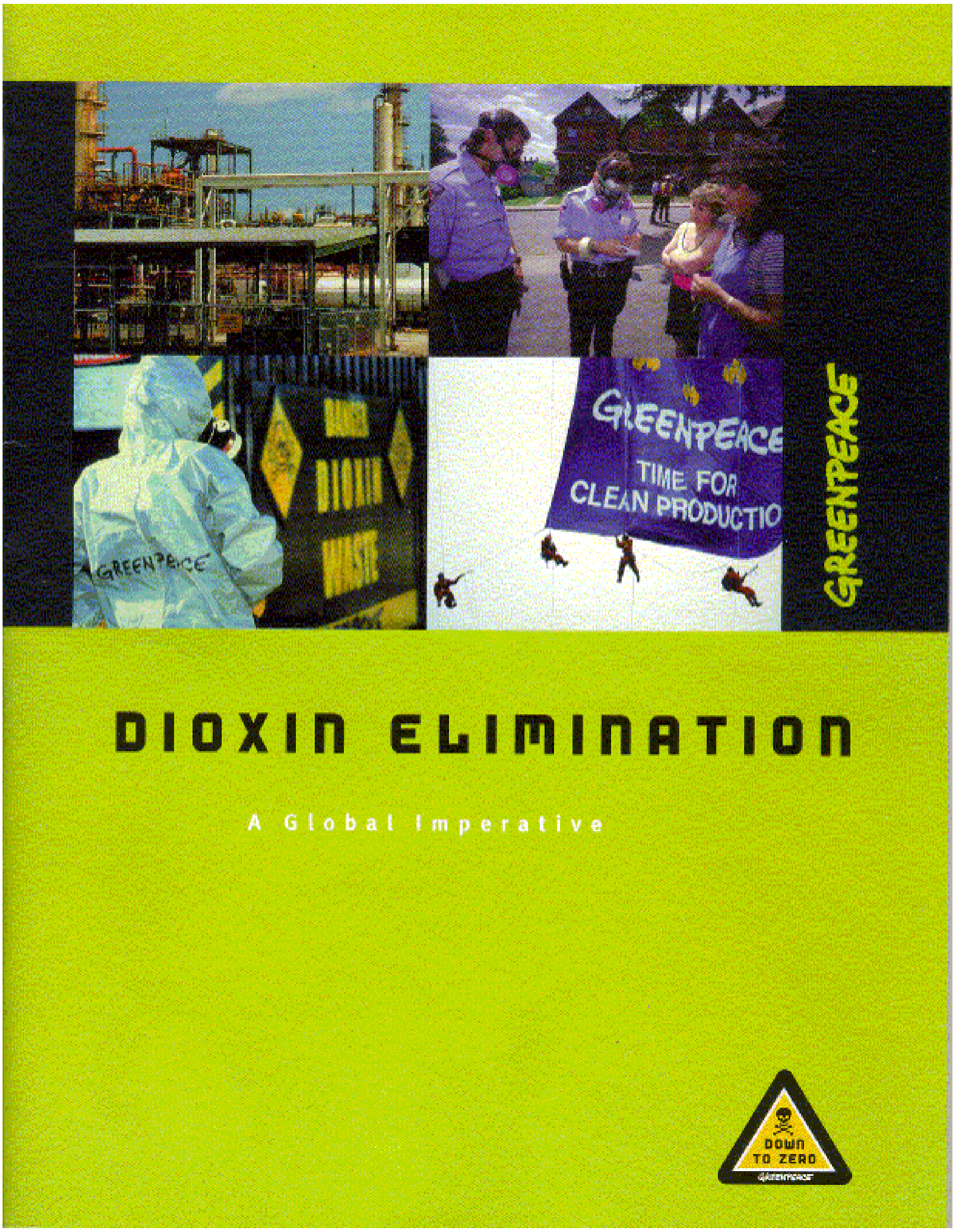

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ISBN: 90-73361-55-9
Revised
8 March 2000

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Executive Summary

Dioxins and furans are unintentional byproducts of industrial and combustion processes involving chlorine. They are among the group of 12 persistent organic pollutants (POPs) that are the initial targets of the global POPs treaty currently being negotiated under the auspices of the United Nations Environment Programme.

The global POPs treaty will be effective only if the overarching objective is the aim to eliminate all persistent organic pollutants of global concern as designated in the treaty.

For dioxins[a], the aim to eliminate means crafting and implementing policies that:

1) prevent the introduction of new dioxin sources, and

2) give priority to practical measures that eliminate dioxin sources ---actions that prevent the creation of dioxins -- in preference to measures that only reduce dioxin releases and do not advance toward elimination of dioxin sources.

Dioxin Source Elimination and Economic Development

It is critically important that the global POPs treaty includes measures to stop countries and corporations from promoting and exporting dioxin-generating technologies and materials

A dioxin source elimination policy will guide investments in both industrialized and newly industrialized nations toward cleaner, more modern and more sustainable economic development.

