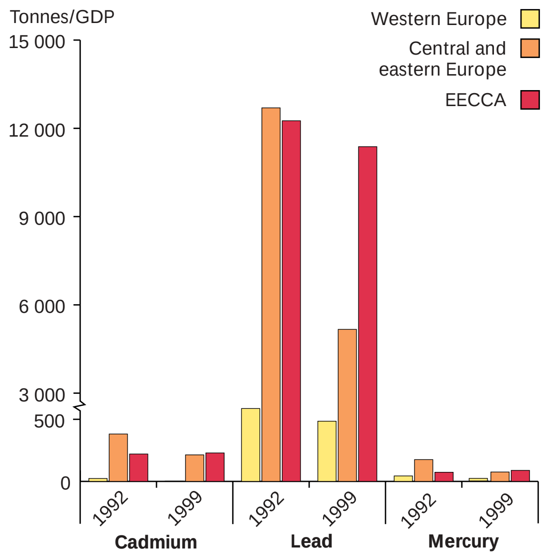
Similarly, the Fourth Ministerial Conference of the North Sea States committed signatory countries to end discharges, emissions and losses of hazardous substances, including cadmium, lead and mercury compounds by the year 2020. This target was incorporated into the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR convention) and the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM convention) in 1998. Although atmospheric emissions of these three metals are decreasing, there is clearly still much to be done under the OSPAR and HELCOM conventions. Through cessation of anthropogenic emissions of hazardous substances by 2020, these conventions aim to achieve concentrations close to background levels for those substances occurring naturally e.g. the heavy metals, or close to zero for man-made substances. Selected heavy metal emissions to inland and marine waters are addressed in Chapter 8.

The need for further global initiatives on mercury has also recently been highlighted (TemaNord, 2002; UNEP, 2002). Some European countries have had success in reducing emissions of this metal (Table 6.2) through a combination of substitution, e.g. of mercury cells used in chlorine production, and improvement in abatement technologies especially flue-gas cleaning.

More worryingly, however, a new report from AMAP (2002) raises concern over increasing levels of mercury in the Arctic, which may be acting as a global sink for the metal transported over long distances through the atmosphere. The most significant global man-made source is combustion, particularly of coal in Asia, which as a region is now responsible for half the world's mercury emissions, and Europe. Although European and North American emissions have decreased significantly since the 1980s, mercury concentrations have clearly continued to rise in some Arctic areas, and neurological development in the children of some native Arctic populations may be suffering damage through dietary exposure to the metal.

The TemaNord (2002) assessment notes that mercury and its compounds share many properties with some of the persistent organic chemicals listed in Table 6.1. The problem of mercury remains under active consideration by the United Nations Environment Programme (UNEP). Its Global Mercury Assessment Working Group meeting in September 2002 concluded that there was sufficient evidence of significant global adverse impacts to warrant international action to reduce the risks to human health and/or the environment arising from the release of mercury into the environment. It agreed on an outline of possible options to address the adverse impacts of mercury at the global, regional, national and local levels and identified a

European emissions (tonnes/GDP) of cadmium, lead and mercury in 1990 and 1999 Figure 6.2.



Notes: GDP as trillion US$. Data were not available for the following countries: Andorra, Kyrgyzstan, Liechtenstein, Malta, Monaco, San Marino, Tajikistan, Turkmenistan and Uzbekistan. Negative GDP growth was observed for eastern Europe, the Caucasus and central Asia during 1990–99.

Source: UNECE/EMEP Convention on Long-Range Transboundary Air Pollution

Trend of mercury emissions in Nordic countries (tonnes) Table 6.2.

Denmark		1982–83	1992–93
	Air	4.0-7.4	1.9-2.5
	Water	1.4	0.25
	Soil	1.4-1.6	0.2-0.3
	Total	6.8-10.4	2.4-3.1
Finland		1990	1997
	Air	1.1	0.6
Norway		1995	1999
	Air	1.1	1.1
	Water	0.6	0.4
	Soil	0.5	0.3
	Total	2.2	1.8
Sweden		1990	1995
	Air	1.5	0.9
	Water	0.2	0.6
	Total	1.7	1.5

Source: TemaNord, 2002

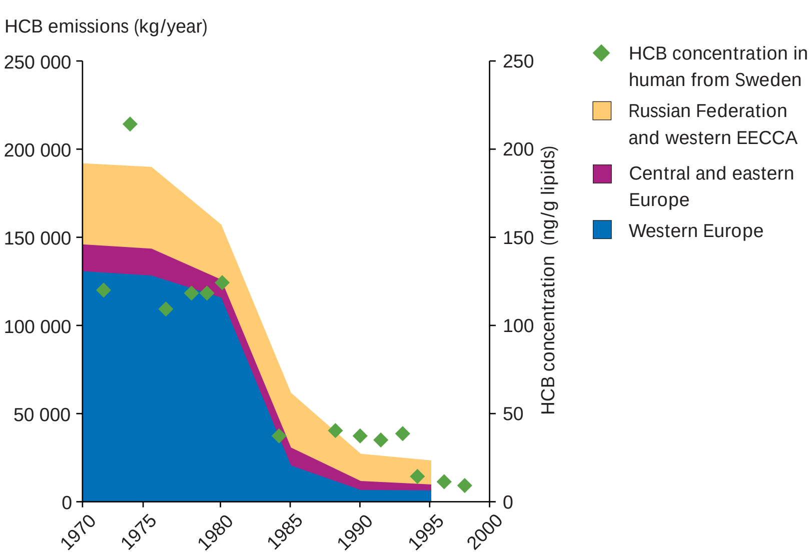
Box 6.1. Monitoring chemicals in the environment

There are many established regional or localised monitoring programmes that sample marine or land-based environmental media to monitor temporal trends in persistent organic pollutant (POP) concentrations e.g. the UNECE collaborative monitoring programmes, and EMEP initiatives based around the Convention on Long-Range Transboundary Air Pollution. However, there remains no comprehensive source of comparable pan-European data that would enable a clear picture of the extent of pollution by POPs to be established. Acknowledging the lack of comparability of present monitoring schemes due to the varied methodologies used, UNEP Chemicals has recently established a global network for monitoring of chemicals in the environment which aims to harmonise the methodologies and analyses of chemicals in the environment.

