DANISH MINISTRY
OF THE ENVIRONMENT

Environmental
Protection Agency

Potential measures for reduction of releases of heavy metals, POPs, HCFCs, BFRs and industrial greenhouse gases with particular reference to Russia, Ukraine and China

Carsten Lassen, Jacob Maag, Sven Havelund, Erik Hansen
Jørn Lauritsen and Jesper Skaarup
COWI

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Preface

Objective

The objective of the present review is to provide background for the Danish Environmental Protection Agency's considerations regarding its contribution to Nordic and Arctic initiatives such as NEFCO, Nordic Council/Nordic Council of Ministers and Arctic Council in the field of hazardous substances. The study focuses on initiatives for reduction of the releases of the substances in Russia, but includes information on Ukraine and China.

The review performed does not pretend to be fully comprehensive as to the status in the countries included. One particular gap for most substances is a detailed survey of national or local measures already under implementation addressing the substances; in some cases that type of information has however been available and is presented in the report.

Content

The project addresses the following substance groups: Heavy metals (mercury, lead, cadmium), persistent organic pollutants (PCBs, PCDD/PDCF, HCB, 9 other pesticides), HCFC, industrial greenhouse gases (HFC, PFC, SF_6) and brominated flame retardants (mainly PBB, PBDE and HBCD).

For each of the substances the review includes:

- A short abstract;
- A short introduction to the environmental problems associated with the substances;
- Sources and releases of the substances;
- Main reduction measures;
- International agreements;
- Ongoing activities supported by donor organisations and international finance institution.

Based on the assessment, recommendations on potential activities for release reduction have been prepared. The list of potential additional activities is included in a memorandum for internal use of the Danish EPA.

Steering group

The study has been followed by a Steering Committee consisting of:

- Morten Skovgård Olsen, Danish Environmental Protection Agency;
- Henri Heron, Danish Environmental Protection Agency;
- Mikala Klint, consultant to Danish Environmental Protection Agency;
- Carsten Lassen, COWI A/S;
- Jakob Maag, COWI A/S.

Study team

The following team has contributed to the solving of this assignment: Carsten Lassen (Project Manager), Jakob Maag, Sven Havelund, Erik Hansen, Jørn Lauridsen and Jesper Skaarup, COWI A/S.

Disclaimer

Please note that publication of this report does not signify that the content of the report necessarily reflect the views of the Danish EPA.

Abbreviations and acronyms

AC	Air conditioning
ACAP	Arctic Council Action Plan to Eliminate Pollution of the Arctic
ADB	Asian Development Bank
AEWA	Agreement on the Conservation of African-Eurasian Migratory Waterbirds
AMAP	Arctic Monitoring and Assessment Programme
AusAID	Australian Agency for International Development
BAT	Best Available Techniques
BEP	Best Environmental Practices
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Germany)
CEE	Central and Eastern Europe
CFCs	Chlorofluorocarbons
Chem. symbols	Ag (silver), Au (gold), Cd (cadmium), Cu (copper), Hg (mercury), Ni (nickel), P (phosphorous), Pb, (lead), Zn (zinc)
CIDA	Canadian International Development Agency
CLRTAP	Convention on Long-range Transboundary Air Pollution
DANCEE	Danish Co-operation for Environment in Eastern Europe
DANCEA	Danish Co-operation for Environment in the Arctic
DANIDA	Danish International Development Assistance
DDT	Dichlorodiphenyltrichloroethane
DFID	Department for International Development (UK)
DGIS	Directorate-General for International Cooperation (the Netherlands)
DKK	Danish kroner
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
EPA	Environmental Protection Agency
EU	European Union
EUR	Euro, €
FAO	Food and Agriculture Organisation of the United Nations
FINNIDA	Finnish International Development Agency
GCD	Gaseous carbon dioxide
GEF	Global Environment Facility

GHGs	Greenhouse gases
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GWP	Global warming potential
GWP_{100}	Integrated global warming potential over a 100 years time-frame
HBCD	Hexabromocyclododecane
HCB	Hexachlorobenzene
HCFCs	Hydrochlorofluorocarbons
HCH	Hexachlorocyclohexane
HELCOM	The Helsinki Commission for the protection of the marine environment of the Baltic Sea
HFCs	Hydrofluorocarbons
HM	Heavy metals
HWM	Hazardous Waste Management
IARC	International Agency for Research on Cancer
IBRD	International Bank for Reconstruction and Development
IMET	Italian Ministry for the Environment and Territory
IPCC	Intergovernmental Panel on Climate Change
I-TEQ	International PCDD/PCDFs toxicity equivalents
LCD	Liquid carbon dioxide
NEFCO	Nordic Environment Finance Corporation
NiCd	Nickel-cadmium (batteries)
NiMH	Nickel-metalhydride (batteries)
NORAD	Norwegian Agency for Development Cooperation
ODA	Official Development Assistance (Japan)
ODS	Ozone depleting substances
OP	Obsolete pesticides
OSPAR	OSPAR Convention and OSPAR Commission for the protection of the marine environment in the North-East Atlantic
PBBs	Polybrominated biphenyls
PBDEs	Polybrominated diphenylethers
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-*p*-dioxins
PCDFs	Polychlorinated dibenzofurans
PCP	Pentachlorophenol
PCP-Na	Sodium pentachlorophenate
PFCs	Perfluorocarbons

PM	Particulate matter
POPs	Persistent Organic Pollutants
PUR	Polyurethane
RAC	Refrigeration and air conditioning
ROHS directive	Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment
SF_6	Sulphurhexaflouride
SIDA	Swedish International Development Cooperation Agency
SME	Small and medium-sized enterprises
TCP	Trichlorobiphenyl
TACIS	Technical assistance to Commonwealth of Independent States (European Union)
TBBPA	Tetrabromobisphenol A
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
US AID	United States Agency for International Development
USD	US dollar, $
US EPA	United States Environmental Protection Agency
WB	World Bank
WEEE directive	Directive 2002/96/EC on waste electrical and electronic equipment
Ww	Waste water

1 Summary

In the following summary a short abstract is presented for each substance/substance group.

An Internet scanning of 27 organisations for aid projects in Russia, Ukraine and China specifically addressing hazardous substances revealed that the main part of ongoing activities is undertaken with support from the Global Environment Facility (implemented by WB, UNIDO, UNEP and UNDP), ACAP (with grants from the Arctic countries) or through bilateral arrangements with Denmark (Russia and Ukraine), Canada (China) and Italy (China). Hazardous substances are not a priority area for the EU TACIS programme, although a few small TACIS BISTRO projects in this field have been identified. Besides these projects specifically addressing the substances, some Climate Change programmes aiming at shifting to other energy sources may indirectly have an impact on the mobilisation of heavy metals and the unintentional formation of PCDD/PCDFs, PCBs and HCB.

The reviews have been used for identification of potential new support activities. The list of activities is included in a memorandum for internal use in the Danish EPA.

1.1 Mercury

Mercury is among the best described pollutants of the World, and the need for global actions to promote release reduction has been commonly accepted in recent years. Mercury and its compounds are toxic to humans and in the environment, and exposures considered to have adverse effects are present today in many parts of the world.

Mercury releases sources can be grouped according to two principally different mechanisms:

Mobilisation of mercury in trace concentrations in materials exploited in large volumes. Examples of major source categories in this group are coal combustion and extraction of non-ferrous metals and minerals. For this group of sources, end-of-pipe reduction measures are most commonly used. Generally certain mercury reductions can be obtained by multi-pollutant controls (filters etc.) and much can still be done by these means, but for major reduction cuts to occur, mercury specific controls may become necessary. A switch of raw materials or technology is sometimes also an option - for example a switch from coal-fired energy production to renewable energy sources.

Intentional use of mercury in products and processes. Examples of source categories in this group are chlor-alkali production with mercury cells, dental amalgam, mercury thermometers, batteries with mercury and mercury switches, among many others. It has been Danish policy for decades to reduce these releases at the primary source by substitution and phase-outs, and promotion of development and commercialisation of adequate alternatives. In many cases end-of-pipe reduction measures have however also been necessary, notably in the industry and in the waste treatment sector, because substitution can generally not be obtained fast, and because end-of-pipe solutions often address several pollutants at the same time. For products the principal types of measures needed today are elimination of mercury in new products, separate collection, mercury specific reduction filters on waste incineration and environmentally safe disposal.

1.2 Lead

Lead and its compounds are toxic to humans and in the environment. The major source of lead releases to the atmosphere, and a major lead problem of concern, has been the release of lead compounds from the use of lead additives in petrol. Leaded petrol for vehicle transport is today 100% phased out in Russia, Ukraine and China. Lead batteries account for more than 50% of global lead consumption, and development of systems for efficient end environmentally sound collection and recycling of lead batteries is an important activity area. The effect of lead shot on waterfowls is internationally recognised, and a ban on lead shot in wetlands may be the first step in the phase out of lead in ammunition. The major Russian (and global) source category of lead releases today is non-ferrous metal industry. Measures for reduction of lead releases from this industry also address releases of cadmium, mercury and the unintentional production of PCDD/PCDF, PCB and HCB, and release reduction measures are stipulated by the UNECE HM protocol. Reduction of releases from non-ferrous industry is thus a major area of action.

1.3 Cadmium

Cadmium and its compounds are toxic to humans and in the environment. Nickel-cadmium (NiCd) batteries account for more than half of the global consumption with China as the major producer. Development of efficient systems for collection and recovery of cadmium batteries as well as batteries containing other hazardous substances is essential for preventing cadmium disposal to landfills and waste incinerators. For most of the major applications of cadmium alternatives are available on the market, e.g. pigments, plastic stabilizers, cadmium plating and batteries. Phase-out programmes for products and processes, for which alternatives are readily available, may include preparation of action plans, surveys of uses and options for substitution and implementation of regulation and substitution demonstration projects. The major global source category of cadmium releases today is non-ferrous metal industry. Measures for reduction of cadmium releases from this sector also address releases of lead, mercury and the unintentional production of PCDD/PCDF, PCB and HCB, and release reduction measures are stipulated by the UNECE HM protocol.

1.4 PCDD/PCDFs

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs) are two groups of persistent substances, both toxic to humans and in the environment. PCDD/PCDFs are not used intentionally, and the reduction measures concern the avoidance of formation and releases of the substances. PCDD/PCDFs reduction is addressed by the Stockholm Convention signed by Russia, Ukraine and China. As part of the enabling activities for implementation of the Stockholm Convention, preliminary PCDD/PCDFs inventories are undertaken in the countries and action plans for addressing PCDD/PCDFs releases will be prepared. Further activities concerning

PCDD/PCDF reduction should preferably be in accordance with the priorities of the countries' individual action plans.

Releases from waste incineration, iron ore sintering, secondary metal production and uncontrolled burning of waste are probably the main PCDD/PCDFs sources in the countries, and reduction of releases from these sources should have high priority. Measurements of PCDD/PCDFs are complicated and expensive, and there is an urgent need for actual measurements and detailed inventories documenting the need for, and costs of, implementation of reduction measures.

PCDD/PCDF-specific air emission controls (e.g. fabric filter and carbon injection) are a prerequisite for reaching acceptable emission levels from the major source categories, and projects implementing such controls may have a significant demonstration effect.

1.5 PCBs

Polychlorinated biphenyls (PCBs) are a group of persistent substances, toxic to humans and in the environment. PCBs are not produced intentionally today, but were formerly widely produced, and used in electrical equipment, paints and a number of minor applications. A significant part of the produced PCBs is still in use, first of all in transformers and capacitors, and elimination of waste PCBs and PCB-containing equipment is addressed by the Stockholm Convention signed by Russia, Ukraine and China. PCBs used for paints and other so-called "open applications" have today to a large extent already been released to the environment, and the remaining part is practically impossible to identify and manage. Inventories of PCB-containing electric equipment have been undertaken in all three countries. The main issue is today preparation of adequate regulation, collection of equipment, development of PCB waste management systems and final destruction of the PCBs. Ongoing projects in Russia address identification of PCB-containing equipment for final treatment and construction of two facilities for destruction of liquid PCBs and PCB-containing capacitors respectively. In China a large project on collection and destruction of PCB-containing equipment in selected regions is in preparation.

1.6 HCB

Hexachlorobenzene (HCB) is persistent and toxic to humans and in the environment. HCB is produced intentionally for use as a pesticide and an intermediate in the production of pentachlorophenol (PCP) and other chemicals. Pesticidal use of HCB is included in the chapter on POPs pesticides. HCB is produced unintentionally by the same thermal processes as PCDD/PCDDs, and measures for PCDD/PCDDs formation also address HCB. The driving force for implementation of the measures will usually be PCDD/PCDDs reduction; the HCB reduction being a desirable side-effect.

Furthermore, HCB is unintentionally produced by some specific chemical and metallurgical processes. HCB is, when certain techniques are applied, produced as by-product by the production of chlorinated solvents, chlorinated aromatics and pesticides, by production of aluminium and magnesium and by production of chlor-alkali. The measures for reduction of HCB releases are changed production processes.

Comprehensive inventories of HCB formation and releases in Russia, Ukraine and China have not been identified, and it is not known to what extent the processes specifically forming HCB are used. The first step in the awareness raising and identification of priority measures may be to assist Russia in undertaking a detailed HCB inventory. The obtained information would also be relevant for other countries from the former Soviet Union.

HCB is in China used for production of PCP (pentachlorophenol), which today has been phased out in most countries because of the presence of PCDD/PCDFs as impurity, and because PCP acts as a precursor for PCDD/PCDFs formation. Phase-out of PCP production consequently addresses more of the POPs. Alternatives to the use of PCP for wood preservation are readily available.

1.7 POPs pesticides

Nine POPs pesticides are addressed by the Stockholm Convention for immediate or future elimination: Aldrin, chlordane, dieldrin, DDT, endrin, heptachlor, mirex, toxaphene, and hexachlorobenzene. In Russia and Ukraine the POPs pesticides are not used today, but the POPs pesticides make a substantial part of the stockpiles of obsolete pesticides. In these countries the issue is thus mainly identification, safe storage and final destruction of obsolete POPs pesticides in close coordination with the management of other obsolete pesticides. Identification, repacking and safe storage of obsolete pesticides in selected oblasts is addressed in ongoing projects, but there is still an urgent need for application of the obtained experience in other regions. The pesticides are today stored intermediately, and in a long-term perspective there is a need for building of destruction facilities, e.g. waste incinerators optimised for pesticide destruction. In China, DDT, mirex and chlordane are still used as pesticides, first of all for termite and disease vector control, and alternative pest management strategies are under development.

1.8 Industrial greenhouse gases

The gases HFCs, PFCs and SF_6 are addressed here. These are the only so-called industrial greenhouse gases (GHGs) covered in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). HFCs (hydrofluorocarbons) and PFCs (perfluorocarbons) are two groups of substances. SF_6 (sulphurhexaflouride) is an individual substance. The so-called flexible mechanisms for implementation of GHG reduction efforts: "joint implementation" with East European Countries, and "clean development mechanism" with developing countries (including China), offer an opportunity to finance reduction initiatives in other countries on a commercial basis. This is a very strong incentive.

The most important environmental property of these fluorinated compounds is the contribution to global climate change. Though the nominal contributions to global warming from these gases are currently in the range of a few percent, the emission reduction amounts that can be reached by reduction of industrial GHGs lie in the same order of magnitude as individual measures on CO_2, because in principle a 100% substitution is possible for the major uses of industrial GHGs. HFCs and SF_6 are deliberately produced and used in equipment and in products. Releases are primarily generated when using the substances or during the disposal of equipment or products. Substitution/phase-out is therefore the main type of measure for these substances. HFCs are also released as a pollutant from production of the ODS HCFC. These releases may decrease as a result of HCFC reductions stipulated in the Montreal Protocol and its amendments; see section 1.9 and Chapter 7. PFCs are also produced deliberately, but the major releases are generated as unwanted pollutants from the production of primary aluminium. For aluminium production improved technology and release reduction measures are the important types of measures.

1.9 HCFCs

The so-called Ozone Depleting Substances (ODS), including HCFCs, damage the stratospheric ozone layer, which protects the biosphere from harmful ultraviolet radiation from the sun. HCFCs have somewhat lower depleting effects (ODPs) than the CFCs targeted first in the international reduction process.

The substitution of HCFCs is closely linked to the substitution of CFCs on one side and on HFC (industrial GHGs) on the other side. HCFCs have been phased in as intermediate substitutes for CFCs. HFCs constitute a next step of intermediate substitutes to CFCs and HCFCs. HFCs have zero ODP, but unfortunately high global warming potentials. In the context of this report, substitution of both HCFCs and HFCs are priority fields due to their ODP and GWP characteristics. The substitution/phase-out options mentioned for refrigeration and foam blowing for HFCs in chapter 6 are therefore also relevant for HCFCs, and a direct substitution to non-ODP, non-GWP substances should be aimed at. Important release reduction measures for refrigeration uses of HCFC are containment, improved maintenance and recycling.

While all three countries - Russia, Ukraine and China - have joined the Montreal Protocol, their ratification of the amendments to the Protocol ruling HCFC is lacking behind. Russia has currently not ratified any obligations as regards reductions of HCFCs, while Ukraine has ratified and China is in accession to obligations as regards consumption of HCFCs, but not to obligations on production and exports of HCFCs. Unfortunately strong economic incentives for HCFC reduction - like the ones existing for greenhouse gases under the Kyoto Protocol - are lacking. Denmark has so far played a major role in Eastern Europe preparing large ODS reduction projects for financing by international financing institutions.

1.10 Brominated flame retardants

The term ‘Brominated Flame Retardants’ (BFRs) covers a diverse group of organic substances having in common that they contain bromine and act as flame retardants. Traditionally the most widely used substances among the brominated flame retardants have been TBBPA (tetrabromo bisphenol A), PBDEs (polybrominated diphenyl ethers), PBBs (polybrominated biphenyls) and HBCD (hexabromocyclododecane). Today PBBs are not produced in any country.

The environmental fate and effects of the BFRs vary considerably among the BFRs, even within the same substance group. In general congeners with lower bromine content are of more concern than congeners with higher bromine content. Two of the BFRs, hexabromobiphenyl (PBB with 6 bromine atoms) and pentabrominated diphenylether (PBDE with 5 bromine atoms) are considered for possible inclusion in the Stockholm Convention. The two substances are already or can easily be replaced by other flame retardants.

BFRs are mainly used in electric and electronic products, textiles and building materials. The electric and electronic products are traded on a global market, and the use of BFRs with finished products will probably be quite similar all over the world. The use of BFRs in building materials and textiles is more variable depending on local tradition and regulation.

The main measure for reduction of the releases of the BFRs is to reduce the use of the substances. The most problematic of the BFRs can easily be replaced by other BFRs, and many of the large companies in the electronics industry have phased out the use of PBDEs and PBBs as part of their corporate environmental strategy. For the major use areas non-halogenated alternatives are available, but for some minor areas no alternatives are available today.

The EU RoHS directive on the restriction of hazardous substances in electric and electronic products stipulates that these products shall not contain PBBs and PBDEs, but most probably the most used of the substances, deca-PBE will be exempted from the restriction, weakening the effect of the Directive as a driving force for the phase-out of the substances in the EU and other parts of the world.

It has not been possible to identify any surveys of BFR use or releases in Russia, Ukraine or China, and most probably they do not exist. Inventory preparation of selected BFR’s in the Arctic is included in a new ACAP project with Norway as the lead country.

2 Methodology

In the following the applied methodology for the review is shortly described.

2.1 Release sources and reduction measures

The main global release sources and reduction measures have been shortly reviewed based on the literature; mainly authorised reports from international or governmental institutions. The use of the substances and releases in Russia, Ukraine and China has been reviewed on the basis of information in English obtained from the Internet and literature. Additionally the information concerning Russia has been supplemented by literature and Internet Search in Russian. For most of the substances only scattered and incomplete information on the use and releases in Russia, Ukraine and China has been available. By combining the scattered information with the information on Global trends it has been attempted to establish a first view of the situation in the countries.

A list of main technical measures for reduction of the use, formation and releases of the substances was developed on the basis of information from literature and the general knowledge of the authors. For the technical reduction measures being effective there is in general a need for development of adequate regulation, development of guidelines, enforcement of regulation and promotion of alternative solutions. These additional measures are considered implicit for all proposed technical measures.

2.2 International agreements

The international agreements addressing the substances have been assessed, and a summary table indicating how the major release source categories and use areas are addressed by the agreements has been prepared. The aim of the table is to demonstrate the source categories or use areas of international concern, the applied types of reduction measures and the time perspective.

2.3 Ongoing activities

Information on ongoing and tendered activities was searched via the Internet April/May 2005 from the web-sites of the organisations listed in Table 2-1. It is in the table indicated to what extent the list of relevant projects identified can be considered comprehensive.

Besides projects specifically addressing the substances, projects addressing hazardous waste management and reduced use of fossil fuels have been identified. Energy-related projects, which indirectly may reduce the releases of a number of the substances have not been listed unless directly relevant to the proposed options for additional initiatives.

Table 2-1 Organisations scanned for ongoing projects in Russia, Ukraine and China

Organisation	Full name	Comprehensive list generated	Project database identified	Comments
GEF	Global Environment Facility	+	+	
WB, IBRD	World Bank, International Bank for Reconstruction and Development	+	+	
UNEP	United Nations Environment Programme	+	no	
UNIDO	United Nations Industrial Development Organisation	+	+	
UNDP	United Nations Development Programme	probably	no	
FAO	Food and Agriculture Organisation of the United Nations	probably	no	
EBRD	European Bank for Reconstruction and Development	+	+	
EIB	European Investment Bank	+	+	
EU TACIS	European Union Technical assistance to Commonwealth of Independent States	+	+	Project for the period 2000 - 2005 searched by use of "Tenders Electronic Daily"
EU TACIS BISTRO	Small-scale TACIS projects (with a duration of no more than six months and a budget of up to 100,000 EUR)	no	no	Projects generally not listed in the project database. Projects known by the authors are included
ADB	Asian Development Bank	+	+	
ACAP	Arctic Council Action Plan to Eliminate Pollution of the Arctic	+	+	
NEFCO	Nordic Environment Finance Corporation	no	no	
DANCEE/DANCEA	Danish Co-operation for Environment in Eastern Europe; Danish Co-operation for Environment in the Arctic	+	no	The dataset including the DANCEE projects at web-site of the Ministry of Foreign Affairs is no longer available
DANIDA	Danish International Development Assistance	probably	no	No environmental projects in Russia, Ukraine and China
US AID	United States Agency for International Development	probably	+ Russia, Ukraine no (China)	US AID has apparently no environmental project in China
US EPA - OIA	United States Environmental Protection Agency - Office of International Affairs	no	no	
CIDA	Canadian International Development Agency	+	+	
SIDA	Swedish International Development Cooperation Agency	Russia, Ukraine: probably China: no	+ no (China)	Country programmes scanned. Probably energy programmes in China not identified

Organisation	Full name	Comprehensive list generated	Project database identified	Comments
NORAD	Norwegian Agency for Development Cooperation	no	no	Country fact sheets scanned. Probably energy programmes in China not identified
FINNIDA	Finnish International Development Agency	no	no	
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Germany)	no	no	
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit	+	+	
IMET	Italian Ministry for the Environment and Territory. Sino-Italian cooperation Program for Environment Protection	+	+	
Japan's ODA	Japans Official Development Assistance	no	no	Energy projects in China
AusAID	The Australian Agency for International Development	Probably	no	
DFID	The Department for International Development (UK)	Probably	no	
DGIS	The Netherlands Directorate-General for International Cooperation	Probably	no	China is not partner country

2.4 Paradigm

As a first phase of the study, a paradigm for the assessment and reporting was developed using mercury as example. The paradigm was presented for the Steering Committee, revised in accordance with the comments obtained and applied on the remaining substances.

3 International agreements overview

Table 3-1 below presents an overview of which substances are covered in relevant international agreements. Further summary aspects are presented in the individual substance sections. In addition, a brief summary description of the objectives, scopes, and addressed substances of some of the included agreements is given in Appendix 1.

Table 3-1 International agreements overview

	Stockholm Convention	Vienna Convention Montreal Protocol *3	UNFCCC Kyoto Protocol	CLRTAP HM protocol	CLRTAP POPs protocol	HELCOM Convention *1	OSPAR Convention *1	Rotterdam Convention *2	UNEP Hg agreement
Lead				X		X	X		
Mercury				X		X	X	X	X
Cadmium				X		X	X		
PCDD/PCDF	X				X	X	X		
HCB	X				X	X		X	
PCBs	X				X	X	X	X	
POPs pesticides	X				X	X	partly	X	
HCFC		X							
HFC			X						
PFC			X						
SF_6			X						
PBDE, PBB. HBCD						partly	X	partly	
Russia, signing	22 May 2002	NDI	11. Mar 1999	-	-	NDI	not relevant	-	
Russia, ratification	-	10 Nov 1988	18 Nov 2004 (R)	-	-	Nov 1999 (RID)	not relevant	-	
Ukraine, signing	23 May 2001	NDI	15 Mar 1999	24 Jun 1998	24 May 1998	-	not relevant	NDI	
Ukraine, ratification	-	20 Sep 1988 (At)	12 April 2004 (R)	-	-	-	not relevant	06 Dec 2002	
China, signing	23 May 2001	NDI	29 May 1998	not relevant	not relevant	not relevant	not relevant	24 Aug 1999	
China, ratification	13 Aug 2004	14 Jun 1991 (AC)	30 Aug 2002 (Ap)	not relevant	not relevant	not relevant	not relevant	22 Mar 2005	

NDI: No data identified; R: Ratification; At: Acceptance; Ap: Approval; Ac: Accession; RID: Ratification instruments deposited

*1 Substances on the OSPAR List of Chemicals for Priority Action and the HELCOM list of Selected Substances for Immediate Priority Action are indicated.

*2 Substances subject to the Prior Informed Consent procedure are indicated

*3 While all three countries have joined the Montreal Protocol, their ratification of the amendments to the Protocol ruling HCFC is lacking behind. Russia has currently not ratified any obligations as regards reductions of HCFCs, while Ukraine has ratified and China is in accession to obligations as regards consumption of HCFCs, but not to obligations on production and exports of HCFCs.

4 Heavy metals

4.1 Mercury

Abstract
Mercury is among the best described pollutants of the World, and the need for global actions to promote release reduction has been commonly accepted in recent years. Mercury and its compounds are toxic to humans and in the environment, and exposures considered to have adverse effects are present today in many parts of the world.

Mercury releases sources can be grouped according to two principally different mechanisms:

Mobilisation of mercury in trace concentrations in materials exploited in large volumes. Examples of major source categories in this group are coal combustion and extraction of non-ferrous metals and minerals. For this group of sources, end-of-pipe reduction measures are most commonly used. Generally certain mercury reductions can be obtained by multi-pollutant controls (filters etc.) and much can still be done by these means, but for major reduction cuts to occur, mercury specific controls may become necessary. A switch of raw materials or technology is sometimes also an option - for example a switch from coal-fired energy production to renewable energy sources.

Intentional use of mercury in products and processes. Examples of source categories in this group are chlor-alkali production with mercury cells, dental amalgam, mercury thermometers, batteries with mercury and mercury switches, among many others. It has been Danish policy for decades to reduce these releases at the primary source by substitution and phase-outs, and promotion of development and commercialisation of adequate alternatives. In many cases end-of-pipe reduction measures have however also been necessary, notably in the industry and in the waste treatment sector, because substitution can generally not be obtained fast, and because end-of-pipe solutions often address several pollutants at the same time. For products the principal types of measures needed today are elimination of mercury in new products, separate collection, mercury specific reduction filters on waste incineration and environmentally safe disposal.

4.1.2 The mercury problem

The following introduction is an extract of the key findings of the Global Mercury Assessment (UNEP, 2002). It was concluded in the assessment report 1) that significant evidence exists of mercury's adverse effects on a global level and 2) that initiatives should be taken to address these effects. These conclusions were later adopted by the Governing Council of UNEP. After two Governing Council meetings in 2003 and 2005 with measures on mercury on the agenda, a number of recommendations for national and international initiatives to enhance mercury release reductions have been agreed on. The Governing Council concluded that, for the time being, no global instrument on mercury reductions should be launched.

Environmental mercury levels have increased considerably since the on-set of the industrial age. Mercury is now present in various environmental media and food (especially fish) all over the globe at levels that adversely affect humans and wildlife. Widespread exposures are occurring due to human-generated sources, and past practices have left an inheritance of mercury in landfills, mine tailings, contaminated industrial sites, soils and sediments. Even regions with no significant mercury releases, such as the Arctic, are adversely affected due to the transcontinental and global transport of mercury.

The most significant releases of mercury pollution are emissions to air, but mercury is also released from various sources directly to water and land. Once released, mercury persists in the environment, where it circulates between air, water, sediments, soil and biota in various forms. Current emissions add to the global pool; mercury that is continuously mobilised, deposited on land and water, and re-mobilised.

Once deposited, the mercury form can change (primarily by microbial metabolism) to methylmercury, which has the capacity to bioaccumulate in organisms and to concentrate up through the food chains (biomagnify), especially in the aquatic food chain (fish and marine mammals). Methylmercury is therefore the form of greatest concern. Nearly all of the mercury in fish is methylmercury.

Mercury has caused a variety of documented, significant, adverse impacts on human health and the environment throughout the world. Mercury and its compounds are highly toxic, especially to the developing nervous system. The toxicity to humans and other organisms depends on the chemical form, the amount, the pathway of exposure and the vulnerability of the person exposed. Human exposure to mercury can result from a variety of pathways, including, but not limited to, consumption of fish, occupational and household uses, dental amalgams and mercury-containing vaccines.

Some populations are especially susceptible to mercury exposure, most notably the fetus, the new-born, and young children because of the sensitivity of the developing nervous system. Indigenous populations and others, who consume higher amounts of contaminated fish or marine mammals, as well as workers who are exposed to mercury, such as in small-scale gold and silver mining, may be highly exposed to mercury and are therefore at risk.

There are also particularly vulnerable ecosystems and wildlife populations. These include top predators in aquatic food webs (such as fish-eating birds and mammals), Arctic ecosystems, wetlands, tropical ecosystems and soil microbial communities.

Intervention

Mercury pollution has significant impacts at local, national, regional and global levels. These impacts can be addressed through a range of actions at each of these levels, targeting reductions in uses, releases and exposures. Numerous actions implemented in Europe, North America and elsewhere have successfully reduced uses and releases of mercury; for example some reduction of releases from coal combustion and waste incineration. However, inventories are still incomplete in these regions, and some releases are still significant. Also, global releases are not reported as decreasing similarly, probably because of the growth of certain sectors in other parts of the world. The extent of decreases in environmental levels and ecosystem improvements in response to decreased releases of mercury will vary considerably depending on local ecosystem characteristics and other factors, and in some cases may take several decades. However, an evaluation of mercury levels in Swedish lakes indicates that by reducing releases, environmental levels of mercury, such as in freshwater fish, may be reduced significantly in specific locations within one to two decades.

4.1.3 Sources and releases

Global release data

The following table illustrates the current comprehension of major contributions to atmospheric mercury releases globally. The data should likely be considered best available data, and is subject to considerable uncertainties; not all sources are included in the inventory. Note that releases to other media (water, land) are not included and may in some cases be significant.

Table 4-1 Estimates of global atmospheric emissions of mercury from a number of major anthropogenic sources in 1995 (metric tons/year; Pirrone et al., 1996 and 2001, as cited in UNEP, 2002)

Continent	Stationary combustion	Non-ferrous metal production	Pig iron and steel production	Cement production	Waste disposal *3	Total, quantified sources
Europe	185.5	15.4	10.2	26.2	12.4	249.7
Africa	197.0	7.9	0.5	5.2		210.6
Asia	860.4	87.4	12.1	81.8	32.6	1074.3
North America	104.8	25.1	4.6	12.9	66.1	213.5
South America	26.9	25.4	1.4	5.5		59.2
Australia & Oceania	99.9	4.4	0.3	0.8	0.1	105.5
Total, quantified sources, 1995 *4	1474.5	165.6	29.1	132.4	111.2	1912.8
Total, quantified sources, 1990 *1	1295.1	394.4	28.4	114.5	139.0	2143.1 *2

Notes

*1 Estimates of maximum values, which are regarded as close to the best estimate value by the authors of the inventory. Totals represent total of the sources mentioned in this table, not all known sources.

*2 The total emission estimate for 1990 also includes 171.7 metric tons from chlor-alkali production and other “less significant” sources.

*3 The authors of the inventory state that releases from waste incineration are most likely underestimated due to lack of national data on wastes (Pirrone et al., 2001).

*4 Not including releases from gold extraction (has been estimated by Lacerda (1997) at up to 460 metric tons/year at about 1990, of which most was released to the atmosphere). Also not including releases from chlor-alkali production and "other sources". The uncertainty on the total is significant – the authors mention that an estimation accuracy of less than 50 percent can be assigned for mercury in Europe (Pirrone et al., 2001). Most likely, the inaccuracy is higher for large parts of the world.

Russia

As part of the ACAP mercury project, ACAP (2005) developed the most detailed inventory of mercury releases, uses and wastes for Russia available so far. The inventory focused on atmospheric releases and total mobilisation (consumption plus releases) of mercury, but presented releases to water, soil, waste etc., where data were available to do so. An overview of reported releases and consumption/mobilisation in the Russia is given in Table 4-2.

Note that the atmospheric releases values presented for production of thermometers, production of light sources and other products (included in "other intentional uses") do not represent all releases from these products in their life cycle; the releases from the incineration of the spent products after their use are included in the waste treatment entries in the table.

*Table 4-2 Overview of reported releases and consumption/mobilisation in Russia (from ACAP 2005a)*1*

Activity category	Mercury consumption /mobilisation	Mercury releases to the air	Mercury in waste disposed of for landfill/waste dumps
Intentional use of mercury			
Chlor-alkali production	103	1.2 * 2	39
Production of VCM	7.5	0.02	0.0
Gold mining using the amalgamation method, mining of sec. placers	5.5	3.1	1.1
Production of thermometers	26	0.009	0.1
Production of light sources	7.5	0.15	0.001
Other intentional uses	5.8 (+ ?)	0.06 (+ ?)	2.4 (+ ?)
Total assessed intentional uses	*155*	*4.5*	*43*
Mobilisation of mercury impurities			
Coal - electricity producing sector	10	8.0	2.0
Coal - other uses (incl. waste from extraction)	12	6.3	3.6
Oil processing and use of petroleum products	33	3.4 (+ ?)	?
Gas, oil-shale and bio-fuels	8.0	1.0	?
Zinc and lead production	31	1.9	8.5
Nickel and copper production	28	5.3	6.6
Production of other metals	7.8	2.6	4.2
Cement and lime	2.0	1.6	0.4
Total mobilisation as impurity	*132*	*30*	*22*
Waste treatment			
Waste incineration		3.5	
Landfilling			24
Sewage sludge		< 0.1	5.7
Total waste treatment		*4*	*30*
Grand total	287	38	95

*1 Best estimates; "+ ?" indicates that the value only represents the assessed activities but some categories not been assessed may add significantly to the total. Note that the total may be equally higher than indicated.

*2 Direct emissions from the chlor-alkali production processes. In 2002 totally 56 t lost from the process was unaccounted for. A part of this may be emitted to the air.

Ukraine

According to the available information no national inventories of mercury releases have been made for Ukraine. At UNEP's mercury workshop in Kiev in 2004 a Ukrainian representative expressed a wish for Ukraine being one of the countries where UNEP's Mercury Inventory Toolkit Demo (under development by COWI for UNEP) could be tested.

China

Much focus has been on China in the discussions of global mercury releases. China is responsible for significant parts of the releases from Asia shown in Table 4-1 above. A rough inventory of atmospheric releases in China was developed by Feng Xinbin (2005), see Table 4-3 below. Note that gold mining was considered a major mercury release source in 1995. Mercury use in artisanal gold mining became illegal in 2000 in China and may perhaps have been reduced since then. Another aspect which Feng Xinbin describes is that the mercury consumption is increasing, and most of the increase seems to take place in the battery manufacturing sector. This is in spite of an observed steady decrease of the demand for mercury containing batteries in the west due to strict regulation in North America and Europe.

Table 4-3 Emission factors and rough inventory of atmospheric mercury releases from China in 1995 (Feng Xinbin, 2005)

Source category	Emission factor	Total Hg emission (tonnes)
1. Coal combustion	0.12 (g/T)	145
2. Non-ferrous metal production		27
-Primary Cu	10 (g/T)	6
-Primary Pb	3 (g/T)	2
-Primary Zn	20 (g/T)	19
3. Pig iron and steel production	0.04 (g/T)	8
4. Cement	0.1 (g/T)	48
5. Gold extraction	107	107
-Large scale	0.68 (g/g)	21
-Artisanal	15 (g/g)	86
6. Hg mining	45 (g/kg)	35
7. Chlor-alkali production	18 (g/T NaOH)	2
8. Battery, electrical light, thermometer	5% mercury used	20
9. Others		10
Total		**402**

Mercury source categories present in China were also summarised by Chengang Lu (2004) as shown in Table 4-4 at UNEP's mercury workshop in Thailand in 2004. The source categories are by and large the same categories as identified in Russia, except for the dedicated mercury mining taking place in China. A source category which is not mentioned in the table, but which other information indicates may perhaps still be substantial, is the intentional use of mercury for amalgamation in both artisanal and large-scale gold mining in China.

Table 4-4 Mercury source categories identified in China (Chengang Lu, 2004)

Releases from mobilisation of mercury impurities	**Releases from intentional extraction and use of mercury**	**Releases from waste treatment, cremation (originating from both impurities and intentional uses of mercury)**
– Coal-fired power (largest single source to atmospheric emissions) – Energy production from other fossil carbon fuels – Cement production (mercury in lime) – Mining and other metallurgic process • iron and steel • ferromanganese • zinc • other non-ferrous metals	– Mercury mining – PVC (production) – Use of fluorescent lamps, instruments and dental amalgam fillings – Manufacturing of products containing mercury, for example: • thermometers • manometers and other instruments • electrical and electronic switches • batteries	– Waste incineration (municipal, medical and hazardous wastes) – Landfills – Cremation and cemeteries (release to soil)

4.1.4 Main reduction measures

The main reduction measures relevant to the Arctic countries, including Russia, were presented and discussed by ACAP (2005b). Suggestions for specific reduction/prevention actions in Russia are under development in cooperation between the Russian Federal Service for Environmental, Technical and Atomic Supervision and the Danish EPA (assisted by COWI). Both of these activities are part of the Arctic Council ACAP mercury project coordinated by the Danish EPA. The measures are listed in Table 4-5 below. The list includes most of the generally applicable reduction measures, but is not exhaustive. Note that most products with intentional mercury use are covered under the waste treatment heading in the table, because most of the mercury releases from products take place in the waste treatment phase. In specific cases manufacturing and use of such products may however also result in mercury releases.