A POPs treaty that has dioxin release reduction and not elimination as a goal will almost certainly set the stage for increased dioxin sources and thus releases in many newly industrialized countries and fail to stop dioxin releases in industrialized countries and, consequently, in the global environment.

Current trends in virtually all regions of the world include increasing generation of domestic waste; rising content of chlorine-containing materials, particularly polyvinyl chloride plastic (PVC), in that waste; and proliferation of waste incineration. Meanwhile, despite years of effort and billions of dollars in improvements to incinerators and their pollution control systems, municipal waste incinerators remain, as a group, the largest source of dioxin releases to the air in most industrialized countries.

Strategies for Dioxin Source Elimination

The basic strategies for the elimination of primary dioxin sources are:

1) phase-outs directed toward ending or substituting the application of processes and technologies that are dioxin sources; and

2) materials policies that are directed toward replacing materials or products that are, in effect, dioxin sources under certain conditions, e.g., during combustion, or controlling the flow of such materials or products so that they do not encounter such conditions.

Secondary dioxin sources – soils, sediments, landfills, and other so-called reservoirs, must be identified and treated using technologies that achieve effectively 100 percent destruction of the dioxins with no formation of new

[a] The term `dioxins' is used to refer collectively to both dioxins and furans.

by-products that are persistent and bio-accumulative and with complete containment of all residues for assay and reprocessing if necessary.

In the absence of phase-out policies, production and use of pesticides and industrial chemicals that are known or suspected to have dioxins as by-products and, in some cases, to carry dioxins as contaminants in their commercial formulations continues today in many regions of the world, particularly in the newly industrialized nations.

Materials policies are the only practical way to address diffuse sources of dioxins, such as open burning of wastes, burning wastes for household heating and cooking, landfill fires, structural and vehicular fires, vehicular exhausts, etc. Diffuse sources may contribute the greatest share of dioxin releases in regions, e.g. where open burning of waste is common. The continued use of chlorinated additives in gasoline and oil for automobiles, motorcycles and motor scooters is, in all likelihood, a major diffuse source of dioxins in some regions of the world. A POPs treaty that has dioxin release reduction as its goal is likely to ignore diffuse sources of dioxins.

Materials policies are also important with respect to large point sources of dioxins, such as incinerators. In 1997, the U.S. Environmental Protection Agency acknowledged that PVC is a dioxin precursor and that studies have identified strong correlations between chlorine content and dioxin emissions from incinerators.

PVC is the primary source of the chlorine necessary for dioxin formation in the materials burned in municipal and medical waste incinerators, open burning of domestic waste, landfill fires, some secondary metal smelters, accidental structural and vehicular fires, etc. For example, PVC is, in effect, the primary dioxin source for more than 80 percent of total dioxin releases to air in the U.S. Given these circumstances, PVC can be considered the single largest contributor to global dioxin releases.

Dioxin Inventories: Reality or Myth?

Even in the industrialized nations of Europe, dioxin inventories are described as *"far away from being complete."* No industrialized country has even a moderately robust inventory of dioxin sources and their releases to the environment. Many industrialized nations have identified their major sources of air releases. However, global dioxin `fallout' from the air is estimated to be 20 times greater than estimated releases to the air from known sources.

No nations have fully identified their major sources of releases to water and land or in products, but dioxin releases to land are said to exceed atmospheric emissions by far. Even less information exists on secondary sources, so-called reservoirs such as soils, sediments, landfills, etc., where dioxins have been stored or have accidentally accumulated.

Identification and Elimination

Given the global extent of dioxin sources and contamination, a POPs treaty with the goal of dioxin source elimination will require programs to identify and eliminate sources, which will require substantial resources. However, as dioxin sources are eliminated, costs for their regulation and monitoring will cease. Indeed, one heretofore unstated objective of a POPs treaty with the goal of dioxin source elimination is the gradual and ultimately complete diversion of financial and other resources that must be devoted to solving the global dioxin problem to other pressing social needs.

Dioxins and Human Health

Recognizing that *"subtle effects might already be occurring in the general* *population in developed countries at current background levels of exposure to dioxins and dioxin-like compounds,"* the World Health Organization established a tolerable daily intake (TDI) of 1-4 picograms of dioxins and dioxin-like PCBs per kilogram of body weight per day.

Studies of humans who have had extraordinary dioxin exposures during adulthood show that dioxins produce an increase in all cancers and in non-cancerous tumors; diminished levels of the male hormone, testosterone; an increased incidence of diabetes; developmental effects; chloracne; and altered immune and endocrine function.

When a woman becomes pregnant, the dioxins in her body can cause irreversible changes in the development of the central nervous system, immune system, reproductive system and endocrine system of the fetus. The dioxins in a woman's body are also passed to her nursing infant in her breast milk.

Some of the effects associated with dioxin exposure before birth and/or during breastfeeding include lower intelligence, decreased memory, hyperactivity, smaller head circumference, lower birth weight, increased skin and respiratory infections, and reduced penis length.