A joint EEA/European Science Foundation study on European monitoring of chemicals (EEA, 2003) concludes that: 'Monitoring is partial, uncoordinated, sometimes out of date, and, on many occasions, irrelevant to current policy needs; centralised knowledge about chemical monitoring activities that are conducted for different purposes is incomplete; there is a lack of integrated exposure assessments that consider all relevant exposure routes; there are huge data gaps in information on chemical exposures and impacts, especially concerning vulnerable groups and ecosystems; filling the data gaps adequately, via conventional approaches, would take several decades and millions of euro.'

New approaches to monitoring and exposure assessments are therefore needed to complement conventional approaches, which have focused mainly on monitoring the environmental media of air, water and soil. These now need to be streamlined and supplemented by macro-monitoring which focuses on material flows of chemicals into and through the environment, and micro-monitoring which focuses on micro-pollutants in biological issues or in sensitive parts of the technosphere such as sewage effluent and the stratosphere. These more integrated exposure assessments would cover a product's life cycle, focus on the intrinsic properties of priority chemicals, for example bioaccumulation and persistence, and make intelligent use of 'proxies' for the mixtures and other complexities that bedevil the control of chemicals in the environment.

Figure 6.3. **Total HCB emissions in Europe and concentrations in human milk in Sweden**



Notes: Data were not available for: Andorra, Armenia, Azerbaijan, Cyprus, Georgia, Kazakhstan, Kyrgyzstan, Liechtenstein, Malta, Monaco, San Marino, Tajikistan, Turkey, Turkmenistan and Uzbekistan. Data available for the former German Democratic Republic (to 1990) were included in the western European country grouping.

Sources: HCB emission data: Münch and Axenfeld, 1999 ; human milk data: Norén and Meironyté, 2000

range of possible immediate actions in light of findings on the impacts of mercury. The UNEP Governing Council addressed the matter at its session in February 2003.

6.3.2. Emissions — persistent organic pollutants

Persistent organic pollutants (POPs) are a group of specific chemicals regulated under international agreements to reduce or eliminate their use and release to the environment. The CLTRAP POPs protocol (UNECE, 1998) lists 16 substances as POPs, and the Stockholm convention on persistent organic pollutants (2001) identifies a subset of 12 of these substances targeted for release reduction or elimination. The manufacture, use or importation of 11 POPs has already been banned under EU legislation. The 16 POPs identified under the UNECE protocol are: aldrin*, chlordane*, [chlordecone*], DDT*, dieldrin*, endrin*, heptachlor*, hexachlorobenzene (HCB*), [hexachlorocyclohexane (HCH)], mirex*, toxaphene*, polychlorinated biphenyls (PCBs*), [hexabrominated biphenyls (HBBs)], polychlorinated dibenzodioxins and the related furans — known collectively as dioxins — and [polyaromatic hydrocarbons (PAHs)]. All the substances listed are also defined as POPs under the UNEP POPs convention, except those shown in [square brackets] and * denotes substances whose manufacture, importation or use within the EU has been prohibited.

The international agreements also have mechanisms by which other chemicals that meet defined criteria of toxicity, persistence and ability to bioaccumulate can be added to the defined POPs list. POPs are released into the environment either as a result of their intentional use e.g. as pesticides such as lindane or DDT, as contaminants of other products, or as by-products from industrial

Although hexachlorobenzene emissions have decreased throughout Europe, the rate of decrease has slowed markedly since 1990. Further reductions in hexachlorobenzene emissions with its eventual elimination from use should be feasible.

Hexachlorobenzene remains widely dispersed throughout the region due to long-range atmospheric transport processes and local 'hot spots' that reflect high levels of local use or contamination.

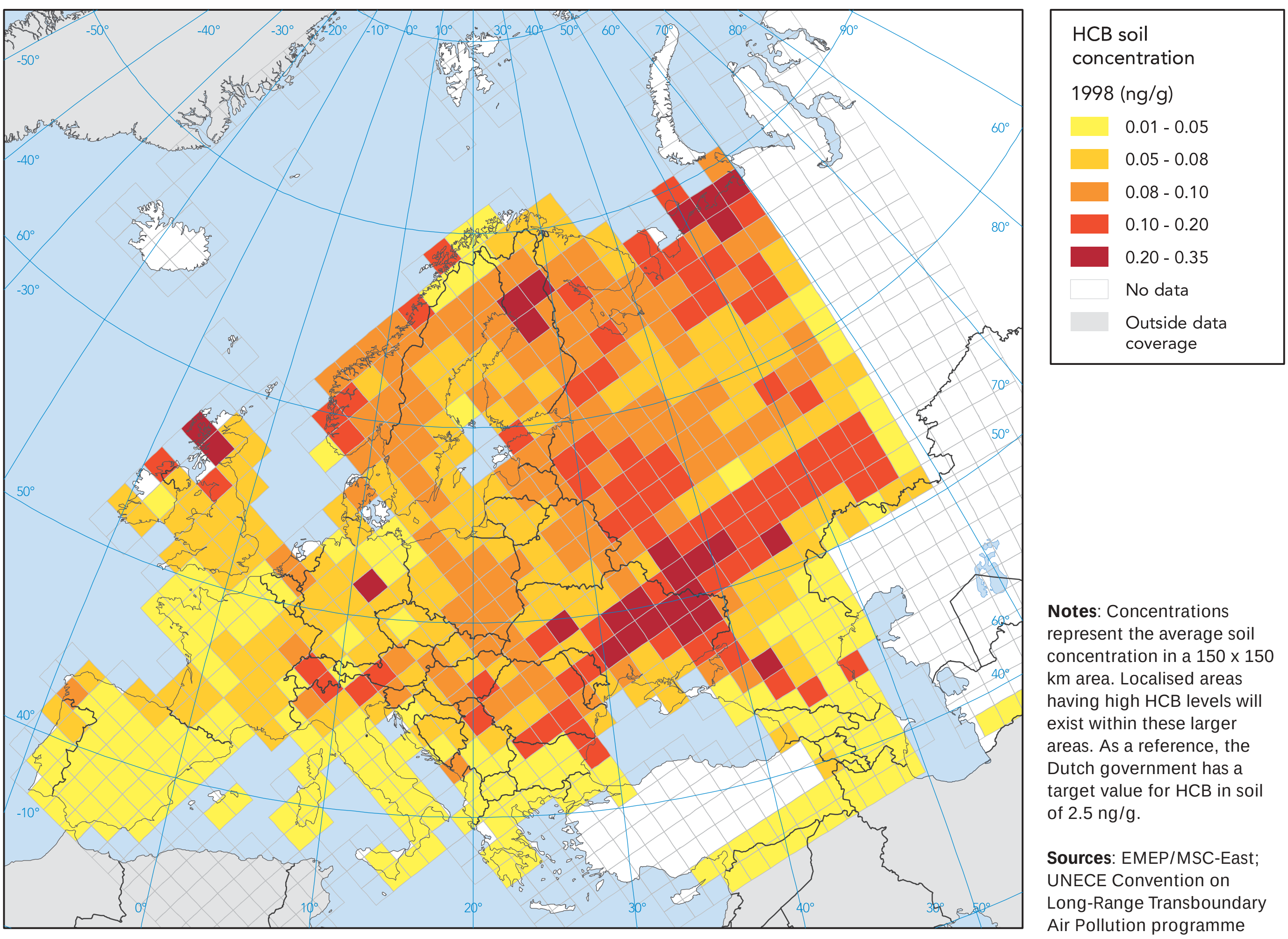
processes e.g. dioxins, PAHs, HCB. The long-range transportation and transboundary distribution of POPs means that they pose an environmental threat not only within the country in which they are used but also to geographically distant countries (Swedish EPA, 1998a). For example, residues from past global use of POPs are found in many remote regions of the Arctic, Baltic and other areas despite their use or emission never having taken place in these regions. Environmental and health monitoring programmes, especially in remote environments, are crucial in identifying future problems resulting from long-range transport of pollutants.