For a summarised introduction to the main principles of reductions measures for mercury, see the introduction to this section on mercury.

Table 4-5 Overview of main release reduction measures for mercury in the Arctic countries (from the ACAP mercury project, including (ACAP, 2005b)

Source category	Release reduction
Combustion of coal	Implement flue gas desulphurization (FGD) on remaining facilities
	Implement flue gas cleaning systems optimised for mercury capture
	Implementation of coal wash on remaining facilities
	Substitution/phase out
	Switch to other energy sources
	Reduce energy consumption
Non-ferrous metal production (incl. large scale gold)	Lift facilities to Best Available Techniques standards: Establish high efficiency mercury removal steps in all facilities or convert production to the direct leach process. Process residues should be handled and stored safely.
Smaller scale gold extraction	Risk reduction at old sites (mercury stabilisation?)
	Promote release reductions with existing technology/techniques at sites, where gold is extracted from Hg amalgam bearing mining wastes
Waste treatment	**Substitution/phase out**
	Establish and implement elimination program for non-essential intentional mercury uses (products and processes, for which alternatives are readily available): Candidates for possible elimination are (among others): Catalysts for chemical manufacturing, batteries, thermometers, switches and relays, manometers and other measuring and control devices, dental amalgam.
	Release reduction
	Improved emission reduction systems on municipal waste incineration plants (general and mercury specific, as needed)
	Stricter threshold concentrations for high-volume materials (packaging etc.)
	Mercury specific emission reduction systems on hazardous and medical waste incineration plants
	Improve separate collection of waste with high mercury contents
	Direct collected hazardous/ medical waste with mercury to other treatment than incineration; i.e. to safe deposition or recycling (as long as there is a major demand for metal mercury in Russia)
Mercury-based chlor-alkali production	Convert remaining facilities to mercury-free technology
	Clean-up of sites with mercury contamination
Other sources	**Oil and gas extraction**: Improve database and investigate options for release control
	Dental amalgam: Promote stronger incentives to consumers for choosing alternatives
	Laboratory chemicals: Promote the development and use of mercury free standard analyses through international co-operation.

4.1.5 International regulation and agreements

Table 4-6 presents a summarised overview of the coverage in relevant agreements of the main mercury release source categories present in the Arctic countries. The source categories are ranked, the largest first, according to their atmospheric releases across all Arctic countries. Measures in bold are binding with specific deadlines and conditions.

CLRTAP-HM

One major agreement for mercury in the Arctic and European context, the UNECE CLRTAP HM Protocol, stipulates that each Party shall reduce its total annual mercury emissions into the atmosphere from the level of the emission in a set reference year, taking effective measures, appropriate to its particular circumstances. For specific sources, BAT and limit values should be applied (indicated in the table below), but a Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission reductions. Any Party whose total land area is greater than 6,000,000 km2 (e.g. Russia) may, provided it can document that similar reductions have been achieved by other means, notify the secretariat that it wishes to be exempted from the obligations regarding limit values and BAT in existing stationary sources. So far only Canada has used this possibility. Ukraine has ratified the HM protocol, whereas the protocol is still not signed by Russia.

UNEP

Besides the agreements mentioned in the table, it should be noted that perhaps the most important agreement on mercury globally is the decisions taken in February 2003 and February 2005 by the Governing Council of UNEP (2003, 2005). They are not included in the table, because they address mercury broadly, and not with any particular stress on individual source categories. The 2005 decision strengthens the UNEP mercury programme, requests UNEP to develop a report on the supply, trade and demand for mercury on the global market for consideration at the 2006 session of the Governing Council and calls for partnerships between Governments and other stakeholders as an additional approach to reducing risks to human health and the environment from mercury. The decision encourages Governments, the private sector and international organizations to take immediate actions to reduce the risks to human health and the environment posed on a global scale by mercury in products and production processes. Possible actions mentioned include: application and sharing of information on best available techniques and measures to reduce mercury emissions from point sources, taking action related to mercury in products (such as batteries) and production processes (such as chlor-alkali facilities) through, for example, when warranted, introduction of bans or restrictions of uses and considering curbing primary production and the introduction into commerce of excess mercury supply. The Governing Council will again consider progress and assess, at the 2006 session of the Governing Council, the need for further action on mercury, considering a full range of options, including the possibility of a legally binding instrument, partnerships and other actions.

For the Stockholm Convention and the CRLTAP HM protocol, a brief summary on the objectives, scope, and included substances is given in appendix 1.

Table 4-6 Summarised overview of the coverage of mercury in relevant agreements (based on Danish EPA, 2005?)

Source category	**CLRTAP-HM *1**	**NARAP-Hg*1**	**Helsinki Convention and recommendations *7**	**OSPAR Convention and recommendations**
Large coal combustion plants	**PM-limit*6, PM-BAT**	Develop strategy		BAT
Other coal combustion and use	**PM-limit (>50MW)**, PM-BAT	Develop strategy		BAT
Primary extraction and processing of non-ferrous metals (Au (except amalgam tech.), Zn, Cu, Pb)*2	**PM-limit**, (BAT)	Observe releases*5		Hg-BAT
Extraction and use of oil, gas and biofuels		Observe releases *4	Hg-limit (mud/cuttings)	
Incineration of hazardous/medical waste *2,4	**Hg-limits, BAT**	Prevention of Hg inputs, Life cycle management		
Incineration of general/municipal waste*3	**Hg-limits, BAT**	Prevention of Hg inputs, Life cycle management	Hg-limits, BAT	
Chlor-alkali production with mercury technology	**(Hg-limits)*4, BAT**	(Hg-limits)*3, other	Hg-limits	Ban, Hg-limits
Primary extraction and processing of other metals	PM-limit, BAT	Observe releases	Secondary ferrous: Prevention of Hg inputs	Secondary ferrous: Prevention of Hg inputs
Cement production	**PM-limit, BAT**	Observe releases		
Other products and processes			**Minimize or substitute Hg pesticides *5**	
Extraction of gold with the mercury-amalgamation process	BAT			
Light sources (except waste phase) *2	Substitution, Life cycle management	Substitution, Life cycle management	Hg-limits, Life cycle management	Substitution, Life cycle management
Waste-water systems		Prevention of Hg inputs, other		Prevention of Hg inputs
Recycling of other materials	PM-limit, (BAT)			
Manometers, blood pressure gauges and education (except waste phase) *2	Substitution, Life cycle management	Substitution, Life cycle management		Substitution, Life cycle management
Dental amalgam fillings (except waste phase)*3	Substitution, Life cycle management	Substitution, Life cycle management	Substitution, Life cycle management	Substitution, Life cycle management
Landfills/waste deposits		Management programs for combustion and industrial waste		
Mercury recycling plants	**PM-limit, (BAT)**			Hg-limits
Batteries (except waste phase) *2	**Hg-limits,** Life cycle management	Hg-limits, substitution, other	Hg-limits, Life cycle management	Hg-limits, Life cycle management
Thermometers (except waste phase) *2	Substitution, Life cycle management	Substitution, Life cycle management		Hg-limits, Life cycle management
Switches, relays (except waste phase) *2	Substitution, Life cycle management	Substitution, Life cycle management		Hg-limits, Life cycle management
Sum of reported atmospheric mercury releases (rounded)				

*1 NARAP-Hg =The North American Regional Action Plan for Mercury. CLRTAP-HM = The Heavy Metals Protocol of the Convention for Long-Range Transboundary Atmospheric Pollution

*2 Note that the primary mercury releases from products happen in the waste treatment phase. Individual products entries in the table do not include releases from the waste treatment phase, but only for manufacture and use. Products constitute large parts of the mercury input to the waste treatment sectors in some countries.

*3 Only for new facilities.

*4 Limit values for medical waste incineration are not included and are to be evaluated by the parties before December 2005.

*5 Annex 1 of the Helsinki Convention states that: "…..the Contracting Parties shall endeavour to minimize and, whenever possible, to ban the use of the following substances as pesticides in the Baltic Sea Area and its catchment area:…..Mercury compounds….".

4.1.6 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions is presented in Table 4-7 below.

It should be noted that in addition to the mentioned projects, a number of projects exist which may affect mercury releases indirectly. This is particularly the case for a large number of energy related projects being implemented in Russia, Ukraine and China, mainly to address the climate change problem. For example, projects on energy efficiency and renewable energy production have the potential for contributing significantly to mercury release reductions due to reduction of coal combustion. Unless such projects have direct relevance to the specific suggestions given for additional measures in this report, they have not been included in the lists of on-going activities.

Table 4-7 Existing initiatives in Russia, Ukraine and China with relation to mercury releases

Donor/finance institution	Projects/comments	Period Budget
ACAP (Russia)	**Reduction of Atmospheric Mercury Releases from Arctic States (The "ACAP Mercury Project"):** Identification of main source categories for mercury emission within the Arctic region. Based on this information, identify and prioritise source categories for possible reduction measures, and promote development of action plan or strategies for mercury emission reduction for those countries or regions that do not have such a plan. Identify and propose cost effective measures at one or a few specific sources or plants at sites were progress in reduction activities is slow. Initiate reduction measures through fund raising, technology transfer and technical assistance. See more detailed descriptions of several project elements in this section (section 3.1).	Phase I+II: 2002 - 2005 3.3 mDKK Phase III: 2006 - To be decided
World Bank Group *1 (Russia)	**Municipal Heating Project**: Substitutes coal and mazut (heavy fuel oil) with gas in municipal heating (Ed: will result in decreases or increases in Hg releases) and improves energy efficiency (Ed: will reduce Hg releases) in a number of municipalities.	2001-2006 85 mUSD
(Russia)	**RUSSIA ENVIRONMENTAL MANAGEMENT PROJECT**: Upgrading and developing environmental management infrastructure and institutions for management of hazardous waste in the MEPNR (Ministry of Environmental Protection and Natural Resources) and its associated agencies and committees at the Republic, oblasts, kray, and local levels for management of hazardous waste (Ed: may in principle have a significant potential for mercury release reduction). Carrying out of pilot projects and action in selected areas to enable the transfer and adoption of modem approaches and technologies and to develop, test and demonstrate new methodologies and approaches especially designed a) to reduce public exposure to hazardous waste, b) minimize creation of new waste and reduce the volume of existing stored waste and c) improve capacity in setting priorities for cleaning up existing disposal sites (Ed: may in principle have a significant potential for mercury release reduction);.	1994-2007 110 mUSD in all, haz. waste is 1 of 6 tasks
EBRD (Russia)	**Chelyabinsk Electrolytic Zinc Plant.** Renovation and expansion of the existing facility to comply with Russian and international environmental standards and produce LME quality zinc (Special High Grade). Key objectives of the programme will be to: - bring the smelter's operations in line with relevant environmental standards, - expand capacity to meet growing domestic demand, - refine zinc meeting London Metal Exchange Standards. In particular, the following improvements will be carried out: (i) decommissioning of the zinc cake filtration and drying plant and installation of two Larox filters; (ii) opening of an electrolysis solution treatment section and decommissioning of the leaching shop; (iii) reconstruction and commissioning of the third sulphuric acid system and major overhaul of some other components; (iv) commissioning of a new zinc-spraying unit for the zinc electrolysis plant and (v) commissioning of a new electrolysis workshop, a cadmium section and a melting section at the zinc electrolysis plant. These improvements will help to reduce emissions (e.g. of dust; lead; zinc oxide; sulphur dioxide; carbon monoxide; sulphuric acid) and will thus help to ensure compliance with relevant standards.	2000 37 mUSD of this 15 mUSD loan
EBRD (Russia)	**Chelyabinsk Electrolytic Zinc Plant** Proposed renovation of the existing zinc smelter and construction of a mercury recovery plant. The facilities would comply with Russian and international environmental standards and	2002 25 mUSD

Donor/finance institution	Projects/comments	Period Budget
MERCURY	produce LME quality zinc (special high grade). Key objectives of the programme will be to: - bring the smelter's operations in line with relevant environmental standards, - expand capacity to meet growing domestic demand, - refine zinc meeting London Metal Exchange Standards. The proceeds of the new loan will contribute to the completion of the EAP, which has the objectives of making all process units comply with EU standards by 2005: - Construction of a mercury recovery plant; - Completion of the double contact sulphuric acid plant; - A complete renovation of the Waelz kiln.	if this 12 mUSD loan
EBRD (Russia)	**The upgrading and expansion of two existing gold mines in the Republic of Buryatia**	
EBRD Denmark (DEPA) Finland NEFCO (Russia)	**St Petersburg Toxic Waste Emergency Clean-Up Programme.** The project consists of grants from Nordic donors and an EBRD loan to the city of St Petersburg to clean up part of the hazardous waste disposal site of "Krasny Bor Polygon". The EBRD loan will finance part of the city's environmental action programme, which aims to upgrade the hazardous waste disposal site in Krasny Bor and extend its lifetime until an alternative hazardous waste disposal facility is developed; and improve the institutional framework for hazardous waste management.	2000 - 2007 (10.2 mUSD, of which 5.5 mUSD EBRD loan)
(Russia)	**Gold Pre-Production Financing.** Pre-production financing of gold-producing companies in the Russian Federation. The facility will be arranged to finance the production of up to 12 tonnes of gold by up to ten Russian GPCs during the spring-summer 2000 alluvial gold production season. The project will have a significant "demonstration effect" as it is the first internationally led pre-production gold financing which has the direct exposure of Russian alluvial gold producers to Western credit criteria and to environmental and due diligence standards. The intermediary bank and due diligence consultants will select a short list of potential GPCs that will receive financial support under the facility. The selection process will include environmental, health and safety performance criteria. Shortlisted GPCs will be subjected to more detailed health, safety and environmental due diligence. For each selected GPC, an outline Environmental Action Plan will be produced, which will indicate both short-term/immediate and longer-term measures that the company will be required to undertake in order to operate in accordance with national requirements and international health, safety and environmental practices for gold mining. Each credit proposal will be appraised by the EBRD's Environmental Appraisal Unit and be subject to Bank approval. GPCs will be monitored during the course of the EBRD's financing and this will include monitoring the implementation of any health, safety or environmental measures required. GPCs will also be required to submit appropriate staff to health, safety and environmental management training that the Bank may organise using technical cooperation funds.	2002 - ? Appr. 17 mUSD
EU Bistro (Russia)	**Development of hazardous waste management system in Moscow.** The main activities of the projects is: To develop recommendations on improvement of the hazardous waste management system in Moscow, To determine conditions in order to provide the environmentally safe hazardous waste management; To develop draft normative and regulatory documents in order to improve the environmentally safe hazardous waste management; To propose economic mechanisms of hazardous waste management; To increase of the level of public awareness in the field of envi-	2005-2006 0.08 m EUR

Donor/finance institution	Projects/comments	Period Budget
	ronmental safety	
ACAP/Norway (Russia)	**Outspread and Implementation of the Cleaner Production Methodology in the Arctic Zone of the Russian Federation**. The project has undertaken an in-company Cleaner Production (CP) programme in the Arctic town of Norilsk, where the objective was to carry out a full CP assessment of all production units and utilities, and to introduce other available instruments of eco-efficiency to these units as appropriate. The training programme was interactive, meaning that concrete environmental projects was developed by the participants and implemented in all participating production units and public utilities as part of the training programme. A system for creating further continual improvements (EMS), based on the acquired capacity within the company was established. New activities may be initiated.	2002-2004
Canadian International Development Agency, CIDA (China)	**Canada-China Cooperation Project in Cleaner Production**. The project emphasizes pollution prevention from source and involves conserving raw materials and energy, eliminating toxic raw materials, reducing the quantity and toxicity of emissions and waste, and decreasing impact along the entire life cycle of a product. Includes assistance in implementing cleaner production in a number of industries, among these a chemical plant using mercury catalyst three chlor-alkali plants.	1996-2006 15.5 mUSD
SIDA (China)	**Capacity Development of the Environment Administration and the Development of a Master Plan for Restoration of Abandoned Mining Areas and Sustainable Zinc Production**. Beneficiary: Guizhou Environment Protection Bureau (GEPB), China. 1 of several components: Assistance to the environment authorities to develop a study that shall serve as a basis for requesting financing to reduce the harmful leakage from abandoned sulphur- and zinc production sites in Bijie Prefecture in Guizhou Province and, if found feasible, formulation of proposed measures for restoration and environmentally safe zinc production and processing in the Bijie Prefecture. (Eds: The project could get substantial influence on Hg releases).	2005 - (initiation in May 2005)

*1 Reference www.world-bank.org; projects: 77 WB projects in Russia; 0 titles including Hg specifically; * 12 titles with possible source category relevance; * Further 8 titles, of less possible relevance (not read);'

Other information about ongoing activities - Russia

Russia is taking part in the ACAP Mercury Project ("Reduction of atmospheric releases of mercury from the Arctic States"). A substantial element of the project is to support mercury reduction activities in the Federation. One action in the ACAP project has been to prepare a national mercury release inventory for Russia (ACAP, 2005). The inventory is the most detailed ever for Russia, and is forming the basis for all other ACAP activities on mercury in Russia. Also, a draft input to priority actions on mercury in Russia was prepared as part of the ACAP Mercury project (ACAP , 2005c). As of April 2005, this document is in finalisation within the ACAP mercury project together with the Russian members of the Steering group (Russian Federal Service for Environmental, Technical and Atomic Supervision "Rostechnadzor"). The catalogue of measures presented in the document has already been used in Rostechnadzor's preparation of input to an expected meeting of the Russian National Safety Council.

Also as part of the ACAP Mercury Project, three potential demonstration projects for mercury reductions in the Russian Federation are under evaluation (by

April 2005). It is expecting that 1-2 projects may be selected for further demonstration implementation:

- Mercury release reductions and mercury-pesticide destruction at a mercury recycling plant.
- Collection and treatment of spent mercury lamps and other mercury-containing waste.
- Mercury release reduction with carbon injection at a coal power plant (pilot scale).

China

The single source category with the largest reported atmospheric mercury releases globally is coal combustion for power production and other uses. China has been mentioned as one of the major contributors to these releases globally. The power demand is increasing very rapidly in China, and the production capacity is continuously built out. The USA and perhaps other countries have measurement and perhaps inventory activities in progress for coal-fired power combustion in China. The details of the US activities are not known.

The study by Feng Xinbin (2005) mentioned above, and a few earlier studies not reviewed here, indicate that a number of studies on mercury pollution have been performed in China over the years, and that a scientific community on the issue exists in China. Most studies address local pollution incidents, but some seam to consider the regional or national level. Most existing studies are only reported in Chinese and have not been published internationally.

4.2 Lead

ABSTRACT. Lead and its compounds are toxic to humans and in the environment. The major source of lead releases to the atmosphere and a major lead problem of concern have been the releases of lead compounds from the use of lead additives in petrol. Leaded petrol for vehicle transport is today 100% phased out in Russia, Ukraine and China. The effect of lead shot on waterfowls is internationally recognised, and a ban on lead shot in wetlands may be the first step in the phase out of lead in ammunition. Lead batteries account for more than 50% of global lead consumption, and development of systems for efficient end environmentally sound collection and recycling of lead batteries is an important activity area. The major Russian (and global) source category of lead releases today is non-ferrous metal industry. Measures for reduction of lead releases from this industry also address releases of cadmium, mercury and the unintentional production of PCDD/PCDF, PCB and HCB, and release reduction measures are stipulated by the UNECE HM protocol. Reduction of releases from non-ferrous industry is thus a major area of action.

Lead is a heavy metal with a high toxicity and has no known beneficial effects in living organisms. Lead is toxic at very low exposure levels and has acute and chronic effects on health and the environment. Lead is not degradable in nature and will thus, once released to the environment, stay in circulation.

In humans lead can affect the nervous system, the reproductive system, and the heart and blood system. Chronic low exposure is of concern. Lead accumulates in the bone structure in humans and can be released under pregnancy from the bone structure to the blood. Lead is causing concern in particular due to the possible impacts on children. Lead influences the nervous system. This influences learning abilities and behaviour. A source of particular importance to the exposure of the general population has been lead additives to petrol.

In the environment lead is known to be toxic to plants, animals and microorganisms. The demonstrated effects of lead on birds ingesting lead shot and sinkers have led to the phase out of lead for these purposes in a number of countries. Lead is, contrary to mercury and the POPs, in general not biomagnified in the food chains.

It is characteristic to lead that many different products containing lead will end up in waste management systems and be a source of lead to incineration plants and/or landfills. Significant quantities of lead are continuously stockpiled in landfills and other deposits and represent a potential for future releases to the environment.

Long-range transport of lead by air is demonstrated from ice core samples from Greenland. Emissions from Eurasia and North America must be considered important sources for lead to the Arctic Region.

4.2.1 Sources and releases

Consumption

The global consumption of lead has during the period 1970 to 2000 increased from 4.5 million tonnes to 6.5 million tonnes (LDAI 2002). In the absence of global consumption figures, the consumption by end uses in the OECD countries in 1970, 1990 and 2000 is shown in table 3.4.

The most significant changes in the overall use pattern in the OECD countries are an increased consumption for batteries and a decrease in the areas of cable sheeting and petrol additives.

Table 4-8 Lead consumption by end uses in OECD countries (based on Hansen and Lassen 2003a)

Application	1970 (%) * 1	1990 (%) * 1	2000 (%) * 2
Batteries	39	63	75
Cable sheeting	12	5	not indicated 3)
Rolled/extruded lead (mainly sheets)	12	9	6
Ammunition	4	3	3
Alloys	7	4	4
Lead compounds	11	10	9
Petrol additives	10	2	1
Miscellaneous	5	4	2
Total OECD (1000 tonnes)	**3,050**	**3,365**	**5,612 4)**
Total World (1000 tonnes)	**4,502**	**5,627**	**6,494 4)**

Original sources: *1 (OECD 1993) and *2 (LDAI 2002). For details see Hansen and Lassen 2003a.

Lead compounds have during the whole period accounted for about 10% of the total, but some major changes within this category have taken place. A breakdown of the production in consumption in OECD countries in 1990 is shown in Table 4-9. The major part of the lead compounds is today glass pigments for cathode ray tubes and crystal glass and stabilisers for PVC. Although lead compounds account only for 10% of the consumption, they take up a more significant part of lead disposed of to landfills and releases to the environment as the compounds are, apart from cathode ray tubes, in general not recycled.

Table 4-9 Lead compounds consumption by end uses in OECD countries 1990 (derived from /OECD 1993/)

Application area	%
Glass pigments	
Cathode ray tubes	40
Crystal glass	15
Speciality glass/optical	4
Light bulbs	3
Other pigments and compounds	
Plastic additives (mainly PVC stabilizers)	23
Glazes	9
Paints	4
Ceramics	2
Total consumption (1000 tonnes lead)	approx 340 tonnes

Emission to air

In the mid-1990s fuel additives still accounted for 74% of the global lead emission to air (Table 4-10). This amount will due to the widespread phase-out today be significantly lower making non-ferrous metal production and stationary fuel combustion (mainly coal combustion) the main source categories. The releases to the atmosphere are of particular concern because of the transboundary nature of the pollution.

Table 4-10 Global atmospheric emission of lead in mid-1990s (Pacyna & Pacyna 2001)

Economic sector	Air emission (tonnes)	%
Stationary fossil fuel combustion	11,690	10
Non-ferrous metal production	14,815	12
Iron and steel production	2,926	3
Cement production	268	0.2
Fuel additives	88,739	74
Waste disposal (incineration)	821	0.7
Total	**119,259**	**100**
Total 1983 emission to air	332,350	

Releases to water and soil

The global releases of lead to land was in 1983 estimated at 804,000-1,820,000 t/year; the main sources being atmospheric deposition, waste of commercial products (landfilled), mine tailings and smelter slags and wastes (Nriagu and Pacyna 1988). The atmospheric fall-out will be smaller today, whereas the other sources most probably have increased. Lead disposed of in waste products represent a potential release to soil and water environments in the future.

The direct releases to water environments excluding atmospheric deposition were estimated at 10,000-67,000 t/year.

Russia

In 1997, a white paper on lead contamination of the environment and the effect on human health in Russia was prepared by Russian Ecological Federal Information Agency by grants from US AID and the Federal Ecological Fund of the Russian Federation (SCEP 1997). The following is extracted from this document unless otherwise indicated.

Total releases to the air and water and waste production in 1995 are shown in Table 4-11.

Table 4-11 Sources of lead releases to the environment in Russia for 1995 by industry and activity (SCEP 1997) tons of lead)

Source	Atmospheric discharges t/year	Discharges into bodies of water t/year	Waste production t/year
Stationary sources			
Goskomstat data for all branches	615.5	50.5	1 864 056 *1
Industry data:			
Metallurgy	671	0.64	
of which, Non-Ferrous	*660*	*0.57*	*900*
Machine Building	38.2	3.5	-
Burning of Fuel (coal, oil, gas)	400 *2	-	-
Chemical, Petrochemical, and Petroleum Processing Industries	0.94	9.55	725 *3
Glass Production (estimate)	100-200	15-20	100
Canning Industry (estimate)	-	-	100-200
Defense Industry (estimate)	150	-	-
Non-Stationary sources:			
Auto transport	4 000	1 000*4	60 000 *5
Aviation and aeronautical and space technology (estimate)	400	-	-

Notes (as indicated in SCEP 1997):

*1 Lead-containing wastes of all branches except those used, neutralized, properly buried at official sites or placed in proper storage.

*2 Estimate for 1993.

*3 Production of lead minimum (Author's comment: = red lead).

*4 Estimate of the amount of lead that leaked into the ground or water as electrolyte and paste from car batteries during their destruction.

*5 Worn-out car batteries except for those collected by the Committee for Secondary Non-Ferrous Metals.

The major source of atmospheric releases, vehicle transport, has in the meantime ceased as leaded petrol has been phased out 100% in Russia (UNEP 2004).

In 1995, approximately 660 tons lead was released to the atmosphere by non-ferrous metallurgical enterprises. Approximately 94% of this was discharged by 5 enterprises: Middle-Ural Copper-Smelting Factory (291 t/yr), JSC Sviatogor-

Krasnouralsk Copper-Smelting Plant (170 t/yr); Kirovgrad Copper-Smelting Plant (11 t/yr); JSC Dalpolimetall (28 t/yr); and the Electrozinc factory (16 t/yr).

According to the white paper the inadequacy of particle detection systems available at non-ferrous metallurgical enterprises in the Urals is a vital factor that also determines the amount of lead discharges into the atmosphere.

The production of car batteries in the machine tool industry consumes half of the lead that was used in the country. In 1995, total discharges into the atmosphere by seven car battery plants in Russia, which form the JSC Elektrozariad, made up approximately 38.2 tons lead; total disposal into bodies of water (through sewers) was 35.3 tons.

The releases from glass production were 100-200 t/year.

With the transition to using plastic materials for sheets in the production of cables, cable factories had decreased their consumption of lead and lead alloys. In 1995, the consumption of lead within factories of this sub-industry has decreased to 5,000 tons, and the releases from these processes were considered insignificant.

According to official Russia statistics, the releases of lead from stationary sources is at the same level today as in 1995. The total releases from stationary sources in 2003 are reported at 632 tonnes lead (MNR 2004).

To what extent the releases from other sources has changed significantly has not been investigated, but most probably the main source categories identified in the white paper are also the main categories today.

Besides measures to reduce the use of leaded gasoline, the white paper proposes measures targeting recycling of batteries, production of batteries, substitution of lead shot, emissions from the metallurgical sector, lead waste from households and industries, substitution of lead pigments and phase-out of tin cans with leaded soldering.

Ukraine

No overview on lead consumption and lead releases in Ukraine has been identified.

Primary lead is not produced in Ukraine, whereas the secondary production totalled 12,000 t in 2003 (Smith 2003.) The totally reported lead emission to the air from Ukraine in 2004 was 144.5 t (EMEP 2005).

Leaded petrol has been phased out 100% in Ukraine as of 2001 (UNEP 2004).

China

It has not been possible to identify any comprehensive assessments of the use and releases of lead in China.

China is the world's second largest producer of primary lead with a mine production of 660,000 t in 2003 (Smith 2003). The refinery production totals 1,100,000 t primary and 230,000 t secondary lead. Further increases in the vehicle fleet, increased exports of automotive batteries, and ongoing investment in the telecommunications and information technology sectors are expected to result in a lead demand growth of 10.5% in 2004 (Smith 2003). Key lead applications in China at present are lead-acid batteries, cable sheets, lead products, chemical products and alloys. Lead-acid battery production is the largest consumer and made up 67% of total lead consumption in China in 1999 (Feng 2005).

According to UNEP (2004) leaded petrol is today 100% phased out in China.

With the large primary and secondary production of lead it must be expected that the lead releases from this sector may be very significant. The state of the secondary lead sector is indicated by the following quotation:

"However, China's lead-recycling industry is underdeveloped, with production lagging far behind that of North America, Europe and Japan, where highly developed auto industries provide adequate raw materials for lead recycling. Most enterprises still use old polluting methods, and, to date, only two have adopted environment-friendly techniques. Experts have called for the strengthening of regulations in the industry, both for development and environmental protection." (China.org 1999)

According to articles of China Daily two issues related to lead in electronics are on the agenda: Complying with the EU RoHS Directive (Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment) and collection and recycling of electronics. China exported about USD 380 billion worth of electric and electronic products in 2003 and about 30 per cent of them went into the European market and the complying with the RoHS directive will result in decreased use of lead in the electronic industry.

According to China Daily (2004) the National Development and Reform Commission (NDRC), the country's top economic policy planning body, is currently circulating on its website a draft regulation on recycling old or scrap electronics, in a hope to elicit opinions from the public, before it is officially enacted. Currently, only a tiny portion of scrap electronics is being adequately handled, resulting in a huge waste of resources and environmental damage (China Daily 2004).

4.2.2 Main reduction measures

Technical measures for reduction of lead releases for major source categories are summarised in Table 5-3.

Contrary to mercury, the main part of lead and cadmium is adhered to particles in the flue gas and effectively captured with air pollution controls for emission of particulate matter (PM) and sulphur/acid flue gases. The driving force for implementing more efficient controls will in power plants, industrial installations (except installations specifically using lead) and waste incinerators primarily be to reduce the emission of particulate matter, acid gases, NOx, mercury and PCDD/PCDFs.

By the flue gas treatment system the lead is directed to other media (waste), and the most efficient measures for reducing the lead releases to all media are thus to reduce the lead input to the processes, e.g. by reducing non-essential intentional lead uses and the use of lead containing fuels and raw materials (particularly coal) and improved recycling of lead in waste products.

Recovery of lead from batteries and printed circuit boards is without proper emission controls highly polluting processes. Although the lead releases from these processes on a national scale are relatively small, the local impact may be very significant.

The options for substitution of lead for 30 different applications have been summarised in Hansen et al. 2002. Only major application areas for which substitution has taken place in many countries is listed in the table below.

Table 4-12 Overview of main technical release reduction measures for lead

Source category	Release reduction measures
Fuel additives	Phase out lead scavengers for all petrol types including aviation gasoline
Combustion of coal	Implement flue gas desulphurization (FGD) on remaining facilities Switch to other energy sources Reduce energy consumption
Primary metal production, cement production, secondary non-ferrous metal production, casting	Lift facilities to BAT standards. Improve air pollution controls
Secondary iron and steel production	Improve air pollution controls Recovery of metals from filter dust Improve scrap pre-treatment: selectively recycle batteries and other lead containing parts
Glass making	Improve air pollution controls (Substitution of lead in lead crystal glass with barium is implemented in a few countries)
Waste treatment	Improve air pollutions controls on incinerators Promote recycling of lead-containing products: batteries, lead sheets, cables, electronics (lead solders and cathode ray tubes) Implement elimination programs for products for which alternatives are readily available. Candidates for possible elimination are among others: plastic stabilizers and pigments
Batteries	Develop waste management system for lead batteries Implement BAT in lead battery recycling plants Implement BAT in facilities for production of batteries
Electronics	Develop waste management system for electronics Establish facilities for recycling of metals in printed circuit boards and other electronic parts using BAT Substitute lead in solders and other applications covered by the EU RoHS Directive
Pigments and PVC stabilisers	Substitute with lead-free alternatives
Ammunition	Phase out use of lead shot (in wet-lands as first priority)

4.2.3 International regulation and agreements

Table 4-13 presents a summarised overview of the coverage of specific lead release source categories in relevant agreements. Measures in bold are binding with specific deadlines and conditions.

The UNECE CLRTAP HM protocol stipulates that each Party shall reduce its total annual lead emissions into the atmosphere from the level of the emission in a set reference year, taking effective measures, appropriate to its particular circumstances. For specific sources, BAT and limit values should be applied (indicated in Table 4-13), but a Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission reductions. Any Party whose total land area is greater than 6,000,000 km2 (e.g. Russia) may, provided it can document that similar reductions have been achieved by other means, notify the secretariat that it wishes to be exempted from the obligations regarding limit values and BAT in existing stationary sources. So far only Canada has used this possibility. Ukraine has ratified the HM protocol, whereas the protocol is still not signed by Russia.

Lead shot used in wetlands is addressed by the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). AEWA is a multilateral environmental agreement, developed within the framework of the Convention of Migratory Species. The agreement is signed by Ukraine (01.01.2003) but still not ratified. The agreement is not signed by Russia which European part is within the geographic area of the agreement.

The "Pan-European Strategy on the Phase Out of Added Lead in Petrol" was presented and adopted at the fourth "Environment for Europe" Ministerial Conference held in June 1998 in Aarhus, Denmark. The Strategy was signed by Ukraine. Both Russia and Ukraine have phased out the use of lead in petrol for vehicle transport.

Table 4-13 Summarised overview of the coverage of lead in relevant agreements

Source category	CLRTAP-HM	AEWA	Helsinki Convention and recommendations	OSPAR Convention and recommendations
Fossil fuel utility and industrial boilers >50 MW	PM-limit (air) BAT			BAT
Primary extraction and processing of non-ferrous metals (Pb, Cu, Zn, Ag)	PM-limit (air) BAT			BAT
Secondary non-ferrous metal production (Pb, Cu, Zn, Ag)	PM-limit (air) BAT			
Primary iron and steel production	PM-limit (air) BAT		Pb limit (ww)	PM limit (air)
Secondary iron and steel	PM-limit (air) BAT			PM limit (air), dust recycling *2
Incineration of waste	PM-limit (air) BAT		Pb limit (ww) BAT	
Cement production	PM-limit (air) BAT			
Batteries			Life cycle management	
Metal surface treatment			Pb limit (ww)	
Chemical industry			Pb limit (ww)	
Glass industry (using lead)	PM-limit (air) BAT		Pb limit (air, ww)	
Lead in petrol	Pb-limit (product) *1		Phase out before 2000	
Ammunition for hunting in wetlands		Endeavour to phase out the use of lead shot by the year 2000		

*1 Lead content of petrol for on-road vehicles shall not exceed 0.013 g/l (=unleaded petrol) with some specified exemptions.

*2 Recommendation that recovery of metals from all zinc-rich (zinc concentration above 16%) filter dust and filter dust from all stainless steel production should be carried out to promote recycling of cadmium and lead.

BAT: Best Available Techniques; ww: waste water, PM-limit (air): limit value for particulate matter emission to air.

4.2.4 Overview of existing activities

Only one project specifically addressing lead use or lead releases in Russia, Ukraine or China has been identified.

One EBRD loan in 2002 for Chelyabinsk Electrolytic Zinc Plant, Russia, includes improvements that reportedly help to reduce the emission of lead from the plant.

Some activities of the ACAP project "Outspread and Implementation of the Cleaner Production Methodology in the Arctic Zone of the Russian Federation" mentioned in table Table 4-7 may indirectly address the lead emission from the Norilsk Nickel smelter, but it has not been investigated.

DEPA has supported a project "National System for Collection, Storage, Transportation and Treatment of used Lead Batteries, 2005" in Bulgaria. The project included preparation of an inventory covering all collection sites for batteries and establishment of a new organisation for environmental safe handling of batteries.

Projects addressing the use of fossil fuels may indirectly to some extent reduce lead emissions among other pollutants.

Table 4-14 Identified initiatives in Russia, Ukraine and China addressing lead releases

Donor/finance institution	Projects/comments	Planned period Budget
EBRD (Russia) Lead, cadmium	**Chelyabinsk Electrolytic Zinc Plant.** Renovation and expansion of the existing facility to comply with Russian and international environmental standards and produce LME quality zinc (Special High Grade). Key objectives of the programme will be to: - bring the smelter's operations in line with relevant environmental standards, - expand capacity to meet growing domestic demand, - refine zinc meeting London Metal Exchange Standards. In particular, the following improvements will be carried out: (i) decommissioning of the zinc cake filtration and drying plant and installation of two Larox filters; (ii) opening of an electrolysis solution treatment section and decommissioning of the leaching shop; (iii) reconstruction and commissioning of the third sulphuric acid system and major overhaul of some other components; (iv) commissioning of a new zinc-spraying unit for the zinc electrolysis plant and (v) commissioning of a new electrolysis workshop, a cadmium section and a melting section at the zinc electrolysis plant. **These improvements will help to reduce emissions (e.g. of dust; lead; zinc oxid**e; sulphur dioxide; carbon monoxide; sulphuric acid) and will thus help to ensure compliance with relevant standards.	2002 15mUSD, loan Total project costs 37mUSD
Blacksmith Institute (partly funded by USAID)	**Polluted Places project.** Polluted Places identify locations in many countries where human health is significantly impacted by pollution. The project then develops and supports local agencies in solving those problems, working in partnership with governments, industry and communities. The program includes the Dalnegorsk lead mine and Karabash copper smelter in Russia.	?

4.3 Cadmium

ABSTRACT. Cadmium and its compounds are toxic to humans and in the environment. Nickel-cadmium (NiCd) batteries account for more than half of the global consumption with China as the major producer. Development of efficient systems for collection and recovery of cadmium batteries as well as batteries containing other hazardous substances is essential for preventing cadmium disposal to landfills and waste incinerators. For most of the major applications of cadmium alternatives are available on the market, e.g. pigments, plastic stabilizers, cadmium plating and batteries. Elimination programmes for products and processes, for which alternatives are readily available, may include preparation of action plans, surveys of uses and options for substitution, and implementation of regulation and substitution demonstration projects. The major global source category of cadmium releases today is non-ferrous metal industry. Measures for reduction of cadmium releases from this sector also address releases of lead, mercury and the unintentional production of PCDD/PCDF, PCB and HCB, and release reduction measures are stipulated by the UNECE HM protocol.

Cadmium is a heavy metal with a high toxicity. Cadmium is not degradable in nature and will thus, once released to the environment, stay in circulation. Cadmium and cadmium compounds are, compared to other heavy metals, relatively water soluble. They are therefore also more mobile in e.g. soil, generally more bioavailable and tend to bioaccumulate.