The fact that a mother's breast milk is contaminated with dioxins is clear evidence that her infant was exposed to dioxins before birth. The only way to prevent dioxin exposure before birth and during breastfeeding is the elimination of dioxin sources.

Breast milk is the first food for most infants and the preferred first food for all infants. The rights of mothers to breast feed and the rights of infants to be breastfed must not be jeopardized.

Numerous studies have found that the benefits of breastfeeding seem to outweigh the negative effects of exposure to dioxins at current levels as they appear in the general population. However, no mother should be forced to choose between the benefits of breastfeeding and adding to the toxic insult her infant has already endured before its birth.

In all nations where mothers' milk has been tested, dioxin levels are higher than the levels allowed in cow's milk in some nations. For example, in both the Netherlands and Belgium, dioxins in mothers' milk are from four to five times higher than the limits for cows' milk.

The Ultimate Goal

For dioxins, the desired results of the POPs treaty are dioxin levels comparable to pre-industrial levels. This can be achieved only by eliminating anthropogenic dioxin sources.

1.0 Introduction

Both the United Nations Environment Programme (UNEP) and the World Health Organization (WHO) have identified dioxins[b] as environmental pollutants of global concern. UNEP has called on governments of the world to develop action plans to reduce and/or eliminate dioxin releases to the environment so that humans and ecosystems will be protected from injury by these ultra-toxic, persistent and bioaccumulative chemical pollutants. The WHO has urged that *"every effort should be made to reduce exposure to the lowest possible level."* [1]

Intergovernmental negotiations are moving forward with crafting the text of a global treaty that will mandate actions and obligations by national governments of the world to protect health and the environment from dioxins and other persistent organic pollutants (POPs). At the same time, the urgency of the dioxin issue and the level of public concern have risen dramatically with recent incidents involving widespread contamination of food and new scientific findings describing the consequences of dioxin exposure.

The global POPs treaty will be effective and meaningful only if it has as its overarching objective the aim to eliminate all persistent organic pollutants of global concern as designated in the treaty.

In 1998, a comprehensive review of scientific studies persuaded WHO experts that *"subtle effects might already be occurring in the general population in developed countries at current background levels of exposure to dioxins and dioxin-like compounds."* [2]

[b] In this paper, the terms "dioxin" and "dioxins" are used to include both the polychlorinated dioxins and furans.

WHO then changed the tolerable daily intake (TDI) for dioxins of 10 pg TEQ/kg bw/day[c] to a TDI of 1-4 pg TEQ/kg bw/day that includes both dioxins and dioxin-like PCBs.

Particularly in industrialized countries, adults routinely ingest dioxins in quantities well above the WHO goal of 1 pg TEQ/kg bw/day for dioxins and dioxin-like PCBs. For nursing infants, dioxin intake is some 50 times higher.[3]

In 1999, dioxins were propelled to the forefront of public attention through highly publicized incidents involving dioxin contamination in Japan and Belgium. Intense public concern about potential health impacts, economic repercussions, and dissatisfaction with the performance of the responsible authorities, provoked responses at the highest levels of government.

National governments, while not always quick to adopt precautionary measures to protect the health of their citizens from the effects of dioxins, must acknowledge the significant economic cost of the recent Belgian food

[c] "pg TEQ/kg bw/day": picograms TEQ per kilogram of body weight per day. "TEQ" is toxic equivalents. Dioxins always occur as mixtures so, to facilitate assessments of such mixtures, each of seventeen dioxins and furans has been assigned a toxic equivalency factor (TEF) based on its potency relative to that of the most toxic dioxin, 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs, in combination with the concentration of each of the dioxins, are used to calculate TEQ concentrations in air, water, soil, foods, animal and human tissues, etc.

Table 1: Median Daily Intake of Dioxins and Dioxin-like PCBs

	Picograms TEQ per kilogram of body weight per day		
	Dioxins	Dioxin-like PCBs	Total
WHO Tolerable Daily Intake			1-4, (the lower value is the desired goal) [1]
Adults* (Papke, 1998)[4]	1-2	~2-4	3-6
Infants, Nursing	~50-100[5]	62-200[6]	150-300
Infants, Formula-fed	2[7]		
Children, 1.5-4.5 years	~2-4[8]	~4-8	~6-12

* Adults in Canada, Germany, United States, United Kingdom, and the Netherlands

contamination episode. The cost to Belgium and the European Union (EU) as a result of the import restrictions around the world has been estimated at US$3 billion. Whether the occurrence, in one year, of national political crises in two distant regions over dioxin contamination from two different sources is a coincidence or a trend remains to be seen. There can be no doubt that public awareness and concern about dioxins will intensify as evidence mounts that, in many countries, the general population – particularly the developing human fetus and nursing infant – is suffering health injury from the dioxins in their everyday food.

What remains to be seen is public response to the question: *Is my government doing all that it can to protect my family and me from this preventable health problem?* The global POPs treaty serves as not only the best but also perhaps the only opportunity to reassure citizens of the world that, yes, national governments are committed to keeping dioxins out of their food, their bodies and the bodies of their infants and children.