Concentrations of several of the priority POPs have decreased over recent decades due to a reduction in their production and use, accompanied by bans and other restrictions. Hexachlorobenzene (HCB) provides one example of recent reduction trends, and the link between decreased emissions and reduced concentrations in breast milk (Figure 6.3). HCB is a potential human carcinogen that was used as a pesticide/fungicide from the 1950s until the early 1980s. Its use as an agricultural chemical was banned in many European countries by the mid-1980s (Münch and Axenfeld, 1999). The presence of hazardous chemicals in breast milk is of concern since babies are particularly sensitive to low doses of chemicals and breast milk is, in most cases, their main source of early nutrition.

Despite the banning of HCB as an agricultural chemical, it continues to be released via a number of other pathways e.g. via chlorinated solvent manufacture, as a contaminant in other pesticide formulations and from combustion processes, and therefore remains widely dispersed in the environment (Figure 6.4).

There are also positive trends in other parts of the European environment as regards chlorinated organic compounds. The pulp and paper industry is very important to the

Modelled HCB background soil concentrations in Europe, 1998 Figure 6.4.



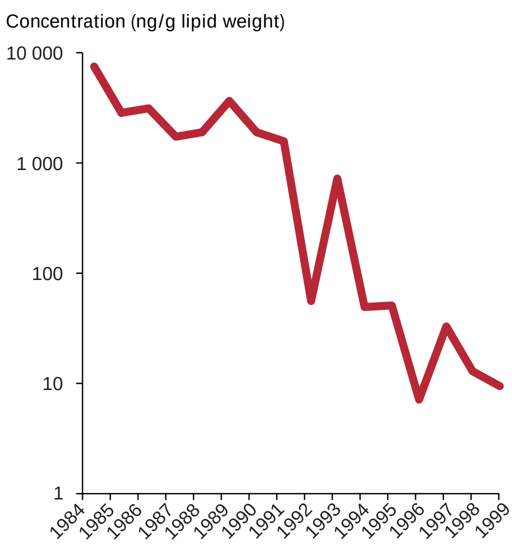
Notes: Concentrations represent the average soil concentration in a 150 x 150 km area. Localised areas having high HCB levels will exist within these larger areas. As a reference, the Dutch government has a target value for HCB in soil of 2.5 ng/g.

Sources: EMEP/MSC-East; UNECE Convention on Long-Range Transboundary Air Pollution programme

Finnish economy, but the industry uses a lot of water and different chemicals in the production processes. One of the main sources of the harmful organic compounds discharged to watercourses has been bleaching processes. Before the early 1980s, bleaching processes were conventional, using elemental chlorine with partial substitution with chlorine dioxide. Between 1985 and 1995, the use of elemental chlorine was phased out and effluent treatment was improved. As a result, the amount of chlorinated organic compounds found in receiving waters has decreased markedly (Figure 6.5).

Figure 6.5. **The concentration of organic chlorine compounds originating from pulp bleaching in incubated mussels**

Source: Herve *et al.*, 2002



Box 6.2. Survey of dioxin sources in the Baltic region

Dioxins and furans are very toxic, lipophilic and persistent. In order to establish an overview of the situation concerning dioxin sources in the Baltic region, the Danish Environment Protection Agency initiated and financed a survey of dioxin releases in the year 2000 from some countries for which detailed dioxin surveys did not already exist.The main route for direct releases to the environment is emission into air. The air emissions from the Baltic countries were previously estimated in the EU financed project entitled POPcycling Baltic. Releases from eastern European countries have been relatively low compared to the western European countries, due mainly to the more widespread use of waste incineration in western Europe.

From the middle of the 1980s, releases from the western European countries decreased considerably — a trend that continued during the 1990s. However in 1993–95 per capita emission from the western European countries was still higher than from eastern European countries.

New studies of air emissions in Poland show that the main sources are waste incineration and uncontrolled combustion processes such as landfill fires and burning of household waste.

Air emissions are also the main source in Estonia, Latvia and Lithuania; 'power generation and heating' and 'uncontrolled burning processes' are the most important source categories in all three countries.