Cadmium accumulates in the human body, especially in the kidneys. According to current knowledge, kidney damage (renal tubular damage) is probably the critical health effect. Other effects of cadmium exposure are disturbances of calcium metabolism, hypercalciuria, ostoemalaci and formation of stones in the kidney. High exposure can lead to lung cancer and prostate cancer.

Atmospheric deposition combined with cadmium impurities in phosphate fertilizers seems continuously to cause an increase of the content of cadmium in agricultural top soil, which by time will be reflected in an increased human intake by foodstuffs and therefore in an increased human risk of kidney damage and other effects related to cadmium.

In the marine environment levels of cadmium may significantly exceed background levels causing a potential for serious effects on marine animals and in particular birds and mammals.

Significant quantities of cadmium are continuously stockpiled in landfills and other deposits, and represent a significant potential for future releases to the environment.

Long-range transport of cadmium by air is demonstrated by ice core samples from Greenland. Emissions from Eurasia and North America must be considered important sources for cadmium to the Arctic Region.

4.3.1 Sources and releases

Intentional consumption

Cadmium is produced mainly as a by-product from mining, smelting and refining of sulphide ores of zinc, and to a lesser degree, lead and copper. As it is a by-product of zinc, the production of cadmium is more dependent on zinc refining than on market demand.

The general trend in the global cadmium consumption over the last two decades has been a steep increase in the use of cadmium for batteries and a decrease in the use for nearly all other applications. In the absence of global consumption figures, total Western World consumption and EU consumption in 2000 is shown in Table 4-15. NiCD batteries take up more than 50% of the total cadmium production. Although the use of cadmium for pigments, PVC stabilisers and plating in some countries by and large has been phased out, these applications at the EU level still account for a significant part of the total cadmium consumption in 2000, a pattern which presumably can also be seen in other parts of the world.

Table 4-15 Intentional cadmium consumption by end-uses in Western World 1990 (based on Hansen and Lassen 2003b)

Application	Western World 1990 * 1		EU about 2000 * 2	
	tonnes Cd/year	%	tonnes Cd/year	%
Ni-Cd batteries	9,100	55	1,900	73
Pigments	3,300	20	300-350	12
Stabilisers	1,650	10	150	6
Plating	1,320	8	200	8
Alloys	500	3	30-40	1
Other	660	4	-	-
Total	**16,500**	**100**	**1,930-1,990**	**100**

Original sources: *1 (OECD 1994b) and *2 (Scoullos et al. 2001). For details, see Hansen and Lassen 2003a.

Unintentional mobilisation as impurity

Cadmium is like other heavy metals mobilised as impurity in raw materials and fuels. In products cadmium in zinc and phosphorous fertilisers has been of major concern, and the content of cadmium in zinc products and fertilisers is regulated in many countries.

Emission to air

From 1983 to mid-1990s the global emission of cadmium to air decreased from about 7,600 tonnes (medium estimates of Nriagu and Pacyna 1988) to 3,000 tonnes (Table 4-16). According to the assessment, by far the major source of cadmium emission to the air is non-ferrous metal production followed by stationary fossil fuel consumption (mainly coal utility boilers).

The estimates should, however, be treated with caution as some sources may be significantly underestimated due to the methodology of the inventories. In particular waste incineration may be underestimated (AMAP 2002).

In countries with extensive waste incineration the pattern may be significantly different. In Denmark, waste incineration accounts for 50% of the total air emission, and combustion of oil products accounts for 35% of the total (Drivsholm et al. 2000).

Table 4-16 Global emission of cadmium to air in mid-1990s (Pacyna & Pacyna 2001)

Economic sector	Air emission (tonnes)	%
Stationary fossil fuel combustion	691	23
Non-ferrous metal production	2,171	73
Iron and steel production	64	2.0
Cement production	17	0.6
Waste disposal (incineration)	40	1.3
Total	**2,983**	
Total, 1983 emission	7,570	

The significant decrease in air emissions noted in Table 4-16 is mainly caused by improved flue gas cleaning, which has partly changed a problem of direct release to the environment to an issue of how to control cadmium being stockpiled in landfills and other deposits in the long-term perspective.

Russia

It has not been possible to identify any assessments of cadmium use or cadmium releases in Ukraine.

Russia produced in 2003 about 950 t of cadmium (Plachy 2005).

Cadmium in phosphorous fertilizers has in many countries been a problem of concern because of the resulting increased cadmium level in agricultural soils. Russia has a significant mining of phosphate rock for fertilizers. The Russian phosphate rock from the Kola Peninsula has a cadmium content of about 8 g Cd per ton P (phosphorous); the lowest among the major phosphate reserves in the world (Karlsson et al. 2004).

Ukraine

It has not been possible to identify any assessments of cadmium use or cadmium releases in Ukraine. Ukraine produced in 2003 about 25 t primary cadmium (Plachy 2005).

China

China is the world's largest producer of cadmium with a production of 2,500 t in 2003 (Plachy 2005). China is today also the major cadmium consumer with an annual consumption of about 5,400 t of cadmium, primarily for production of NiCd batteries. According to a preliminary proposal by the State Environmental Protection Administration of China, domestic battery manufacturers and importers will be required to set up collection networks for discarded batteries, based on their distribution chains (Plachy 2003). Releases of cadmium from two NiCd factories in China have recently been studied by Greenpeace (Brigden and Santillo 2004) demonstrating contamination by heavy metals in environmental samples in the vicinity of both factories.

Major Chinese battery producers advertising on the Internet provide both NiCD and NiMH (nickel metal hydride) batteries.

4.3.2 Main reduction measures

Contrary to mercury, the main part of lead and cadmium in flue gas is adhered to particles in the flue gas and effectively captured with air pollution controls for emission of particulate matter (PM) and sulphur/acid flue gases. The driving force for implementing more efficient controls will in power plants, industrial installations (except installations specifically processing cadmium) and waste incinerators primarily be to reduce the emission of particulate matter, sulphur/hydrochloric acid, mercury or PCDD/PCDF.

By the flue gas treatment system the cadmium is directed to other media (waste), and the most efficient measures for reducing the cadmium releases to all media are thus to reduce the cadmium input to the processes, e.g. by reducing non-essential intentional cadmium uses and the use of cadmium containing fuels and raw materials (particularly coal).

The major source of cadmium directed to the waste treatment systems is in many countries NiCd batteries. The releases (today and in the future) from discarded batteries can be reduced by implementation of effective battery collection systems and promotion of cadmium-free batteries, in particularly nickel metal hydride, NiMH.

The options for substitution of cadmium for 7 different applications have been summarised in Hansen et al. 2002. Only major application areas, for which substitution has taken place in many countries, are listed in the table below.

Table 4-17 Overview of main technical release reduction measures for cadmium

Source category	Technical release reduction measures
Combustion of coal	Implement flue gas desulphurization (FGD) on remaining facilities Switch to other energy sources Reduce energy consumption
Zinc/cadmium production	Lift facilities to BAT standards. Improve air pollution controls
Other primary metal production, cement production, secondary non-ferrous metal production, casting	Lift facilities to BAT standards. Improve air pollution controls
Secondary iron and steel production	Improve air pollution controls Phase out cadmium plating and reduce cadmium content of zinc for surface treatment Recover metal from the filter dust
Waste treatment	Improve air pollution controls on incinerators Promote recycling of NiCd batteries and the use of alternative batteries (e.g. NiMH) Implement elimination programs for products for which alternatives are readily available. Candidates for possible elimination are among others: PVC stabilizers, pigments, cadmium plating
Pigments and PVC stabilisers	Substitute with cadmium-free alternatives
Zinc an zinc compounds	Reduce cadmium content of zinc and zinc compounds
Fertilizers	Reduce cadmium content of fertilizers (probably not a problem in Russia)

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4.3.3 International regulation and agreements

Table 4-18 presents a summarised overview of the coverage of specific cadmium release source categories and cadmium products in relevant agreements. Measures in bold are binding with specific deadlines and conditions.

The UNECE CLRTAP HM protocol stipulates that each Party shall reduce its total annual cadmium emissions into the atmosphere from the level of the emission in a set reference year, taking effective measures, appropriate to its particular circumstances. For specific sources, BAT and limit values should be applied (indicated in Table 4-18), but a Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission reductions. Any Party whose total land area is greater than 6,000,000 km2 (e.g. Russia) may, provided it can document that similar reductions have been achieved by other means, notify the secretariat that it wishes to be exempted from the obligations regarding limit values and BAT in existing stationary sources. So far only Canada has used this possibility. Ukraine has ratified the HM protocol, whereas the protocol is still not signed by Russia.

Cadmium is specifically addressed by a number of OSPAR and HELCOM recommendations and the minimised use of cadmium compounds as pesticides (among a list of other pesticides) is included by the Helsinki Convention.

UNEP Governing Council adopted at its February 2005 meeting a plan to study lead and cadmium releases to determine the transboundary impacts of the two metals, with a view toward possible international action if found to be warranted.

Table 4-18 Summarised overview of the coverage of cadmium in relevant agreements

Source category	CLRTAP-HM	Helsinki Convention and recommendations	OSPAR Convention and recommendations
Fossil fuel utility and industrial boilers >50 MW	PM-limit (air), BAT		BAT
Primary extraction and processing of non-ferrous metals (Pb, Cu, Zn, Ag)	PM-limit (air), BAT		BAT
Zinc mining		Cd limit (ww)	Cd limit (ww)
Secondary non-ferrous metal production (Pb, Cu, Zn, Ag)	PM-limit (air), BAT		
Primary iron and steel production	PM-limit (air), BAT	Cd limit (ww)	Dust limit (air)
Secondary iron and steel	PM-limit (air), BAT	Prevention of Cd inputs,	Cd limit (ww), PM limit (air) dust recycling *2
Incineration of waste	PM-limit (air), BAT	Cd limit (ww) BAT	
Chemical industry		Cd limit (ww)	
Extraction of oil and gas		Cd limit (mud)	
Cement production	PM-limit (air), BAT		
Waste-water systems		Prevention of Cd inputs	
Batteries		Life cycle management, Collection and recycling Cd limit (ww) from manufacture	Life cycle management Cd limit (ww) from manufacture
Electroplating		Use limitations, Cd limit (ww) from manufacture	Subst. if possible, Cd limit from manufacture (ww)
Pigments, stabilizers		Use limitations, Cd limit (ww) from manufacture	Cd limit (ww) from manufacture
Cadmium compounds		Cd limit (ww) from manufacture	Cd limit (ww) from manufacture
Cadmium pigments in textiles			Should not be used, Cd limit (ww)
Cadmium compounds as pesticides		Minimize use / ban *1	
Fertilizers		Cd limit (product)	

*1 The parties of the Helsinki Convention shall endeavour to minimize and, whenever possible, to ban lead and cadmium compounds as pesticides in the Baltic Sea Area and its catchment area.

*2 Recommendation that recovery of metals from all zinc-rich (zinc concentration above 16%) filter dust and filter dust from all stainless steel production should be carried out to promote recycling of cadmium and lead.

BAT: best available techniques; ww: waste water, PM-limits: limit value for particulate matter emission.

4.3.4 Overview of existing activities

Only one project specifically addressing cadmium use or releases in Russia, Ukraine or China has been identified (see Table 4-19).

One EBRD loan in 2002 for Chelyabinsk Electrolytic Zinc Plant, Russia, includes improvements addressing cadmium production by the plant.

Projects addressing the use of fossil fuels may to some extent reduce lead emissions among other pollutants.

Table 4-19 Identified initiatives in Russia, Ukraine and China addressing cadmium use and releases

Donor/finance institution	Projects/comments	Planned period Budget
EBRD (Russia) Lead, cadmium	**Chelyabinsk Electrolytic Zinc Plant.** Renovation and expansion of the existing facility to comply with Russian and international environmental standards and produce LME quality zinc (Special High Grade). Key objectives of the programme will be to: - bring the smelter's operations in line with relevant environmental standards, - expand capacity to meet growing domestic demand, - refine zinc meeting London Metal Exchange Standards. In particular, the following improvements will be carried out: (i) decommissioning of the zinc cake filtration and drying plant and installation of two Larox filters; (ii) opening of an electrolysis solution treatment section and decommissioning of the leaching shop; (iii) reconstruction and commissioning of the third sulphuric acid system and major overhaul of some other components; (iv) commissioning of a new zinc-spraying unit for the zinc electrolysis plant and (v) commissioning of a new electrolysis workshop, a cadmium section and a melting section at the zinc electrolysis plant. These improvements will help to reduce emissions (e.g. of dust; lead; zinc oxide; sulphur dioxide; carbon monoxide; sulphuric acid) and will thus help to ensure compliance with relevant standards.	2002 15 mUSD, loan Total project costs 37mUSD

5 Persistent organic pollutants (POPs)

5.1 PCDD/PCDFs

ABSTRACT
Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs) are two groups of persistent substances toxic to humans and in the environment. PCDD/PCDFs are not used intentionally, and the reduction measures concern the avoidance of formation and releases of the substances. PCDD/PCDFs reduction is addressed by the Stockholm Convention signed by Russia, Ukraine and China. As part of the enabling activities for implementation of the Stockholm Convention preliminary PCDD/PCDFs inventories are undertaken in the countries, and action plans for addressing PCDD/PCDFs releases will be prepared. Further activities concerning PCDD/PCDF reduction should preferably be in accordance with the priorities of the countries' action plans.

Releases from waste incineration, iron ore sintering, secondary metal production and uncontrolled burning of waste are probably the main PCDD/PCDFs sources in the countries, and reduction of releases from these sources should have high priority. Measurements of PCDD/PCDFs are complicated and expensive, and there is an urgent need for actual measurements and detailed inventories documenting the need for and costs of implementation of reduction measures.

PCDD/PCDF-specific air emission controls (e.g. fabric filter and carbon injection) are a prerequisite for reaching acceptable emission levels from the major source categories, and projects implementing such controls may have a significant demonstration effect.

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) have never intentionally been produced, but they are formed as by-products or impurities in several industrial chemical processes as well as in most combustion processes. Historically PCDD/PCDF formation as impurity in chlorinated chemical compounds like PCP (pentachlorophenol), Agent Orange and PCBs (polychlorinated biphenyls), was of major concern. Due to changed synthesis pathways, and the fact that the production of the chlorinated compounds concerned has ceased in most countries, the focus has changed to the formation of the compounds by combustion processes.

PCDD/PCDFs are formed in combustion processes by two mechanisms: formation from precursors (e.g. PCBs) and formation by *"de novo"* synthesis from their basic elements - carbon, hydrogen, oxygen and chlorine.

As dioxins are unintentional by-products, substitution of dioxin furans is not an issue for reducing the releases, but the releases may be reduced by substituting the precursors for formation and chlorine in general.

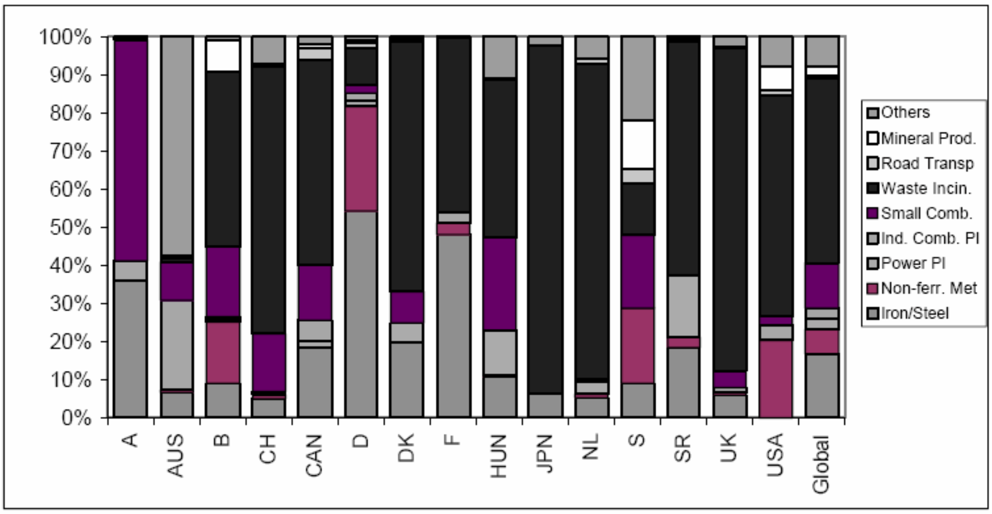
The substances are very toxic, lipophilic (fat-soluble) and persistent, accumulate in organisms and biomagnify in the natural food chains. The main exposure of the general population to dioxins and furans is via food products; in particular fish, meat and diary products.

5.1.1 Sources and releases

UNEP Chemicals have in order to facilitate the comparison of release inventories among countries in its toolkit for PCDD/PCDF release inventories proposed a division on the main PCDD/PCDF sources into 10 main categories - a categorisation that will be followed here (UNEP 2002).

UNEP chemicals prepared in 1999 a summary of national and regional PCDD/PCDF release inventories. As illustrated in the figure below, the distribution between the different source categories varies considerably among countries. The global distribution (the bar to the right) shows that waste incineration globally accounted for about 40% of the total releases. However, most probably in many countries the releases from metallurgical processes and uncontrolled burning processes have been underestimated and not included in the inventories (uncontrolled burning processes are in the figure included in "others", but categorised as a particular source category in the UNEP toolkit).

Figure 5-1 Percentage contribution per sector and country to the overall PCDD/PCDFs air emission inventory; reference year 1995 (UNEP 1999)



Until now no comprehensive inventory of dioxins sources in Russia, Ukraine or China has been undertaken.

PCDD/PCDFs inventory in Poland

An inventory of PCDD/PCDF emission in Poland 2002, undertaken by using the toolkit for PCDD/PCDF inventories prepared by UNEP Chemicals (UNEP 2002), may give an indication of the expected distribution among the source categories. Only releases to air and residues, the main and most well described release pathways, are shown here.

The distribution among categories reflects the general global trends. Concerning releases to water and products the following two sources within source category 7 not significant in Poland should, however, be considered:

- Pulp and paper production using chlorine bleaching (releases to water and residues);
- Production of chlorinated chemicals (releases to products and residues).

Table 5-1 Potential releases of PCDD/PCDFs from all sources in Poland in 2000 by main source categories (based on Lassen et al. 2002)

	Main category	Potential release in g I-TEQ/year	
		Air	Residues
1	Waste incineration	140	89
2	Ferrous and non-ferrous metal production - sinter plants - secondary metal production	80	140 ?
3	Power generation and heating - fossil fuel power plant - fossil fuel domestic heating - household heating and cooking	62	55
4	Production of mineral products - cement production - lime production	18	0.63 ?
5	Transport	3.6	?
6	Uncontrolled combustion processes - uncontrolled waste combustion - landfill fires - fires	180	210 ?
7	Production and use of chemicals and consumer products	0.07	1.1 ?
8	Miscellaneous	1.7	0.1 ?
9	Landfilling and wastewater		35
10	Hot spots	?	?
	Total	490	530 ?

* An empty cell indicates that the release route is considered insignificant. '?' indicates that the release route may be significant, but no emission factors have been determined. A "?" after a number indicates that the number may be underestimated, as some subcategories have not been quantified due to lack of emission factors.

Russia-US EPA Dioxin Inventory Programme

In 1996, a co-operation partnership was initiated between Russian and North American experts and NGOs to address dioxin contamination in Russia. As part of the partnership, an inventory project was started in July 1999. The U.S. EPA has funded the project. Its main objectives were to assess the major dioxin sources in Russia, compile a database of information on dioxin contamination in Russia and draft a white paper document to set priorities for Russia in terms of source reduction and public health protection. Training programmes for Russian laboratories and experts have been carried out as part of the project. The first phase of the inventory project (July 1999 - December 2000) resulted in the estimation of emissions by different sources. According to the initial inventory, total annual dioxin emission to the air from Russian sources was estimated to be within the interval of 6,900 to 10,900 g I-TEQ with hazardous waste incineration as the major source (6,330-10,128 g I-TEQ). Metallurgical processes, uncontrolled burning of waste and a number of minor sources are not included in the inventory, and the inventory must be considered highly uncertain.

ACAP Dioxin Project

In Phase I of the ACAP dioxin project an inventory as well as standardized sampling and analysis protocols, assessment of relevant RF regulations and standards of dioxin sources has been undertaken in three regions of the Russia: Murmansk, Archangelsk and Komi. Phase 2 will focus on reduction of dioxin emissions from Archangelsk pulp and paper facilities by implementing Cleaner Production techniques. Cleaner Production training at selected facilities in Archangelsk is also in progress.

Dioxin pollution

The most urgent problems regarding dioxins in Russia have until now been pollution with dioxins within and around chemical plants producing chlorinated and brominated compounds in which dioxins and furans were present as impurities. The dioxin pollution problems in connection with the chemical industry have been studied by a number of institutions and reported on in both Russia and internationally in a large number of publications and is reviewed in the report *"Status on POPs in the Russian Federation, January 2002*" prepared by DANCEE (COWI 2002).

Ukraine

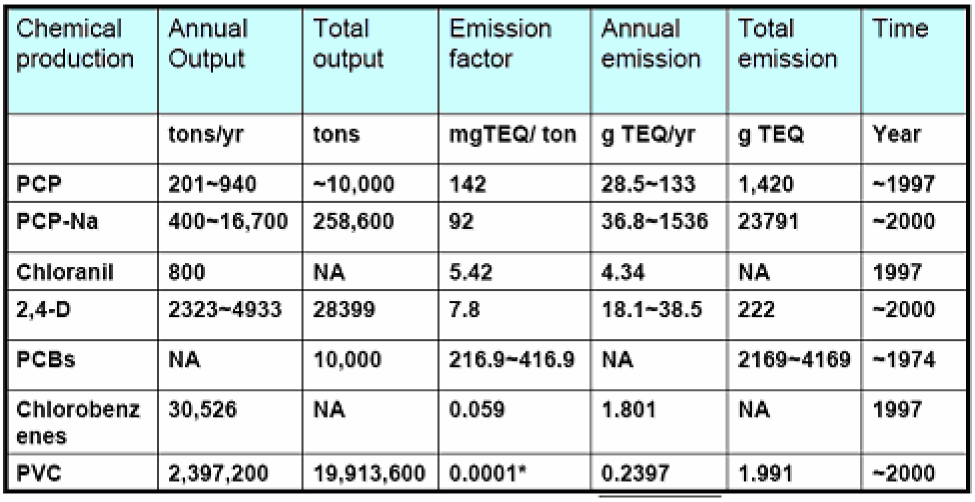
No inventory of PCDD/PCDF emission in Ukraine has been identified. An inventory is probably under development as a part of the enabling activities of the Stockholm Convention.

China

According to a presentation of Gaolai 2004, representative of the State Environmental Protection Administration of China (SEPA), no dioxin inventories exist in China, but chlor-alkali, metallurgy, paper making, organic chemicals production (e.g. PCP) and waste incineration are recognised as sources.

Dioxin emission from production of chlorinated chemicals seems to be significant, and Yonglong (2004) provides the table below. It is not clear whether the emission volumes concerns emission from production or the total amount of PCDD/PCDFs in the produced products. In any case the PCDD/PCDFs content of PCP (pentachlorophenol) and PCP-Na (sodium pentachlorophenol), both used as preservative, is very significant even considering the size of the country. PCP has been phased out in most western countries, but is i.a. still produced in the USA using synthesizing pathways resulting in less PCDD/PCDFs formation.

Table 5-2 Estimated dioxin emission from chemical production in China (Yonglong, 2004)



Chemical production	Annual Output	Total output	Emission factor	Annual emission	Total emission	Time
	tons/yr	tons	mgTEQ/ ton	g TEQ/yr	g TEQ	Year
PCP	201~940	~10,000	142	28.5~133	1,420	~1997
PCP-Na	400~16,700	258,600	92	36.8~1536	23791	~2000
Chloranil	800	NA	5.42	4.34	NA	1997
2,4-D	2323~4933	28399	7.8	18.1~38.5	222	~2000
PCBs	NA	10,000	216.9~416.9	NA	2169~4169	~1974
Chlorobenzenes	30,526	NA	0.059	1.801	NA	1997
PVC	2,397,200	19,913,600	0.0001*	0.2397	1.991	~2000

5.1.2 Main reduction measures

The main technical measures can be divided into measures for reducing the formation (primary measures) and measures for reducing the releases (secondary measures) of PCDD/PCDFs.

Measures for reducing the formation

Formation of PCDD/PCDFs in chemical processes has in most countries been avoided by phase out of relevant substances or by changed synthesis pathways.

Primary measures for reducing the formation in thermal processes, which have been implemented in European countries, included reduction of chlorine or chlorinated compounds in raw materials, products and fuels and changes in processes that may lead to formation of dioxins and furans.

Measures for reduction of releases

The measures for reduction of releases may be divided into measures for destruction of dioxins and furan already formed and measures for reducing the direct releases to the environment by adsorbing the dioxins and furans to the residuals.

Primary measures and measures where the formed PCDD/PCDFs are destructed have higher priority than measures moving the formed PCDD/PCDFs from one media to another. PCDD/PCDFs are formed in the temperature range 250-500 ºC, and a short residence time for flue gas in this temperature interval is essential for preventing the formation of PCDD/PCDFs.

Main measures by source category are shown in Table 5-3. A more detailed list of measures can be found in Annex V to the UNECE POPs Protocol and in the draft guidelines on BAT and BEP for substances included in Annex C of the Stockholm Convention (Expert group 2004).

Table 5-3 Overview of main release reduction measures for PCDD/PCDFs

Source category	Release reduction	Type of measure *
1. Waste incineration	Reduce the use of halogen-containing products in the society, especially precursors for PCDD/PCDFs formation Reduce the amount of waste for incineration	P
	Optimise the combustion conditions	P
	Improve flue gas cleaning system (e.g. by use of quick cooling (quenching) and bag filters)	Quenching: P Other: S
	Implement emission reduction systems optimised for PCDD/PCDFs reduction on municipal, hazardous and medical waste incineration plants (e.g. adsorption with activated charcoal or catalytic reduction)	S or SD depending on techniques
2. Ferrous and non-ferrous metal production	Improve flue gas cleaning system on sinter plants and secondary ferrous and nor-ferrous metal plants (e.g. by use of quick cooling (quenching) and bag filters)	Quenching: P Other: S
	Implement emission reduction systems optimised for PCDD/PCDFs reduction on sinter plants and secondary ferrous and nor-ferrous metal plants (adsorption with activated charcoal or another adsorbent)	S or SD depending on techniques
	Recirculate waste gas in sinter plants	SD
	Scrap sorting and pre-treatment (in practice difficult to manage cost-efficiently)	P
3. Power generation and heating	Implement flue gas desulphurization (FGD) on remaining facilities (PCDD/PCDFs not the main reason)	S
	Reduce energy consumption	P
4. Production of mineral products	Improve flue gas cleaning system on cement and lime plants (e.g. by use of quick cooling (quenching) and bag filters)	S
5. Transport	Phase out of halogenated scavengers in gasoline (phase out of leaded gasoline)	P
6. Uncontrolled combustion processes	Improve waste collection systems	P
	Improve landfill management to prevent fires	P
	Reduce the use of halogen-containing products, especially precursors for PCDD/PCDFs formation Reduce the amount of waste	P
7. Production and use of chemicals and consumer products	Phase out elemental chlorine and hypochlorite for bleaching (in particular for pulp and paper production)	P
	Phase out of chlorinated chemicals like PCP and PCB	P
	Implement synthesis pathways with less formation of PCDD/PCDFs by-products	P
8. Miscellaneous	No priority measures	
9. Disposal/landfilling	No priority measures (landfill fires included in category 6)	
10. Hot spots	Remediation of sites around plants for production of chlorinated chemicals and PCB-containing equipment	S or SD depending on techniques

* (P): Primary measure; (S) Secondary measure (SD): Secondary measure with destruction

5.1.3 International regulation and agreements

Table 5-4 present a summarised overview of the coverage in relevant agreements of the PCDD/PCDFs release source categories. Subcategories specifically addressed in any of the agreements are indicated.

The obligations of the CLRTAP-POPs protocol and the Stockholm Convention are further summarised in Annex 1.

The significance of waste incineration as a PCDD/PCDFs source is reflected in the fact that specific emission limit values for this source category are set in several of the agreements.

For a number of sub-categories, in the agreements considered most significant (next to waste incineration), it is specified that BAT (best available techniques) should be implemented for reduction of the PCDD/PCDFs emission. The BAT is not specifically defined, but the CLRTAP-POPs protocol lists for these subcategories a number of potential reduction measures. Application of limit values of particulate matter (PM) emission, included in the CLRTAP-HM protocol, will also reduce PCDD/PCDFs emission, as a significant part of the PCDD/PCDFs is released adsorbed to the particles.

Table 5-4 Summarised overview of the coverage of PCDD/PCDFs in international agreements (binding obligations indicated in bold)

Agreement	**CLRTAP POPs**	**Stockholm Convention**	**Helsinki Convention**	**OSPAR Convention**	**CLRTAP HM *****
1 Waste incineration	**Limit PCDD/PCDFs**	**Promote BAT in 4 years *1**	LIMIT PCCD/PCDFs		**Limit PM *4**
- Combustion of animal carcasses		**Promote BAT *2**			
2 Ferrous and non-ferrous metal production		**Promote BAT *2**			**Limit PM *4**
- Secondary copper, zinc and aluminium production	**Apply BAT *3**	**Promote BAT in 4 years *1**			
- Secondary iron and steel production	**Apply BAT *3**		Prepare reduction plan Research	Limit PM,D	
- Sinter plants in the iron and steel industry	**Apply BAT *3**	**Promote BAT in 4 years *1**	Prepare reduction plan	Limit PM	
- Blast furnaces and iron pelletizing	**Apply BAT *3**		Prepare reduction plan		
- Shredder plants		**Promote BAT *2**			
- Smouldering of copper cables		**Promote BAT *2**			
3 Power generation and heating					**Limit PM *4**
- Fossil fuel-fired utility and industrial boilers		**Promote BAT *2**			
- Firing installations for wood and biomass fuels		**Promote BAT *2**			
4 Production of mineral products					**Limit PM *4**
- Cement kilns firing hazardous wastes		**Promote BAT in 4 years *1**			
5 Transport					
- use of halogenated scavengers (leaded gasoline)	**Avoid use**	**Promote use of substitutes**			
6 Uncontrolled combustion processes					
- residential combustion sources	**Reduce burning of waste**	**Promote BAT *2**			
7 Production and use of chemicals and consumer products		**Promote use of substitutes**			
- production of pulp using elemental chlorine or chemicals generating elemental chlorine for bleaching			Harmonise analysis methods Reduce Cl load		
- production of vinyl monomer				Limit PCDD/PCDFs	
- use of PCP for textiles			non-use		
- textile and leather dying and finishing		**Promote BAT *2**			
8 Miscellaneous					
- crematoria		**Promote BAT *2**			
9 Disposal/landfills					
- waste oil refineries		**Promote BAT *2**			
10 Hot spots					
Research and development in general	X	X			
Preparation and maintenance of release inventories	X	X			

*1 Annex C Part II lists source categories with potential for comparatively high formation and releases of PCDD/PCDFs (indicated by *1). For these sources the convention requires that BAT is phased in no later than four years after enter into force of the Convention for that party.

*2 Annex C Part III lists other source categories with potential for formation and releases of PCDD/PCDFs (indicated by *2). For these sources the convention requires that BAT is phased in no later than four years after enter into force of the Convention for that party.

*3 Annex V of the protocol identify BAT for a number of source categories (indicated by *3). Parties shall no later than the specified timescales specified apply BAT to new stationary sources within those categories. More differentiated requirements to existing sources within the same categories.

*4 The limit values of the CLRTAP- HM protocol for dust emission may imply reduced PCDD/PCDFs emission

BAT: Best available techniques (in some cases combined with BEP (best environmental practices)). All limit values refer to limit of air emissions.

5.1.4 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions is presented in Table 5-5 below.

PCDD/PCDF specific activities are marked with "PCDD/PCDFs:" In the beginning of the text summarising each project in the table. Other projects which may affect PCDF releases, but do not focus on PCDD/PCDFs, will have no such mark.

Table 5-5 Identified initiatives in Russia, Ukraine and China addressing PCDD/PCDFs releases

Donor/finance institution	Projects/comments	Planned period Budget
UNEP/GEF (Russia)	**Stockholm Convention enabling activities in Russia**. Executing agency: Centre of International Projects See description for China below	Not yet approved (May 2005) Project Cost 4.575 mUSD of this GEF grant 2.375 mUSD
ACAP (Russia)	**Evaluation of Dioxins and Furans in the Russian Federation**. The project includes three phases: Phase I – Evaluation of major dioxin/furan sources; Phase II – Identifying existing technology of source type; Phase III - Prototype demonstration. Phase I, Inventory development, is fully financed by Sweden and USA and implemented by Centre of International Project (CIP), Russia. The proposal for Phase 2 focuses on the evaluation of dioxins and furans in the northern regions of the Russian Federation. Cement plant, power plant, and pulp and paper sites in Arkhangelsk, Murmansk, and the Republic of Komi are being considered for evaluation based on the following criterion: contribution to total dioxin and furan releases, and the ability to address the present lack of data on dioxin content of gas releases and the high uncertainty of dioxin emission factors for particular sites. Results will be obtained by conducting a measurement program.	2002-2006 Project budget: 0.95 USD (for Russian experts)
UNEP/AMAP/GEF (Russia)	**Persistent Organic Pollutants, Food Security, and Indigenous Peoples in Arctic Russia.** The overall goal of the project is to reduce the contamination of the Arctic environment by persistent toxic substances (PTS). Recent studies have shown significantly elevated environmental levels of PTS in the Russian Arctic, where, due to the present economic problems, consumption of highly contaminated country food by indigenous peoples is increasing (walrus, bowhead whale, etc.). Specifically, the project will: a) assist the indigenous peoples in developing appropriate remedial actions to reduce the health risks resulting from the contamination of their environment and traditional food sources; b) enhance the position of the Russian Federation in international negotiations to reduce the use of PTS, and empower indigenous peoples to participate actively and fully in these negotiations; and c) enable the Russian Federation and the Russian Association of Indigenous Peoples of the North (RAIPON) to increase their involvement in the work of the eight-nation Arctic Council to reduce emissions of PTS.	Approved: February 22, 2000 Project cost: 2.76 mUSD of this GEF Grant: 0.75 mUSD
UNEP/GEF (Ukraine)	**Stockholm Convention enabling activities in Ukraine.** See description for China below	Approval: May 06, 2003 Project Cost 0.499 mUSD of this GEF grant 0.499 mUSD

Donor/finance institution	Projects/comments	Planned period Budget
UNIDO/GEF (China)	**Stockholm Convention enabling activities in China.** The enabling activities are primarily oriented to the preparation of a National Implementation Plan (NIP) for the Stockholm Convention and capacity building associated with this preparatory process and creating sustainable local capacity to support NIP implementation and participation as a Convention party. The activities include undertaking inventories of sources and emissions of POPs; preparation of assessments of stockpiles of POPs and of waste products contaminated with POPs; identification of sites contaminated by POPs; identification of management options for addressing identified POPs sources; development of Action Plans for the reduction of releases of unintentional by-products; assessment of national institutional and technical capacity and requirements for NIP implementation; preparation of the NIP.	Approval: May 16, 2003 2003-2005 Project Costs: 11.1 mUSD of this GEF grant: 4.4 mUSD
Italian Ministry for the Environment and Territory / UNIDO Sino-Italian cooperation Program for environment protection (China)	**Strategy to Reduce Unintentional Production of POPs in China.** This project will demonstrate methodologies to promote the implementation of BAT and BEP to reduce unintentional production of POPs in key sectors of industry recognized as important sources of such production in China. Working with enterprise staff, local and international experts will establish improved information on unintentional production at enterprise level, and identify opportunities to reduce unintentional production through: ·Improved process management; ·Modified raw material and product specifications and emission standards; ·Introduction of new technology at key stages.	2003 - ? (ongoing) 0.95 mUSD
GEF/UNEP/UNIDO (Global)	**Fostering Active and Effective Civil Society Participation in Preparations for Implementation of the Stockholm Convention. (NGO-POPs Elimination Project).** The NGO-POPs Elimination Project aims to increase the capacity of NGOs in developing countries and countries with economies in transition to play a constructive and effective role in Stockholm Convention implementation. Activities in 39 countries. Activities in Russia and Ukraine according to International POPs Elimination Project (IPEP) web page: **Russia:** Country situation report ; Guide to obsolete pesticide dumps ; The Time to Act: Identifying and characterizing pesticide hotspots in Chelyabinsk Oblast ; Health status in the impact zone of the Magnitogorsk Metallurgical Plant: Breast milk screening for POPs; PCB monitoring and inventory in Nizhergorodskaya Oblast ; Egg sampling for POPs in Dzerjinsk ; Inter-sectoral partnership in developing regional and local PRTRs of POPs ; A number of "Global day of action" activities. **Ukraine:** Partnerships between NGOs and R&D facilities for capacity building to reduce adverse health and environmental impacts of POPs; Participation in the National Implementation Plan formulation; Country situation report; Global day of action; roundtable and NGO dissemination; Global day of action; informing students about the Ukrainian NIP	2003- Project Cost: 2 mUSD of this GEF grant: 1 mUSD

5.2 PCBs

ABSTRACT
Polychlorinated biphenyls (PCBs) are a group of persistent substances, toxic to humans and in the environment. PCBs are not produced intentionally today, but were formerly widely used in electrical equipment, paints and a number of minor applications. A significant part of the produced PCBs is still in use, first of all in transformers and capacitors, and elimination of waste PCBs and PCB-containing equipment is addressed by the Stockholm Convention signed by Russia, Ukraine and China. PCBs used for paints and other so-called "open applications" are today to a large extent released to the environment, and the remaining part is practically impossible to identify and manage. Inventories of PCB-containing electric equipment have been undertaken in all three countries. The main issue is today preparation of adequate regulation, collection of equipment, development of PCB waste management systems and final destruction of the PCBs. Ongoing projects in Russia address identification of PCB-containing equipment for final treatment, and construction of two facilities for destruction of liquid PCBs and PCB-containing capacitors respectively. Further activities may await further progress in the construction of destruction facilities.

In China a large project on collection and destruction of PCB-containing equipment in selected regions is in preparation, and it is proposed to await the experience of this project, before further activities are initiated.

Polychlorinated biphenyls (PCBs) are a class of chlorinated hydrocarbons that have been used extensively since 1930 for a variety of industrial uses. Today PCBs are most probably not produced in any country.