2.0 The Global Goal: Elimination of Dioxins and Other POPs

The UNEP Governing Council decision to begin the process for a global POPs treaty states that even though different approaches will be needed for each category of POPs[d], the different measures or action plans should be developed *"in the framework of overarching objectives to be negotiated by an intergovernmental negotiating committee."*[9] In other words, national governments must agree on the overarching objective of the treaty -- POPs release reduction or POPs elimination.

Elimination, phase-out, or reduction with the aim of elimination of substances that are toxic, persistent and bioaccumulative was called for by UNEP Governing Council in 1990[10] and the Paris Commission in 1992[11]

The aim to eliminate dioxins and other unintentional by-products means:

preventing the introduction of new dioxin sources, and

giving priority to practical measures that eliminate dioxin sources ---actions that prevent the creation of dioxins -- in preference to measures that only reduce dioxin releases and do not lead to source elimination.

Elimination of releases of substances that accumulate in the marine environment was called for in the UNCED Rio Earth Summit Agenda 21 of 1992[12] as well as in the Barcelona Convention of 1993[13]. Similarly, the 1998 OSPAR agreement has a goal of *"cessation"* of releases of hazardous substances.[14] Elimination of PCBs, DDT and chlorinated hydrocarbons has also been recommended by the five nations of the Nordic Council in 1993.[15] The 34 nations of the International Whaling Commission resolved in 1993 that efforts should be made to eliminate releases of organohaolgens to the marine environment.[16] In 1992, the Canadian-U.S. International Joint Commission (IJC) on the Great Lakes[17] recommended elimination of dioxins, furans and hexachlorobenzene.

Greenpeace and many other public interest organizations regard the elimination of POPs as an imperative. The global treaty will be effective and meaningful only if it establishes as its overarching objective the elimination of all POPs of global concern.

For POPs that are deliberately produced, the aim to eliminate means a long-term commitment to end all production, use and trade of such chemicals and to destroy properly all remaining stocks, stockpiles and reservoirs.

With respect to dioxins and other POPs that are unintentional by-products, the UNEP Governing Council specifically noted that *"currently available measures that can achieve a realistic and meaningful level of release reduction and/or source elimination should be pursued expeditiously, and this should be done by actions that are feasible and practical and additional measures should be explored and implemented."*[18]

The aim to eliminate dioxins and other unintentional by-products means preventing the introduction of new dioxin sources and giving priority to practical measures that eliminate dioxin sources – actions that prevent the creation of dioxins – in preference to measures that only reduce dioxin releases and do not lead to source elimination.

[d] The categories of POPs are pesticides, industrial chemicals, unintentionally produced by-products and contaminants.

3.0 POPs Sources: Identification and Elimination

POPs elimination is an iterative two-step process. The first step is *source identification* -- to identify properly the source of the POP-- and the second step is *source elimination* -- to phase-out, replace or otherwise remove the source so that the POP is no longer produced. This is true for POPs that are produced intentionally as well as those produced unintentionally, such as the dioxins.[e]

POPs sources fall into two general classes: 1) primary sources, processes or materials that produce or generate POPs; and 2) secondary sources, products or materials in which POPs are present, or reservoirs where POPs have accumulated (e.g., soils, sewage sludge, landfills, sediments, forests, etc.).

In addressing POPs sources, first priority is given to primary sources so that accumulation of new stocks, stockpiles and reservoirs and additions to existing stockpiles and reservoirs will be avoided. However, the importance of identifying and destroying, by appropriate means, secondary sources must not be underestimated, as evidenced by the global dispersal of PCBs.[f]

Table 2: Basic Steps in Eliminating POPs

Intentionally-produced POPs	Unintentionally-produced POPs
1. Identify primary sources	1. Identify primary sources
2. Prohibit or phase-out processes that produce the POP	2. Prohibit or phase-out processes and/or materials that lead to the formation of the by-product POP;
3. Identify secondary sources, e.g., stocks held by formulators, distributors and users as well as other stockpiles and reservoirs.	3. Identify secondary sources, e.g., stocks of substances containing the by-product POP that are held by formulators, distributors and users as well as stockpiles and reservoirs of contaminated materials.
4. Collect and properly destroy remaining stocks, stockpiles and reservoirs.	4. Collect and properly destroy remaining stocks, stockpiles and reservoirs.

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[e] Among the twelve short-listed POPs, those identified as by-products include hexachlorobenzene, PCBs and possibly toxaphene. Other toxic, persistent, bioaccumulative organic pollutants are being found in biota and environmental media that apparently are by-products and that display dioxinlike toxicity, e.g., the polybrominated dioxins and furans, mixed halogenated dioxins and furans, the polychlorinated azo- and azoxybenzenes, etc.

[f] Most nations banned PCB production more than twenty years ago. However, PCB use has continued and many stockpiles and reservoirs have not been destroyed. As a consequence, PCBs are still being released into the global environment, circulating at levels that are potentially harmful to humans and the environment.