Source: Lassen, *et al.*, 2003

Mirroring the reduced emissions and concentrations of many POPs, human exposure to POPs and other substances with similar properties has also decreased over the past few decades (Figure 6.6; see also Box 6.2.).

With the exception of the flame retardant polybrominated diphenyl ethers (PBDEs — see Box 6.3.), all substances declined in absolute concentration values during this time. The spatial distribution of the contaminants also changed over the time period studied.

Although the environmental concentrations of some chemicals currently defined as POPs have fallen, this is not so for all of them. For example, PCB concentrations remain sufficiently high in several Arctic areas to raise concerns about the possible ecological effects of disturbances that they may cause to the immunological, reproductive and neurobehavioural systems of marine mammals and other animals (AMAP, 2002). Elevated levels of PCBs in maternal pregnancy serum have also been observed in the Faroe Islands' population where exposure levels were three to fourfold higher than in other studies performed in the United States, the Netherlands, Germany and in northern Quebec (Longnecker *et al.*, 2003).

There is also concern about the wide dispersion and increasing environmental concentrations of persistent, bioaccumulative and toxic (PBT) chemicals that are not currently classified as POPs such as chlorinated paraffins and certain flame retardants (Figure 6.7). A number of such chemicals are included in the OSPAR and HELCOM conventions which aim for the cessation of emissions, discharges and losses of these substances within a generation i.e. by 2020. For example, the extremely persistent fluorinated compound used as a stain repellent and in other applications, has been measured in some Arctic animals (AMAP, 2002). The principal manufacturer announced a voluntary phase-out of this chemical in 2000, after its persistency and bioaccumulative properties in humans were demonstrated. Several bodies currently advocate the classification of these PBT substances as 'new' POPs under the POPs protocol and the Stockholm convention.

Another potentially significant environmental problem arises from the large quantities of old and out-dated pesticides (some of which

Concentrations of a variety of contaminants in human milk from Sweden have decreased significantly since the 1970s. The contaminant levels reflect the decreasing levels of general environmental contamination and background levels in the population.

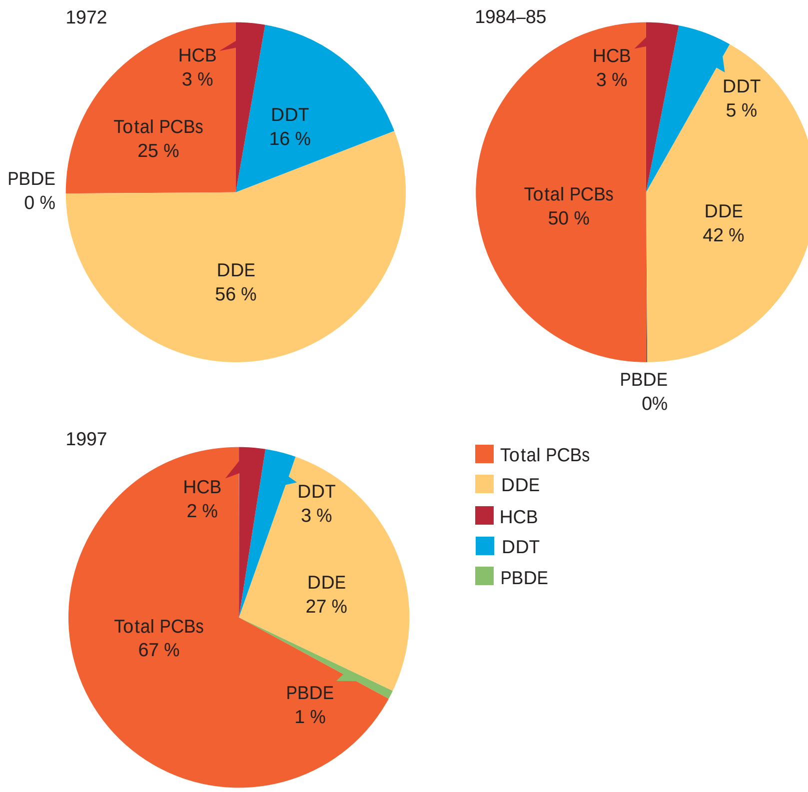
There is concern over the dispersion of polybrominated flame retardants in the environment. Concentrations of polybrominated diphenyl ethers have risen steeply in Swedish human milk since the 1970s despite these substances never having been manufactured in that country. Although concentrations are now declining, they remain many times higher than previously.

are POPs) that are known to be stockpiled in many CEE countries and EECCA (see Table 6.3). Storage facilities for these chemicals are frequently inadequate, ranging from simple holes in the ground and open sheds in fields to decomposing concrete bunkers. In many cases the poor storage facilities create high levels of potential risk to both the environment and humans (Klint, 2001). Factors contributing to the build-up of unwanted pesticide stocks include poor stock management, inappropriate marketing, lack of adequate regulatory infrastructures, poor product packaging, purchases (or donations) of unsuitable products in impractical quantities, and prohibition of use (Jensen, 2000).

Progress in destroying stocks of unwanted pesticides is impeded by a lack of information on quantities and location. Although the quantities referred to in Table 6.3 are from the latest official compilation produced by the International HCH and Pesticides Association (IHPA), it is recognised that they are subject to great uncertainty. The estimates will be revised by IHPA in June 2003 taking into account newly available data, although developing an accurate inventory will necessarily be a long-term goal for some countries.