PCBs include mobile oily liquids and hard transparent resins, depending on the degree of substitution. The value of PCBs derives from their chemical inertness, resistance to heat, non-flammability, low vapour pressure and high dielectric constancy. The compounds were used in industry as heat exchange fluids, in electric transformers and capacitors, and as additives in paint, carbonless copy paper, and plastics.

PCBs consist of two benzene rings joined by a carbon-carbon bond, with chlorine atoms on any or all of the remaining 10 carbon atoms.

Many of the individual PCB congeners exhibit toxic properties. PCBs rarely cause acute toxic effects, but most of the effects observed are the result of a repetitive or chronic exposure. There is growing evidence linking PCBs to reproductive and immunotoxic effects in wildlife. Effects on the liver, skin, immune system, reproductive system, gastrointestinal tract and thyroid gland of laboratory rats have been observed, and PCBs are classified as probable human cancer promoters.

The PCB issue today first of all concerns collection and environmentally sound elimination of used transformer oils and PCB-containing electric equipment.

Unintentional production of PCBs

Apart form the intentional use of PCBs, the compounds are also found at trace levels in fossil fuels. Furthermore, PCBs are - like dioxins and HCB - formed in combustion processes. Default emission factors for emission of PCBs from different combustion processes have been developed by EMEP for use in emission inventories. The measures for reduction of releases from unintentional production of PCBs are mainly the same as for PCDDs/PCDFs and are not addressed specifically in this chapter.

5.2.1 Sources and releases

PCBs are not produced today in Russia, Ukraine or China, but are released from PCB-containing products, stockpiles and waste dumps. From transformers PCBs may be released by maintenance operations and leakage from the transformers. Capacitors are closed boxes, and PCBs are only released by corrosion of the capacitors or breakage by disposal.

The production and consumption of PCBs in the Soviet Union, and the presence in equipment in use in Russia today, have been assessed in the Multilateral Co-operative Project on Phase-out of PCB Use, and Management of PCB-Contaminated Wastes in the Russian Federation (ACAP 1999; 2003).

The application and consumption, which are quite well in accordance with the global PCB consumption pattern, are summarised below.

PCBs in the Soviet Union

PCBs were in the Soviet Union produced by two factories located in Dzerzhinsk and Novomoskovsk, Russia. During the period from 1939 to 1993 they produced a total of about 180,000 tonnes.

Table 5-6 Application of PCBs in the former Soviet Union

Application	Total consumption (tonnes)	PCB type	Plants using PCBs for equipment production
Open applications:			
Varnish and paint	37,000	Sovol: a mixture of tetra- and pentachlorinated PCBs Produced: 1939-1993	Many
Lubricants	10,000		
Defence-related industry plants and other not-identified enterprises	5,500		
Closed applications:			
Transformers	57,000	Sovtol 10: Sovol mixed with 1,2,4 trichlorobenzene Produced: 1939-1987	98% used in Chirchik transformer factory (Uzbekistan)
Large capacitors	40,000	Mixed isomers of trichlorobiphenyl (TCP) Produced: 1968- 1990	Two factories in Ust-Kamenogorsk, (Kazakhstan) and Serpukhov (Russia)
Small capacitors	30,000		Two factories in Kamairi (Armenia)
Total	180,000		

PCBs in equipment in Russia

Based on an inventory carried out within the framework of Phase 1 of the ACAP PCB project it was concluded that in Russia in year 1999 about 10,000 transformers and about 500,000 capacitors were either in operation, in reserve, or removed from operation, but not destroyed. The transformers contained about 19,000 tonnes of PCBs (Sovtol), whereas the capacitors contained about 10,000 tons of trichlorobiphenyl (TCB).

The distribution of the PCB-containing equipment among branches is summarised in Table 5-7.

Table 5-7 Approximate distribution of PCB-containing equipment among branches in Russia (based on ACAP 2003)

Branches	Percentage of total amount	
	transformers	capacitors
Chemical and petrochemical	5-10	0.1-0.5
Ferrous metallurgy	20-30	5-10
Non-ferrous metallurgy	4-10	0.1-0.5
Pulp and paper industry and timber processing	40-50	5-10
Fuel and energy complex	10-30	80-90

An adequate system for management of PCB-containing equipment and final destruction of equipment does not exist in Russia today.

PCBs in China

The following information on PCBs in China is summarised from the Project Information Document and Environmental Impact Assessment for PCB sites cleanup in the Zhejiang. China prepared it as part of the project preparation of a GEF "PCB Disposal and Management Demonstration Project" (WB 2005, SEPA 2005).

In China, PCBs were mainly used in electric appliances and as an additive in paint. China began to produce PCBs in 1965 and stopped in early 1974. The total production amounted to about 10,000 tons, including 9,000 tons of trichlorobiphenyl (TCP) and 1,000 tons of pentachlorobiphenyl (PCB5).

PCB5 oils were mostly used in a wide variety of open systems, such as in oil paints and exterior dopes. While some wastes may remain at production or formulation facilities, it is reasonable to assume that most of this material has been released into the environment.

TCP was principally used in manufacturing capacitors that were used in the electrical supply industry. An estimated 12 kg of PCB3 was used in each capacitor and, based on a production of 9,000 tonnes, it is estimated that about 750,000 PCB-containing capacitors were produced in China. However, estimates based on the installed transmission capacity in China in 1975 indicate that 1.15 million capacitors would have been required, suggesting that as many as 400,000 PCB-containing capacitors were imported into China. If this estimate were correct, then an estimated 4,000-4,500 tonnes of TCP oils would have been imported with this equipment, so that a total of 13,000-13,500 tonnes of TCP would have been introduced into China as a result of the manufacture and import of capacitors. Transformers containing PCB oils were never produced in China, but an unknown number was imported. While 30 PCB-containing transformers have so far been found and disposed of, there is no basis to estimate how many PCB-containing transformers may remain in China, either in service or in storage for disposal.

Since the lifetime of capacitors made in China is estimated to be 15 years, it follows that most of the 1.15 million PCB-containing capacitors have now been retired from service. Some specialized transformers were imported into China in the 1970s and 1980s, and their lifetime is expected to be 25-40 years. Therefore approximately 1 million capacitors and an unknown number of transformers are in storage and on disposal sites throughout China.

During the 1980s, pieces of electrical equipment taken out of service were collected at temporary storage sites prior to disposal in accordance with the requirements proposed by relevant Ministries. Surveys and investigations conducted in recent years indicate that discarded PCB-containing equipment remain in some temporary storage facilities. Few of the sites were recorded on files and many of those for which file details have been found are no longer marked on the ground.

An adequate system for management of PCB-containing equipment and final destruction of equipment does not exist in China today, but a new large GEF financed project will address these issues.

PCBs in Ukraine

An inventory in 2003 undertaken as part of the Stockholm Convention enabling activities based on enquiries to 5000 enterprises identified 960 PCB-containing transformers in Ukraine, of which 760 were still in use, the remaining being stored (Sukhoreba 2004). In total 92,500 capacitors were identified, of these 70,000 in use. Engineering industry and metallurgy were the main sectors with 576 and 900 tonnes PCBs in the hold equipment respectively.

5.2.2 Main reduction measures

Intentional use of PCB

The main reduction measures for reduction of releases of PCBs are listed in Table 5-8.

Table 5-8 Overview of main release reduction measures for PCBs

Source category	Release reduction
Transformers with oils of high PCB content	Identification, labelling, maintenance, collection, (storage) Dismantling, cleaning and destruction of PCBs by high temperature incineration or a number of other processes
Transformers with oils of low PCB content (PCB-contaminated transformers)	Identification, labelling, maintenance Decontamination of transformers by replacement of PCB-contaminated oils with alternative oils (or destruction like transformers with oils of high PCB content) Destruction of PCB-contaminated oils perhaps by use of dechlorination processes
PCB-containing power capacitors	Identification, labelling, collection, (storage) Shredding and direct feed into high temperature incinerator or plasma arc destruction facility
Small PCB-containing capacitors	Dismantling of electric and electronic products, collection of capacitors (storage) Direct feed into high temperature incinerator or plasma arc destruction facility
PCB-containing liquids	Destruction by high temperature incineration or a number of other processes
PCB-containing sealants	Identification, replacement by other sealants, destruction (only implemented in a few countries) - no evidence of the use of PCB as sealant in the USSR and China
Paints, varnishes, etc.	Identification and removal is practically impossible

Unintentional production of PCB

PCBs is formed unintentionally by the same processes and mechanisms as PCDD/PCDFs and the measures mentioned for PCDD/PCDFs also apply to PCBs. The driving force for implementation of the measures will usually be PCDD/PCDF release reduction, with PCB release reduction as a desirable side-effect.

5.2.3 International regulation and agreements

Table 5-9 presents a summarised overview of the coverage in relevant agreements concerning PCB. The obligations of the CLRTAP-POPs protocol and the Stockholm Convention are further summarised in Annex 1.

Table 5-9 Summarised overview of the coverage of intentionally used PCBs in relevant agreements

Agreement	CLRTAP POPs	Stockholm Convention	Helsinki Convention	OSPAR Convention
PCBs production, import and export	**eliminate *1**	**eliminate**	eliminate from 1987	
Marketing and use of PCBs	**eliminate *1**	**eliminate**	eliminate from 1987 ***5**	
Use of equipment with >5 dm^3 and >0.05 % PCB	**determined efforts to remove before 31.12.2010**	**determined efforts to remove before 2025**	determined efforts to remove before 31.12.2010 *3	
Use of equipment with >0.05 dm^3 and >0.005 % PCB	**determined efforts to remove before 31.12.2015 *2**	**endeavour to remove before 2025**	determined efforts to remove before 31.12.2015 *3	
Liquids and equipment contaminated with PCBs >0.005% PCB	**determined efforts to destruct before 31.12.2015 *2**	**sound management before 2028**		
All identifiable PCBs				**phase out and destroy *4**
Programmes for for identifying, labelling, collection, interim storage, disposal	X	X	x	

*1 For countries in transitions no later than 31 Dec 2005

*2 For countries in transition no later than 31 Dec 2020

*3 For countries in transition no later than 31 Dec 2015

*4 Phase out and destroy PCBs by the end of 1999 at the latest, for Iceland and the Contracting Parties which are riparian to the North Sea; by the end of 2010 at the latest, for the remaining Contracting Parties. (PARCOM DECISION 92/3)

'*5 Prohibition of the use in the Baltic Sea area its catchment area is included as a binding obligation of the Helsinki Convention.

5.2.4 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions is presented in Table 5-5 below.

Table 5-10 Identified initiatives in Russia, Ukraine and China addressing PCBs management and releases

Donor/finance institution	Projects/comments	Planned period Budget
UNEP/GEF (Russia)	**Stockholm Convention enabling activities in Russia.** Executing agency: Centre of International Projects	See PCDD/PCDFs in Table 5-5
ACAP (Russia)	**Multilateral co-operation project on phase-out of PCB use, and management of PCB-contaminated wastes in the Russian Federation - Phase III.** Phase I and II of the project have been finalised and reported. (ACAP 2000; ACAP 2003. Phase III consist of four projects:	1999 - 2007
- DANCEE	**PCB collection in St. Petersburg.** Implementation of a system for one Oblast that secure the identification, labelling and transport of PCB-containing transformers from enterprises to a destruction facility. The system shall contain explicit description on how the responsibility is divided between authorities, enterprises, transporters and the destruction company. Furthermore a small database shall be created that secure that information about destructed amounts of PCB is registered.	2004-2006 2.1 mDKK
- USA/Nordic countries/ the Netherlands	**Plasma Arc Destruction of PCB-Containing Capacitors in Russia** The American Norfolk Navy Base is granting a Retech plasma arc plant to Russia. This task involves the planning, development, and implementation of activities required to safely and expeditiously start up the plasma system and to conduct the demonstration program	2004-2006 1.2-2.5 mUSD
- NEFCO	**Cleaning of PCB from transformers and destruction of PCB waste from transformers (two projects)** The first phase, the PCB Fast Track Project Feasibility study of methods to remove PCB from transformers and to thermally decompose these toxic liquids is still ongoing. Based on the feasibility study two technologies has been selected: a destruction technology based on Russian cyclone incineration technology and novel, solvent based transformer cleaning technology. Supervision of detailed design and implementation is ongoing by end 2004. Problems with authority approvals have caused a temporary halt to the project (end 2004) where the feasibility of other locations is being investigated.	2001-2007 Destruction: 1-2 mUSD Cleaning: 0.9 mUSD
EU Bistro (Russia)	**Development of hazardous waste management system in Moscow.** The project includes the following elements: to develop recommendations on improvement of the hazardous waste management system in Moscow, To determine conditions in order to provide the environmentally safe hazardous waste management; To develop draft normative and regulatory documents in order to improve the environmentally safe hazardous waste management; To propose economic mechanisms of hazardous waste management; To increase of the level of public awareness in the field of environmental safety	2005-2006 0.08 m EUR
UNEP/GEF (Ukraine)	**Stockholm Convention enabling activities in Ukraine.**	See PCDD/PCDFs in Table 5-5
UNIDO/GEF (China)	**Stockholm Convention enabling activities in China.**	See PCDD/PCDFs in Table 5-5

Donor/finance institution	Projects/comments	Planned period Budget
IBRD (WB)/GEF (China)	**PCB Management and Disposal Demonstration.** The objective of the project is to remove the threats to human health and the environment posed by PCBs presently in unsafe temporary storage, as well as PCBs in use, in a demonstration area to be determined during project preparation. The project envisages six components: (1) institutional strengthening; (2) development of a policy framework for PCB management and disposal; (3) PCB management and disposal in Zhejiang Province; (4) disposal in Liaoning Province of highly-contaminated PCB wastes; (5) project monitoring and evaluation; and (6) design of a national replication program	Approval: November 19, 2004 Project Cost 31.810 mUSD of this GEF Grant 18.636 mUSD and other donors 1.84 mUSD
Italian Ministry for the Environment and Territory Sino-Italian cooperation Program for environment protection (China)	**Strategy and Program on Reduction and Phase out of PCB in China.** The following activities are carried out: - Identification of pilot provinces that have reasonable statistics on PCB use and PCB-containing equipment; - Collection of historical data on PCB (e.g. use, production, import and export, etc.); - Organization of workshop and training on PCBs inventory methodologies; - Investigation of PCB devices in use as well as of obsolete devices in storage or being sealed up; - Development of a Management Information System for pilot provinces for a systematic storage of collected information; - Assessment of existing institutional framework of PCB policy and management; - Assessment of PCB disposal/reduction in China; - Review of the draft strategy and dissemination of information	2003-2005 (still ongoing) Budget: no data
GEF/UNEP/UNIDO (Global)	**Fostering Active and Effective Civil Society Participation in Preparations for Implementation of the Stockholm Convention. (NGO-POPs Elimination Project).**	See PCDD/PCDFs in Table 5-5

5.3 HCB

ABSTRACT

Hexachlorobenzene (HCB) is persistent and toxic to humans and in the environment. HCB is produced intentionally for use as pesticide and intermediate in the production of pentachlorophenol (PCP) and other chemicals. Pesticidal use of HCB is included in the chapter on POPs pesticides. HCB is produced unintentionally by the same thermal processes as PCDD/PCDDs, and measures for PCDD/PCDDs formation also address HCB. The driving force for implementation of the measures will usually be PCDD/PCDDs reduction; the HCB reduction being a desirable side-effect.

Further HCB is unintentionally produced by some specific chemical and metallurgical processes. HCB is, when certain techniques are applied, produced as by-product by the production of chlorinated solvents, chlorinated aromatics and pesticides, by production of aluminium and magnesium and by production of chlor-alkali. The measures for reduction of HCB releases are changed production processes.

Comprehensive inventories of HCB formation and releases in Russia, Ukraine and China have not been identified, and it is not known to what extent the proc-

esses specifically forming HCB are used. The first step in the awareness raising and identification of priory measures may be to assist Russia in undertaking a detailed HCB inventory. The obtained information would also be relevant for other countries from the former Soviet Union.

HCB is in China used for production of PCP (pentachlorophenol), which today has been phased out in most countries because of the presence of PCDD/PCDFs as impurity, and because PCP acts as a precursor for PCDD/PCDFs formation. Phase-out of PCP production consequently addresses more of the POPs. Alternatives to the use of PCP for wood preservation are readily available.

Hexachlorobenzene (HCB), consisting of a benzene ring with six chlorine atoms, does not occur naturally.

It is both produced intentionally and unintentionally by anthropogenic processes, and both the intentional and unintentional production have been addressed by international agreements.

HCB was formerly used extensively as a seed dressing to prevent fungal disease on grains, but this use was discontinued in most western countries in the 1970s. The use of HCB as pesticide has continued in some countries, among these China, until today. The use of HCB as pesticide is included in section 2.4 on POPs pesticides.

HCB is a highly persistent environmental toxin. It undergoes long-range transport in the atmosphere and bioaccumulates in fish, marine animals, birds, and animals that feed on fish. HCB accumulates significantly in the fatty tissues and is resistant to biodegradation. The primary route of exposure for the general population is dietary ingestion of foods that contain residue levels of HCB.

HCB is toxic by all routes of exposure. Both the US EPA and the International Agency for Research on Cancer (IARC) have listed HCB as a possible carcinogen for humans. Acute high-dose exposures can lead to kidney and liver damage, central nervous system excitation and seizures, circulatory collapse and respiratory depression. Chronic low-dose exposures may damage a developing foetus, cause cancer, lead to kidney damage, liver damage and fatigue, and cause skin irritation.

Unintentional formation and emissions of HCB result from the same type of thermal processes as those emitting PCDD/PCDF, and HCB is formed by a similar mechanism. Measures for PCDD/PCDF releases reduction consequently also reduce HCB releases.

In Denmark, specific reduction of HCB releases has not been on the agenda, and no detailed description of HCB formation and releases in Denmark has been undertaken. A short survey from 1995 concludes that the release of HCB is insignificant, but the survey included intentional uses only (Hansen 1995).

For a comprehensive description of HCB sources, environmental fate and risk characterisation, see Jones 2005.

5.3.1 Sources and releases

Use of HCB

The use of HCB as pesticide is included in section 5.4.

The draft Basel Convention guidelines mention that HCB is used as a chemical intermediate in the manufacture of other substances (Basel 2005). According to the guidelines it is believed that these chemical intermediate applications have ceased in most countries except for China and Russia. HCB has in western counties been used as a peptising agent in the production of nitroso and styrene rubbers for use in vehicle tyres. Other uses as a chemical intermediate have included the manufacture of certain dyestuffs, the production of pentachlorophenol and the production of aromatic fluorocarbons.

In Russia HCB is still used in pyrotechnical compounds (Jones 2005).

Formation of HCB

HCB is unintentionally formed in a number of processes, of which the main process seems to be (Environment Canada 2005; Jones 2005; Bailey 2001, GLBTS. 2000):

- Incineration and burning of waste (in particular incineration of chlorinated organics);
- Thermal metallurgical processes;
- Cement production;
- Burning of chlorine-containing fuels;
- Aluminium manufacturing using hexachloroethane;
- Magnesium manufacturing using processes involving $MgCl_2$;
- Manufacturing of chlorinated pesticides and other chlorinated organics such as perchloroethylene, trichloroethylene and ethylene dichloride;
- Manufacturing of chlor-alkali using graphite anodes;
- Manufacturing of tyres.

The US draft national action plan for HCB mentions manufacturing of silicone products as the major source of HCB emission in the USA, but this source category is not mentioned in other assessments and reports (US EPA 2000).

Atmospheric releases

Annual atmospheric emission of HCB in Europe, USA and globally is shown in Table 5-11. Globally, non-ferrous metal industry, waste incineration and pesticide use are the major sources.

Table 5-11 Annual atmospheric emission of HCB in Europe, USA and globally (based on Jones 2005)

Source category	Europe *1 (1990)		USA *2 (mid-1990s)		Global *2 (mid-1990s)	
	t/year	%	t/year	%	t/year	%
Fuel combustion	0.46	6.3	0.024	0.9	0.843	3.7
Iron and steel industry	0.24	3.3	0.018	0.6	0.070	0.3
Non-ferrous metal industry	0.05	0.7	0.156	5.6	8.154	36
Organic chemical industry	0.56	7.6	0.399	14	1.308	5.8
Other solvent use	0.21	2.9	0.0003	0.01	0.001	0.004
Waste incineration	0.07	1	0.917	33	5.862	26
Pesticide use	5.76	78	1.270	46	6.463	28
Total	7.35	100	2.785	100	22.703	100

*1 Source: Berdowski et al. 1997.

*2 Source: Bailey 2001.

HCB as by-product in chemical industry

Organic chemical industry accounts globally for about 6% of the atmospheric emission, but this source category may regionally be more significant depending on the presence of the relevant industry.

Besides the direct atmospheric release significant unaccounted releases may occur from waste products.

HCB is formed as byproduct and/or impurity in several chemical processes, such as the manufacture of chlorinated solvents, chlorinated aromatics and pesticides (Jones 2005). Jones (2005) refers that in the USA from 1980 to 1983 approximately 4,130 tonnes HCB were generated annually as a waste product and 3,178 tonnes of this was produced from the manufacture of perchlorethylene, trichloroetylene and tetrachloride. Similar data are referred from Germany and Japan. Compared with the total atmospheric emission in Table 5-11, which is in the order of magnitude of 1000 times lower, the data indicate that the releases via waste streams may be significant. The fate of the HCB in the waste is highly dependent on whether the waste is treated by incineration of dumped in landfills.

Since the 1980s, HCB levels in products have decreased dramatically, at least in Western countries.

Russian Federation

HCB is reported to be used in Russia as feedstock for pyrotechnical compounds used by the Army (Jones 2005). No information on HCB releases in Russia by source categories has been identified.

China

HCB is in China according to UNIDO/GEF (2003) produced in quantities of 1000-10000 t/year. HCB is not used as pesticide in China. In China, HCB is mainly used as the chemical mediate of pentachlorophenol (PCP) and sodium pentachlorophenate (PCP-Na), and something which in the report is designated "chemical dissolvent and other chemical assistant" (UNIDO/GEF 2003). The usages in different purposes of HCB need according to UNIDO/GEF a thorough survey. PCP and PCP-Na are in general used as disinfectant for wood and textile preservation and have been phased out in most western countries.

As shown in chapter 5.1.1 on PCDD/PCDFs the annual releases of PCDD/PCDFs by production of PCP and PCP-Na in China are very significant. The applied synthesis pathway using HCB result in significantly higher formation of PCDD/PCDFs than other pathways applied e.g. in the USA, which is one of the few western countries still producing PCP.

Ukraine

The Basel Convention draft technical guidelines in HCB (Basel 2005) mentions without reference that there are in the World at least two identified stockpiles of over 10,000 tonnes of waste HCB from past production of chlorinated solvents, in particular perchloroethylene, carbon tetrachloride and trichloroethylene. One of these is in Ukraine. No further information on the issue has been identified.

5.3.2 Main reduction measures

For the discussion of reduction measures it is relevant to distinguish between unintentional formation from combustion and other thermal processes and formation by other processes; first of all chemical processes.

Combustion and other thermal processes

HCB is formed unintentionally by the same thermal processes and mechanisms as PCDD/PCDFs, and the measures mentioned for PCDD/PCDFs in Table 5-3 also apply to HCB. The driving force for implementation of the measures would usually be PCDD/PCDF release reduction, with HCB release reduction as a desirable side-effect.

HCB formed as by-product/impurity by the production of chlorine and chlorinated chemicals can be reduced by process changes. Such measures have been implemented with success the last two decades and as mentioned above resulted in a dramatic reduction of the formation.

When formed, the release of HCB from the waste can be reduced by adequate waste management, e.g. hazardous waste incineration.

Great Lakes Binational Toxics Strategy (GLBTS 2000) has identified a number of measures for reduction of the formation and releases of HCB from both thermal and chemical processes. The proposed measures, as regards production of chemicals in Table 5-12, are based on this assessment.

Table 5-12 Overview of main release reduction measures for HCB

Source category	Release reduction
Production of HCB	Reduction in the demand by phasing out the use of PCP Alternatives to PCP for wood preservation are available PCP is reportedly difficult to replace for preservation of cotton in tropic areas (e.g. still used by the UK army for this purpose). The alternative may be to use textiles of synthetic fibre
Combustion and other thermal processes	HCB is formed unintentionally by the same thermal processes and mechanisms as PCDD/PCDFs and the measures mentioned for PCDD/PCDFs in Table 5-3 also apply to HCB.
Production of chlorinated solvents	Process modifications (e.g. synthesis pathways) and improved waste management practices that will capture the HCB that escapes during manufacturing operations.
Pesticides manufacture and use (HCB as an impurity of other chlorinated pesticides)	Process modifications and improved waste management practices Promote reduced use of HCB-containing pesticides Promote collection of unused pesticides in households and agriculture
Chlor-alkali production (HCB result from the electrolytic production of chlorine using graphite anodes)	Conversion from graphite anodes to metal anodes capped with noble metal coating
Secondary aluminium production using hexachloroethane (HCE)	Replace hexachloroethane (HCE) to remove hydrogen gas bubbles from molten aluminium with alternative degassing substances (e.g., argon or nitrogen gas)
Magnesium production (electrolysis	Replace processes involving $MgCl_2$ with other processes

5.3.3 International regulation and agreements

Table 5-13 presents a summarised overview of the coverage in relevant agreements of the HCB release source categories. Subcategories specifically addressed in any of the agreements are indicated. The source categories developed by UNEP for PCDD/PCDF emission have been used.

The obligations of the CLRTAP-POPs protocol and the Stockholm Convention are further summarised in Annex 1. Both instruments include HCB in a group of unintentionally produced substances including PCDD/PCDFs and PCBs, and stipulate requirements for the group of substances as a whole.

None of the agreements mention measures specifically addressing unintentionally produced HCB, and for this reason the specific sources mentioned in the previous sectors (e.g. aluminium and magnesium production) are not mentioned specifically in the table.

HCB is not specifically addressed by any OSPAR or HELCOM recommendation or decision. HCB is not included in the OSPAR list of substances of possible concern, but included in the OSPAR 1998 list of candidates for selection, assessment and prioritisation. HCB is included in the HELCOM list of selected substances for immediate priority action.

Agreements concerning the use of HCB as a pesticide are included in section 5.4.

Table 5-13 Summarised overview of the coverage of unintentionally produced HCB in international agreements (binding obligations indicated in bold)

Agreement	CLRTAP POPs	Stockholm Convention	Helsinki Convention	OSPAR Convention	CLRTAP HM ***
1 Waste incineration	**Apply BAT *3**	**Promote BAT in 4 years *1**			**Limit PM *4**
- Combustion of animal carcasses		**Promote BAT *2**			
2 Ferrous and non-ferrous metal production		**Promote BAT *2**			**Limit PM *4**
- Secondary copper, zinc and aluminium production	**Apply BAT *3**	**Promote BAT in 4 years *1**			
- Secondary iron and steel production	**Apply BAT *3**				
- Sinter plants in the iron and steel industry	**Apply BAT *3**	**Promote BAT in 4 years *1**			
- Blast furnaces and iron pelletizing	**Apply BAT *3**				
- Shredder plants		**Promote BAT *2**			
- Smouldering of copper cables		**Promote BAT *2**			
- Secondary aluminium industry					
3 Power generation and heating					**Limit PM *4**
- Fossil fuel-fired utility and industrial boilers		**Promote BAT *2**			
- Firing installations for wood and biomass fuels		**Promote BAT *2**			
4 Production of mineral products					**Limit PM *4**
- Cement kilns firing hazardous wastes		**Promote BAT in 4 years *1**			
5 Transport					
- use of halogenated scavengers (leaded gasoline)	**Avoid use *5**	**Promote use of substitutes *5**			
6 Uncontrolled combustion processes					
- residential combustion sources	**Reduce burning of waste**	**Promote BAT *2**			
7 Production and use of chemicals and consumer products		**Promote use of substitutes**			
- textile and leather dying and finishing		**Promote BAT *2**			
8 Miscellaneous					
- Crematoria		**Promote BAT *2**			
9 Disposal/landfills					
- waste oil refineries		**Promote BAT *2**			
10 Hot spots					
Research and development in general	X	X			
Preparation and maintenance of release inventories	X	X			

*1 Annex C Part II lists source categories with potential for comparatively high formation and releases of PCDD/PCDFs, PCBs and HCB (indicated by *1). For these sources the convention requires that BAT is phased in no later than four years after enter into force of the Convention for that party.

*2 Annex C Part III lists other source categories with potential for formation and releases of PCDD/PCDFs, PCBs and HCB (indicated by *2). For these sources the convention requires that BAT is phased in no later than four years after enter into force of the Convention for that party.

*3 Annex V of the protocol identify BAT for a number of source categories (indicated by *3). Parties shall no later than the specified timescales specified apply BAT to new stationary sources within those categories. More differentiated requirements to existing sources within the same categories.

*4 The limit values of the CLRTAP- HM protocol for dust emission may imply reduced PCDD/PCDFs emission

*5 Avoiding halogenated scavengers is in the CLRTAP POPs protocol more specifically described as a PCDD/PCDFs emission control, but may also reduce HCB emission.

BAT: Best available techniques (in some cases combined with BEP (best environmental practices))

5.3.4 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions specifically addressing HCB releases is presented in Table 5-14 below. It has not been possible to identify any projects specifically addressing non-pesticidal HCB use. This reflects the fact that the HCB releases in general is considered a less important issue than PCBs and PCDD/PCDFs.

As HCB is released from the same sources as PCDD/PCDFs, all projects described in the PCDD/PCDFs section will also have relevance to HCB.

Table 5-14 Identified initiatives in Russia, Ukraine and China addressing HCB releases (apart from pesticides uses)

Donor/finance institution	Projects/comments	Planned period Budget
UNEP/GEF (Russia)	Stockholm Convention enabling activities in Russia. Executing agency: Centre of International Projects	See PCDD/PCDFs in Table 5-5
UNEP/GEF (Ukraine)	Stockholm Convention enabling activities in Ukraine.	See PCDD/PCDFs in Table 5-5
UNIDO/GEF (China)	Stockholm Convention enabling activities in China.	See PCDD/PCDFs in Table 5-5
GEF/UNEP/UNIDO (Global)	**Fostering Active and Effective Civil Society Participation in Preparations for Implementation of the Stockholm Convention. (NGO-POPs Elimination Project).**	See PCDD/PCDFs in Table 5-5

5.4 POPs pesticides

ABSTRACT
Nine POPs pesticides are addressed by the Stockholm Convention for immediate or future elimination: aldrin, chlordane, dieldrin, DDT, endrin, heptachlor, mirex, toxaphene, and hexachlorobenzene. In Russia and Ukraine the POPs pesticides are not used today, but the POPs pesticides make a substantial part of the stockpiles of obsolete pesticides. In these countries the issue is thus mainly identification, safe storage and final destruction of obsolete POPs pesticides in close connection with the management of other obsolete pesticides. Identification, repacking and safe storage of obsolete pesticides in selected oblasts are addressed in ongoing projects, but there is still an urgent need for application of the obtained experience in other regions. The pesticides are today stored and in a long-term perspective; there is a need for building of destruction facilities, e.g. waste incinerators optimised for pesticide destruction.

In China, DDT, mirex and chlordane are still used as pesticides, first of all for termite and disease vector control, and alternative pest management strategies are under development. The experience in undertaking inventories and collection of obsolete pesticides in Eastern Europe may be applied in China, where stockpiles of obsolete pesticides probably are a widespread, but not recognised, problem.

Nine pesticides are included in the Stockholm Convention on Persistent Organic Pollutants, in the following designated the POPs pesticides. The POPs pesticides are all toxic persistent substances. They bioaccumulate in fatty tissues in the food chain and are transported over long distances in the atmosphere. The pesticides included in the Stockholm Convention are the following:

- aldrin;
- chlordane;
- dieldrin;
- DDT;
- endrin;
- heptachlor;
- mirex;
- toxaphene;
- hexachlorobenzene (HCB);

Besides these pesticides the UNECE POPs protocol includes two pesticides: chlordecone and lindane (99% gamma HCH, hexachlorocyclohexane).

Most of the POP pesticides are banned or subject to restrictions in most countries today. However, the use of particularly DDT, chlordane, mirex and heptachlor is still reported. The POP pesticides have mainly been used for control of disease-carrying insects and for protection of crops, buildings and constructions against pests.

5.4.1 Sources and releases

Russia

At present POP pesticides are not produced in Russia. Production of DDT was discontinued in 1998. The production facilities still exist and may resume production of DDT in quantities needed for disease vector control (malaria) in accordance with the provisions of the Stockholm Convention on POPs. Production and use would be under strict control of environmental protection, health and other authorities. DDT was, and still is, considered a strategic military chemical in many countries that might have to operate in a tropical climate.

Table 5-15 Production, import and use of POPs pesticides in Russia (Based on COWI 2002)

POP pesticides	End of Production	End of Use	Comments
DDT	1998	1989-1990	
Heptachlor	1976	Practically no application	Production stopped right after commissioning and commercialisation of plant
Hexachlorobenzene	1993	1993	
Toxaphene			Produced in the Soviet Union under the names of polychlorpinen and polychlorcamfen
- polychlorpinen	1980	1980-1981	
- polychlorcamfen	1988	1988-1990	
Aldrin Chlordane Dieldrin Endrin Mirex	Were neither produced nor used in Russia and the Soviet Union		

The recorded use of hexachlorobenzene was 7,000 tonnes in 1987 against 15,000 tonnes in 1981. The Russian authorities have estimated the use of DDT at 1,300 tonnes in 1981, down from 12,000 tonnes in 1970. In 1988 it was permitted to use 126 tonnes of DDT and 333 tonnes hexachlorobenzene for disease vector control (COWI 2002).

Releases of POPs pesticides to the environment today are primarily generated though in-secured stockpiles of obsolete pesticides (OP). Stockpiles of obsolete pesticides in Russia and Ukraine are shown in Table 5-16. New experience indicates that the volumes may quite well be underestimated.

Table 5-16 Estimated amounts (tonnes) of OPs, POPs (including PCBs) and hazardous waste in general based on extrapolation of obsolete pesticide data (DANCEE 2004)

Country	Obsolete pesticides (OP) tonnes	POPs fraction (including PCBs) tonnes *1	Hazardous waste in general tonnes *2
Russian Federation	17,000-20,000	25,000-30,000	180-185 million *4 OP=0.01%
Ukraine	15,000	5,000 +	110-115 million OP = 0.01%

Notes (as in DANCEE 2004):

*1: The POPs fraction is for selected CEE countries positively identified to be between 20-30% of identified obsolete pesticides. A median value of 25% is used for the calculation. Added hereto actual known amount of PCBs generated from various DANCEE financed studies and mass flow calculations.

*2: Based on information from three independent sources of expertise, obsolete pesticides are estimated to provide approx. 0.01% of the anticipated total amount of hazardous waste in selected (Ukraine and Russia) countries. Figures in () are the estimated amount based on a 0.01% fraction of obsolete pesticides in relation to the total hazardous waste.

*3: The figure is officially announced and is from 1998. The figure includes class 1-3 waste equal to EU classified “toxic waste”.

*4: The figure is officially announced and is from 1999. The figure includes class 1-3 waste equal to EU classified “toxic waste”.

China

The POPs pesticide situation in China is summarised in a background document for the Project Brief for the GEF financed Stockholm Enabling Activities project (UNIDO/GEF 2003). Table 5-17 gives an overview of the situation, although the presentation is somewhat inconsistent and difficult to interpret. Four of the POPs pesticides are still used in China: DDT, HCB, chlordane and mirex.

DDT is used for disease (malaria) vector control and has been prohibited for use in agriculture since 1983.

HCB is not used as pesticide in China. In China, HCB is mainly used as the chemical mediate of pentachlorophenol and sodium pentachlorophenate, and something which in the report is designated "*chemical dissolvent and other chemical assistant*" (UNIDO/GEF 2003). The usages in different purposes of HCB need according to UNIDO/GEF a thorough survey. The use and reduction measures are further described in section 5.3.1.

Chlordane and Mirex are used for termite control.

Contrary to the situation on Russia and Ukraine, stockpiles of obsolete pesticides seem not to have been an issue in China, and no information on stockpiles have been available. However, stockpiles of obsolete pesticides may be widespread as indicated by UNIDO: "*Considering less sound management and treatment capacity, it could be deduced tentatively that a lot of stockpiles or waste of pesticidal POPs still remained across the China.*" (UNIDO/GEF 2003).

Table 5-17 Pesticidal POPs in China (UNIDO/GEF 2003)

	Production capacity (ton/year)	Production quantity (ton/year)	Consumption quantity (ton/year)	Import/export (ton/year)	Number of plants	Comments
DDT	16000	4000-6000	3000-4500	100-1000 (export)	2	Existing
HCB	--	1000-10000	--	--	1-2	Existing
Chlordane	--	160	130-200	30 (export)	--	Existing
Mirex,	--	--	0.3	--	--	Existing
Toxaphene		3000 (max. quantity in 1970s)			None	Used to produce, stopped in 1980s
Heptachlor		1.0 (1969)			None	Used to produce, stopped in 1980s
Aldrin		None	--	--	None	Used to research, no production
Dieldrin		None	--	--	None	Used to research, no production
Endrin		None	None	None	None	No production

Note: "--" denotes no detailed data, and the sources and notes are in the footnotes and text

Ukraine

Obsolete pesticide stocks in Ukraine is shown in Table 5-16.

5.4.2 Main release reduction measures

The main measures for reducing the releases of POPs pesticides to the environment are listed in Table 5-18.

Only the use of DDT, Chlordane and Mirex is mentioned, because these are the only POPs pesticides used in the countries addressed. The substances cannot simply be replaced by the use of other substances; there is a need for alternative strategies for pest and vector management. It is beyond the limits of this report to review all these different management options, but reference is made to UNEP (2000) and Mörner et al. (2000).

Table 5-18 Overview of main measure for reduction of release from production, use and stockpiles of POPs pesticides

Source category	Release reduction option
DDT use	Alternative decease (primary malaria) vector management (reviewed by Mörner et al. 2000)
Chlordane and Mirex use	Alternative termite pest management (reviewed by UNEP 2000)
Obsolete pesticides	Collection, package and safe storage of obsolete pesticides
	Destruction of obsolete pesticides, e.g. by incineration
	Implementation of destruction facility

5.4.3 International regulation and agreements

Table 5-19 presents a summarised overview of the coverage in relevant agreements of the POPs pesticides. Binding agreements are indicated in bold.

The obligations of the CLRTAP-POPs protocol and the Stockholm Convention are further summarised in Annex 1. Both instruments aim at eliminating the production and use of the substances, but list a number of exemptions.