4.0 Dioxin Source Elimination versus Dioxin Release Reduction

The steps leading toward the two possible goals of the POPs treaty – dioxin source elimination or dioxin release reduction – differ in critically important ways and will have very different outcomes:

- For dioxin source elimination, the economic activities, technologies and materials that are, in effect, dioxin sources are identified. First priority is given to preventative measures: dioxin sources are changed or replaced with alternative activities, technologies, and materials so that dioxins are no longer created and released.
- For dioxin release reduction, dioxin sources are identified and then modified so that dioxin formation and/or releases are reduced. Priority is given to the sources that are most easily identified and measures, such as pollution control systems, are introduced so that dioxin releases to some but not necessarily all environmental media are reduced.

For dioxins, the desired results of the POPs treaty are levels comparable to pre-industrial levels. This can be achieved only through a treaty that eliminates anthropogenic dioxin sources.

In either case, the desired outcome at the national level is a program of action that will bring measured levels of dioxins in the environment, in food and in humans to the lowest possible levels. These levels are comparable to those found in ancient human tissues,[19,20] archived soils and vegetation, [21] etc.[22] According to the U.S. Environmental Protection Agency (USEPA), pre-industrial dioxin levels in the environment were no more than 1 percent of current levels.[23]

Greenpeace and many other public interest organizations are of the firm opinion that the desired results of the POPs treaty are dioxin levels comparable to pre-industrial levels. This can be achieved only through a global POPs treaty that eliminates anthropogenic dioxin sources**.** This perspective stems from comparisons of the probable courses of action and outcomes of the two respective goals, dioxin source elimination or dioxin release reduction.

4.1 Resource Allocation

Whether the goal is source elimination or release reduction, the success of the global POPs treaty depends, in great part, on the resources that national governments are willing to allocate to solving the global dioxin problem. In each nation, existing dioxin sources must be identified and addressed at the same time that steps are taken to prevent the introduction of new sources. National dioxin hotspots will require clean up and further releases to these locales must be prevented.

Some newly industrialized countries will require ambitious, carefully crafted programs of action simply to prevent a rapid rise in the rate at which dioxins are now being released into their environment. The most important aspect of such programs will be measures for avoiding the increased dioxin releases that are likely to arise if current development trends are allowed to continue (see Section 4.2).

Substantial financial and other assistance will be necessary to develop and carry out national programs of action. Moreover, the results of such programs may not come quickly. Even a well-designed, well-funded national program of action will require a significant period of time to achieve a real and stable solution.

It is not clear how, or even if, a treaty that has dioxin release reduction as its objective can be configured to address the expansion and/or spread of dioxin sources --activities, technologies and materials. This is particularly important for those newly industrialized nations and nations with economies in transition where investment in such dioxin sources may still be relatively small.

… a POPs treaty that has dioxin source elimination as its goal will guide foreign investment and donor assistance toward cleaner, more modern and more sustainable economic development.

While the release reduction approach can achieve reductions from point sources of dioxins, these reductions will be nullified and perhaps overwhelmed at the national, regional and/or global level if the number of such dioxin sources continues to increase.

A dioxin release reduction program may put an enormous, potentially intolerable burden on some national governments. The regulatory and laboratory infrastructures required to monitor and enforce such a national program is both costly and complex. For example, fewer than 50 laboratories in the world have been certified by WHO for the analysis of dioxins in human tissue, and the cost of such an analysis ranges from US$1,000 to US$3,000 per sample.[24] The cost of establishing such a laboratory is estimated at US$1.5-2 million.[25] Even in the wealthiest countries, such costs are barriers to adequate monitoring of industrial releases and environmental burdens.

Many industrialized countries are heavily invested in economic activities, technologies and the production and use of materials that are, in effect, dioxin sources. In such cases, dioxin elimination may require a realistic transition period so that potential economic and social dislocations can be avoided or minimized. However, it is encouraging that a Canadian economic assessment reported *"probable net benefits to society"* for such a transition in that country.[26]

If the goal of the POPs treaty is dioxin source elimination, reduction measures may be necessary on an interim basis. They are not, however, endpoints. This distinction is very important for long-term investment decisions. Investments are preferentially made in reduction measures that also serve as interim steps toward elimination, e.g., better digesters and delignification technologies in pulp and paper mills. In contrast, expensive filters or other reduction measures that become obsolete as the goal of elimination comes closer are not sound investments and may simply shift the dioxin burden from one environmental medium to another.

In many newly industrialized countries, technologies and materials that are dioxin sources are not yet as pervasive as in industrialized countries. In addition, the corporations most heavily invested in such technologies and materials may be headquartered elsewhere so that related economic activity is a rather small fraction of national capital. The goal of elimination is particularly important for newly industrialized countries and countries with economies in transition. Unlike a global treaty with the goal of release reduction, a treaty that has source elimination as its goal will guide foreign investment and donor assistance toward cleaner, more modern and more sustainable economic development.