A number of international organisations have programmes for the collection and disposal of obsolete pesticides in developing countries and those with economies in transition. These include the Food and Agriculture Organization of the United Nations (FAO), UNEP, Inter-Organization Programme for the

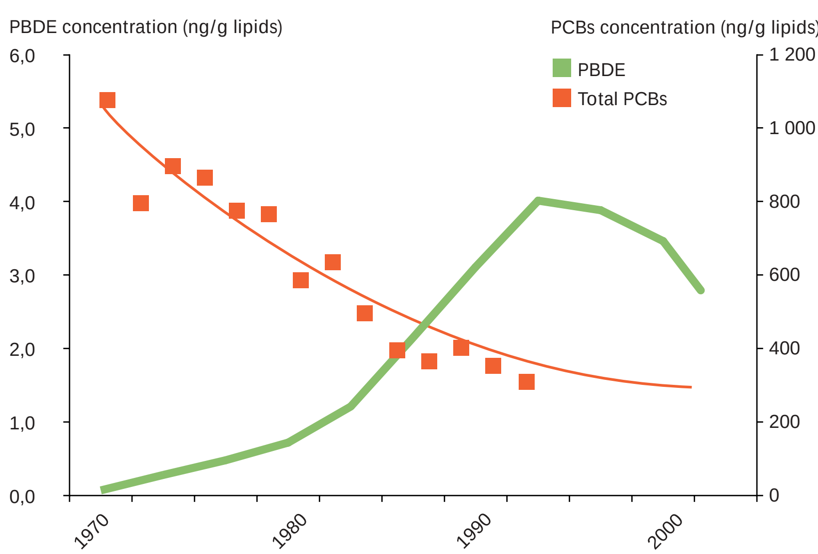
Amounts and distribution of organohalogen contaminants in human milk — Figure 6.6.



Notes: The area of the pie charts is proportional to the total sum of the contaminants in human milk from Sweden in the given years. Some metabolites e.g. DDE derived from DDT have much higher concentrations in milk than the original pollutant.

Source: Norén and Meironyté, 2000

Concentrations and temporal trend of polybrominated diphenyl ethers (flame retardant substances) and polychlorinated biphenyls in human milk, 1972–2000 — Figure 6.7.



Sources: Swedish human milk data: Norén and Meironyté, 2000; Peltola and Ylä-Mononen, 2001

Table 6.3. **Estimated stockpiles of obsolete pesticides in central and eastern Europe and EECCA countries**

Notes: The quantities shown are based on estimated data in 1990s. New estimates will be reviewed and the inventory updated by IHPA in June 2003.

Source: IHPA, 2001

Country	Production and estimated waste in tonnes	Related problems in soil and water
Albania	Former lindane production sites	
Azerbaijan	20 000	
Armenia	Incomplete information but known to possess considerable stocks of obsolete pesticides	
Belarus	6 000	
Bosnia-Herzegovina	Data not available	
Bulgaria	4 000	
Croatia	Some estimates exist	
Czech Republic	The main stocks of obsolete pesticides were destroyed in early 1990s. Inventory and control is done by new Waste Act and new Chemical Act	
Estonia	700	
Eastern Germany (former)	Several 100 000s	Large-scale soil pollution with HCH and DDT
Georgia	2 000 (1999 report)	
Hungary	Ideas for inventory presented and start-up of pilot project	49 000 tonnes soil?
Kazakhstan	Production sites in west Kazakhstan, east Kazakhstan in Akmolinsk	Large diffuse soil pollution. Former agricultural aerodromes
Kyrgyzstan	171	Large-scale diffuse soil pollution? In former agricultural aerodromes in the southern regions (Osh), groundwaters are polluted by pesticides and fertilisers
Latvia	2 000	
Lithuania	3 280	3 500 tonnes polluted soils
FYR of Macedonia	33 000–38 000. Former lindane production	
Republic of Moldova	6 600	
Poland	50 000–60 000. Large numbers of time-bombs (bunkers) stored in the former producer's area	Direct spread from bunkers to surrounding soils and threat to groundwater
Romania	1 030	Big chemical plants at Bacau, Râmnicu, Vâlcea, Craiova, Pitesti and Turda historically produced large quantities of pesticides
Russian Federation	17 000–20 000. Former production at 23 factories	
Slovenia	350–400	
Slovak Republic	Ideas for inventory presented and start-up of pilot project	
Tajikistan		Large areas of soil pollution in the Amu-Darya and Syr-Darya basins
Turkmenistan	1 671	
Ukraine	15 000	Large regional soil pollution
Uzbekistan	10 000–12 000	Large diffuse soil pollution in Fergana, Andijan and Khorezm regions. Agricultural aerodromes

Sound Management of Chemicals, World Health Organization (WHO), United Nations Industrial Development Organization (UNIDO), industry and various non-governmental organisations. Signatory developed countries to the Stockholm POPs convention (UNEP, 2001) are also obliged to cooperate with countries requiring assistance in identifying POPs stockpiles, and ensure that they are managed or disposed of in an environmentally sound manner, which it is hoped will improve the existing situation in many countries.

6.4. Exposures and impacts of chemicals: selected illustrations

Human exposure to toxic chemicals can occur through a number of routes with diet and exposure via consumer products being two significant pathways. Recent examples of such exposures include elevated dioxin concentrations in UK fish oil supplements (where 12 of 33 products exceeded the new EU food safety limit) (FSA, 2002), and high concentrations of phthalates in children's toys in Denmark (Figure 6.8).

However, any adverse impacts of such exposures on human health or wildlife remain unclear. This is due to the large number of confounding factors, e.g. diet, exposure pathways, exposure to degradation products, and delays between exposure and observation of effects that hinder the establishment of causal relationships. Some of the issues are illustrated in the case of chemicals suspected of interfering with the hormonal systems of animals — the endocrine disrupting chemicals (see Box 6.4). Issues concerning trends in health impacts from chemicals are discussed further in Chapter 12.

Table 6.1 listed several chemicals known to persist in the environment together with examples of their uses and emission sources. Ecological impacts documented for wildlife which are associated with the presence of such chemicals are shown in Table 6.4, together with an assessment of the strength of the evidence for the association.