The Stockholm Convention includes more exemptions than the POPs Protocol reflecting the fact that more of the pesticides have essential applications in developing countries in tropical areas, for which substitution is not straightforward. A register is established for identifying Parties that have specific exemptions and all exemptions shall expire five years after the data of entry into force of the Convention.

The POPs protocol includes two substances, chlordecone and HCH (linadane), not included in the Stockholm Convention. The Parties to the Stockholm Convention agreed, however, May 2005 that HCH and chlordecone should be considered for possible inclusion on the convention's list.

The Helsinki Convention (July 2004 version with amendments) stipulates that Parties shall prohibit DDT for all uses (except for drugs). For a list of pesticides including the POPs pesticides (except mirex and HCB) the Parties *"shall endeavour to minimize and, whenever possible, to ban the use"* in the Baltic Sea Area and its catchment area. Mirex and HCB are included in the HELCOM list of substances for immediate priority action. The HELCOM list includes also a number of pesticides not covered by the Stockholm Convention and the POPs protocol. The HELCOM recommendations regarding procedures for approval of pesticides in the catchment area of the Baltic Sea indirectly set up procedures that would imply that the POPs pesticides most probably could not be approved for use (HELCOM recommendations 20/2).

None of the substances are included in the OSPAR list of chemicals for priority action, but are all included in the OSPAR 1998 list of candidates for selection, assessment and prioritisation.

Table 5-19 Summarised overview of the coverage of POPs pesticides in international agreements

Agreement	**CLRTAP POPs**	**Stockholm Convention**	**Helsinki Convention**	**OSPAR Convention**
Production				
Aldrin, dieldrin, endrin, toxaphene, heptachlor	Eliminate *1	Eliminate		*7
Mirex	Eliminate *1	Eliminate, exc. parties listed in register *4		
DDT	Eliminate within one year of consensus *2	Eliminate, exc. vector control and dicofol production *5		
HCB	Eliminate *1; exc. specific purposes for countries with economy in transition	Eliminate, exc. parties listed in register *4		
Chlordane	Eliminate *1	Eliminate, exc. parties listed in register *4		
Chlordecone	Eliminate *1	-		
Use				
Aldrin	Eliminate *1	Eliminate, exc. local ectoparasiticide, insecticide	Minimize use/ ban *5	*7
Chlordane	Eliminate *1	Eliminate, exc. ectoparasiticide, insecticide, termiticide, additive in plywood adhesives	Minimize / ban *5	
Dieldrin	Eliminate *1	Eliminate, exc. agricultural operations	Minimize use / ban *5	*7
Mirex	Eliminate *1	Eliminate, exc. termiticide	Indirectly addressed *6	
Heptachlor	Eliminate *1; exc. control of fire ants in electrical junction boxes	Eliminate, exc. termiticide, wood treatment, use in underground cable boxes	Minimize use / ban *5	
Endrin, toxaphene	Eliminate *1	Eliminate	Minimize use / ban *5	*7
DDT	Eliminate, exc. vector control and Dicofol production *3	Eliminate, exc. vector control and Dicofol production *5	Eliminate	
HCB	Eliminate *1; exc. specific purposes for countries with economy in transition	Eliminate, exc. intermediate , solvent in pesticide, closed system intermediate	Indirectly addressed *6	
Chlordecone	Eliminate *1	-		
Lindane (gamma HCH)	Eliminate, exc. a number of applications	-		
Stockpiles (incl. obsolete pesticides)				
Identification	X	X		
Destruction/disposal undertaken in environmentally sound manner	X	X		

*1 Eliminate by entry into force of the protocol.

*2 Eliminate production within one year of consensus by the parties that suitable alternatives are available.

'3* Restricted use for public health protection from diseases such as malaria encephalitis: Use allowed only as a component of an integrated pest management strategy and only to the extent necessary and only until one year after the date of the elimination of production.

As a chemical intermediate to produce Dicofol: Such use shall be reassessed no later than two years after the date of entry into force of the present Protocol (Dicofol is a organochlorine acaricide (a chemical that kills mites) that is structurally similar to DDT.

*4 A register is established for the purpose of identifying Parties that have specific exemptions.

*5 Parties shall endeavour to minimize and, whenever possible, to ban the use of the substances as pesticides in the Baltic Sea Area and its catchment area.

*6 Not specifically covered by the Convention, but the substances may indirectly be addressed by the recommendation regarding procedures for approval of pesticides.

*7 "PARCOM Decision to Phase Out the Use of Aldrin, Dieldrin and Endrin" (1985) has been revoked of OSPAR Convention Parties (OSPAR Decision 98/1).

5.4.4 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions specifically addressing POPs pesticides is presented in Table 5-20 below.

Table 5-20 Identified initiatives in Russia, Ukraine and China addressing POPs pesticides

Donor/finance institution	Projects/comments	Planned period Budget
UNEP/GEF (Russia)	**Stockholm Convention enabling activities in Russia.** Executing agency: Centre of International Projects	See PCDD/PCDFs in Table 5-5
ACAP (Russia)	**Environmentally sound management of stocks of obsolete pesticides in the Russian Federation.** A Pilot Project in the Arkhangelsk Region including inventory development, screening analysis, repackaging, and safe storage of 100 tonnes of obsolete and prohibited pesticides has been completed. The model project developed in the Arkhangelsk Region will be applied to the other ten priority regions where pesticides releases impact the Arctic environment. Similar projects in Komi, Murmansk, Gorney Altai, Kurgan and Magadan are carried out. In Omsk, Karelia and Tyumen regions similar projects are underway.	2003-2006 Project cost 0.49 mUSD
DANCEE (Russia)	**Obsolete Pesticides, NW Russia.** The objective of this project is to provide assistance to Pskov and Vologda regions to: - prepare inventories of obsolete pesticides (OP), - develop action plans for future management and disposal of OP's - demonstrate safe and environmentally sound management of obsolete pesticide stockpiles. Finally the obsolete pesticides in the two regions are collected and stored under safe environmental conditions.	2004-2006 6.0 mDKK
DANCEE (Ukraine)	**Obsolete Pesticides, Ukraine.** Phase 1: to strengthen the central Ukrainian unit responsible for the management of obsolete pesticides. Preparation of national plan for elimination of risks related to obsolete pesticides. Phase 2: Demonstration of handling, transportation, interim storage and disposal facilities. Raising of national and international funds for investments, based on concrete proposals.	1999-2005 11.7 mDKK

Donor/finance institution	Projects/comments	Planned period Budget
UNEP/GEF (Ukraine)	**Stockholm Convention enabling activities in Ukraine.**	See PCDD/PCDFs in Table 5-5
UNIDO/GEF (China)	**Stockholm Convention enabling activities in China.**	See PCDD/PCDFs in Table 5-5
IBRD (WB)/GEF (China)	**Demonstration of Alternatives to Chlordane and Mirex in Termite Control.** The objective of this project is to design and implement a demonstration program to introduce alternatives to Chlordane and Mirex for termite control in a demonstration area to be determined during project preparation, and to disseminate the results and replicate the program in China and globally. The project will create the conditions for the sustainable phase-out of chlordane and mirex in China through demonstration of the effectiveness of alternative practices for termite control and the education of the end-user community about their use. Integrated Pest Management techniques will be applied that rely on a thorough ecological analysis of the problem and understanding of the full range of management options.	Not yet approved (May 2005) 2005-2008 Project Cost 28.331 mUSD GEF Grant 14.641 mUSD
Italian Ministry for the Environment and Territory Sino-Italian cooperation Program for environment protection (China)	**Strategy and Program for the Reduction and Phase-out of Pesticidal POPs in China.** The immediate objectives of this two-year project are to develop a strategy and programs for the reduction and phase-out of pesticidal POPs in China, and to strengthen the capacity and infrastructure of SEPA in the formulation and coordination of national actions on POPs. The results produced by this project will contribute to the formulation of the National (POPs) Implementation Plan with respect to pesticidal POPs and in linkage with the activities carried out by UNIDO. Through this project, a financing package may also be designed for certain pioneer innovative components, initiatives, or subsectors that could potentially move faster within the pesticides sector program.	2002-2004 (still ongoing) Budget: no data
GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) Sino-German cooperation	**Management of obsolete pesticides.** The provinces : Hubei, Jiangsu, Jilin.	2004-2008 2.56 mEUR
GEF/UNEP/UNIDO (Global)	**Fostering Active and Effective Civil Society Participation in Preparations for Implementation of the Stockholm Convention. (NGO-POPs Elimination Project).**	See PCDD/PCDFs in Table 5-5

6 Industrial greenhouse gases

ABSTRACT

The industrial greenhouse gases HFCs, PFCs and SF_6 are addressed here. These are the only so-called industrial greenhouse gases (GHGs) covered in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). HFCs (hydrofluorocarbons) and PFCs (perfluorocarbons) are two groups of substances. SF_6 (sulphurhexaflouride) is an individual substance. The so-called flexible mechanisms for implementation of GHG reduction efforts: "joint implementation" with East European Countries, and "clean development mechanism" with developing countries (including China), offer an opportunity to finance reduction initiatives in other countries on a commercial basis. This is a very strong incentive.

The most important environmental property of these fluorinated compounds is the contribution to global climate change. Though the nominal contributions to global warming from these gases are currently in the range of a few percent, the emission reduction amounts that can be reached by reduction of industrial GHGs lie in the same order of magnitude as individual measures on CO_2, because in principle a 100% substitution is possible for the major uses of industrial GHGs.

HFCs and SF_6 are deliberately produced and used in equipment and in products. Releases are primarily generated when using the substances or during the disposal of equipment or products. Substitution/phase-out is therefore the main type of measure for these substances. HFCs are also released as a pollutant from production of the ODS HCFC. These releases may decrease as a result of HCFC reductions stipulated in the Montreal Protocol and its amendments; see section 1.9 and Chapter 7.

PFCs are also produced deliberately, but the major releases are generated as unwanted pollutants from the production of primary aluminium. For aluminium production improved technology and release reduction measures are the important types of measures.

Most of the descriptive text in sections 6.1-6.3 is extracted from a recent authoritative review for the German Umweltbundesamt (UBA, 2004). Where other references were used, this is noted in the text.

6.1 Introduction to industrial greenhouse gases

Perspective

From an environmental point of view, of all of the fluorinated compounds' properties, the contribution to global climate change is by far the most significant one. The biological impact of fluorinated compounds is low. Only high concentrations lead to adverse effects. Although today's additional greenhouse effect caused by fluorinated gases is low, it will increase enormously owing to the replacement of CFCs and HCFCs. This will pose a significant problem in the future. Today, fluorinated greenhouse gases account for approximately 1-2 % of the total emissions of climate-damaging gases.

On the other hand, it should be taken into account that emissions of industrial GHG can often be reduced by 100%, if suitable measures are taken - e.g. substitution. Where traditional greenhouse gases are concerned, this is almost never the case. The emission reduction amounts that can be reached with CO_2 for example, by applying individual measures lie in the same order of magnitude as those that can be achieved with fluorinated gases.

HFCs, PFCs and SF6 have high Global Warming Potentials (GWP, unit reflecting the global warming effect compared to the effect of CO_2), meaning that per kg emitted they contribute much more than per kg CO_2 emitted. The global warming potential (GWP_{100}) of HFCs ranges between 140 and 7,000, the GWP_{100} of PFC ranges between 6,000 and 9,000, and SF_6 has a GWP_{100} of 23,900 (UBA, 2004).

Table 6-1 below gives an overview of GWP, atmospheric lifetime etc. for individual HFCs, PFCs, SF_6 and some other GHG for reference. Note the high GWP and lifetimes of the industrial GHGs, particularly PFCs and SF_6.

Reduction measures

Generally, HFCs and SF_6 are deliberately produced and used in equipment and in products. Releases are primarily generated when using the substances or during the disposal of equipment or products. Substitution/phase-out is therefore the main type of measure for these substances.

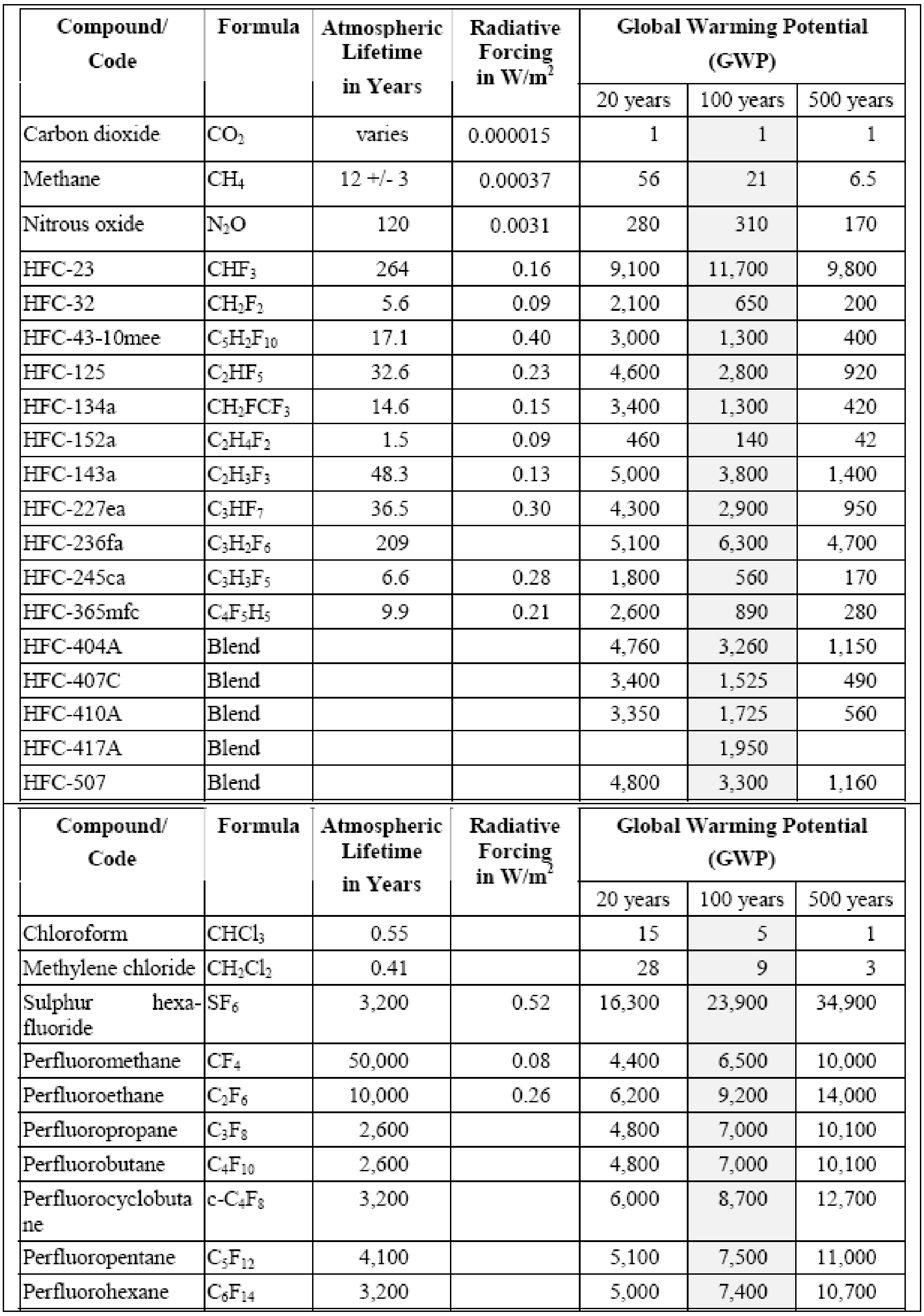
PFC releases, on the other hand, are mainly generated as unwanted pollutant formation from the production of primary aluminium. Here, improved production technology and release reduction measures are the important types of measures.

Since HFCs and PFCs were developed as substitutes for ODSs, their application areas are almost identical. Particularly HFCs have contributed in several areas to a fast ODS phase-out. On the other hand, halogen-free ODS substitutes established themselves right from the beginning in many areas of application, for example, as solvents or cleaning agents, as refrigerants, as fire extinguishing agents and in many application areas of the foam industry. However, some products and processes based on halogen-free substances have only in recent years reached a technical level which makes their use economically and ecologically viable. This applies to the use of CO_2 as refrigerant and the use of halogen-free blowing agents in the foam production. Today, these techniques can fully replace processes and products that were based on fluorinated gases and were indispensable at the time.

Comparative release trends

The relative importance of releases from the addressed industrial GHGs has shifted in the EU over the last decades. The GWP contributions from HFC releases have doubled due to their role as substitutes for ODSs, while releases of PFCs and SF_6 have shown a downward trend. HFCs now clearly constitute the major contributions to global warming from the industrial GHGs (EEA, 2004).

Table 6-1 Overview of the Global Warming Potential, Radiative Forcing Values and Atmospheric Lifetime (IPCC 1994; IPCC 1995; WMO 1999: From: Harnisch et al. 2003; IPCC 2001: From: Harnisch et al.)



Compound/ Code	**Formula**	**Atmospheric Lifetime in Years**	**Radiative Forcing in W/m²**	**Global Warming Potential (GWP)**		
				20 years	100 years	500 years
Carbon dioxide	CO_2	varies	0.000015	1	1	1
Methane	CH_4	12 +/- 3	0.00037	56	21	6.5
Nitrous oxide	N_2O	120	0.0031	280	310	170
HFC-23	CHF_3	264	0.16	9,100	11,700	9,800
HFC-32	CH_2F_2	5.6	0.09	2,100	650	200
HFC-43-10mee	$C_5H_2F_{10}$	17.1	0.40	3,000	1,300	400
HFC-125	C_2HF_5	32.6	0.23	4,600	2,800	920
HFC-134a	CH_2FCF_3	14.6	0.15	3,400	1,300	420
HFC-152a	$C_2H_4F_2$	1.5	0.09	460	140	42
HFC-143a	$C_2H_3F_3$	48.3	0.13	5,000	3,800	1,400
HFC-227ea	C_3HF_7	36.5	0.30	4,300	2,900	950
HFC-236fa	$C_3H_2F_6$	209		5,100	6,300	4,700
HFC-245ca	$C_3H_3F_5$	6.6	0.28	1,800	560	170
HFC-365mfc	$C_4F_5H_5$	9.9	0.21	2,600	890	280
HFC-404A	Blend			4,760	3,260	1,150
HFC-407C	Blend			3,400	1,525	490
HFC-410A	Blend			3,350	1,725	560
HFC-417A	Blend				1,950	
HFC-507	Blend			4,800	3,300	1,160
Chloroform	$CHCl_3$	0.55		15	5	1
Methylene chloride	CH_2Cl_2	0.41		28	9	3
Sulphur hexa-fluoride	SF_6	3,200	0.52	16,300	23,900	34,900
Perfluoromethane	CF_4	50,000	0.08	4,400	6,500	10,000
Perfluoroethane	C_2F_6	10,000	0.26	6,200	9,200	14,000
Perfluoropropane	C_3F_8	2,600		4,800	7,000	10,100
Perfluorobutane	C_4F_{10}	2,600		4,800	7,000	10,100
Perfluorocyclobutane	c-C_4F_8	3,200		6,000	8,700	12,700
Perfluoropentane	C_5F_{12}	4,100		5,100	7,500	11,000
Perfluorohexane	C_6F_{14}	3,200		5,000	7,400	10,700

The GWP values indicated in Table 6-1 have been agreed upon by the countries that are party to the UNFCCC. The only exceptions are the values indicated for newer substances. For them, no GWP has been determined so far. It may be possible that other publications list other GWP values, because they are based on other models. Current data are based on improved spectroscopic data and modified atmospheric lifetime values.

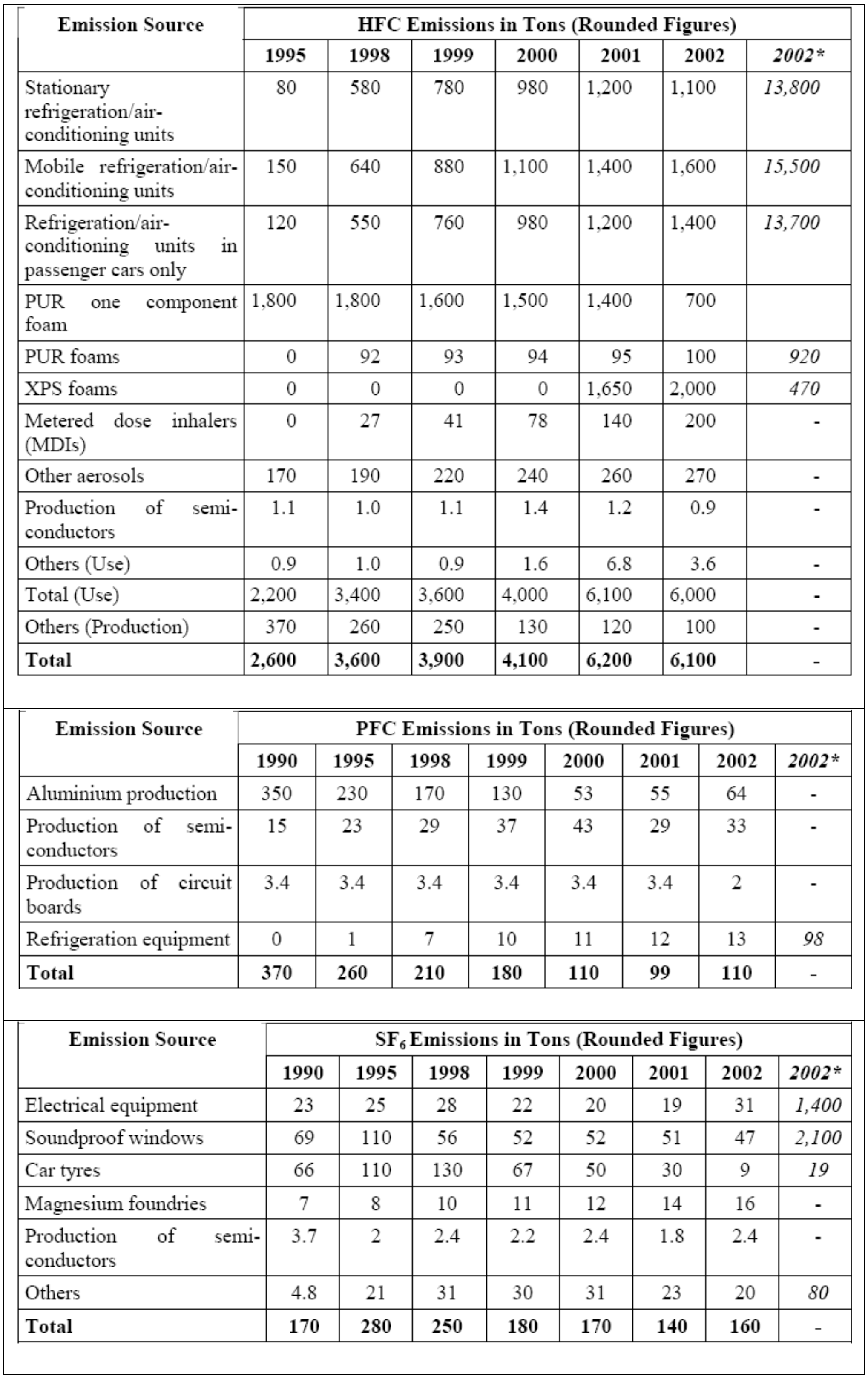
6.2 Sources and releases

No data adequately describing releases distributed on major source categories were identified for the global situation, for Russia, Ukraine or China. Relevant data on releases for Germany, Denmark, Ireland and the USA were reviewed. Fragmented data from some Russian and Ukrainian sources were however identified and reviewed. Based on the review, the emission patterns in all these countries appear relatively similar, except for some major industrial source categories not present in Denmark and Ireland (UBA, 2004; Poulsen, 2004; Pedersen, 2003; Irish EPA, 2003; US EPA, 2004). As the German data illustrate the widest range of sources and the most suitable data series, these data are presented below. Though national and regional differences exist, these data are considered relevant indicators of the general importance of the major source categories. One potential difference could be that consumption/emissions of gases used for air conditioning and refrigeration may be relatively more important in warm climates, such as in China. On the other hand, the high economic activity per capita in Western countries may perhaps partly outweigh such a potential difference. This issue has not been investigated in more detail for this report.

While in open systems emission and consumption rates are identical, closed systems generate large amounts of stored gas (stock). From this yearly growing stock, the substances are - completely or partially – emitted throughout the entire lifetime of the product and during disposal. Reports on fluorinated greenhouse gases therefore distinguish between actual and potential emissions.

Table 6-2 presents time series for the releases of industrial greenhouse gases from various sources in Germany. A listing in text form of applications (and formation sources) is also given below the table.

Table 6-2 *Emissions of industrial greenhouse gases in Germany 1995-2002, by gas and application (from UBA, 2004, quoting BReg, 2004)*



Emission Source	**HFC Emissions in Tons (Rounded Figures)**						
	1995	**1998**	**1999**	**2000**	**2001**	**2002**	***2002****
Stationary refrigeration/air-conditioning units	80	580	780	980	1,200	1,100	*13,800*
Mobile refrigeration/air-conditioning units	150	640	880	1,100	1,400	1,600	*15,500*
Refrigeration/air-conditioning units in passenger cars only	120	550	760	980	1,200	1,400	*13,700*
PUR one component foam	1,800	1,800	1,600	1,500	1,400	700	
PUR foams	0	92	93	94	95	100	*920*
XPS foams	0	0	0	0	1,650	2,000	*470*
Metered dose inhalers (MDIs)	0	27	41	78	140	200	-
Other aerosols	170	190	220	240	260	270	-
Production of semi-conductors	1.1	1.0	1.1	1.4	1.2	0.9	-
Others (Use)	0.9	1.0	0.9	1.6	6.8	3.6	-
Total (Use)	2,200	3,400	3,600	4,000	6,100	6,000	-
Others (Production)	370	260	250	130	120	100	-
Total	**2,600**	**3,600**	**3,900**	**4,100**	**6,200**	**6,100**	-

Emission Source	**PFC Emissions in Tons (Rounded Figures)**							
	1990	**1995**	**1998**	**1999**	**2000**	**2001**	**2002**	***2002****
Aluminium production	350	230	170	130	53	55	64	-
Production of semi-conductors	15	23	29	37	43	29	33	-
Production of circuit boards	3.4	3.4	3.4	3.4	3.4	3.4	2	-
Refrigeration equipment	0	1	7	10	11	12	13	*98*
Total	**370**	**260**	**210**	**180**	**110**	**99**	**110**	-

Emission Source	**SF_6 Emissions in Tons (Rounded Figures)**							
	1990	**1995**	**1998**	**1999**	**2000**	**2001**	**2002**	***2002****
Electrical equipment	23	25	28	22	20	19	31	*1,400*
Soundproof windows	69	110	56	52	52	51	47	*2,100*
Car tyres	66	110	130	67	50	30	9	*19*
Magnesium foundries	7	8	10	11	12	14	16	-
Production of semi-conductors	3.7	2	2.4	2.2	2.4	1.8	2.4	-
Others	4.8	21	31	30	31	23	20	*80*
Total	**170**	**280**	**250**	**180**	**170**	**140**	**160**	-

Notes: * Data in the column "*2002**" designate potential emissions, that is stocks of the substance built up in products and processes in that year. The column "2002" designates actual releases in 2002.

Major intentional uses and other source categories

HFCs

Application areas of HFCs include mainly the following:

- Stationary and mobile refrigeration and air-conditioning units (as refrigerant); a main emission source in Germany;
- Insulating materials/foams (as blowing agent); a main emission source in Germany;
- Aerosols (as propellant).

Other applications include the following:

- The production of semi-conductors (as etching gas);
- Their use as fire extinguishing agent;
- Medical applications;
- Their use as solvent.

Another source of HFC releases is by-product formation in production of HCFCs. This source is decreasing in the western world due to ongoing substitution of HCFC uses, but may be increasing in the developing world due to their need for it as a transitional substitute for CFCs. Misuse of (CDM) funding for establishment of new HCFC production facilities with lower HFC releases is reported; apparently because the trading of associated CO_2 credits alone enables such transactions economically. This is counterproductive to the goals of Montreal Protocol.

PFCs

Despite comprehensive upgrade and emission reduction measures, the largest PFC emission source in Germany is the aluminium industry. Unlike other PFC emission sources, the aluminium industry does not use PFCs, but generates them in the production process. The main application area of PFCs is the production of semi-conductors (BReg 2004). The global emissions of CF_4 (one of the PFCs) was appr. 15,000 tonnes in 1990 and fell to appr. 10,500 tonnes in 1995. The annual global emission of C_2F_6 was about 2,000 tonnes in 1990 and 1995 (Pedersen, 2003).

PFCs are specifically used for the following applications:

- Production of semi-conductors (as etching gas); a main application area in Germany;
- Production of circuit boards (as etching gas);
- Refrigeration systems (as refrigerant),
- Medical applications;
- As tracer gas.

SF_6

SF_6 is not a substitute for ODSs. It has been used since the late 1960s (UBA, 2004). The global consumption is about 7,500 tons annually, of which approximately 6,000 tons are used as dielectric (insulating) gas in high-voltage electrical installations. Much of this is applied in the growing energy sector in Asia. The consumption is relatively lower now in western countries, because the sector here was built out earlier, and existing stocks are recycled. Magnesium production is the second largest application field globally; app. 500 tons annually (Pedersen, 2003).

SF_6 is used in a large variety of applications:

- Double-glazing applications (as insulating gas; soundproof glass);
- Electrical equipment (as insulating and arc-quenching gas);
- Magnesium foundries (as cover gas);
- Production of semi-conductors (as etching gas);
- Trainers/shoes (as cushioning);
- Car tyres (as filling gas);
- Electronic high-voltage equipment (electron microscopes, x-ray devices etc.);
- Aluminium foundries (e.g. as degasser);
- Tracer gas;
- Leak detection gas.

Until a few years ago, the major emission source in Germany was car tyres. Today, major emission sources include soundproof windows, electrical equipment, magnesium foundries and production of semi-conductors. All other applications are of less relevance as emission sources (BReg 2004). The various applications make use of the different properties of SF6.

6.2.1 Available release data from Russia and Ukraine

The data shown in Table 2-1 below was extracted from the Third National Communication of the Russian Federation (2002). The Third National Communication of the Russian Federation on activities under the Convention was compiled by the Federal Service of Russia for Hydrometeorology and Environmental Monitoring (Institute of Global Climate and Ecology under Roshydromet and the Russian Academy of Sciences was the leading contributor) at the request of the Inter-Agency Commission of the Russian Federation on Climate Change. This Communication was prepared in accordance with the decisions, methodological guidelines and recommendations of the UNFCCC. Federal Ministries and Agencies participating in the Federal Target Programme “Prevention of Dangerous Changes of Climate and their Adverse Effects”, many organizations, and scientific institutions of the Russian Federation have been involved in its preparation. Total anthropogenic emissions of greenhouse gases from the territory of Russia in 1999 (in CO2-equivalent) amounted to 61.5 % of the 1990 emission. Table 6-3 presents GHG emission trends in 1990 - 1999 (without CO2 removal by forests).

Table 6-3 Anthropogenic emission of GHGs (million metric tons of carbon dioxide equivalents) in the Russian Federation

Emission	**Year**							
	1990	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**1999 *1 (% of 1990)**
CO2	2360	1660	1590	1500	1530	1510	1510	64

CH_4	550	410	390	390	300	310	290	53
N_2O	98	49	43	41	44	34	35	36
PFC, HFC, SF_6	40	35	38	36	39	41	42	106
Total	3050	2150	2060	1970	1910	1900	1880	62

Note: *1: Calculated using un-rounded emission figures

The US EPA (2001) calculated rough estimates and projections of industrial GHG releases from a number of countries including the Russian Federation and Ukraine. The estimates and projections were for most countries based on emission profiles derived from the US situation, and should therefore likely be considered as associated with significant uncertainties. The US estimates operate with a term called "ODS substitution". This category of release sources includes applications of HFCs and, to a lesser extent, PFCs, and hydrofluoroethers (HFEs) which are replacing ODSs in a wide variety of applications, including as refrigerants, aerosol propellants, solvents, foam blowing agents, medical sterilization carrier gases, and fire extinguishing agents.

A further split of emissions of industrial GHG in Russia is provided in based on personal communication from the Russian Institute of Global Climate and Ecology.

Table6-4 Fluorinated gases emissions in the Russian Federation by gas, 1990–1999 (tonnes CO_2 equivalent)

Source categories	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Emissions of HFCs	9 700	9 800	9 800	9 800	7 000	7 600	5 900	9 449	9 458	9 466
Emissions of PFCs	30 000	29 700	29 700	29 700	28 000	30 600	30 200	30 487	31 411	32 982
Emissions of SF6	NA	NA	NA	NA	NA	NA	NA	16	16	16
Total emissions	39 700	39 500	39 500	39 500	35 000	38 200	36 100	39 952	40 885	42 464

NA stands for Not Available

The US EPA (2001) estimates thus derived for Russia and Ukraine are presented in Table 6-5.

Table 6-5 Industrial GHG releases in Russia and Ukraine roughly estimated/projected by US EPA (2001)

	Releases in million tonnes of CO2 equivalent				
	1990	1995	2000	2005	2010
Russia:					
ODS substitutes (refrigeration and other uses of HFCs, PFCs and HFEs)	n.a.	0	6	21	41
HFC-23 fugitive emissions	5.1	1.6	0.6	0.5	0.5
PHC from aluminium production	15.4	10.0	9.8	9.5	8.7
SF_6 from magnesium smelters	n.a.	n.a.	n.a.	n.a.	n.a.
SF6 from electric appliances (switches etc.)	0.0	3.1	1.6	1.4	1.4
HFC, PFC from semiconductor production	<0.05	0	0	1	1
Ukraine:					
ODS substitutes (refrigeration and other uses of HFCs, PFCs and HFEs)	n.a.	0	0.3	0.9	1.7
HFC-23 fugitive emissions	n.a.	n.a.	n.a.	n.a.	n.a.
PHC from aluminium production	0.4	0.3	0.3	0.3	0.2
SF_6 from magnesium smelters	0.6	0.3	<0.05	<0.05	<0.05
SF6 from electric appliances (switches etc.)	0	0.7	0.3	0.3	0.3
HFC and PFC from semiconductor production	n.a.	n.a.	n.a.	n.a.	n.a.

Note: n.a.: releases from the source were not estimated.

Russian and Ukrainian data submitted for UNFCCC secretariat

Russia

No national emission inventory report (so-called NIR) for greenhouse gases for the Russian Federation had been posted on the UNFCCC inventory web site by May 2005 (UNFCCC 2005). Parties are expected to submit their fourth national communication to the secretariat by 1 January 2006.

Ukraine

A national emission inventory report (so-called NIR) for greenhouse gases for Ukraine is also available from the UNFCCC inventory web site (UNFCCC 2005).

Of the industrial GHG, the report only mentions PFC releases from aluminium production (an unintended formation of pollutants). These GHG releases from aluminium production in Ukraine are shown in Table 6-6.

Table 6-6 GHG releases from aluminium production in Ukraine (tonnes CO_2 equivalents)

GHG	2001	2002
CO2	181.50	189.00
CF4	0.21	0.21
C2F6	0.02	0.02

China

No information on industrial GHGs in China was identified at authoritative web sites on the issue (IPCC and UNFCCC). It cannot be ruled out however that information exists which could be identified through a more extensive data search.

6.3 Main reduction measures

Substitution/phase-out

The main measure for emission reduction for the addressed industrial greenhouse gases is substitution of intentional uses. The alternatives available are other substances and adjusted techniques - see Table 6-7 below. For most applications the alternatives are commercially available today.

Release reductions

For a few major source categories, the emissions are generated through unintended formation in industrial processes. This is the case for PFC emissions from aluminium production and HFC emissions from production of HCFCs. The latter has been reduced significantly in the EU over the last decade due to the substitution of the ozone depleting HCFCs, which are covered by the Montreal Protocol and its amendments (EEA, 2004). This development may likely be expected in Russia, Ukraine and China at a later stage too, if they eliminate their production/use of HCFC in accordance with the Montreal protocol and its amendments.

General reduction measures

Table 6-8 overleaf gives a quite detailed overview of general measures applicable for the reduction of industrial GHG releases by substance (group) and sector.

Table 6-7 Main alternatives for halogenated industrial greenhouse gases in important applications (from UBA, 2004, unless noted)

Substance	**Formula (R-Code *1)**	**Application area, current (and under development) ****	**Comments**
Carbon dioxide	CO_2 (R 744)	Compressed propellant in spray cans; foam production; fire extinguishing agent; refrigerant (degreasing solvent)	GWP=1. CO_2 can be produced from process waste gases that would otherwise be emitted, and is therefor climate-neutral when used in this manner. CO_2 is stabile and has hardly any adverse effects except climate impacts and "drowning" if air is displaced quickly by CO_2 (as must be the case for all compressed gases)
Propane /butane	C_3H_8 $/C_4H_{10}$ (R 290 /R 600a)	Propellant in spray cans - an important substitute here; refrigerants in domestic and small commercial units, as well as in larger "cascade" systems	GWP_{100} <5. Highly flammable. Not toxic, but drug-like effect at high concentrations.
Pentane (linear /cyclic)	C_5H_{12} $/C_5H_{10}$	Foaming of plastics	GWP_{100} <5. Highly flammable. Forms explosive mixtures with air, meaning that stringent safety measures are required. Health effects at high concentration of vapours, but drug-like effect, liquid may irritate eyes and skin.
Ammonia	NH_3 (R 717)	Refrigerant	Odorous. Strong irritant, toxic if inhaled, very toxic in aquatic environments.
Dimethyl ether, DME	$(CH_3)_2O$	An important alternative propellant in spray cans; sometimes used as refrigerant	Drug-like effect at high concentrations. Highly ignitable.
Nitrogen	N_2	Compressed propellant in spray cans; fire extinguishing agent; filling gas in car tyres	No adverse effects except "drowning" if air is displaced quickly by N_2 (as must be the case for all compressed gases)

*1 R-codes are used for refrigerants only.