4.2 Trends in Technology Transfer

With current trends in technology transfer from industrialized to newly industrialized nations, it is critically important that the global POPs treaty include measures to discourage wealthy countries and corporations from promoting and exporting dioxin-generating technologies and materials to the newly industrialized nations. Alternatively, measures must be included that encourage wealthy countries and aid programs to assist newly industrialized countries in crafting and implementing development programs that give preference and support to technologies and materials that are not dioxin sources.

… it is critically important that the global POPs treaty include measures to discourage wealthy countries and corporations from promoting and exporting dioxin-generating technologies and materials to the newly industrialized nations.

According to the European Environment Agency, production of *"low value bulk chemicals"* is being shifted from Europe *"to Asia and other areas."*[27] Such chemicals include, for example, polyvinyl chloride (PVC), or "vinyl". The manufacture of PVC is known to produce dioxin-enriched wastes, while PVC products are among the world's largest single dioxin source. (See Section 6.0.)

Such technology transfers will certainly benefit European economies while decreasing the PVC-related dioxin burden in the European Union. However, the recipient nations will have increased dioxin releases and associated health care and regulatory costs. Even if such technology transfers are accompanied by investments in production facilities, waste management technologies, laboratories, and governmental infrastructures capable of regulating both production and waste treatment to European standards, dioxin releases will increase.

Industrialized nations also need to devote more resources to solving their own dioxin problems. Their industrial sectors are moving away from technologies, practices and patterns of materials use that were once major dioxin sources. However, as suggested by Figure 1, more stringent, persistent efforts are necessary if these nations are to achieve WHO's recommended *"lowest possible level"* of dioxins in their populations[28] and, necessarily, in their food supplies and environments.

Annual per capita dioxin releases to air in the countries included in the UNEP inventory range from about 30 to 3,000 times an annual per capita acceptable intake of 21.9 to 87.6 nanograms TEQ, which is based on the WHO TDI. (The sole intent of this comparison is to allow the mass of dioxins released to be understood in terms of its toxicological potential. No inference is intended or should be taken as to the relationship between these dioxin releases to air and the resulting amount of immediate human exposure.)

Authors of the European Dioxin Inventory note, *"Despite considerable effort having been spent during the last years to decrease the emissions from municipal waste incinerators this source type still dominates the input of PCDD/F* [dioxins] *into the atmosphere."*[29] This effort has included construction costs of some US$500 million for new municipal waste incinerators built to German standards. Two-thirds of such costs can be attributed to the incinerator's pollution control system.[30]

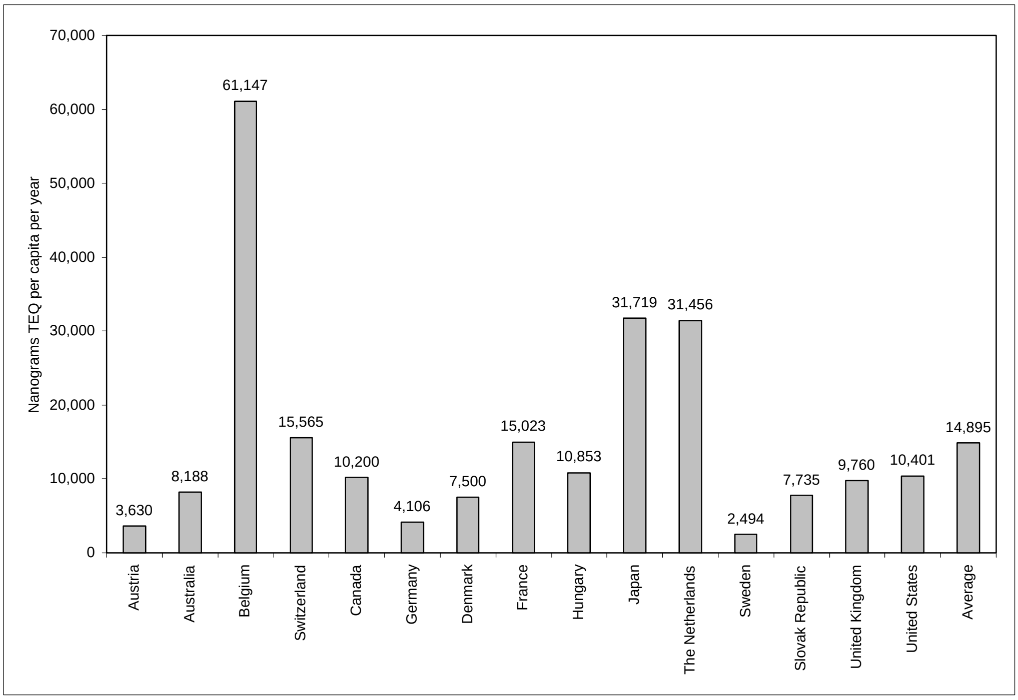

Figure 1: Per Capita Dioxin Releases to Air in Various Countries.[31]