6.5. Progress in risk management?

Despite more than 25 years of chemical regulation in Europe and elsewhere, there remains a serious lack of public information on the amounts of hazardous chemicals

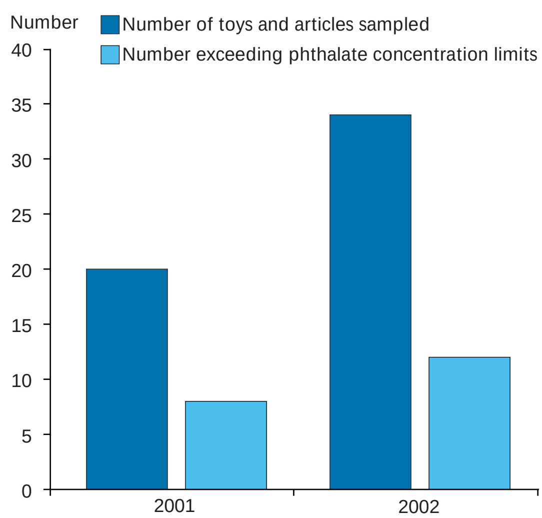
Box 6.3. Polybrominated flame retardants

PBDEs (polybrominated diphenyl ethers) are a family of structurally related flame retardant chemicals widely used in polyurethane foams and electronic goods. Some of these substances have high potential for uptake and accumulation by fish and other aquatic and terrestrial organisms. Concern has also recently been expressed that the octa-and deca- members of the PBDE suite of chemicals may break down in the environment to form more harmful compounds. The main non-workplace exposure pathway for humans is thought to be via the food chain.

In contrast to other organohalogen compounds, PBDE concentrations increased rapidly in breast milk from Swedish mothers during the period 1972–97 (see Figure 6.6) although recent levels appear to be decreasing due to due to substitution of one main substance (penta-BDE) in products.

PBDEs can migrate from flame-retardant materials in which they are contained and are therefore now widely dispersed in the environment. In December 2002, the European Union decided to ban the use of penta- and octa-BDE. The ban does not cover a third main controversial flame retardant (deca-BDE), with the law instead calling for the drafting of an 'immediate' risk reduction strategy for this chemical. Brominated flame retardants are also included in the list of chemicals for priority action under the OSPAR hazardous substances strategy.

Number of Danish toys and other articles for children found to contain phthalates above the maximum concentration limit (0.05 %) specified in Danish law Figure 6.8.



Source: Rastogi and Worsoe, 2001; Rastogi *et al.*, 2002

Box 6.4. Endocrine disruptors in the environment

For more than 30 years, concern has been expressed over the potential adverse effects that may result from exposure to the group of chemicals known as endocrine disruptors which affect the functioning of the endocrine systems in wildlife and humans. For example, recent UK research on hormone disruption in fish performed for the Environment Agency of England and Wales revealed changes in the sexual characteristics of two coarse fish species in 10 river catchments and confirmed the presence of feminised male fish of both species (Environment Agency, 2002). The reproductive capability of the fish was also affected with up to half of the male fish at several sites failing to produce sperm. Steroid oestrogens which are released in small quantities from sewage works are thought to be the most important endocrine disruptors in British rivers (CEH, 2000).

The World Health Organization (WHO) has published a global assessment of the state of the science with respect to endocrine disruption in humans, experimental studies and wildlife species (WHO, 2002).

Table 6.4. **Some ecological impacts and possible associations with chemicals**

Observation/impact	Species	Substance	Association
Large-scale effects			
Eggshell thinning	Guillemot, eagle, osprey, peregrine falcon	DDT/DDE	5
Reproduction	Seal, otter	PCB	4
Skeletal malformation	Grey seal	DDT, PCB	4
Pathological changes	Seal	PCB, DDT, metabolites	3
Reproduction	Mink	PCB	5
Reproductive disturbances	Osprey	DDT, PCB	5
Reproductive disturbances	Eagle	DDT, PCB	2-3
Reproduction (M74 syndrome)	Salmon	Chlorinated substances	2
Imposex	Molluscs e.g. dogwhelk	TBT	5
Impairments in wildlife in relation to endocrine disrupting chemicals (EDCs)			
Sperm quality, cryptorchidism	Panther		2-3 (effects observed in inbred population)
Population decrease	Mink, otter		2-3
Female reproductive disorders, adrenocortical hyperplasia	Seal		4-5 4-5
Eggshell thinning Embryotoxicity and malformations Malformation of reproductive tract Reproductive behaviour	Birds		4-5 4-5 2-3 2-3
Microphalli and lowered testosterone levels	Alligators		3-4 (effects seen in connection with accidental contamination)
Vitellogenin	Fish		4-5
Masculinisation Lowered testosterone levels Reduced testis size M74 and early mortality syndromes			3-4 2-3 2-3 1-2
Imposex	Molluscs		5

Notes: The strength of the association is assessed on the scale: 1 = no observed association, 2 = suspected association, 3 = weak association, 4 = clear association, 5 = significant association.

Sources: EEA, 1998 (large-scale effects); Swedish EPA, 1998b (impairments in wildlife in relation to EDCs)

produced, the uses of such chemicals in downstream products and processes, the amounts released to the various environmental media, and the effects of environmental and human exposures. Such information has either never been established, or else is not publicly available because of 'commercial confidentiality' issues. For example, there are insufficient data to conduct a basic risk assessment for 86 % of EU high production volume chemicals (ECB, 1999). The threat that chemical releases may pose to humans and the environment cannot, in many cases, be assessed. It must be remembered too, that absence of evidence (of ill effects) is not the same as evidence for the absence of such effects (EEA, 2001 — see Box 6.5.). A number of wider questions remain that Wallström (2002) and others have raised, for example:

- How can risks be combined to reflect different types of exposures and cumulative impacts?
- How can we account for interactions between host and exposure factors (including genetic, lifestyle, host susceptibility)?
- What options are there for developing policies that address mixtures of chemicals and the 'cocktail effect'?

- What are the current research priorities: exposure pathways and low dose impacts, or mechanisms of action?

Releases or use of some chemicals have resulted in significant environmental damage (EEA, 2001 — see Box 6.5.). Unlike products such as pharmaceuticals, no pre-market toxicity testing was required for most of these and so knowledge about their adverse effects was not available before they were used in large quantities e.g. DDT.

Evidence of dioxins and PCBs in food and livestock feedstuffs (in Belgium in 1999, 2000), phthalates exceeding permitted concentrations in children's toys (in Denmark in 2001, 2002), and flame retardants in human milk (in Sweden in 2000) illustrate the potential for accumulation from low exposures and possible risks.