Table 6-8 Overview of general release reduction measures for HFCs, PFCs and SF_6 (based on UBA, 2004, and Pedersen, 2003)

Application / sector	**GHG addressed *1**	**Measures**
Centralised multi-compressor systems (super-markets etc.)	HFCs	New units: Prefer halogen-free substitutes widely available today (state of the art in some countries): CO_2, ammonia, hydrocarbons; use indirect systems when necessary for safety reasons (in indirect systems the refrigeration unit is placed outside the shopping area). Old units: Minimise HFC losses.
Large scale industrial refrigeration systems (food, chemical and pharma industry, cold storage)	HFCs, PFCs	New units: Prefer ammonia systems (already widely applied) - and perhaps in the future CO_2 systems. Old units: Avoid PFC use due to high GWP; minimise refrigerant losses.
Domestic refrigerator units	HFCs	Prefer halogen-free units now widespread on the market in Europe and other places (both refrigerants and insulation in units).
Commercial plug-in refrigerator units	HFCs	Prefer halogen-free units now commercially available (for smaller units - up to 150g refrigerant charges - halogen-free units are state of the art). These technologies also reduce energy demand and thereby CO_2 releases. Support development of safe hydrocarbon units with 150g - 500g refrigerant charges, as well as CO_2 units.
Large scale air conditioning systems	HFCs (PFCs?)	New units: Prefer ammonia (already widely applied) or hydrocarbon systems. Old units: Avoid PFC use due to high GWP; minimise refrigerant losses.
Room air conditioning systems (domestic)	HFCs	Minimise HFC losses. Support development of hydrocarbon and CO_2 systems.
XPS insulating foams (rigid)	HFCs	Prefer production/products with CO_2 as blowing agent (widely used today in Germany and the Nordic countries).
Insulating PUR foams (rigid)	HFCs	Prefer production/products with hydrocarbons or CO_2 as blowing agents
Soft and integral skin PUR foams	HFCs	Prefer production/products with CO_2 or water as blowing agents. State of the art for soft foams in the Nordic countries.
Jointing foams (one component sealants)	HFCs	Prefer production/products with hydrocarbons as blowing agents.
Solvent use for degreasing	HFCs	Prefer halogen-free alternative techniques (water based, alcohol based, aliphatic hydrocarbon based), or solvent-free techniques (such as plasma cleaning).
Aluminium production (PFC formation as pollutant)	PFCs	Release reduction measures, process optimisation, cleaner technologies (measures not investigated in detail here)
Semi-conductor and circuit board manufacture	PFCs (HFCs; SF_6)	Release reduction measures (afterburners for waste gas etc.). Support ongoing development of alternatives
Switches in electricity production and supply	SF_6	Prefer use of existing SF_6-free installations (vacuum switches) in medium voltage installations (1-36 kV); Support development of alternatives for high voltage installations
Cover gas in magnesium foundries	SF_6	Prefer traditional SO_2 as cover gas (in closed systems to protect working environment), or a new substitute: perfluoroketone ($C_6F_{12}O$, GWP_{100} = appr. 1)
Sound insulating windows	SF_6	Eliminate the use of SF_6 and improve construction of window (a planned measure in the EU; UBA, 2004)

*1 For many applications HCFCs and CFCs have also been used, and in some cases substitution has happened directly from theses substances to non-GHG substitutes.

6.4 International regulation and agreements

6.4.1 Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC)

HFCs, PFCs and SF_6 are addressed in the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC). Other substances covered by the Protocol are the high volume gases CO_2, methane and N_2O. The Protocol defines binding reduction targets for the total emission of all addressed greenhouse gases, calculated by use of so-called carbon dioxide equivalents, for each of the Parties to the Protocol.

The targets are expressed as a percentage of the total emission of the Party in question in 1990 (or another predefined baseline year), and are defined for each of the Parties individually. The reduction targets for the countries of primary interest here are presented in Table 6-9. The target must be met as an annual average over the years 2008-2012 (incl.).

Table 6-9 Reduction targets for GWP releases of the addressed countries (based on the Kyoto Protocol, Annex B, unless noted)

Country	Reduction t o be achieved, in percentage of total GWP of base year *1
Russian Federation	0 %
Ukraine	0 %
China	?*2
Denmark	8 % (21%)

*1 A reduction of 0% actually means conserving status quo for releases in spite of expected increases in the economical activity. Denmark's reduction target is 8% according to what is presented in Annex B to the Protocol. As a result of Danish commitments within the EU (which is also a party to the Protocol), Denmark's actual reduction target is 21%.

*2 China is a so-called Annex II Party (a developing country). No reduction target for China is presented in the Protocol.

Carbon dioxide equivalents - also called global warming potential, GWP - are units reflecting the ability of a substance to contribute to the greenhouse effect relative to the contribution of the same amount of carbon dioxide (which by definition has GWP =1) over a specified time period. In the context of the Climate Change Convention and the Kyoto Protocol, the international community has agreed to use 100 years (GWP_{100}) as a standard to enhance comparability.

Meeting the reduction target for a country can be achieved by cutting emissions of the addressed substances, or by increasing greenhouse gas removals in predefined so-called "sinks", for example by planting forests which accumulate CO_2 from the atmosphere. It is important to understand that all the addressed substances contribute to the same adverse effect, though at different rates per amount, and reduction targets are not defined individually for the substances. This means that the Parties may decide for themselves which substances in which sectors they prefer to address with reduction measures. Reducing the overall national emissions of carbon dioxide equivalents through reductions of emissions of HFCs, PFCs or SF_6 are just some of the options available.

Besides national reductions on a Party's own territory, the Protocol also establishes three “mechanisms” for bilateral or multilateral cooperation to cut releases known as **joint implementation** (with parties to the Protocol), the **clean development mechanism** (with developing countries including China), and **emissions trading**. These are designed to help Parties cut the cost of meeting their individual emission targets by taking advantage of opportunities to reduce releases, or increase greenhouse gas removals, that cost less in other countries than at home.

With joint implementation (JI) a party to the Kyoto Protocol can implement reduction initiatives in other parties to the Protocol which fulfil certain documentation and registration requirements. Most JI projects are expected to take place in countries with economies in transition in Eastern Europe. The financing country can subtract the achieved reductions on its own climate gas budget and thereby reduce the need for reduction efforts on their own territory. A system has been developed whereby such reduction efforts can be traded commercially through what could be called "carbon credits". For example, Denmark calls for tenders from industry and other commercial partners, for such projects that reduce climate gas emissions in other countries, and the tenders can be evaluated according to how many tons of CO_2 equivalents reductions can be achieved per US dollar, Euro or DKK. A JI project might involve, for example, replacing a coal-fired power plant with a more efficient combined heat and power plant.

The clean development mechanism (CDM) works in a similar manner, but applies only to developing countries (which have not committed themselves to specific CO_2 reduction targets stated in the Protocol). CDM projects must be evaluated and approved in a special forum set up under the Protocol and its later accords.

More information on the Kyoto Protocol, the UNFCCC and later documents laying down rules for the mentioned mechanisms is available at the UNFCCC homepage at
http://unfccc.int/essential_background/kyoto_protocol/items/2830.php

6.4.2 Other agreements

The addressed industrial greenhouse gases are not covered in other agreements assessed in this project.

6.5 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions is presented in Table 6-10.

Table 6-10 Existing initiatives in Russia, Ukraine and China with relation to industrial GHG releases

Donor/finance institution	Projects/comments	Period Budget
GEF (China)	**Barrier Removal for the Widespread Commercialization of Energy-Efficient CFC-Free Refrigerators in China** (UNOPS/China National Environmental Protection Agency): This project will reduce GHG emissions in China by removing barriers to the widespread commercialization of energy-efficient refrigerators. The project addresses the key market, technological, social, and commercial barriers both to the adoption of high-efficiency refrigerator technology by Chinese manufacturers and to the acceptance of high-efficient refrigerators by Chinese consumers. Activities include technical assistance and training for compressor and refrigerator manufacturers, incentives for energy efficient product design or modification and conversion of factory production lines, national efficiency standards, a national labelling program, consumer education and outreach, dealer and manufacturer incentive programs, and a consumer buyback/recycling program. (Eds.: The project does appear to explicitly include reduction of industrial GHGs, but was mentioned here due to its relevance to the specific recommendations mentioned in section 6.6)	1998 - Project cost: 41 mUSD of which GEF Grant: 9.9 mUSD
CIDA/USAID (Ukraine)	Ukrainian activities pertaining to climate change are described on the web site of the so-called "Climate Change Initiative" - see text below table.	
UNIDO *1 (China)	**Replacement of CFC-11 and CFC-12 with cyclopentane and HFC-134a in the production of refrigerators at Banshen electric appliances co.** The objective of the project is to phase out the average direct use of 90 mt CFC-12 and 473 mt CFC-11 in the production of refrigerators and freezers at Banshen Electlric Appliances Co. in China. The selected ODS substitutes are cyclopentane blowing agent and HFC-134a refrigerant. (Eds.: Direct jump to cyclopentane blowing agent and phase-in (!) of HFC).	? (completed) 2.8 mUSD budget
(China)	**Replacement of CFC-11 with HCFC-141b foam blowing agent and CFC-12 with HFC- 134a in the manufacture of domestic refrigerators/freezers at the Beijing freezing equipment factory.** (Eds.: Phase-in (!) of HFC).	? - 2000 0.27mUSD
(China)	**Phasing out ODS at the household refrigerator compressor factory of the Guangzhou Wanbao Compressor Group.** Phase out the direct use of CFC-12 refrigerant in the production of the household refrigerator compressors at the Household Refrigerator Compressor Factory of the Guangzhou Wanbao Compressor Group in Guangzhou and the indirect elimination of the use of 250 mt of CFC-12 refrigerant in the manufacturing of refrigerators and freezers at plants using these compressors. It was decided to select HFC-134a as replacement refrigerant. (Eds.: Phase-in (!) of HFC).	? (completed) 2.2 mUSD
EU - Tacis (Russia)	**Tacis - institutional support to Kyoto Protocol implementation.** The overall objective of the project is to assist the Russian government in preparing the necessary conditions for implementation of the UNFCCC and Kyoto Protocol provisions. The main components include: - development of recommendations for improving the Russian greenhouse gases (GHG) emissions monitoring and reporting system, including the institutional organisation of this system, and the methodology for preparing the national GHG emissions inventory; - development of recommendations for improving the legal basis for the Russian national GHG emissions monitoring and reporting system; - transfer of knowledge to key Russian stakeholders of EU 'Best practice' principles for monitoring and reporting of GHG emissions; - assistance in establishing a Russian National GHG registry as required under article 7 of the Kyoto Protocol, including the design, institutional organisation and legal basis of the registry; - Transfer of knowledge to key Russian stakeholders of EU 'Best practice' principles for setting up a national GHG registry; and	2004 -? 2 mEUR

Donor/finance institution	Projects/comments	Period Budget
	- Development of recommendations for a Russian system for the realisation of projects under the Kyoto Protocol and national guidelines for the approval of such projects, including its institutional organisation and any necessary legal provisions.	
(Ukraine)	**Tacis - technical assistance to the NIS with respect to their global climate change commitments.** (One of several components :) The contract for Ukraine and Belarus: - the establishment of a greenhouse-gas inventory system; - the development of the infrastructure for joint implementation projects;	2003 - ? 1.3 mEUR

Notes: *1: Various other UNIDO projects in China may include the phase-in of HFCs in refrigeration units with the aim of phase-out of ODSs. Not all ODS substitution projects were checked for industrial GHG relevance.

Other information about ongoing activities

Ukrainian activities pertaining to climate change are described on the web site of the so-called "Climate Change Initiative" (http://www.climate.org.ua/index.html). The web page is funded by USAID assisted by the Canadian International Development Agency. The web page describes the overall organisation set up for developing and implementing Ukrainian policies on GHG, initiated HGH reduction projects, and elements of a national inventory for CO_2, methane and N_2O for selected sectors. Except for the release data for PFCs from aluminium production shown in Table 6-8 above, the web site does not mention industrial greenhouse gases explicitly. The web page lists various potential projects related to general implementation of the UNFCCC/Kyoto Protocol requirements. The (anticipated?) organisations funding/financing the projects are USAID, CIDA (Canada), The World Bank, Switzerland and the GEF (via UNDP).

7 HCFCs

ABSTRACT
The so-called Ozone Depleting Substances (ODS), including HCFCs, damage the stratospheric ozone layer, which protects the biosphere from harmful ultraviolet radiation from the sun. HCFCs have somewhat lower depleting effects (ODPs) than the CFCs targeted first in the international reduction process.

The substitution of HCFCs is closely linked to the substitution of CFCs on one side and on HFC (industrial GHGs) on the other side. HCFCs have been phased in as inter006Dediate substitutes for CFCs. HFCs constitute a next step of intermediate substitutes to CFCs and HCFCs. HFCs have zero ODP, but unfortunately high global warming potentials. In the context of this report, substitution of both HCFCs and HFCs are priority fields due to their ODP and GWP characteristics. The substitution/phase-out options mentioned for refrigeration and foam blowing for HFCs in chapter 6 are therefore also relevant for HCFCs, and a direct substitution to non-ODP, non-GWP substances should be aimed at. Important release reduction measures for refrigeration uses of HCFC are containment, improved maintenance and recycling.

While all three countries - Russia, Ukraine and China - have joined the Montreal Protocol, their ratification of the amendments to the Protocol ruling HCFC is lacking behind. Russia has currently not ratified any obligations as regards reductions of HCFCs, while Ukraine has ratified and China is in accession to obligations as regards consumption of HCFCs, but not to obligations on production and exports of HCFCs.

Denmark has so far played a major role in Eastern Europe preparing large ODS reduction projects for financing by international financing institutions.

Most of the descriptive text in this chapter is extracted from recent authoritative reviews (UNEP-RTOC, UNEP-TEAP, 2002). Where other references were used, this is noted in the text.

7.1 Introduction to HCFCs

Perspective

The so-called Ozone Depleting Substances (ODS), of which HCFCs are one group, interfere in certain atmospheric physio-chemical reactions taking place in the stratospheric ozone layer, resulting in a lowering of ozone concentrations in this layer; so-called "holes" in the ozone layer. The ozone layer protects the biosphere from harmful ultraviolet radiation from the sun.

Intergovernmental negotiations for an international agreement to phase out ozone depleting substances started in 1981 and concluded with the adoption of the Vienna Convention for the Protection of the Ozone Layer in March 1985 (UNEP, Ozone 2005). In 1987, the Montreal Protocol to the convention was adopted. The Protocol sets quantitative goals for the reduction of production and use of selected ODSs. Periodically the Protocol has been amended, whereby more substances have been included in the Protocol and other adjustments and supplements have been made. HCFCs were introduced in the Protocol by amendments in 1992 and in 1999. HCFCs have somewhat lower ODPs than the CFCs targeted first in the international process (see table below).

Table 7-1 Name, formula, ODP and GWP for selected HCFCs and a few CFCs and a halon for reference

Substance	R-code (for refrigeration purposes)	Formula	ODP-value *1	GWP-value (100 years)
Halon-1301	R-13B1	$CBrF_3$	10	5,600
CFC-11	R-11	$CFCl_3$	1.0	4,000
CFC-12	R-12	CF_2Cl_2	1.0	8,500
CFC-115	R-115	$CClF_2CF_3$	0.6	9,300
HCFC-21	**	$CHFCl_2$	0.04	**
HCFC-22	R-22	CHF_2Cl	0.055	1,700
HCFC-123	**	$C_2HF_3Cl_2$	0.02-0.06	**
HCFC-124	R-124	CF_3CHClF	0.02-0.04	480
HCFC-141b	**	CH_3CFCl_2	0.11	*2
HCFC-142b	R-142b	$C_2H_3F_2Cl$	0.065	2,000

*1 Intervals indicate the range of ODPs for several isomers with the same name and net overall formula.

*2 Indicates that the data in question have not been collected for this report.

Consumption trends

CFC use has dropped 87% globally since 1989 largely due to the phase-out of its use in developed countries. With the current cap in developing ("Article 5") countries and reductions in use during the rest of this decade, this use will continue to drop. HCFC production has concurrently increased. It is expected that this will begin a downturn, as use in developed countries will be reducing due to current regional and national regulations that are even more restrictive than those of the Montreal Protocol. The latter would mandate reductions in consumption of 35% in developed countries by 2004. This may have been slightly offset due to expected increases in developing countries as HCFCs play an important role in facilitating CFC phase-out in those countries. HFC-134a has emerged as the key agent in replacing CFC use in many applications. Its production has levelled due to improved product stewardship in selection of uses, minimisation of emissions during use, and, in certain regions recovery and recycling. The net impact of these activities is to reduce the net ozone depletion by about 83% as compared to the levels seen in 1989 (UNEP, TEAP, 2002).

A major use of HCFCs is as foam blowing agents. Historically, the foam blowing agent selection made by the foam plastics manufacturing industry was based heavily on CFCs. The first technology transition in the early 1990s led to the introduction of transitional substances such as HCFCs as well as the increasing use of hydrocarbons and other non-ODSs. This transition is still taking place in developing countries. In developed ("non-Article 5") countries, particularly in Europe and North America, attention is now firmly focused on the second phase of technology transition out of the transitional substances. This transition is concentrating attention on the emerging HFC-based technologies, although it should be stressed that much consideration is still being given to the optimisation of hydrocarbon and CO_2 technologies and these technologies are gaining market share in several sectors. The technical acceptability of hydrocarbons, particularly in polyurethane formulations, has expanded as several previous shortcomings have been overcome. In several key sectors market penetration now exceeds 50%.

7.2 Sources and releases

In the global scale official data presented via the UNEP Ozone Secretariat are mainly production data and consumption data, and not emission data. This is because the Montreal Protocol works with quantitative reductions of production and consumption and not emissions. This is relevant, because by far the most of the ODSs used are ultimately emitted - in many cases the emission is however somewhat delayed, because it is contained in refrigeration systems, closed cell polymer foams etc. This means that stocks are build up which will have impacts in the future. Some emission data may exist, but they have for this reason not been searched for systematically.

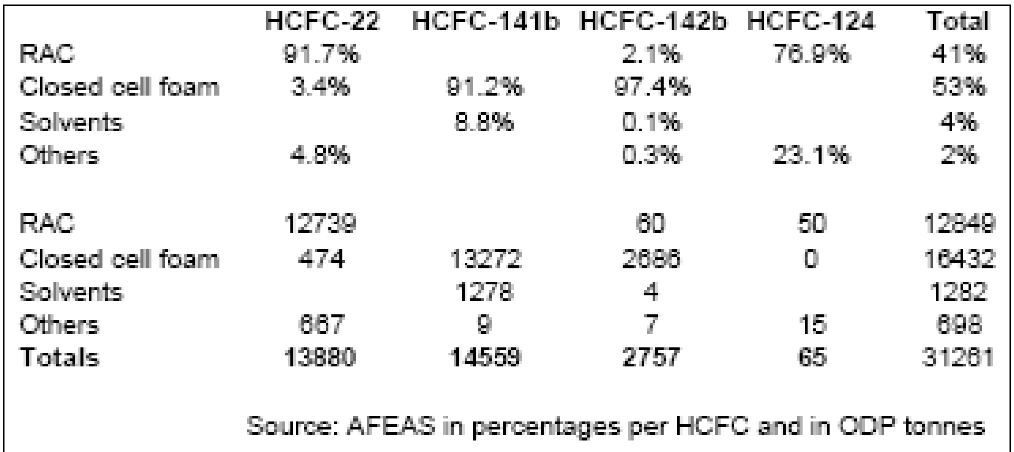
Global HCFC consumption distributed on sectors

A sector analysis of HCFC use is provided in Table 7-2. These data represent about 86% of global consumption. The largest consumption of HCFCs was in the closed cell foam application as blowing agents and represents 53% of all HCFC on an ODP-weighted basis. This was due to the use of HCFC-141b. This application is declining and may by now have been phased out in Europe and the USA. Therefore, total consumption in this sector should be decreasing. This will be somewhat offset by growth in developing countries.

Use in refrigerants was nearly as large on an ODP-weighted basis with 47% of the total. The vast majority of this was from HCFC-22 with minor amounts from the use of HCFC-124 and HCFC-142b mostly as components in refrigerant blends. It is expected that blends will grow somewhat in the future, as these are service replacements, which can be used for CFC installations with minor modifications.

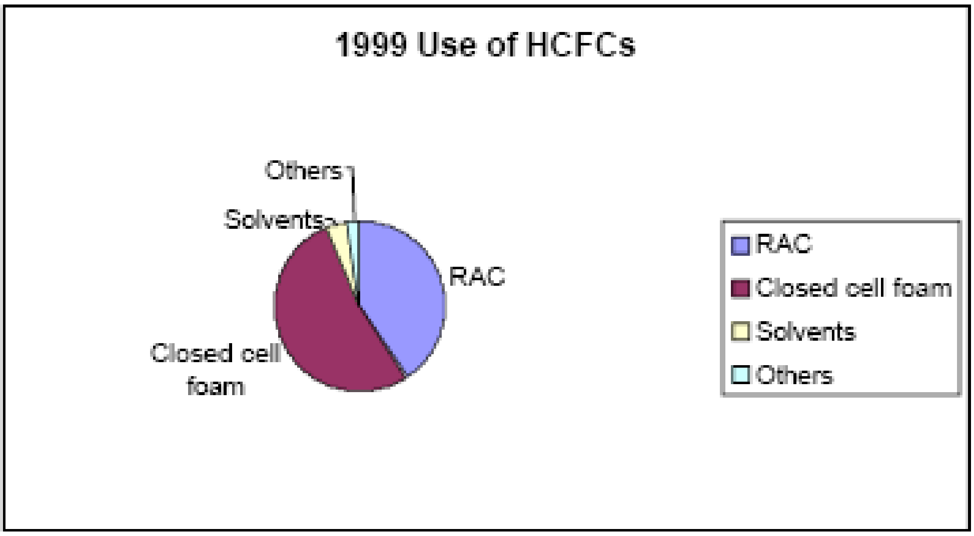
The use of HCFCs for other purposes seems marginal and is therefore not given priority here.

*Table 7-2 Industry data on consumption of HCFCs in 1999 distributed on applications - data here represent about 86% of total global consumption; in % of HCFC and in tonnes ODP (AFEAS, as cited by UNEP- TEAP, 2002) *1*



	HCFC-22	HCFC-141b	HCFC-142b	HCFC-124	Total
RAC	91.7%		2.1%	76.9%	41%
Closed cell foam	3.4%	91.2%	97.4%		53%
Solvents		8.8%	0.1%		4%
Others	4.8%		0.3%	23.1%	2%
RAC	12739		60	50	12849
Closed cell foam	474	13272	2686	0	16432
Solvents		1278	4		1282
Others	667	9	7	15	698
Totals	**13880**	**14559**	**2757**	**65**	**31261**

Source: AFEAS in percentages per HCFC and in ODP tonnes



[*1] The reported AFEAS (industry) data do not include HCFC-123, and do not include use of any HCFC in China, India and Korea. RAC means refrigeration and air conditioning.

HCFC production data

Global data for production and consumption are given emphasis here because they illustrate the important contributions from especially China, and they show how production and consumption have evolved dramatically in the regions of interest due to the successive substitution of CFCs with HCFCs.

Data for global HCFC production are presented in Table 7-3.

China, India and Korea made sharp increases in HCFC production in 1993 and 1994 and then again in 1999. The total increase was from 249 ODP-tonnes in 1989 to 5013 ODP-tonnes in 1999 and to 6713 ODP-tonnes in the year 2000 (of which about 6000 ODP-tonnes are produced in China. If one compares it to the consumption, it makes China and India net exporters of HCFC chemicals at about 1,300 ODP-tonnes per year. The almost 30-fold increase has made particularly China (and to a lesser extent, India) a significant source of HCFCs.

HCFC consumption data (1989-2000)

Global HCFC consumption data are included in Table 7-4. Total consumption for all Parties has increased on a fairly continuous basis (except for 1996 during which there was a dip; however, this was a year for which consumption data reported might be incomplete). Consumption increased about 160% for the years 1989-2000.

HCFC consumption in Central and Eastern Europe decreased during 1989-1999 by 36%; however, significant increases during 2000 suggest transition from CFC use.

Consumption in China, India and Korea increased 540% over the period 1989-2000. The increase had appeared to peak in 1995 with declines during following years. There were dramatic increases in HCFC consumption between 1998, 1999 and 2000 going from 1,756 to 5,355 ODP-tonnes in just two years.

Over the period 1989-1999, the proportion of HCFCs consumed by OECD countries has averaged about 80% of the total global consumption. Most recently, this has fallen to 61% in 2000 largely due to consumption growth in China, India and Korea and a significant reduction in such use in the OECD countries in 2000. It is expected that the proportion of HCFC global consumption used in developing countries will increase as the HCFC use restrictions will have serious impacts on the consumption in Europe and the USA.

Table 7-3 Reported HCFC production in selected regions and globally 1989-2000 (tonnes ODP as aggregated by UNEP (UNEP- TEAP, 2002)

	1989	1992	1993	1994	1995	1996	1997	1998	1999	2000
China/India/Korea	249	731	1212	1840	1877	1831	1526	1522	5013	6713
Eastern Europe	1084	267	172	198	184	74	72	67	146	169
Reported global production (UNEP)	13867	13942	20875	27266	30180	28674	29868	32648	36207	37228

Table 7-4 Reported HCFC consumption in selected regions and globally 1989-2000 (tonnes ODP as aggregated by UNEP (UNEP, TEAP, 2002)

	1989	1992	1993	1994	1995	1996	1997	1998	1999	2000
China/India/Korea	991	748	1407	2140	2392	2265	1516	1756	4871	5355
Central/Eastern Europe	564 (437)	316 (267)	258 (172)	228 (107)	259 (84)	195 (73)	345	304	362	586
Reported global consumption (UNEP)	14184	14403	19134	21739	27904	25077	30209	32793	37062	37213

Russia

Un-official data for production and imports of HCFCs in the Russia are presented in Table 7-5 below (anonymous, 2005). Keeping in mind that on the global scale, HCFC-22 represents the most of the consumption used for refrigeration purposes, these data could perhaps indicate that the majority of the currently reported Russian production and import is used in the refrigeration sectors (if the Russian export is smaller than its consumption). These data do however not reflect whether foaming with HCFC-141b is done or not in the Russian Federation.

Table 7-5 HCFCs production and import in the Russian Federation 2000-2003; tonnes of substance

	2000	2001	2002	2003
HCFC-21 production	2	135	195.9	221.2
HCFC-22 production	1815	28443	21039	20827
HCFC-142b production	398	824	1051	1455
Total of reported production (22, 141b and 142b)	2215	29402	22286	22503
Import of all HCFCs' types (22, 141b and 142b)	726	1140	7753	4184

Ukraine

According to UNEP (2004), the 1989 base year HCFC production (82 t ODP) in Ukraine had been terminated in 2003, and consumption had dropped to 49% (80.4 t ODP) in 2003 from a consumption in the base year 1989 of 164 t ODP.

China

According to UNEP (2004), the 2003 HCFC production in China was 11,745 t ODP, and consumption was 7,809 t ODP); that means China was a net exporter of HCFCs.

7.3 Main reduction measures

Substitution/phase-out

The substitution of HCFCs is closely linked to the substitution of CFCs on one side and on HFC on the other side (see chapter 6 on industrial greenhouse gases). HCFCs have been - and perhaps still are - phased in as intermediate substitutes for CFCs, because HCFCs can be used more or less directly in some applications designed for CFC use. For some uses, of which refrigeration is a major category, HFCs are also technically quite suitable alternatives to CFCs and HCFCs, and HFCs have zero ODP. In the context of this report, substitution of both HCFCs and HFCs are priority fields due to their ODP and GWP characteristics. The substitution/phase-out options mentioned for refrigeration and foam blowing for HFCs in chapter 6 are therefore also generally relevant for HCFCs, and a direct substitution to non-ODP, non-GWP substances should be aimed at. Such substitutes include hydrocarbons, CO_2, ammonium, DME and water depending on application.

Release reductions

For refrigeration uses containment, improved maintenance and recycling are important release reduction measures; primarily for existing units and technologies/geographical regions where non-ODS, non-GWP alternatives development and commercialisation is slow.

Refrigeration applications

New equipment

As per 2002, the primary zero ODP/low GWP solutions for substitution of CFCs in new refrigeration equipment were summarised by application by (UNEP-RTOC, 2002) as shown in Table 7-6 below.

Table 7-6 Primary zero ODP/low GWP solutions for substitution of CFCs and HCFCs in new refrigeration equipment (UNEP-RTOC, 2002)

Application	Zero ODP/low GWP refrigerants
Domestic refrigeration	Isobutane (HC-600a)
Commercial refrigeration	Hydrocarbons in some self-contained units as well as in a few indirect systems and, to a small extent, carbon dioxide (R-744)
Industrial refrigeration	Ammonia (R-717), and to some extent carbon dioxide for low temperature
Stationary air conditioning equipment	Hydrocarbons (HCFC-22 and HCFs dominate)
Water chillers	Ammonia and hydrocarbons (HCFCs and HCFs dominate)
Heat pump water heaters	Propane (HC-290), and, to some extent, carbon dioxide
Mobile air conditioning	Carbon dioxide is introduced by many car brands per 2004 (UBA, 2004). (HCFs dominated globally in 2002 according to UNEP-RTOC, 2002)

The above solutions are also being applied in developing countries (so-called Article 5(1) countries), where in several sectors the conversion is not complete, however, the number of conversions is steadily increasing. As per 2002, there still were a certain amount of new equipment manufactured with CFCs, also in domestic, but particularly in commercial and transport refrigeration.

Existing equipment

Worldwide, a significant amount of installed refrigeration equipment still uses CFCs and HCFCs. As a consequence, service demand for CFCs and HCFCs remains high. The refrigerant demand for these service needs is best minimised by preventive service, containment, retrofit, recovery and recycling. Recovery at decommissioning or scrapping of equipment, not only in the case of refrigerators, is an important topic, which receives increasing attention now that the ODS consumption in developed countries has been restricted to essential uses. The first step in addressing the refrigerant conservation topics cited above is through training of installers and service technicians, together with certification and regulations. Countries where programs have been successful have had comprehensive regulations requiring recovery and recycling.

Foam blowing agents

The major zero ODP, low GWP substitutes are shown in Table 7-7 (UNEP-TEAP, 2002). Carbon dioxide or CO_2 as a blowing agent in polyurethane foam can be chemically generated from the reaction between water and isocyanate but also added in both polyurethane and other foams as an auxiliary blowing agent in liquid or gas form. The different options are hereafter referred to as CO_2 (water), CO_2 (LCD) or CO_2 (GCD).

Table 7-7 Zero ODP, low GWP foaming agents (UNEP-TEAP, 2002)

Application	Zero ODP/low GWP foaming agents
Extruded polystyrene sheet	CO_2 (LCD), hydrocarbons
Polyolefin foams	Hydrocarbons
Polyurethane packaging	CO_2 (water or LCD)
Flexible polyurethane slabstock for cushioning	Methylene chloride or CO_2 (water or LCD)
Flexible moulded polyurethane	CO_2 (water, LCD or GCD), and methylene chloride (hot cure only)
Extruded polystyrene rigid insulation foams	CO_2 (LCD), alone or with organic secondary blowing agents, and even HCs in specific Japanese markets

LCD: Liquid carbon dioxide; GCD: Gaseous carbon dioxide; "water": Intrinsic chemical reaction between water and isocyanate to form CO_2; see text above.

A broader 2002 description of the anticipated substitution development for foaming agents in the period 2005-2010 is given in Table 7-8 below. The table illustrates how HCFCs and HFCs are expected to serve as intermediate (or permanent?) substitutes for CFCs in the near future.

Discussion of options

The phase-out of ODS in the foam sector has forced the industry to innovate. The first technology transition in the early 1990s led to the introduction of transitional substances such as HCFCs as well as the increasing use of hydrocarbons and other non-ODSs. This transition step is still taking place in developing countries. Meanwhile, attention in developed countries is on phasing out transitional HCFCs. This is concentrating attention on the emerging HFC-based technologies as well as the further optimisation and use of hydrocarbon and CO_2 technologies, which are continuing to gain market share in several subsectors.

The phase-out of CFC use in the polyurethane flexible foam sector is now largely complete, even in developing countries, although some small discontinuous processes still represent a challenge. In the flexible sector there has been little use of transitional technologies.

In the appliance polyurethane rigid foam sector, there has been a tendency to switch in one-step transition to hydrocarbons. CFC usage has been totally phased out in the construction-foam markets.

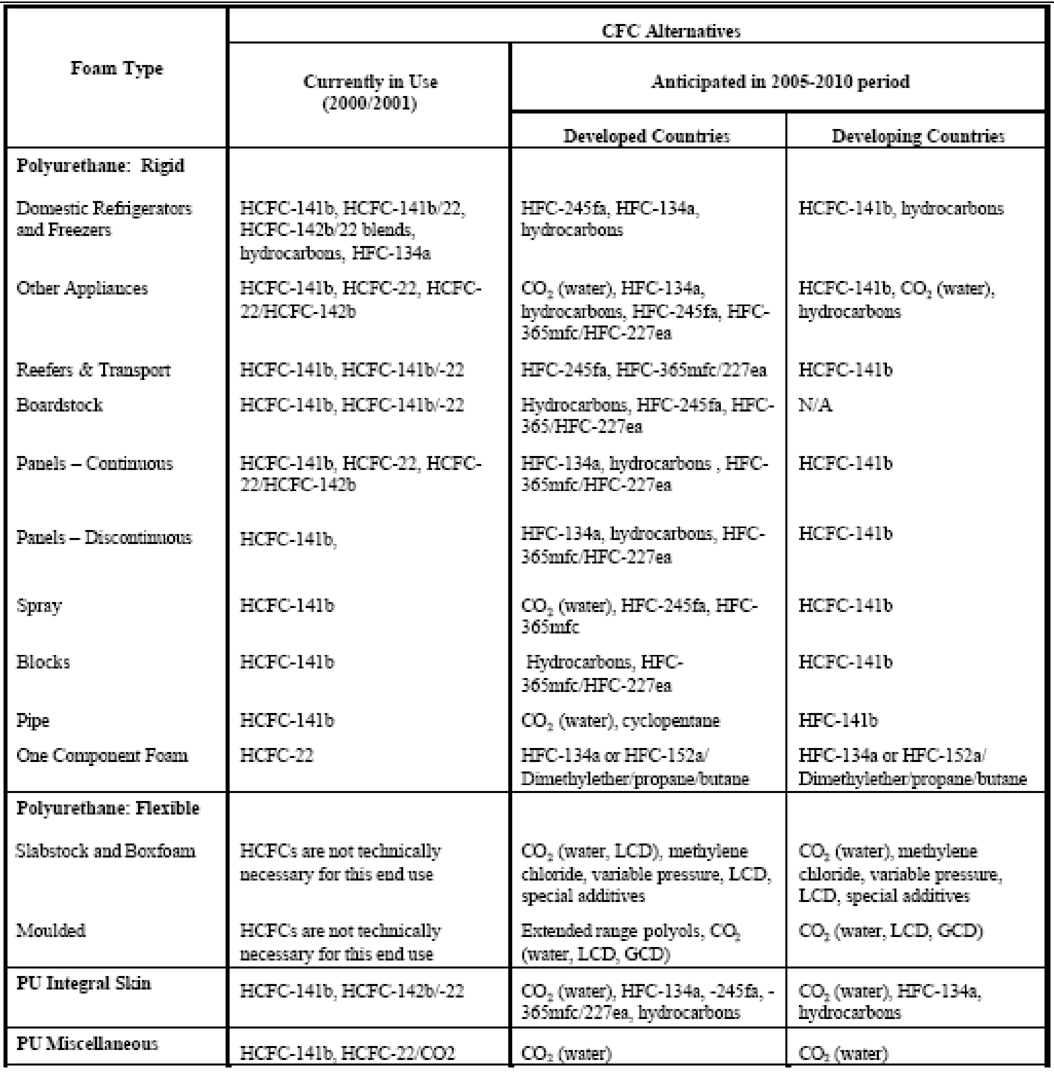
As annual consumption of ODSs decreases, the focus is shifting towards the management of emissions from delayed release sources such as closed cell foams.

Both Japan and Europe have already taken steps related to ODS recovery and destruction from appliances. However, recovery of ODSs from buildings is likely to pose a more significant and costly challenge. This may be a further driver towards HC or CO_2 options or wider changes in building practice to facilitate recovery. The technical and economic feasibility of the recovery of blowing agents from foam at end-of-life will continue to be an area of significant study over the next few years.

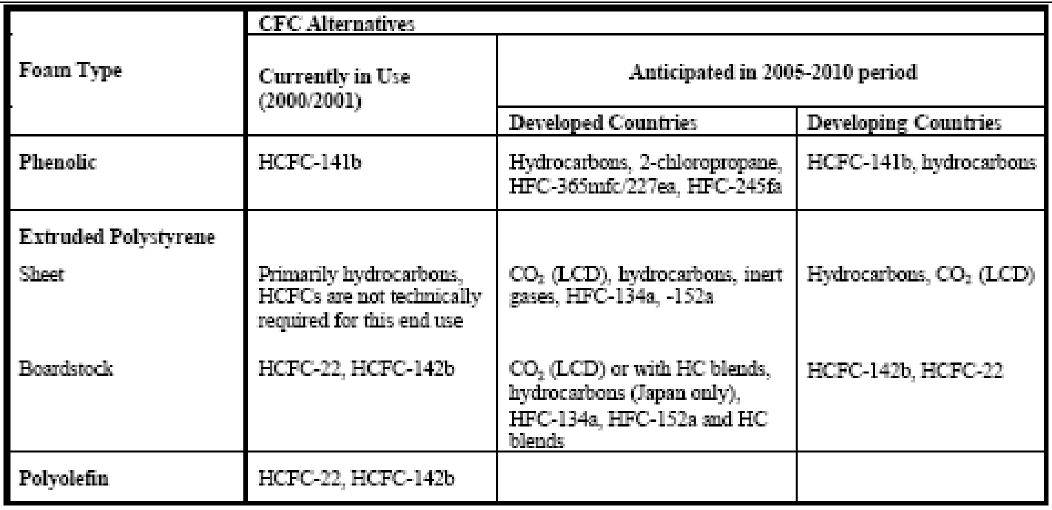
For SMEs and particularly low volume users, there is no economically feasible solution unless the financial implications of investments are overcome. In many foam sectors, the alternative blowing agents are hydrocarbons, which are less expensive than HFC blowing agents but require expensive investments to satisfy safety requirements. A solution might be interest-free loan schemes, even in developed countries, where the investment cost is repaid from savings in blowing agent expense. However, no such schemes are yet being considered.

The requirements of the Montreal Protocol and most national implementation procedures provide little economic incentive. However, recovery and destruction would be economic if credit was given to mitigation of greenhouse gas emissions also, in addition to the direct benefit to the ozone layer. Regulatory or trading schemes would have to reclassify ODS destruction to engage the necessary economic drivers.