The European Environment Agency predicts an overall 10 percent decrease in dioxin deposition between 1990 and 2010 in the 15 countries of the European Union. In contrast, dioxin deposition in Spain and Portugal are forecast to increase sharply, by a factor of 3.[32]

With no commitment to dioxin source elimination, countervailing trends will eventually negate the predicted decrease in dioxin releases in the European Union. For example household waste is expected to increase by *"around 20% to 2010 for the EU as a whole"* while economic growth in the nine so-called Accession Countries[g] may lead to a doubling of the amount of their municipal wastes. Meanwhile, *"the amount of plastic waste is estimated to increase by 63% from 1993 to 2005 …"* [33]

PVC plastic, a known dioxin precursor[h] when burned,[34] already constituted about 12 percent of all plastic waste, or about 2.1 million tonnes of PVC wastes, in the European Union, Norway and Switzerland in 1994.

With recycling rates for PVC of only 1 to 3 percent, the mass of PVC sent to incinerators and landfills[i] can only continue to escalate.[35] Trends of increasing domestic waste with rising PVC content in Europe and the Accession Countries can be expected to be mirrored in the newly industrialized nations.

[g] Estonia, Slovenia, Lithuania, Slovak Republic, Bulgaria, Hungary, Czech Republic, Romania, and Poland.

[h] "precursor": a compound that leads to another compound in a series of chemical reactions. [A Concise Dictionary of Chemistry, New Edition. Oxford: Oxford University Press, 1990.]

[i] Higher rates of PVC disposal in landfills can be expected to lead to greater dioxin releases during landfill fires, which have been identified as a large source of dioxin releases to air in the U.S. and Sweden.

To the extent that increasing waste generation with increasing PVC content occurs concurrently with increased incineration, landfilling, and open burning, a proportional rise in dioxin releases can be expected. Certainly such trends are apparent in Asia. For example, more than 22 municipal waste incinerators are expected to be constructed on the island of Taiwan by 2001.[36] In Korea, incineration will be increased to 20% by 2001, with approximately forty municipal waste incinerators to be in operation.[37]

4.3 Diffuse Sources of Dioxins

Diffuse sources – open burning of domestic and other wastes, motorized vehicle exhausts, burning domestic and other wastes for heating and cooking, accidental structural and vehicle fires, etc. – have been identified as significant contributors to dioxin releases to air in some of the industrialized nations. For example, a preliminary estimate for the U.S. indicates those annual dioxin releases to air from open burning of domestic waste accounts for almost one-fourth of all air emissions.[38] Unlike incinerators and other large point sources, diffuse sources are not amenable to pollution control devices.

Diffuse sources may contribute the greatest share of dioxin releases in regions where open burning of waste is common and where vehicles are fueled by leaded gasoline containing chlorinated additives. …

A POPs treaty that has dioxin release reduction as a goal is likely to ignore diffuse sources of dioxins.

Diffuse sources may contribute the greatest share of dioxin releases to air in regions where open burning of waste is common and where vehicles are fueled by leaded gasoline containing chlorinated additives.

Diffuse sources are also becoming more important in industrialized countries as releases from point sources are reduced. For example, in Sweden, some 54 percent of dioxin releases to air are from residential stoves that burn wood and unknown quantities of household wastes.[39]

A POPs treaty with the goal of dioxin release reduction is likely to ignore diffuse sources of dioxins. Dioxin release reduction is commonly regarded as a matter of installing pollution control systems on exhaust stacks for large, point sources, such as incinerators and metal smelters. This does not necessarily reduce total dioxin releases, which includes releases in fly ash, bottom ash and slag, scrubber water, scrubber water treatment residues, etc. In fact, some pollution control systems increase dioxin levels in fly ash by a factor of four or more as they reduce releases to air.[40] For diffuse sources, there are no pollution control devices with even these capabilities.

With dioxin source elimination as the goal, diffuse sources are addressed through materials policies. Indeed, such policies are perhaps the only effective means to reduce and, over time, eliminate dioxin releases from diffuse sources. Materials policies can be designed 1) to ensure that dioxin precursors are no longer produced; and/or 2) to control the flow of such materials so that they do not encounter conditions under which dioxins can be formed. (See Section 5.2.)

A POPs treaty that has a goal of dioxin release reduction is most likely to establish measures to reduce releases from individual dioxin sources in certain large dioxin source categories. A release reduction treaty seems highly unlikely to contain provisions addressing certain aspects of economic development that are critically important for newly industrialized nations:

- expansion of diffuse and/or point sources of dioxins;
- increases in the numbers and/or sizes of dioxin sources in each category; and

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materials use patterns which, if current trends continue, will result in the escalation of dioxin releases.

… a POPs treaty that has dioxin release reduction as a goal will almost certainly set the stage for increased dioxin releases in many newly industrialized countries and, consequently, in the global environment.

In other words, a POPs treaty that has dioxin release reduction as a goal will almost certainly set the stage for increased dioxin releases in many newly industrialized countries and, consequently, the global environment.