Clearly, a top priority should be to get basic data on the properties of such substances that are produced and used, and especially those where emissions during production, use or disposal are significant (compared to their hazard potential). Currently industry has to submit notification dossiers for 'new chemicals' e.g. chemicals that were not identified on the European market in 1981. About 300 to 350 new substances are notified every year. The notification dossier should provide information on the substance, e.g. production process, proposed uses, results from analysis of physical and chemical properties, and test reports from toxicological and eco-toxicological assays.

However, even having such basic data cannot exclude the possibility that effects will occur at low doses and/or over a lifelong exposure. The precautionary principle may guide in the direction of reacting on early warnings, but data are still needed to provide a basis for applying the precautionary principle in practice. Having publicly available data and information on the substances in use may allow both the manufacturers, the industrial users (downstream users) and even consumers to take informed decisions on the risk associated with the use of a substance (see Box 6.6.) — little information is currently available about which substances can be safely used.

The European Commission acknowledges that current policies for risk assessment and control of chemicals take too long to implement. It also recognises that the current risk assessment process used for 'existing' substances (those declared to be on the market before 1981) is 'slow and resource-intensive and does not allow the system to work efficiently and effectively' (European Commission, 2001). In addition to the proposals contained within the recent EU chemicals policy White Paper (see below), a number of other initiatives have been agreed in recent years that aim to reduce the environmental levels of chemicals (see Table 6.5).

Box 6.5. Association and causality

It is sometimes relatively easy to show that a measure of ill health, e.g. the number of hospital admissions per day, is associated with a possible cause such as the day-to-day variation in levels of air pollutants. To show that a causal relationship exists, a number of guideline tests have been developed. These include the consistency of results between different studies, the way in which the results of different studies fit together (coherence), whether there is a 'dose-response' relationship between the proposed causal factor and the effect, and whether the sequence of events makes sense i.e. the cause always precedes the effect.

Proof of causality is often very difficult to establish, but by the application of these and other criteria, an expert judgement as to whether an association is likely to be causal can often be made. Where effects are likely to be serious and/or irreversible, then a low level of proof as in the 'precautionary principle' may be sufficient to justify the removal or reduction of the probable causes.

Sources: WHO; EEA

6.6. Three recent initiatives: the EU chemicals policy White Paper, the Stockholm convention on POPs and the globally harmonised system of classification and labelling of chemicals (GHS)

The proposals outlined in the EU chemicals policy White Paper (European Commission, 2001) are among the most significant

Box 6.6. Voluntary phase-out of perfluorooctanyl sulphonate production

The oil and water repellent chemical perfluorooctanyl sulphonate (PFOS) was developed in the 1950s and has been used worldwide in a variety of specialist fire-fighting foams and oil and grease-resistant coatings for textiles and paper packaging.

Concerns over the potential health and environmental risks of this and similar chemicals were raised after its recent discovery at low concentrations in human and animal tissues from around the world. Despite there being no unambiguous evidence of toxicity, in a rare precautionary initiative to stop the use of the substance its principal manufacturer announced a voluntary phase-out of production. The move led other makers of similar compounds to launch their own investigations into the environmental fate, transport and effects of perfluorinated substances. A number of manufacturers have since agreed to phase-out these compounds and a subsequent 2002 Danish Environmental Protection Agency study found only three of 21 samples contained PFOS-like compounds. Danish environment minister Hans Christian Schmidt commended the phase-out as a good example of producer responsibility, noting that 'A number of companies have made a conscious choice not to use these problematic chemicals even though they are free to do so' (ENDS, 2002).

Table 6.5. **Some initiatives for reducing chemicals in the environment**

Instrument	Year	Objectives
Montreal protocol	1987	Phase out certain ozone-depleting substances
Responsible care	1989	Industry initiative to promote environmental responsibility via concepts such as: • Sustainable development • Product stewardship • Implementation of good practice • Take-back schemes • Integrated product placement • Development of company pollutant release and transfer registers (PRTRs)
HELCOM convention	1992	Prevent and eliminate pollution to the Baltic Sea
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Text concluded in 1989, and convention entered into force in 1992	Reduce/minimise hazardous wastes at source
OSPAR and HELCOM conventions	1998	Reduce discharges, emissions and losses of hazardous substances to the North Sea to near-zero or background levels by 2020
Rotterdam Convention on Prior Informed Consent	1998	Exporters of hazardous chemicals to get consent of receiving country before delivery
International Council of Chemical Associations (ICCA)	1998	Compiling hazard assessment information on 1 154 HPV chemicals by 2004
UNECE POPs protocol	1998	Reduce air emissions of POPs
UNECE heavy metals protocol	1998	Reduce emissions of cadmium, mercury and lead to 1990 levels
EU water framework directive	2000	An integrated approach to protecting water resources. Defines emission reduction/ elimination targets for a limited number of priority hazardous substances. No comparable legislation currently exists for soils
Stockholm convention on POPs	2001	Elimination of POPs (production and use)
UNEP Global Assessment of Mercury	2001	Review health and environmental impacts of mercury and compile information on control and prevention strategies to potentially form a basis for international action
Globally harmonised system of classification and labelling of chemicals	2002	1. To enhance the protection of human health and the environment by providing an internationally comprehensible system for hazard communication 2. To provide a recognised framework for those countries without an existing system 3. To reduce the need for testing and evaluation of chemicals 4. To facilitate international trade in chemicals whose hazards have been properly assessed and identified on an international basis
Johannesburg summit	2002	Minimise adverse effects of chemicals on health and the environment by 2020. Implement the new globally harmonised classification and labelling system for chemicals by 2008

potential developments for risk assessment and management processes in the European region. The White Paper recognises that the public has a right of access information about the chemicals to which they are exposed (see Box 6.7). It reassesses existing EU directives and amendments and advocates a high level of protection for human health and the environment based on the precautionary principle. The Commission proposes to shift responsibility for generating and assessing data concerning the risks of use of substances onto industry. Downstream users would also be responsible for all aspects of the safety of their products and would have to provide information on use and exposure.