Table 7-8 Anticipated development in substitution of foaming agents in developed and developing countries according to (UNEP - TEAP, 2002); polyurethane foams first and other foams last



Foam Type	CFC Alternatives		
	Currently in Use (2000/2001)	Anticipated in 2005-2010 period	
		Developed Countries	Developing Countries
Polyurethane: Rigid			
Domestic Refrigerators and Freezers	HCFC-141b, HCFC-141b/22, HCFC-142b/22 blends, hydrocarbons, HFC-134a	HFC-245fa, HFC-134a, hydrocarbons	HCFC-141b, hydrocarbons
Other Appliances	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b	CO_2 (water), HFC-134a, hydrocarbons, HFC-245fa, HFC-365mfc/HFC-227ea	HCFC-141b, CO_2 (water), hydrocarbons
Reefers & Transport	HCFC-141b, HCFC-141b/-22	HFC-245fa, HFC-365mfc/227ea	HCFC-141b
Boardstock	HCFC-141b, HCFC-141b/-22	Hydrocarbons, HFC-245fa, HFC-365/HFC-227ea	N/A
Panels – Continuous	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b	HFC-134a, hydrocarbons , HFC-365mfc/HFC-227ea	HCFC-141b
Panels – Discontinuous	HCFC-141b,	HFC-134a, hydrocarbons, HFC-365mfc/HFC-227ea	HCFC-141b
Spray	HCFC-141b	CO_2 (water), HFC-245fa, HFC-365mfc	HCFC-141b
Blocks	HCFC-141b	Hydrocarbons, HFC-365mfc/HFC-227ea	HCFC-141b
Pipe	HCFC-141b	CO_2 (water), cyclopentane	HFC-141b
One Component Foam	HCFC-22	HFC-134a or HFC-152a/ Dimethylether/propane/butane	HFC-134a or HFC-152a/ Dimethylether/propane/butane
Polyurethane: Flexible			
Slabstock and Boxfoam	HCFCs are not technically necessary for this end use	CO_2 (water, LCD), methylene chloride, variable pressure, LCD, special additives	CO_2 (water), methylene chloride, variable pressure, LCD, special additives
Moulded	HCFCs are not technically necessary for this end use	Extended range polyols, CO_2 (water, LCD, GCD)	CO_2 (water, LCD, GCD)
PU Integral Skin	HCFC-141b, HCFC-142b/-22	CO_2 (water), HFC-134a, -245fa, -365mfc/227ea, hydrocarbons	CO_2 (water), HFC-134a, hydrocarbons
PU Miscellaneous	HCFC-141b, HCFC-22/CO2	CO_2 (water)	CO_2 (water)



Foam Type	CFC Alternatives		
	Currently in Use (2000/2001)	Anticipated in 2005-2010 period	
		Developed Countries	Developing Countries
Phenolic	HCFC-141b	Hydrocarbons, 2-chloropropane, HFC-365mfc/227ea, HFC-245fa	HCFC-141b, hydrocarbons
Extruded Polystyrene			
Sheet	Primarily hydrocarbons, HCFCs are not technically required for this end use	CO_2 (LCD), hydrocarbons, inert gases, HFC-134a, -152a	Hydrocarbons, CO_2 (LCD)
Boardstock	HCFC-22, HCFC-142b	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a and HC blends	HCFC-142b, HCFC-22
Polyolefin	HCFC-22, HCFC-142b		

7.4 International regulation and agreements

7.4.1 Montreal Protocol and Vienna Convention

HCFCs are covered since 1994 by the Montreal Protocol (1987) to the Vienna Convention for the Protection of the Ozone Layer (1985). The Montreal Protocol addresses a number of other substance groups with ozone depleting properties (CFCs, halons, etc.).

The Vienna Convention encourages intergovernmental cooperation on research, systematic observation of the ozone layer, monitoring of CFC production, and the exchange of information.

The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in September 1987. It was designed so that the phase out schedules could be revised on the basis of periodic scientific and technological assessments. The Protocol was adjusted to accelerate the phase out schedules. It has also been amended to introduce other kinds of control measures and to add new controlled substances to the list.

While most governments have ratified the Protocol, ratification of the Amendments and their stronger control measures lag behind.

The Copenhagen Amendment was adopted in 1992 and entered into force on 14 June 1994. The amendment introduced control measures for consumption only for HCFCs (Annex C, Group I substances). The amendment further introduced control measures for both production and consumption for two new groups of substances, namely HBFCs (Annex C, Group II substances) and methyl bromide (Annex E, Group I).

The Montreal Amendment was adopted in 1997 and entered into force on 10 November 1999. This is the only amendment that did not introduce new substances to the protocol. Instead, the amendment introduced the requirement for licensing systems to allow control and monitoring of trade in substances controlled under the protocol.

The Beijing Amendment was adopted in 1999 and entered into force on 25 February 2002. The amendment introduced control measures for production for HCFCs (Annex C, Group I substances) and imposed restrictions on trade with non-Parties for these HCFCs. The amendment further introduced control measures for both production and consumption for one new group of substances, namely bromochloromethane or BCM (Annex C, Group III substance).

China and Ukraine have not ratified the last two amendments (Montreal and Beijing amendments). Russia has not ratified the last three amendments (Copenhagen, Montreal and Beijing amendments); (UNEP, Ozone, 2005). This means that Russia has currently not ratified any obligations as regards reductions of HCFCs, while Ukraine has ratified and China is in accession to obligations as regards consumption of HCFCs, but not to obligations on production and exports of HCFCs.

Requirements to HCFC of the Montreal Protocol as amended (per 2005)

As mentioned above, the current version of the Protocol as amended defines binding requirements regarding consumption, production, imports and exports of HCFCs. The Protocol provides special conditions for developing countries which had a limited consumption of CFCs (below specific thresholds) before 1999 ("article 5 Parties"). According to documents accessed on the Ozone secretariat homepage (UNEP-Ozone, 2005) China falls under this category.

HCFC consumption

For non-article 5 Parties, the Protocol defines a set of binding, consecutive reduction targets relative to a baseline consumption. The baseline consumption is the sum of the consumption of HCFCs calculated in ODP (ozone depletion potential) in the country in 1989, and 2.8% of the consumption of CFCs calculated in ODP in the country in that same year (presumably to allow for intermediate substitution of CFCs with HCFCs during the overall substitution process). The annual consumption of HCFCs must not exceed 65% of this baseline consumption in and after 2004, 35% in and after 2010, 10% in and after 2015, 0.5% in and after 2020 (and may only be used for servicing of refrigeration/AC systems), and from 2030 and thereafter HCFC consumption must not exceed zero (must be completely eliminated).

For developing (article 5) countries (China among others), the consumption of HCFCs must after 2015 not exceeds its 2015 consumption level, and must be eliminated by 2040.

The Protocol defines a mechanism by which developing (article 5) countries can be provided with specific financial and technical assistance paid by developed parties (non-article 5 parties). In case the developing country (party) has not been able to meet its deadlines, it has the possibility of claiming that this assistance has not been made adequately available to the country. This will initiate scrutiny among the assembly of parties, as for deciding appropriate steps to be taken.

HCFC production

In and after 2004, the annual HCFC production in non-article 5 countries (parties) must not exceed a baseline production calculated as the *average* of the *consumption baseline* (1989) calculated as described above, and a *production baseline* calculated as the sum of the production of HCFCs calculated in ODP in the country in 1989, and 2.8% of the production of CFCs calculated in ODP in the country in that same year.

For developing (article 5) countries (China among others), the annual production of HCFCs in and after 2015 must not exceed a 2015 baseline production calculated according to the principles described above, but with 2015 as the baseline year. However, in order to satisfy basic domestic needs, article 5 countries may exceed the 2015 baseline production by up to 15%.

Other principles

The Protocol defines a number of other important principles and requirements which will however not be described in detail here. These include (among others) principles/requirements for:

- trade and target transfers among parties to the protocol;

- trade with non-parties (banned according to specific principles and deadlines);
- calculation of consumption and production;
- data reporting (rather comprehensive);
- licensing of imports and exports;
- assessment and review of control measures of the Protocol (at least every 4 years);
- research, development, public awareness and exchange of information;
- a financial mechanism and transfer of technology to assist article 5 countries.

7.4.2 Other agreements

HELCOM

By the Helcom Recommandation 11/11 on "Measures to reduce the emissions of harmful chlorofluorocarbons from ships" adopted in 1990, the Helsinki Commission (HELCOM) recommends that the Governments of the Contracting Parties to the Helsinki Convention cooperate within the International Maritime Organization (IMO) to promote early and effective global measures for minimizing air pollution from ships, including in particular decisions on reduction objectives and target dates, and to take actions:

- To prohibit the use of R-12/R-11 and other harmful CFCs on new ships;
- To take steps to promote, instead, the use of HCFC R-22 or other less harmful refrigerants in marine refrigeration installations as they become available;
- To prohibit the use of CFCs as detergents on ships; and
- To apply the following measures in order to reduce the emission into the air of R-12, R-11 and other harmful CFCs from existing marine refrigeration installations:
    - to modify such installations, storage receptacles, valves and means of transferring harmful refrigerants to such installations etc. so that the emission into the air of these can be reduced;
    - to require that those maintaining such installations using harmful refrigerants are capable of taking the necessary precautions to limit or eliminate emissions of such refrigerants during maintenance;
    - to require further that those responsible for the operation and maintenance of such installations are made aware of and motivated to avoid the environmental effects of CFCs

Other agreements

Besides these, HCFCs are not covered by any other agreements addressed in this study.

7.5 Overview of existing activities

An overview of identified, existing activities conducted by donor organisations and international finance institutions is presented in Table 7-9.

Table 7-9 Identified initiatives in the Russian Federation, Ukraine and China addressing HCFC

Donor/finance institution	Projects/remarks	Planned period Budget
IBRD/GEF (Russia)	**Ozone Depleting Substance Consumption Phase-out Project : Tranche III - Small Grant Program (SGP) - Residual ODS Phase Out Management Component.** The project consists of a number of subprojects. Three projects specifically address phase in of HCFC. The enterprises manufacture domestic refrigerators and freezers. In one enterprise CFC 11 used as a blowing agent for the rigid polyurethane foam, as an interim measure, is replaced by HCFC 141b. In two projects a large number of commercial refrigeration equipment are retrofitted to phase in of HCFC based blends.	Approval May 1999 (ongoing) Project Cost: 108.2 mUSD Of this GEF Grant: 31.3 mUSD
IBRD/GEF (Russia)	**Phaseout of Ozone Depleting Substances (second tranche):** HCFC is not specifically mentioned in the prject document. The project's more specific objectives are: i) to allow Russia to credibly meet its consumption phase-out obligations under the Montreal Protocol within a realistic time frame; ii) to facilitate access to financial resources needed for ODS consumption phase-out from a range of international and domestic sources; iii) to provide modest technical assistance and institutional strengthening; iv) to fund enterprise specific investments in critical high consumption sectors; and v) to ensure that ODS phase-out activities accommodate economic and social impacts that may result.	Appr. 1996 (Status?) Project Cost: 56.5 mUSD of this GEF Grant: 35 mUSD
IBRD/GEF (Ukraine)	**Ozone Depleting Substances Phaseout Project.** The project document does not specifically mention HCFC phase-out or phase-in, This project will target priority ODS-consumption phase-out opportunities in 16 subprojects in the refrigeration, aerosol, foam and solvent sectors. It also will provide technical assistance in both government and enterprises to facilitate implementation of the ODS Country Program and supports infrastructure investments and related training to recover and recycle refrigerants from commercial and industrial refrigeration equipment; it also provides funds for handling and retrofitting equipment associated with substitute refrigerants.	Approval Oct 01, 1996 1997-2004 (ongoing) Project Co st: 55.5 mUSD GEF Grant: 23.34 mUSD
UNDP (Ukraine)	National Capacity Self-Assessment for Global Environment Management in Ukraine	
WB (China)	Montreal Protocol Ozone Depleting Substances Phase Out Project (04) (Eds.: No descriptive documents)	1997-2011 100 mUSD loans

Donor/finance institution	Projects/remarks	Planned period Budget
WB (China)	Montreal Protocol Ozone Depleting Substances Phase Out Project (03): 1) support China ' s total ODS phase-out program by establishing an efficient and flexible institutional mechanism to prepare, appraise, finance and implement a large number of subprojects; 2) implement cost-effective priority subprojects; and 3) allow ODS phase-out to proceed at or ahead of current schedule. The project will support 60 to 80 subprojects in all ODS user and producer industries. The subprojects will provide: 1) technical and financial assistance to enterprises for technology transfer, design, training and implementation; 2) assistance in closing Chlorofluorocarbons (CFC) production and halon plants; and 3) technical assistance to the National Environmental Protection Agency (NEPA) and the financial agents in project development and implementation. **Sub-projects where HCFC is explicitly mentioned:** PUR foam piping at plant Shanghai #6: Chose the "water blown" as a main option. However, this option will need time for formulators to optimize recipes and engineers to adjust production process to ensure the quality of foams produced be the same as the original ones. HCFC-141b was selected as an interim solution for those formulations that are not yet successfully optimized. Household refrigerators, Chang Ling Ltd.: The objective of this project is to establish a phased introduction of technology for use of HFC-152a/HCFC-22 blended refrigerant in domestic refrigerators produced by Chang Ling (Eds.: Phase in of HFC and HCFC). Shanghai Shuanglu Electrical Appliances Co. Ltd.: Similar to Chang Ling above. Beijing Refrigerating Machinery Factory: This project will phase out CFC-12 consumption in the production of medium-size semihermetic compressors by converting the production to HCFC-22 compressors. (Eds.: Phase in of HCFC). Nanjing Refrigerator General Works: Similar to the Beijing factory above (Eds.: Phase in of HCFC). Jiangsu Taizhou Commercial Machinery Factory: Similar to the Beijing factory above (Eds.: Phase in of HCFC).. Anhui Refrigerating Machinery Factory: Similar to the Beijing factory above (Eds.: Phase in of HCFC).	1995-2010 90.1 mUSD loans
UNIDO (China)	**Replacement of CFC-11 with HCFC-141b foam blowing agent and CFC-12 with HFC- 134a in the manufacture of domestic refrigerators/freezers at the Beijing freezing equipment factory.** (Eds.: Phase-in of HCFC and HFC).	? - 2000 0.27 mUSD
UNIDO (China)	PHASING OUT CFC-11 WITH HCFC-141B AT SIX COMPANIES (HONGYU, LONGAN, SONGLIAO, TIANYUN, XINYANG AND YIZHENG) AND PHASING OUT CFC-11 BY CONVERSION TO WATER BLOWN TECHNOLOGY AT ONE COMPANY (YINKIAN). The seven companies Hongyu, Longan, Songliao, Tianyun and Xinyang, Yinxian and Yizheng are small and medium scale enterprises producing equipment for the transportation refrigeration sector. The project will phase out 100% of the total use of CFC-11 as foam blowing agent used either for the insulation of refrigeration appliances or for components necessary for the automotive industry produced by these manufacturers. In six companies the selected substitute is HCFC-141b and in one company water is the new foam blowing agent.	Ongoing 1.1 mUSD

Donor/finance institution	Projects/remarks	Planned period Budget
UNIDO (China)	REPLACEMENT OF CFC-11 WITH HCFC-141B IN MANUFACTURING OF PU RIGID SPRAY FOAM FOR INSULATION AT 26 ENTERPRISES To assist the State Environmental Protection Administration (SEPA) to implement the programme of CFC-11 phase-out from PU foam subsector in most effective way within the timeframe of the Country Programme. The project is designed as an aggregate of 26 subprojects for individual and independent enterprises with similar production programmes.	5.3 mUSD

Other information about ongoing activities

The homepage of the Ozone Secretariat (UNEP-Ozone, 2005) provides a large number of meeting documents etc. which may provide additional information on the implementation status at various years of ODS-reducing activities in various countries. It has been beyond the framework of this study to investigate these large amounts of information in detail. Such documents may however be one data source that could be investigated further prior to initiation of projects on HCFCs in the countries addressed in this report.

8 Brominated flame retardants

ABSTRACT

The term 'Brominated Flame Retardants' (BFRs) covers a diverse group of organic substances having in common that they contain bromine and act as flame retardants. Traditionally the most widely used substances among the brominated flame retardants have been TBBPA (tetrabromo bisphenol A), PBDEs (polybrominated diphenyl ethers), PBBs (polybrominated biphenyls) and HBCD (hexabromocyclododecane). Today PBBs are not produced in any country.

The environmental fate and effects of the BFRs vary considerably among the BFRs, even within the same substance group. In general congeners with lower bromine content are of more concern than congeners with higher bromine content. Two of the BFRs, hexabromobiphenyl (PBB with 6 bromine atoms) and pentabrominated diphenylether (PBDE with 5 bromine atoms) are considered for possible inclusion in the Stockholm Convention. The two substances are already or can easily be replaced by other flame retardants.

BFRs are mainly used in electric and electronic products, textiles and building materials. The electric and electronic products are traded on a global market, and the use of BFRs with finished products will probably be quite similar all over the world. The use of BFRs in building materials and textiles is more variable depending on local tradition and regulation.

The main measure for reduction of the releases of the BFRs is to reduce the use of the substances. The most problematic of the BFRs can easily be replaced by other BFRs, and many of the large companies in the electronics industry have phased out the use of PBDEs and PBBs as part of their corporate environmental strategy. For the major use areas non-halogenated alternatives are available, but for some minor areas no alternatives are available today.

The EU RoHS directive on the restriction of hazardous substances in electric and electronic products stipulates that these products shall not contain PBBs and PBDEs, but most probably the mostly used substance, deca-PBE will be exempted from the restriction, weakening the effect of the Directive as a driving force for the phaseout of the substances in the EU and other parts of the world.

It has not been possible to identify any surveys of BFR use or releases in Russia, Ukraine or China, and most probably they do not exist. An assessment of the uses of BFRs in the Arctic including Russia is included in a new ACAP project on BFRs. It is proposed to wait for the result of the survey, before new initiatives in Russia are launched.

It is deemed to premature to start initiatives in the other countries before some of the used BFRs are included in international agreements.

The term ‘Brominated Flame Retardants’ (BFRs) covers a diverse group of organic substances having in common that they contain bromine and act as flame retardants. Bromine has an inhibitory effect on the formation of fire in organic materials. Flame retardants are added to plastics and textiles in order to comply with fire safety requirements.

Because of the diversity of the group it is necessary to discuss the properties of the flame retardants in relation to specific sub-groups.

Traditionally the most widely used substances among the brominated flame retardants have been TBBPA (tetrabromo bisphenol A), PBDEs (polybrominated diphenyl ethers), PBBs (polybrominated biphenyls) and HBCD (hexabromocyclododecane). TBBPA, the PBDEs and the PBBs contain two chlorinated carbon rings, making them very stable and efficient in a large number of plastics. HCBD contains another type of cyclic structure making this substance stable.

The chemical stability of the substances is also one of the reasons why brominated flame retardants for years have been of environmental concern. PBDEs and PBBs, particularly the lower brominated congeners, are spread widely in the environment, are bioaccumulated and accumulated in sediments, where they are degraded only very slowly.

Some of the frequently used brominated flame retardants, TBBPA, HBCD and PBDEs, are present in sediment, mussels and fish. PBDEs have been found in whales and seals. Some of the PBBs and the PBDEs are highly hydrophobic and resistant to degradation processes. It is therefore possible that these chemicals may accumulate in aquatic sediments or bioconcentrate in living organisms. Signs of toxicity of individual PBB and PBDE to early life stages in rainbow trout were reported. The presence of some of the PBBs and PBDEs in mussels, fish, seals and dolphins as well as in sperm whales, which normally stay and feed in deep ocean water, combined with the ongoing industrial production of these compounds indicates that an environmental problem is rising (Simonsen et al. 2000).

In the Arctic, PBDEs have been detected in air and in biological samples from remote areas, although their levels are much lower than levels of some other POPs, such as PCBs (AMAP/ACAP 2003).

The toxicity varies considerably among the BFRs, even within the same subgroup. The effects of PBBs on laboratory animals include body weight loss, skin disorders, nervous system effects and injuries of livers, kidneys, thyroid glands, and immune systems (ATSDR 2004). In general little is known about the long-term effects of low level exposure (ATSDR 2004). The lower brominated congeners are of more concern that the higher brominated, e.g. penta-BDE (five bromine) and octa-BDE (eight bromine) are considered more problematic than deca-BDE (ten bromine).

Brominated flame retardants may further act as precursors or bromine donors for the formation of polybrominated dioxins and furans (PBDD/PBDFs) by incineration of the flame retarded materials. In particular the BFR with carbon ring structures, which may act as a precursor, is of concern.

8.1 Introduction to brominated flame retardants

The following is extracted from an assessment of BFRs and their alternatives published by the Danish EPA (Lassen et al. 1999) unless otherwise indicated.

A distinction is made between reactive and additive flame retardants.

Additive flame retardants

Additive flame retardants are incorporated in the plastic either prior to, during, or, more frequently, following polymerisation. They are used especially in thermoplastics and thermoplastic polyesters. They act as plasticizers or fillers and are not built into the molecular structure of the plastics. They are sometimes volatile and can tend to bleed, so their flame retardancy may be gradually lost. High molecular weight products are developed to enable plastics to be made more permanently fire retardant by the additive method.

The most used additive brominated flame retardants are polybrominated diphenyl ethers (PBDEs), tetrabromobispehol A (also used as reactive BFR) and hexabromocyclododecane (HBCD), but a large number of different compounds are used addtively.

Reactive flame retardants

Reactive flame retardants are built chemically into the polymer molecule together with the other starting components. They are used mainly in thermosets, especially polyesters, epoxy resins and polyurethanes (PUR), in which they can be easily incorporated. The result is a brominated plastic with the original flame retardant present only at trace level as un-reacted constituent. The most used reactive brominated flame retardant is TBBPA, the main use of which is in printed circuit boards of electronic products.

PBDEs

The polybrominated diphenyl ethers (PBDEs) are a group of aromatic brominated compounds formed by substituting bromine for hydrogen in diphenyl oxide. The bromine content can vary between two and ten. Three different flame retardants are commercially available. They are referred to as penta-BDE, octa-BDE and deca-BDE, but each product is a mixture of different brominated diphenyl ethers. They are additive flame retardant, i.e. they are physically combined with the material being treated rather than chemically combined.

Penta-BDE is of most international concern, and the Parties to the Stockholm Convention have agreed that penta-BDE should be considered for possible inclusion on the Convention's list of substances for elimination. Penta-BDE is nearly 100% used an additive flame retardant in flexible polyurethane foam used for mattresses, car seats and other products.

Octa-BDE is mainly used in housing for electronic products.

DecaBDE ether is used for a wide range of applications in plastic and textiles.

PBBs

Polybrominated biphenyls (PBBs) are a group of halogenated hydrocarbons which are formed by substituting bromine for hydrogen in biphenyl. The bromine content can vary between two and ten.

Three different flame retardants have been commercially available. They are referred to as hexa-PBBs, octa/nona-PBBs and deca-PBBs, but each product is a mixture of different brominated diphenyl ethers (WHO 1994).

Hexa-PBBs were widely used in the USA in 1970s, but the use of all PBBs in the USA ceased in the late 1970s (WHO 1994).

Decabromobiphenyl (DeBB) was in 1998 the only brominated biphenyl in commercial use (Lassen et al. 1999). DeBB has traditionally been used as additive flame retardant for styrenic polymers and engineering plastics.

Of most international concern has been hexabromobiphenyl (the pure substance, which makes up the main part of the commercial hexa-PBBs), which is covered by the CLRTAP POPs protocol. No use of hexabromobiphenyl has been identified.

HBCD

HBCD has traditionally been used as additive flame retardant for textiles coatings and production of flame retarded expanded polystyrene used for insulation in the building industry.

TBBPA

Tetrabromobisphenol A is mainly used as reactive flame retardant. In countries where the PBDEs have been phased out (e.g. Denmark) additively used TBBPA has to some extent been used as substitute for the PBDEs. Besides the Tetrabromobisphenol A, a number of derivates of the substance is used as flame retardants.

8.2 Sources and releases

Global consumption

The market volume of the major BFRs by region in 2001 is shown in Table 8-1. The total demand for PBDEs was 67,000 tonnes, of which deca-BDE accounted for 56,000 tonnes. Asia represents the largest market, particularly for TBBPA, reflecting the significance of the production of electronic products in the Asian countries.

Table 8-1 Market volume of the major BFRs by region in 2001 in tonnes (BSEF 2005)

	Americas	Europe	Asia	Rest of the world	Total
TBBPA	18,000	11,600	89,400	600	119,700
HBCD	2,800	9,500	3,900	500	16,700
Deca-BDE	24,500	7,600	23,000	1,050	56,100
Octa-BDE	1,500	610	1,500	180	3,790
Penta-BDE	7,100	150	150	100	7,500
TOTAL	53,900	29,460	117,950	2,430	203,790

It has not been possible to identify any detailed survey of the global market for the remaining brominated flame retardants.

The total BFR market in Western Europe in 1998 is shown in Table 8-2. The volumes of TBBPA, PBDEs and HBCD are at the same level as the 2001 volumes shown in Table 8-1, but these BFRs represent only about 46% of the total volume, the remaining part taken up by a large number of other flame retardants. This may also be the fact for other parts of the world. The table clearly demonstrates the variety of substances used.

The PBBs (in the form of decabromobiphenyl) were in 1999 used in Western Europe in volumes of 600 t/years. The production of PBBs ceased in 2001, and PBBs are today according to BSEF (2005) not used in any part of the world.

Table 8-2 Western European market for brominated flame retardants, 1998 (IAL Consultants as quoted in Lassen et al. 1999)

Flame retardant	Market volume tonnes	%
Reactive *1		
TBBPA	13,150	21
TBBPA polycarbonate oligomer	2,150	3
TBBPA bis(2,3-dibromopropyl ether)	1,500	2
Brominated polyols *2	8,400	13
Brominated epoxy oligomers *3	1,250	2
Dibromoneopentyl glycol	1,150	2
Other reactive	250	0.4
Subtotal, reactive	**28,800**	**45**
Additive		
PBDEs	7,050	11
PBBs	600	1
HBCD	8,950	14
Ethylene bis(tetrabromophtalimide)	5,250	8
Polybrominated polystyrenes *4	4,175	7
Polydibromophenylene oxide	3,250	5
Saytex 8010 proprietary product	2,500	4
Polybrominated imides *5	850	1
Brominated phenyl indane	750	1
Poly(pentabromobenzyl) acrylate	500	0.8
Other additive	775	1
Subtotal, additive	**34,700**	**55**
Total	**62,500**	**100**

Notes: (as indicated in Lassen et al. 1999)

*1 Some of these flame retardants may actually be used as additives. The TBBPA derivatives are cf. OECD 1994 used as additives (see table 3.1).

*2 Includes TBPA diester/ether diol and brominated polyetherpolyol in appendix 3.

*3 Presumably identical to TBBPA epoxy oligomer in table 3.1 and appendix 3.

*4 Include polydibromostyrene and brominated polystyrene in table 3.1 and appendix 3.

*5 The market analysis says by mistake amides.

Applications of the BFRs

The main application areas of BFRs are electric and electronic products, building materials (insulation sheets) and textiles. The use of BFRs by end-use area in Denmark in 1997 is shown in Table 8-3. The use of the substances in electric and electronic products most probably reflects the application pattern in most countries, as the electric and electronic products are traded on a global market. Contrary to this, the use of BFRs for building materials (expanded polystyrene) and textiles may vary considerably among countries dependent on tradition and national regulation. Imported products accounted for about 90% of the BFRs in products sold in Denmark reflecting the extensive import and export of BFR-containing products.

Table 8-3 Consumption of brominated flame retardants with end products in Denmark 1997(based on Lassen et al. 1999)

	Annual consumption		Consumption (tonnes)				
	Tonnes	%	PBDEs	TBBPA	PBBs	HBCD	Other
Printed circuit boards	100-180	29	0.3-5.2	100-180			0-2
Housing of EE appliances and machines	80-130	21	3-10	56-89			25-49
Other parts of EE appliances and machines	20-50	7	5-14	3-8	0-2		16-43
Lighting	4-14	2	1-7	4-11			1-9
Wiring and power distribution	30-80	11	7-29	4-15	1-5	2-4	20-49
Textiles, carpets and furniture	2-11	1.3	0-5			2-9	0-5
Building materials	50-100	15	1-5	0-2		13-36	41-66
Paint and fillers	0.6-1.7	0.2	0.1-0.5				0.5-1.2
Transportation	30-90	12	13-46	14-52		9.4-30	19-71
Other uses	0-3	0.3	0-2	0-2		0-1	0-2
Total (round)	320-660	99	30-120	180-360	1-7	26-80	120-300

Releases of BFRs to the environment

The sources of releases to the environment are dependent on the actual applications of each flame retardant. The total releases have until now only been estimated with high uncertainty, and no overview of the releases by substance is available from any country.

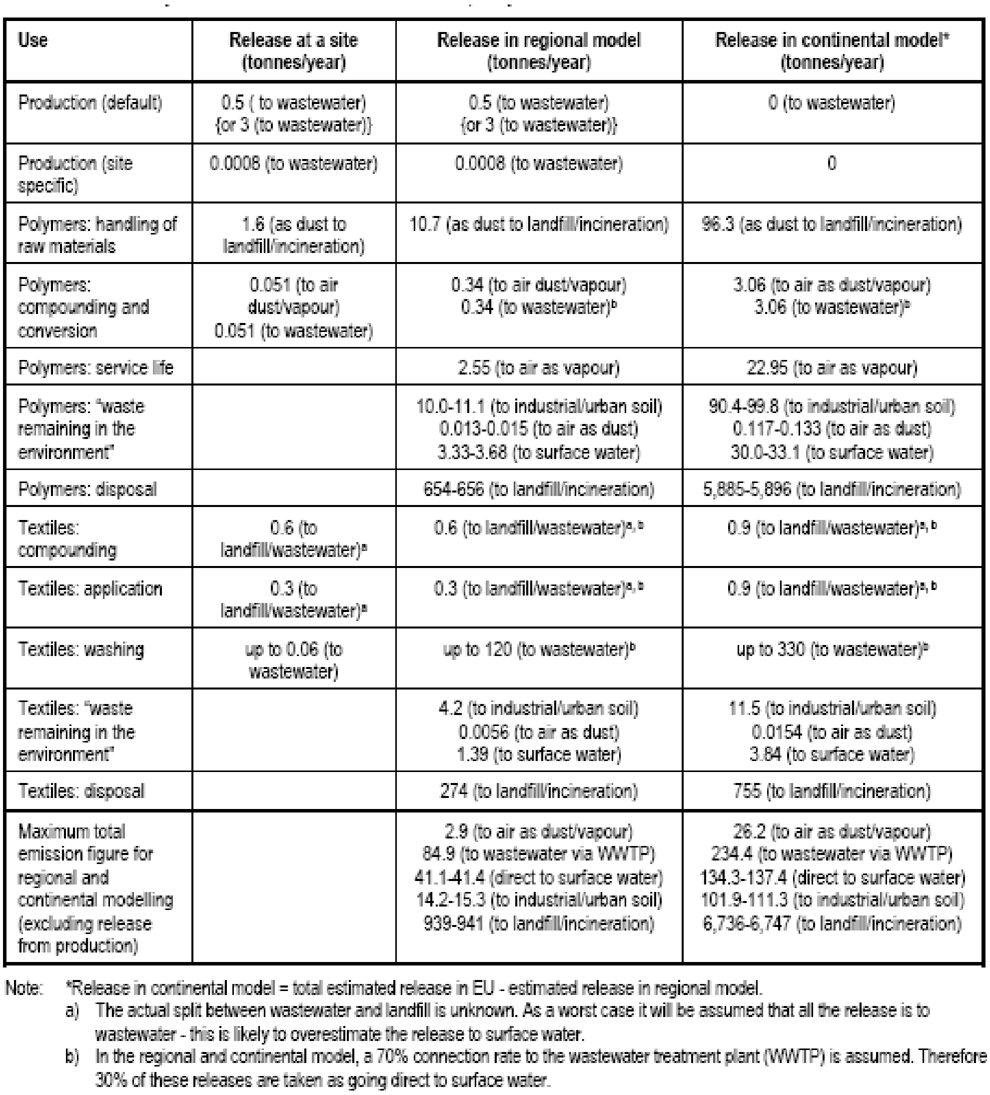
As an example of the releases of the PBDEs, the estimated worst-case releases to the environment and wastes of the EU Risk Assessment of deca-BDE are shown in Table 8-5.

The main source of releases to air is releases from products in use, and the levels of the emission are of same size as the worst-case scenario used in the Danish substance flow analysis.

Textile washing is by far the main source of deca-BDE releases to wastewater. The releases will be highly dependent on whether the substance is used for textile application, and the releases by this pathway are estimated to be significantly lower in e.g. Denmark because BFRs are replaced by other flame retardants in most textiles used in Denmark (Lassen et al. 1999).

The main sources of releases to soil and surface water are flame retarded textiles and plastics remaining as waste in the environment. The releases by this pathway are in the Risk Assessment higher than the releases to air. These releases are highly dependent on the actual efficiency of the waste management systems and the public behaviour.

Table 8-4 Estimated worst-case releases of deca-BDE to waste and the environment (ECB 2002)



Use	Release at a site (tonnes/year)	Release in regional model (tonnes/year)	Release in continental model* (tonnes/year)
Production (default)	0.5 (to wastewater) {or 3 (to wastewater)}	0.5 (to wastewater) {or 3 (to wastewater)}	0 (to wastewater)
Production (site specific)	0.0008 (to wastewater)	0.0008 (to wastewater)	0
Polymers: handling of raw materials	1.6 (as dust to landfill/incineration)	10.7 (as dust to landfill/incineration)	96.3 (as dust to landfill/incineration)
Polymers: compounding and conversion	0.051 (to air dust/vapour) 0.051 (to wastewater)	0.34 (to air dust/vapour) 0.34 (to wastewater)^{b}	3.06 (to air as dust/vapour) 3.06 (to wastewater)^{b}
Polymers: service life		2.55 (to air as vapour)	22.95 (to air as vapour)
Polymers: "waste remaining in the environment"		10.0-11.1 (to industrial/urban soil) 0.013-0.015 (to air as dust) 3.33-3.68 (to surface water)	90.4-99.8 (to industrial/urban soil) 0.117-0.133 (to air as dust) 30.0-33.1 (to surface water)
Polymers: disposal		654-656 (to landfill/incineration)	5,885-5,896 (to landfill/incineration)
Textiles: compounding	0.6 (to landfill/wastewater)^{a}	0.6 (to landfill/wastewater)$^{a, b}$	0.9 (to landfill/wastewater)$^{a, b}$
Textiles: application	0.3 (to landfill/wastewater)^{a}	0.3 (to landfill/wastewater)$^{a, b}$	0.9 (to landfill/wastewater)$^{a, b}$
Textiles: washing	up to 0.06 (to wastewater)	up to 120 (to wastewater)^{b}	up to 330 (to wastewater)^{b}
Textiles: "waste remaining in the environment"		4.2 (to industrial/urban soil) 0.0056 (to air as dust) 1.39 (to surface water)	11.5 (to industrial/urban soil) 0.0154 (to air as dust) 3.84 (to surface water)
Textiles: disposal		274 (to landfill/incineration)	755 (to landfill/incineration)
Maximum total emission figure for regional and continental modelling (excluding release from production)		2.9 (to air as dust/vapour) 84.9 (to wastewater via WWTP) 41.1-41.4 (direct to surface water) 14.2-15.3 (to industrial/urban soil) 939-941 (to landfill/incineration)	26.2 (to air as dust/vapour) 234.4 (to wastewater via WWTP) 134.3-137.4 (direct to surface water) 101.9-111.3 (to industrial/urban soil) 6,736-6,747 (to landfill/incineration)

Note: *Release in continental model = total estimated release in EU - estimated release in regional model.

a) The actual split between wastewater and landfill is unknown. As a worst case it will be assumed that all the release is to wastewater - this is likely to overestimate the release to surface water.

b) In the regional and continental model, a 70% connection rate to the wastewater treatment plant (WWTP) is assumed. Therefore 30% of these releases are taken as going direct to surface water.

In a recent Japanese study the releases to the atmosphere from Japan are estimated by the use of the emission factors of i.a. the European Risk Assessment and the Danish substance flow analysis. The estimated emission is compared to emission estimated on the basis of actually observed air concentrations and a dissipation model. The authors conclude that the worst-case emission of the EU Risk Assessment is probably overestimated by a factor of 4 to 25 (Hirail and Sakail 2004).

Russia

It has not been possible to identify any information on the use and releases of BFRs in Russia. A survey of the use of BFRs in the Arctic countries including Russia has recently been approved by the Arctic Council. The ACAP project with Norway as the lead country will identify and develop safe waste-handling and recycling practices for BFR-containing products, identify alternative flame retardant chemicals and technologies and promote safe alternatives.

China

It has not been possible to identify any information on the use and releases of BFRs in China.

According to Bromine Science and Environment Forum (BSEF 2005) ICL Industrial Products (Dead Sea Bromine Group) has production of BFRs in China. A number of Chinese manufacturers advertise different BFRs on the Internet.

Ukraine

It has not been possible to identify any information on the use and releases of BFRs in Ukraine.

8.3 Main reduction measures

The main measure for reduction of the releases of BFRs is to reduce the use of the BFRs.

The substitution of BFRs can take place at three levels:

- The BFR can be replaced by another flame retardant without changing the base-polymer;
- The plastic material, i.e. the base polymer with flame retardants and other additives, can be replaced by another plastic material;
- The product can be replaced by a different product or the function of the product can be fulfilled by use of a totally different solution.

For specific BFRs of concern (e.g. PBBs or PBDEs) in practice the BFRs have often been replaced by other BFRs with less problematic environmental characteristics or with less described environmental characteristics. As an example PBDEs have for some purposes been replaced by additively used TBBPA. Many of the large companies in the electronics industry have phased out the use of PBDEs and PBBs as part of their corporate environmental strategy.

The PBBs and PBDEs can for all applications be replaced by other BFRs, but for some applications as indicated in Table 8-5alternatives to BFRs are not available. The information shown in Table 8-5 is about 6 years old, but it is deemed that the information on alternatives still applies.

The availability of halogen-free flame retardants for the major application areas has been reviewed in Lassen et al. 1999 (Table 8-5).

For several of the alternatives, however, only few data are available on the potential environmental and health effects, and some of the alternatives are themselves of environmental concern (Stuer-Lauridsen et al. 2000).