The White Paper sets out a timetable under which 'existing' substances (for which very little risk assessment data exist) would have to undergo assessment. 'Existing' and 'new' substances would be subject to the same risk assessment procedures using a single REACH (registration, evaluation, and authorisation of chemicals) system. The requirements that manufacturers/users of chemicals have to follow will depend on the proven or suspected hazardous properties, uses and exposures of the chemical concerned. The costs of implementing the REACH system have been estimated at between EUR 1.4 billion and EUR 7 billion over 10 years (most probably EUR 3.6 billion (RPA, 2002)). In comparison, EU chemical production in 2001 was valued at EUR 518 billion (CEFIC, 2002). No estimates have yet been made of the external health and environmental costs of chemicals (EEA, 1999), although such estimates are available for the energy and transport sectors (EEA, 2000).

Even though the proposed regime is a substantial improvement over that which currently exists, the new proposals do not go as far as some environmental organisations would like. For example, it has been recommended that: an EU chemicals policy should ensure that transparency of information is guaranteed; persistent and bioaccumulative chemicals should be phased out; the strength of evidence for regulation should be such that 'reasonable doubt' over safety is sufficient to lead to regulatory measures; endocrine disrupting substances should be included in the 'authorisation' procedure; and new non-animal testing techniques awaiting approval are reviewed as a matter of priority (FoE, 2002). Furthermore, the new system operates on higher volume boundaries to trigger the need for testing than currently in force. There is therefore likely to be a need to check in future regulations that this compromise with industry is not under-protective for new chemicals.

The Stockholm convention on POPs (2001) aims to protect health and the environment through controlling POPs production and emissions. Like the EU chemicals policy White Paper, the concept of precaution as an important element in chemical risk management is acknowledged within the convention (Willis, 2001). For example, whether chemicals proposed as meeting POPs criteria are accepted under the convention is to be decided 'in a precautionary manner'.

Further progress in the protection of the public against chemical hazards and the risk associated with their exposure necessitates that better information on chemicals be made available. The new globally harmonised system of classification and labelling of chemicals (GHS) that was adopted in December 2002 (UNECE, 2002) will dramatically increase the level of information and access to it. Chemicals will be classified according to their potential hazards to humans and the environment. Related information will be communicated and displayed to the public so that appropriate protective measures can be

Box 6.7. Information for policy-makers and the public: pollutant release inventory initiatives

Pollutant release and transfer registers (PRTRs) are inventories of pollutant releases and transfers to the environment detailed by source. They provide an important means for members of the public to obtain information about the chemicals to which they are exposed, and governments to assess the relative contributions of different emission sources. They therefore enable prioritisation of sources in terms of developing strategies to eliminate or reduce the releases of pollutants, and measurement of progress towards the goal of minimising their emissions.

Increasing numbers of European countries now operate pollutant release inventories, although they often differ both with respect to media covered (air, water, land, waste, etc.) and the threshold and types of chemicals for which reporting is mandatory (OECD, 2000). Regional and international PRTR initiatives have also been developed e.g. OSPAR for emissions to the North Sea, and the pan-European EMEP/Corinair atmospheric emissions inventory.

Recognising both the utility of registers and the need to encourage their development on a national scale, a number of initiatives have been taken to facilitate their introduction in countries currently without release inventories. For example, the UNECE Aarhus convention on access to information, public participation in decision-making and access to justice in environmental matters was adopted in 1998. Under the convention, a working group on pollutant release and transfer registers was established to assist in the implementation of Article 5, establishing public access to information dealing with the environmental release or transfer of pollutants through the provision of national pollutant release and transfer registers. A protocol concerning implementation of this aspect of the convention has been prepared for the fifth 'Environment for Europe' ministerial conference, Kiev, 2003.

taken. Through the different steps from production, handling and transport to use, chemical products will be marked with universally understandable pictograms. The GHS also includes safety data sheets, presenting standardised content and extended information. The system, called for by the Rio summit in 1992, is now ready to be implemented, as requested at the Johannesburg summit (Article 22(c) of the plan of implementation).

Implementing EU environmental legislation will help the accession countries to meet the challenges in environmental protection. They need to include around 300 pieces of EU environmental law (some of them relevant to chemicals) into their national legislation, as well as to implement and enforce these laws. Most of these countries need to strengthen the environmental administration of ministries and agencies but especially also of local and regional offices.

In order to help the countries, the EU is assisting financially, for example with the LIFE programme, the Phare programme and the instrument for structural policies for pre-accession (ISPA); as well as with technical support through the twinning system. Furthermore, the EU has acknowledged some specific problems for which transitional periods are necessary. Table 6.6 shows transitional periods of relevance to chemicals (European Commission, 2003).

Chemicals policy-making is undergoing a period of unprecedented change. It offers the prospect of reducing the risks to human health and the environment from chemicals in Europe and beyond. It can also lay the foundation for a more sustainable approach to the safety of chemicals throughout their entire life cycle and for stimulating innovation through 'greener' chemistry (European Commission, 2001) and other improvements in eco-efficiency. Future generations may therefore avoid paying the price of current deficiencies in chemical policies whilst retaining the benefits of chemical products.

Table 6.6. **EU accession countries: transitional periods for compliance to chemicals-related legislation**

Country	Transitional agreement
Estonia	Emissions of volatile organic compounds from petrol storage (until 2006)
Latvia	Emissions of volatile organic compounds from petrol storage (until 2008) Prevention and reduction of environmental pollution by asbestos (until 2004) Health protection of individuals against ionising radiation in relation to medical exposure (until 2005)
Lithuania	Emissions of volatile organic compounds from petrol storage (until 2007)
Poland	Emissions of volatile organic compounds from petrol storage (until 2005) Discharge of dangerous substances into surface water (until 2007) Integrated pollution prevention and control (until 2010) Health protection of individuals against ionising radiation in relation to medical exposure (until 2006)
Slovakia	Emissions of volatile organic compounds from petrol storage (until 2007) Discharge of dangerous substances into surface water (until 2006) Integrated pollution prevention and control (until 2011)
Slovenia	Integrated pollution prevention and control (until 2011)

Source: European Commission, 2003

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