Table 8-5 Halogen-free flame retardants in commercial materials (Lassen et al. 1999)

Material	Application	Halogen-free flame retardant in commercial materials *1	Alternative material. Non-flammable or containing halogen-free FR. *2
Epoxy	Printed circuit boards. Electronic component encapsulation. Technical laminates	Reactive nitrogen and phosphorus constituents Ammonium polyphosphate and aluminium trihydroxide	Polyphenylene sulphide
Phenolic resins	Printed circuit boards. Technical laminates	Nitrogen and phosphorus compounds Aluminium trihydroxide	
Unsaturated polyester	Technical laminates. Plastic parts of means of transport	Ammonium polyphosphate and aluminium trihydroxide	
ABS	Housing of electronic products	No alternative	PC/ABS blends or PPE/PS blends with organic phosphorus compounds
HIPS	Housing of electronic products. Wiring parts	Organic phosphorus compounds	Polyethylene with magnesium hydroxide
PBT/PET	Switches. Sockets. Parts of electric machines	No alternatives Alternatives at experimental stage	Some applications: polyamide, polyketone, ceramics or selfextinguishing plastics
Polyamide	Parts of electric and electronic equipment	Magnesium hydroxide Red phosphorus Melamine cyanurate Melamine polyphosphate	
Polycarbonate	Parts of electric and electronic equipment	Organic phosphorus compounds	
Polypropylene	Roofing foils	Ammonium polyphosphate	
Expanded polystyrene	Insulation of foundation, ground deck, parking deck, etc.	No alternatives	No requirements on flame retardancy in Denmark
Rigid polyurethane foam	Insulation of cold-storage plants, freezing rooms, etc.	Ammonium polyphosphate and red phosphorus	Some applications: mineral wool or other technical solutions
Soft polyurethane foam	Furniture. Means of transport	Ammonium polyphosphate Melamine Reactive phosphorus polyols	
Cotton textiles	Furniture. Means of transport	Ammonium polyphosphate Diammonium phosphate	
Synthetic textiles	Furniture. Means of transport. Protective clothing	Reactive phosphorus constituents	

Notes (as indicated in Lassen et al. 1999)

*1 The list of halogen-free flame retardants is not complete, but indicates flame retardants in known commercial products cf. chapter 9. For some specific applications the flame retardants may not be immediately useful.

*2 Alternative materials are only mentioned where no flame retardants grades of the material are commercially available, or where alternative materials actually are chosen in order to substitute BFRs.

8.4 International regulation and agreements

Table 8-6 presents a summarised overview of the coverage in relevant agreements of the brominated flame retardants.

The CLRTAP - POPs protocol includes hexabromobiphenyl (one of the PBBs) for elimination. Hexabromobiphenyl is today most probably not produced in any country.

The Parties to the Stockholm Convention agreed at their meeting May 2005 that hexabromobiphenyl and penta-BDE should be considered for possible inclusion on the Convention's list of substances for elimination.

Penta-BDE is nearly 100% used as additive flame retardant in flexible polyurethane foam used for mattresses, car seats and other products. The penta-BDE was in 2001 primarily used in the Americas, whereas it was widely replaced by other flame retardants on the other markets (see Table 8-1).

PBCDs, PBBs and HBCD are included in the OSPAR List of Chemicals for Priority Action, but release reduction of BFRs is not specifically addressed in the Convention text or any recommendation.

Hexabromobiphenyl is included in the HELCOM list of substances for immediate priority action, and substitution of BFRs in the leather industry is addressed by one recommendation.

EU RoHS Directive

It is beyond the present study to review EU instruments addressing the substances. However, the EU ROHS Directive may significantly influence the use of the PBDEs and PBBs also in other parts of the world.

The Directive stipulates that Member States shall ensure that electrical and electronic equipment put on the market after 1 July 2006 does not contain PBDEs and PBBs (among other substances). The Commission has in recent years evaluated whether deca-BDE should be exempted from the Directive. On a Commission-proposed vote on 19 April 2005, a majority of the EU Member States voted in favour of exempting Deca-BDE from the Directive. The required qualified majority of 72.3% for immediate adoption was however not reached, so the proposal has now been sent to the EU Council of Ministers. They have a maximum of three months to come up with a decision.

EU has adopted a general restriction on the marketing and use of penta-BDE and octa-BDE in all products from 15 August 2004.

Table 8-6 Summarised overview of the coverage of brominated flame retardants in relevant agreements

Source category	CLRTAP-POP	Stockholm Convention	Helsinki Convention and recommendations	OSPAR Convention and recommendations
Production and use of hexabromobiphenyl	Elimination	Considered for possible inclusion		
Penta-BDE		Considered for possible inclusion		
Leather processing industry			Substitution of BFRs	

8.5 Overview of existing activities

Only one project specifically addressing the use and releases of brominated flame retardants has been identified (Table 8-7).

Table 8-7 Identified initiatives in the Russian Federation, Ukraine and China addressing brominated flame retardants

Donor/finance institution	Projects/comments	Planned period Budget
ACAP (Arctic, Russia)	**Reduction or elimination of sources of releases of brominated flame retardants.** The project is planned to be implemented in three phases: Phase I (2005-2006). Inventory of sources and identification of alternatives and management strategies in all eight countries including Russia. Include collection, compilation and quantification of information from the Arctic countries on production of BFRs, production of products with BFRs, waste management practices and releases of BFR. Identify alternatives, management practices and strategies and develop Fact Sheet and report on BFRs. For the reporting to ACAP, Russia is assisted in undertaking a survey of BFR use in Russia. Phase II (2007-2008): Actions to reduce or eliminate priority sources and releases. Review management practices, evaluate alternatives, evaluate need for inclusion of new hazardous BFRs, develop proposals for actions, cooperative activities and/or pilot projects. Phase III (2009-2010): Pilot projects	2005-2010 Phase 1 budget: 0.125 mUSD

9 References

ACAP. 2000. ***PCB in the Russian Federation: Inventory and proposals for priority remedial actions. Executive summary.*** Multilateral Co-operative Project on Phase-outPhaseoutPhase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation. Published by: Arctic Monitoring and Assessment Programme (AMAP); Ministry of Industry, Science and Technologies of the Russian Federation; Ministry of Natural Resources of the Russian Federation; Center for International Projects (CIP), Moscow.
http://amap.no/documents/index.cfm?action=getfile&dirsub=/ACAP PCB Project&FileName=pcb-es.pdf

ACAP. 2003. ***Environmentally sound management and elimination of PCBs in Russia. Executive summary.*** Multilateral Co-operative Project on Phase-outPhaseoutPhase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation. Published by: Arctic Monitoring and Assessment Programme (AMAP); Ministry of Industry, Science and Technologies of the Russian Federation; Ministry of Natural Resources of the Russian Federation; Center for International Projects (CIP), Moscow.
Supporting documentation:
Report of Activity 1: Assessment of regulations and requirements for handling PCB and PCB-containing materials in the Russian Federation. Report of Activity 2: Design of PCB collection and storage schemes
Report of Activity 3: Preparation of input to a "least cost" overall Russian PCB phase-outphaseoutphase-out strategy
Report of Activity 4: Selection of alternatives for replacement of PCB, with acceptable environmental characteristics and feasible production.
Report of Activity 5: Construction/retrofit of a prototype facility for production of alternative fluids.
Report of Activity 6: Construction/retrofit of a prototype facility for use of non-PCB alternative compounds in a major PCB use sector
Report of Activity 7: Selection/development of environmental sound technologies for destruction of PCB/containing liquids.
Report of Activity 8: Selection/development of environmentally sound technologies for destruction/ decontamination of PCB contaminated containers, equipment and their sub-components.
Report of Activity 9: Study of PCB-contaminated site and evaluation of rehabilitation methodology.
http://amap.no/documents/index.cfm?action=getfile&dirsub=/ACAP PCB Project&FileName=ExSum-Phase2.pdf

ACAP. 2005a. ***Assessment of mercury releases from the Russian Federation***. Russian Federal Service for Environmental, Technological and Atomic Supervision and Danish Environment Protection Agency for Arctic Council. Lassen et al. for Danish EPA, December 2004. Available at http://www.mst.dk/udgiv/Publications/2005/87-7614-539-5/pdf/87-7614-540-9.PDF

AMAP 2002. ***Arctic Pollution 2002.*** Arctic Monitoring and Assessment Programme, Oslo.

AMAP/ACAP. 2003. ***Brominated flame retardants briefing note for SAOs*** Prepared by AMAP/ACAP, 23 March 2003. http://www.arctic-council.org/files/infopage/89/ACAPappendix2.pdf

ATSDR. 2004. ***Toxicological profile for polybrominated biphenyls and polybrominated diphenyl ethers.*** US Agency for Toxic Substances and Disease Registry, Atlanta. http://www.atsdr.cdc.gov/toxprofiles/tp68.pdf

Bailey, R.E. 2001. ***Global hexachlorobenzene emissions***. Chemosphere: 43:167-82.

BASEL. 2005. ***Draft technical guidelines on HCB***. Basel Secretariat, Geneva, February 2005. http://www.basel.int/techmatters/hcb/guidelines/techguid020205.doc

Berdowski, J.J.M., Baas, J., Bloos, J.P.J., Visschedijk, A.J.H., and Zandveld, P.Y.J. 1997. ***The European emission inventory of heavy metals and persistent organic pollutants for 1990***. , Rep. UBA-FB, TNO Inst. of Environ. Sci., Apeldoom, The Netherlands.

BReg. 2004. BReg - Bundesregierung (2004): ***Berichterstattung der Bundesrepublik Deutschland gemäß Artikel 5, 7 und 8 des Kyoto-Protokolls der UN-Klimarahmenkonvention zu fluorierten Treibhausgasen an das Sekretariat der Klimarahmenkonvention im Jahr 2004***. (http://unfccc.int/program/mis/ghg/submis2003.html 8.1.2004). As quoted by UBA (2004).

Brigden, K and D. Santillo. 2004. ***Environmental heavy metal contamination arising from the Xianjin and GP NiCd battery manufacturing facilities Huizhou, Guangdong, China, 2004***. Greenpeace Research Laboratories, Technical Note 08/2004. http://www.greenpeace.to/publications_pdf/NiCd_China_2004.pdf

BSEF. 2005. ***Major brominated flame retardants volume estimates***. Bromine Science and Environmental Forum, Brussels. http://www.bsef-site.com/bromine/what_are_bfrs/

China Daily. 2004. ***Gov't Brewing Law to Recycle Old Electronics.*** China Daily October 14, 2004. http://service.china.org.cn/link/wcm/Show_Text?info_id=109389&p_qry=lead%20and%20recycling

China.org. 1999. ***Huge Potential of Lead-Recycling Industry*** *http://www.china.org.cn/Beijing-Review/Beijing/BeijingReview/99Jun/bjr99-24e-12.html*

COWI. 2002. ***Status on POPs in the Russian Federation***. COWI for DANCEE, January 2002, unpublished.

DANCEE. 2004. ***Detailed Review of Selected Non-Incineration and Incineration POPs Elimination Technologies for the CEE Region.*** Danish EPA, Copenhagen. http://www.mst.dk/udgiv/publications/2005/87-7614-543-3/pdf/87-7614-544-1.pdf

ACAP, Danish EPA and Rostechnadzor. 2005c. ***Preliminary Priority Setting on Mercury Release Reductions*** (for the Russian Federation). Draft in progress. May 2005.

ACAP, 2005d: ***Background document on mercury in existing agreements.*** Drafted by Maag J., COWI, for the Danish EPA, on behalf of ACAP. Draft in progress. May 2005.

Drivsholm, T., E. Hansen, J. Maag and S. Havelund. 2000. ***Massestrømsanalyse for cadmium*** [Substance flow analysis for cadmium]. Environmental Project No. 557. The Danish EPA, Copenhagen. (In Danish)

ECB. 2002. ***European Union Risk Assessment Report: Bis(pentabromophenyl)ether***. European Chemicals Bureau, European Communities, 2002.
http://ecb.jrc.it/php-bin/reframer.php?A=ECB&B=/DOCUMENTS/Existing-Chemicals/RISK_ASSESSMENT/

EEA, European Environment Agency. 2004. ***Annual European Community greenhouse gas inventory 1990-2002 and inventory report 2004***. Copenhagen. For the European Comission.

EMEP. 2005. ***Detailed information for Ukraine for 2004***. Co-operative Programme for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe (EMEP).
http://www.msceast.org/countries/Ukraine/

Environment Canada. 2005. ***The four new groupings of ATH substances - Substance-specific context hexachlorobenzene (HCB)***.
(http://www.ec.gc.ca/pdb/npri/npri_hcb_e.cfm)

Eurometaux. 1997. ***Comments to the Danish EPA's draft to Statutory order regarding lead***. Eurometaux, European Association of Metals, Intersectorial Lead Group, Bruxelles.

Expert Group. 2005. ***Guidelines on Best Available Techniques (BAT) and Guidance on Best Environmental Practice (BEP) relevant to the provisions of Article 5 and Annex C of the Stockholm Convention***. Advance Draft, December 2004. Prepared by Expert Group on Best Available Techniques and Best Environmental Practices established by the sixth session of the Intergovernmental Negotiating Committee for an International Legally Binding Instrument for Implementing International Action on Certain

Persistent Organic Pollutants, http://www.baselpretoria.org.za/Documents/Draft-BAT-BEP.pdf

Feng, J. 2003. ***Industrial profile: Lead sector promises huge market potential.*** TDC trade.com. http://www.tdctrade.com/report/indprof/indprof_031104.htm

Gaolai, L. 2004. ***Preliminary plan for POPs program in China.*** Presentations at the seminar described in Yonglong, 2004.

GLBTS. 2000. ***Draft report for hexachlorobenzene (HCB): Reduction options.*** Great Lakes Binational Toxics Strategy. U.S. EPA Great Lakes National Program Office. http://www.epa.gov/glnpo/bns/baphcb/HCB_Rdcn.html

Hansen, E. and C. Lassen. 2003a. ***Lead review***. Nordic Council of Ministers, Copenhagen.

Hansen, E. and C. Lassen. 2003b. ***Cadmium review***. Nordic Council of Ministers, Copenhagen.

Hansen, E., C. Lassen, F. Stuer-Lauridsen and J.Kjølholt. 2002. ***Heavy metals in waste.*** European Commission DG ENV. E3 http://europa.eu.int/comm/environment/waste/studies/heavy_metalsreport.pdf

Hansen, J.H. 1995. ***Nationale og industrielle emissioner af 38 stoffer***. Arbejdsrapport fra Miljøstyrelsen 65/1995. Danish EPA, Copenhagen.

Hirai1, Y. and S. Sakai1. 2004. ***Atmospheric emission of BDE-209 in Japan***. Organohalogen Compounds 66: 3761-3766. http://dioxin2004.abstract-management.de/pdf/p329.pdf

IAL Consultants. 1999. ***The European flame retardant chemical industry 1998.*** IAL Consultants, London.

ILZSG. 2002. International Lead and Zinc Study Group, London. http://www.ilzsg.org/ilzsgframe.htm

IPCC. 1996. ***Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories***. Intergovernmental Panel on Climate Change.

IPCC. 2000. ***Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories***. Intergovernmental Panel on Climate Change.

IPCS. 1997. ***Flame retardants: A general introduction.*** Environmental Health Criteria 192. WHO, Geneva. http://www.inchem.org/documents/ehc/ehc/ehc192.htm

Irish EPA. 2003. ***CLIMATE CHANGE - Emissions of Industrial Greenhouse Gases (HFCs, PFCs and Sulphur Hexafluoride)***. University of Bristol and Clean Technology Centre, Cork Institute of Technology, for the Irish Environment Protection Agency. Westford, Ireland, 2003.

Jones, K. 2005. ***Hexachlorobenzene - Sources, environmental fate and risk characterisation.*** Eurochlor, Brussels. http://www.eurochlor.org/chlorine/science/HCB-Main-final.pdf

Karlsson, S., F. Fredrikson and J. Holmberg. 2004. ***Future redistribution of cadmium to arable Swedish soils: A substance stock analysis***. Journal of Industrial Ecology 8: 41 - 58.

Lacerda, L.D. 1997. ***Global mercury emissions from gold and silver mining.*** Water, Air and Soil Pollution 97: pp 209-221, 1997, Kluwer Academic Publishers, The Netherlands.

Lassen C., E. Hansen, A.A. Jensen, K. Olendrzynski, W. Kolsut, J. Zurek, I. Kargulewicz, B. Debski, J. Skoskiewicz, M. Holtzer, A. Grochowalski, E. Brante, H. Poltimae, T. Kallaste and J. Kapturauskas. 2003. ***Survey of dioxin sources in the Baltic region***. Extended Summary. ESPR – Environmental Sci-ence & Pollution Research 10: 49 – 56.

Lassen, C., S. Løkke L.I. Andersen. 1999. ***Brominated flame retardants. Substance flow analysis and assessment of alternatives***. Environmental Project. No. 494. The Danish EPA, Copenhagen

LDAI. 2002. Lead Development Association International, London. http://www.ldaint.org/default.htm

Lu, C. 2004. In: ***Regional awareness-raising workshop on mercury pollution - A global problem that needs to be addressed***. Bangkok, Thailand, 26 - 29 April 2004. Proceedings available at http://www.chem.unep.ch/mercury/workshops/Bangkok-proceedings-final.pdf

ACAP 2005b. ***Reduction of atmospheric mercury releases from Arctic States - Arctic Mercury Releases Inventory.*** ACAP project coordinated by the Danish EPA for the Arctic Council. Drafted by Maag J., COWI, for Danish EPA, Copenhagen. http://www.mst.dk/udgiv/Publications/2005/87-7614-515-8/pdf/87-7614-516-6.PDF.

MNR. 2004. ***Yearbook on Pollutant Emissions to the Atmosphere of Cities and Regions of the Russian Federation in 2003***. Ministry of Natural Resources of the Russian Federation, Research Institute for Air Protection, St. Petersburg.

Mörner, J. R. Bos and M. Fredrix. 2002. ***Reducing and eliminating the use of persistent organic pesticides. Guidance on alternative strategies for sustainable pest and vector management***. Inter-Organization Programme for the Sound Management of Chemicals (IOMC), Geneva. http://www.chem.unep.ch/pops/pdf/redelipops/redelipops.pdf

Nriagu, J. and J. Pacyna. 1988. ***Quantitative assessment of worldwide contamination of air, water and soils by trace metals***. Nature. 333: 134-139.

OECD. 1993. ***Risk Reduction Monograph No.1***: ***Lead***. OECD/GD (93) 67. OECD Environment Directorate, Paris.

OECD. 1994a. ***Risk Reduction monograph no. 3: Selected brominated flame retardants.*** OECD Environment Monograph Series no. 102, Paris. http://www.olis.oecd.org/olis/1994doc.nsf/ee9c698a0a7c4fdfc12569fa005d3e31/6c72ef374c0c4f6bc12562ed008123da/$FILE/ENE535.ENG

OECD. 1994b. ***Risk Reduction Monograph No. 5: Cadmium***. OECD Environment Monograph Series No. 104. OECD Environment Directorate, Paris

Pacyna J.M. and E.G. Pacyna. 2001. ***An assessment of global and regional emissions of trace metals to the atmosphere from anthropogenic sources worldwide***. Environmental Reviews 9: 269-298.

Pedersen, P.H. 2003. ***Evaluation of the possibilities of substituting potent greenhouse gases (HFCs, PFCs and SF6).*** Environmental Project No. 771 2003, Danish Environmental protection Agency. Copenhagen. Available at www.mst.dk, publications.

Pirrone, N., G.J. Keeler and J.O. Nriagu, JO. 1996. ***Regional differences in world-wide emissions of mercury to the atmosphere.*** Atmospheric Environment Vol. 30, No. 37, pp. 2981-2987, 1996.

Pirrone, N., J. Munthe, L. Barregård, H.C. Ehrlich, G. Petersen, R. Fernandez, J.C. Hansen, P. Grandjean, M. Horvat, E. Steinnes, R. Ahrens, J.M. Pacyna, A. Borowiak, P. Boffetta and M. Wichmann-Fiebig. 2001. ***EU Ambient Air Pollution by Mercury (Hg) - Position Pape***r. Office for Official Publications of the European Communities, 2001. Submitted by Italy. http://europa.eu.int/comm/environment/air/background.htm#mercury

Plachy, J. 2003. **Cadmium**. Minerals Yearbook. US. Geological Survey. http://minerals.usgs.gov/minerals/pubs/commodity/cadmium/cadmimyb03.pdf

Poulsen, T.S. 2004. ***Ozone depleting substances and the greenhouse gases HFCs, PFCs and*** SF_6 ***- Danish consumption and emissions 2002***. Environmental Project No. 890 2004, Danish Environment protection Agency, Copenhagen. Available at www.mst.dk, publications.

SCEP. 1997. ***White paper: Lead contamination of the environment in the Russian Federation and its effect on human health.*** State Russian Committee for Environmental Protection of the Russian Federation, Moscow. (In Russian) English summary available at: http://www.refia.ru/html/18-e/

Scoullos, M., G. Vonkeman,I. Thornton & Z. Makuch. 2001. ***Mercury, cadmium, lead: Handbook for sustainable heavy metals policy and regulation***. Kluwer Academic Publishers, Dordrecht

SEPA. 2005. ***EIA for PCB Sites Cleanup in the Zhejiang.China***. GEF PCB Disposal and Management Demonstration Project (P082993) Province, China (see WB 2005)

Simonsen, F.A., L.M. Møller, T. Madsen and M. Stavnsbjerg. 2000. ***Brominated flame retardants: Toxicity and ecotoxicity.*** Environmental Project No. 568. Danish EPA, Copenhagen. http://www.mst.dk/udgiv/Publications/2000/87-7944-288-9/pdf/87-7944-289-7.pdf

Skaarup, J., J. Lauridsen, E. Hansen and A. Elbæk-Jørgensen. 2005. ***Detailed review of selected non-incineration and incineration POPs elimination technologies for the CEE region.*** Danish EPA, Copenhagen. http://www.mst.dk/udgiv/Publications/2005/87-7614-543-3/pdf/87-7614-544-1.pdf

Smith, R.S. 2003. **Lead**. Minerals Yearbook. US. Geological Survey. http://minerals.usgs.gov/minerals/pubs/commodity/lead/lead_myb03.pdf

Stuer-Lauridsen, F., S. Havelund and M. Birkved. 2000. ***Alternatives to brominated flame retardants. Screening for environmental and health data***. Working Report 17/2000. Danish EPA, Copenhagen.

Sukhorebra, S.A. 2004. ***PCBs inventory in Ukraine: provisional results and conclusions.*** Consultation Meeting on PCB Management and Disposal under the Stockholm Convention on POPs. Geneva, 9–10 June 2004

Third National Communication of the Russian Federation (2002). (Submitted in accordance with articles 4 and 12 of the United Nations framework convention on Climate Change). Available from:
http://unfccc.int/resource/docs/natc/rusnce3.pdf
http://unfccc.int/resource/docs/natc/rusncr3.pdf and
http://www.climatechange.ru/climchang/nat_comm.htm

UBA. 2004. ***Fluorinated greenhouse gases in products and processes - Technical climate protection measures***. Umweltbundesamt (German Federal Environment Protection Agency), Berlin.

UN ECE. 2003. ***Progress report on the implementation of the Pan-European Strategy to Phase out Added Lead in Petrol***. (Executive summary). UNECE Committee on Environmental Policy. http://www.unece.org/env/documents/2003/cep/cep.2003.15.e.pdf

UNEP 2000. ***Finding alternatives to persistent organic pollutants (POPs) for termite management.*** Prepared by members of the UNEP/FAO/Global IPM Facility Expert Group on Termite Biology and Management. http://www.chem.unep.ch/pops/termites/termite_fulldocument.pdf

UNEP Ozone Secretariat. 2005. ***Status of ratification of Vienna Convention and the Montreal Protocol and amendments***. Accessed May 2005 at http://www.unep.org/ozone/Treaties_and_Ratification/index.asp

UNEP, RTOC. 2002. ***2002 Report of the Refrigeration, Air Condition and Heat Pumps Technical Options Committee.*** UNEP Ozone Secretariat, accessed 2005 at http://www.unep.org/ozone/teap/reports/RTOC/RTOC2002.pdf

UNEP, TEAP. 2002. ***2002 Report of the Technology and Economy Assessment Panel.*** UNEP Ozone Secretariat, accessed 2005 at http://www.unep.org/ozone/teap/Reports/TEAP_Reports/TEAP2002.pdf

UNEP. 1999. ***Dioxin and furan inventories***. National and Regional Emissions of PCDD/PCDFs. UNEP Chemicals, Geneva. http://www.chem.unep.ch/pops/pdf/dioxinfuran/difurpt.pdf

UNEP. 2001. ***Standardized toolkit for identification of dioxin and furan releases.*** UNEP Chemicals, Geneva.

UNEP. 2002. ***Global Mercury Assessment.*** United Nation Environment Programme, Geneva. http://www.chem.unep.ch/mercury/Report/Final%20Assessment%20report.htm

UNEP. 2003. ***UNEP Governing Council decisions from its meeting in 2003***. United Nation Environment Programme, Geneva. http://www.chem.unep.ch/mercury/mandate-2003.htm

UNEP. 2004. ***Lead matrix. Central and Eastern Europe, and Asia-Pacific.*** Dec. 2004. UNEP Partnership for Clean Fuel and Vehicles. http://www.unep.org/PCFV/documents/MatrixCEELead.pdf; http://www.unep.org/pcfv/Documents/LeadMatrix-Asia-Pacific.pdf

UNEP. 2005. ***UNEP Governing Council decisions from its meeting in 2005***. United Nation Environment Programme, Geneva. http://www.chem.unep.ch/mercury/GC23-results.htm

UNFCCC. 2005. http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/2761.php). May 2005.

UNIDO/GEF. 2003. Project Brief to the project "***Building the Capacity of the People's Republic of China to implement the Stockholm Convention on POPs and develop a National Implementation Plan***." Appendix 1: Primary assessment report on pesticidal POPs in China. http://www.gefonline.org/ProjectDocs/POPs/ENABLING%20ACTIVITIES%20Folder%20-%20POPs/CHINA/Full%20Project/Revised%20document%20April%20-1-03/4-1-03%20Appendix1-15-%20final%20revision.pdf

US EPA. 2000. ***Draft PBT National Action Plan For Hexachlorobenzene (HCB) for Public Review.*** Prepared by The USEPA Persistent, Bioaccumulative and Toxic Pollutants (PBT) HCB Workgroup December 8, 2000 http://www.epa.gov/pbt/hcbactionplan.pdf

US EPA. 2004. ***INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990 – 2002.*** United States Environment Protection Agency. Washington DC. Available at http://www.epa.gov/globalwarming/publications/emissions

WB. 2005. ***China -PCB management and disposal. Project Information Document, Concept stage.*** February 2-4, 2005 http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2005/02/18/000112742_20050218164328/Rendered/PDF/E10960v10rev0Zhejiang0EIA0217105.pdf

WHO. 1994. ***Polybrominated biphenyls***. Environmental Health Criteria 152. WHO, Geneva. http://www.inchem.org/documents/ehc/ehc/ehc152.htm

Xinbin, F. 2005. ***Mercury pollution in China - an overview***. In: Dynamics of Mercury Pollution on Regional and Global Scales: Atmospheric Processes, Human Exposure Around the World, N. Pirrone and K. Mahaffey (Editors), Springer Publisher, Norwell, MA, USA. Chapter-27, pp. 657-678

Yonglong, L. 2004. ***POPs pollution and environmental management in China.*** Presentations at the seminar: "Strengthening Science-Based Decision Making to Reduce Risks from Persistent Organic Pollutants (POPs)", hosted by the State Environmental Protection Administration of China (SEPA), Scope of China, The Chinese Academy of Sciences and the US National Academy of Sciences, Beijing, China, June 7-10, 2004. http://www7.nationalacademies.org/sustainabilityroundtable/Type_II_Workshop_Beijing_China.html

Appendix 1 International agreements in short

A1-1 The Stockholm Convention

The Stockholm Convention requires that all Parties endeavour to develop and implement a plan for meeting their obligations under the Stockholm Convention. The plan is to be transmitted to the Conference of the Parties within two years of the date on which the Convention enters into force. Further, the plan is to be reviewed and updated, as appropriate, on a periodic basis and in a manner to be specified by a decision of the Conference of the Parties.

The Stockholm Convention does not specify what should be the size and coverage of a survey, action plan or any other of the NIP elements. It is fully up to the country to decide how comprehensive and detailed they should be. The only condition is that they should serve as appropriate tools for meeting the obligations of the Stockholm Convention listed below.

PCBs. Concerning intentional uses of PCBs the Stockholm Convention requires that all Parties must:

- cease the production of new PCBs immediately (at the date of entry into force);
- eliminate the use of PCBs in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025;
- make determined efforts to identify, label and remove from use, equipment containing greater than 10% PCBs and volumes greater than 5 litres;
- make determined efforts to identify, label and remove from use, equipment containing greater than 0.05% PCBs and volumes greater than 5 litres;
- endeavour to identify and remove from use equipment containing greater than 0.005% PCBs and volumes greater than 0.05 litres of PCBs;
- prohibit export and import of PCBs and PCB-containing equipment (except for environmentally sound management of wastes);
- not allow recovery of liquids with a PCB content above 0.005% for reuse in other equipment, except for maintenance and servicing operations;
- achieve environmentally sound management of PCB wastes as soon as possible and not later than 2028;
- develop and implement strategies for identifying stockpiles, products and articles in use and wastes containing PCBs;
- manage stockpiles in a safe, efficient and environmentally sound manner until they are deemed to be wastes;

- take measures to handle, collect, transport and store PCB wastes in an environmentally sound manner and dispose of the wastes in a way that destroys the PCB content, or otherwise in an environmentally sound manner taking into account international rules, standards and guidelines;

- not allow recovery, recycling, reclamation, direct reuse or alternative uses of PCBs.

- not transport these materials across international boundaries taking into account international rules (e.g. the Basel Convention);

- develop strategies for identifying contaminated sites and, if remediation is attempted, do it in an environmentally sound manner.

Unintentional releases of PCDD/PCDFs, PCB and HCB. Releases of unintentionally produced by-products listed in Annex C (dioxins, furans, PCBs and HCB) are subject to continuous minimisation with, as objective, the ultimate elimination where feasible. The main tool for this is the National Action Plans, which should cover the source inventories and release estimates as well as plans for release reductions.

The Stockholm Convention requires that all Parties must:

- Promote application of available, feasible and practical measures to achieve realistic and meaningful levels of release reduction or source elimination;

- Promote development and, where appropriate, require use of substitute or modified materials, products and processes to prevent formation and release of Annex C POPs;

- Promote and phase in best available techniques (BAT) as soon as practicable, but no later than 4 years after entry into force for new sources within specified industrial source categories that have potential for comparatively high formation and release of POPs to the environment (Annex C, Part II);

- Promote the use of BAT and BEP (best environmental practice) for existing sources within all categories (Annex C Part II and III) and new sources within categories specified in (Annex C Part III).

Pesticides. The POPs pesticides covered by the Stockholm Convention consist of mainly chlorinated insecticides and include aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex and toxaphene (Annex A, Part I) and DDT (Annex B).

The Stockholm Convention requires that all Parties must:

- prohibit and/or take legal and administrative measures necessary to eliminate production, use, import and export of Annex A POPs pesticides upon entry into force - except as provided for in the Convention and where Parties that have registered specific production and use exemptions as provided for in Annex A;

- monitor the use of Annex A POPs pesticides for non time-limiting purposes such as laboratory-scale research, reference standards, unintentional trace contaminant in products and articles;

- limit the import and export of Annex A POPs pesticides only as allowed according to Article 4 (exemptions registered with the Secretariat) or for purposes of disposing of Annex A POPs pesticides in an environmentally sound manner. Export to non-Parties is further restricted by certification requirements;

- develop and implement strategies to identify stockpiles, products and articles in use and wastes containing Annex A POPs pesticides;

- prohibit the recovery, recycling, reclamation, direct reuse or alternative uses of Annex A POPs pesticides;

- manage stockpiles in a safe, efficient and environmental safe manner until they are deemed to be wastes;

- take measures to handle, collect, transport and store Annex A POPs pesticide wastes in an environmentally safe manner and dispose of such wastes in a way that destroys the POPs content or irreversibly transforms it such that it does not exhibit the characteristics of POPs, or otherwise dispose of it in an environmentally safe manner taking into account international rules, standards and guidelines.

A1-2 CLRTAP HM and POPs protocols

The objective of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) is to protect man and his environment against air pollution and to endeavour to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution. The Convention sets up an institutional framework, bringing together policy and research components. It establishes a number of co-operative programmes for assessing and monitoring the effects of air pollution.

The Convention requires Parties to develop policies and strategies that will serve as a means of combating the discharge of pollutants, by means of exchanges of information, consultation, research and monitoring. Parties are also required to co-operate in the conduct of research into and/or development of technologies for reducing emissions of major air pollutants, instrumentation and other techniques for monitoring and measuring emission rates and ambient concentrations of air pollutants, improved models for understanding the transmission of long-range transboundary air pollutants, the effects of major air pollutants on human health and the environment and education and training programmes related to the environmental aspects of pollution by major air pollutants. Implementation of the Convention has already contributed successfully in reducing sulphur emissions across Europe, and there has also been progress in reducing emissions of nitrogen oxides and volatile organic compounds.

The Convention and its protocols are open to member States of the United Nations Economic Commission for Europe (UNECE), as well as States having consultative status with the UNECE and regional economic integration organizations, constituted by sovereign States Members of the UNECE. The UNECE has 55 member States, mainly from Central and Eastern Europe, but also includes Canada and the United States of America as members.

The Convention entered into force on 16 March 1983 and had 49 Parties as of 1 October 2002. Since its entry into force, it has been extended by eight protocols, of these the 1998 Aarhus Protocol on Heavy Metals and the 1998 Aarhus Protocol on Persistent Organic Pollutants.

The CLRTAP HM-Protocol

The Executive Body of the Convention adopted the Protocol on Heavy Metals on 24 June 1998 in Aarhus, Denmark. It targets three particularly harmful metals: cadmium, lead and mercury, and requires Parties to the Protocol to reduce their releases for these three metals. It aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport) and waste incineration. It lays down stringent limit values for emissions from stationary sources and suggests best available techniques for these sources. The Protocol requires Parties to phase out leaded petrol and introduces measures to lower heavy metal releases from other products. Emission levels must be reported using as a minimum methodologies specified by the Steering Body of EMEP, the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe.

Article 3 describes the following basic obligations set out in the Protocol:

A) Reduction of total annual emissions of the substances into the atmosphere, compared to the reference year for the Party (1990, or an alternative year between 1985 and 1995 set when becoming a Party), through application of best available techniques, product control measures or other emission reduction strategies.

B) Use of best available techniques for stationary sources - for new plants within 2 years, for existing plants within 8 years. The standards for best available techniques are given as examples in Annex III to the Protocol, and include both cleaning technology and substitution of the substances, e.g. substitution of mercury based technology, for example in chlor/alkali plants.

C) Application of limit values to control emissions from major stationary sources, both new and existing – Limit values for a number of sources are specified in Annex V of the Protocol, for example for particulate emissions from combustion plants, mercury emissions from chlor-alkali plants and mercury emissions from municipal, medical and hazardous waste incineration.

D) Application of product control measures concerning mercury – The Protocol requires Parties to achieve specific mercury levels in alkaline manganese batteries within 5 years, or 10 years for Parties with economies in transition. Alkaline manganese button cells and batteries composed of button cells are exempted from this obligation. In addition, Parties should consider applying additional product control measures as described in Annex VII of the Protocol. Recommendations are given for mercury-containing products such as electric equipment, electrical components (thermostats, switches), measuring devices (thermometers, manometers, barometers), fluorescent lamps, dental amalgam, pesticides including seed dressings, paints and batteries other than alkaline manganese batteries, and include prohibition of specific products, voluntary agreements and recycling programmes.

The CLRTAP POPs Protocol

The Executive Body of the Convention adopted the Protocol on Persistent Organic Pollutants on 24 June 1998 in Aarhus, Denmark.

The basic obligations of the Protocol stipulate a wide range of actions ranging from production and use bans and phase-outs, restricted uses and emission controls, and conditions for the disposal of POPs. The 16 substances included in the present Protocol are:

- The pesticides aldrin, chlordecone, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), hexachlorocyclohexane (HCH), mirex, and toxaphene;
- The industrial chemicals hexabromobiphenyl and PCBs;
- Unintended byproducts - PCDD/PCDFs, HCB and PAHs.

PCBs. Concerning intentional uses of PCBs the POPs protocols requires that all Parties must:

- Cease the production of new PCBs immediately (at the date of entry into force); eliminate the use of PCBs in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by Dec 2010;
- Make determined efforts designed to lead to:
    - The elimination of the use of identifiable PCBs in equipment containing PCBs in volumes greater than 5 dm3 and having a concentration of 0.05% PCBs or greater, as soon as possible, but no later than 31 December 2010, or 31 December 2015 countries with economies in transition;
    - The destruction or decontamination in an environmentally sound manner of liquid PCBs referred to in the paragraph above and other liquid PCBs containing more than 0.005% PCBs as soon as possible, but no later than 31 December 2015, or 31 December 2020 for countries with economies in transition;
    - The decontamination or disposal of equipment containing PCBs in volumes greater than 5 dm3 and having a concentration of 0.05% PCBs or greater in an environmentally sound manner.

Unintentional releases of PCDD/PCDFs, PAHs and HCB. Releases of unintentionally produced by-products listed in Annex III of the Protocol

(PCDD/PCDFs, PAHs and HCB) are subject to continuous minimisation with, as objective, the ultimate elimination where feasible.

The POPs Protocol requires that all Parties must:

- Reduce its total annual emissions from the level of the emission in a reference year by taking effective measures appropriate in its particular circumstances;

- Apply BAT to new or existing stationary sources within a major stationary source category for which the annex V to the Protocol identifies best available techniques (different requirements for new and existing sources);

- Apply limit values for PCDD/PCDF emission. A Party may, as an alternative, apply different emission reduction strategies that achieve equivalent overall emission levels (different requirements for new and existing sources);

- Apply effective measures to control emissions from mobile sources.

Aldrin, chlordecone, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene and PCBs.

The POPs Protocol requires that all Parties must:

- Eliminate production and use of the substances ;

- Ensure that, when the substances are destroyed or disposed of, such destruction or disposal is undertaken in an environmentally sound manner;

- To endeavour to ensure that the disposal of the substances is carried out domestically, taking into account pertinent environmental considerations;

- To ensure that the transboundary movement of the substances listed is conducted in an environmentally sound manner, taking into consideration applicable subregional, regional, and global regimes governing the transboundary movement of hazardous wastes;

- Develop appropriate strategies for identifying articles still in use and wastes containing such substances, and shall take appropriate measures to ensure that such wastes and such articles, upon becoming wastes, are destroyed or disposed of in an environmentally sound manner.

DDT and hexachlorocyclohexane

The POPs Protocol requires that all Parties must:

- Restrict the substances to the uses described in annex II of the protocol.

- Develop appropriate strategies for identifying articles still in use and wastes containing such substances, and shall take appropriate measures to ensure that such wastes and such articles, upon becoming wastes, are destroyed or disposed of in an environmentally sound manner.