5.0 Identifying and Eliminating Dioxin Sources

The categories of primary and secondary dioxin sources that have been identified in the USEPA's dioxin inventory are listed in Table 4. The relative contribution of each source category to national dioxin releases varies greatly from nation to nation.

Primary dioxin sources share one common feature – the availability of chlorine. These sources fall into three general classes:

1) **Processes in which chlorine or a chlorine-containing material is essential. In almost all cases, these are chemical manufacturing processes. In some cases, the primary route of dioxin release to the environment is in products and materials (e.g., some organochlorine pesticides, such as pentachlorophenol). Most often, dioxins are concentrated in production wastes so that the wastes and/or the gaseous, liquid and solid residues from their treatment are the primary routes of dioxin release.**
2) **Processes in which chlorine or a material containing chlorine is used for a specific purpose that can be fulfilled by a non-chlorinated material (e.g., the use of elemental chlorine for bleaching wood pulp); and**
3) **Processes in which chlorine or chlorine-containing materials have no purpose but are only incidentally present, e.g., the burning of wastes, some metallurgical processes, power generation, accidental fires, etc.**

There are two basic policies for eliminating primary dioxin sources: 1) phase-outs directed toward ending the application of processes that are dioxin sources; and 2) materials policies that are directed toward replacing materials that are, in effect, dioxin sources under certain conditions, e.g., during combustion, or controlling the flow of such materials so that they do not encounter such conditions.

Table 3: Primary Dioxin Sources – Measures for Their Elimination

Primary Dioxin Sources	Means of Elimination	Examples
Processes for making chlorine-containing products, e.g., chlorinated pesticides and industrial chemicals	*Phase-out*	Ban PCBs, DDT, etc.
Processes for making products that do not contain chlorine but involve the use of agents that are chlorine-based.	*Materials policies* requiring the use of chlorine-free materials in place of chlorine or chlorine-containing materials.	Bleach wood pulp using an oxygen-based, rather than chlorine-based process.
Processes that neither use nor require chlorine in any form	*Materials policies* to prevent exposure of chlorine-containing materials to conditions conducive to dioxin formation.	Remove chlorine-containing materials from wastestreams that may be subject to combustion.

Table 4: Dioxin Source Categories Identified and/or Described by USEPA[41]		
COMBUSTION SOURCES		
Municipal waste incinerators	Biogas combustion	Carbon reactivation furnaces
Open burning of domestic waste	Pulp & paper mill - kraft black liquor recovery boilers	Forest and brush fires
Medical waste incinerators	Combustion of landfill gas	Waste tire combustion
Hazardous waste incinerators Dedicated (commercial & on-site) Industrial boilers/furnaces	Cement kilns Conventional fuels Hazardous waste	Accidental fires Structural fires Vehicle fires PCB fires Landfill fires
Petroleum refining catalyst regeneration	Pulp & paper mill sludge incineration	Cigarette smoking
Light-weight aggregate kilns	Lime kilns	Crematoria
Sewage sludge incinerators	Asphalt mixing plants	Candles
Kraft Mill Wood Residue Boilers		
CHEMICAL MANUFACTURING		
Chlorine & chlorine dioxide bleaching pulp & paper mills	Mono- to tetrachlorophenols	Chloranil
Elemental chlorine	Pentachlorophenol	Printing Inks
Sodium hypochlorite	Chlorobenzenes	Tetrachlorobisphenol-A
Metal chlorides Iron chlorides Aluminum chlorides Copper chlorides	Ethylene dichloride/vinyl chloride monomer (EDC/VCM)	Alkylamine tetrachlorophenate
PCBs (leaks and spills)	Polyvinyl chloride (PVC)	Chlorinated pesticides
Dioxazine dyes & pigments		2,4-D
Phthalocyanine dyes & pigments		
POWER/ENERGY GENERATION		
Motor vehicle fuel combustion Leaded gasoline Unleaded gasoline Diesel fuel	Wood combustion Industrial & residential Waste wood - salt-soaked - preservative-treated - PVC-clad	Oil combustion Industrial/Utility Residential/commercial
		Coal combustion Electric utilities/industrial Residential/commercial
METAL SMELTING & REFINING & PROCESSING		
Primary nonferrous metals	Secondary nonferrous metals	Iron & steel production
Magnesium	Aluminum	Ore sintering
Nickel	Copper	Coke production
Aluminum	Lead	Electric arc furnaces
Copper	Scrap electric wire recovery	Ferrous foundries
Drum & barrel reclamation furnaces		
BIOLOGICAL & PHOTOCHEMICAL PROCESSES		
Biotransformation of chlorophenols and highly chlorinated dioxins & furans		
Phototransformation of chlorophenols		
Photolysis of highly chlorinated dioxins & furans		
RESERVOIR SOURCES		
Sediments	Forests	Landfills
Soils	Pentachlorophenol-treated wood	

5.1 Phase-Outs

Some prolific dioxin sources have been eliminated through phase-outs and bans. In the earliest examples, dioxin sources were eliminated by accident rather than by design as certain organochlorine pesticides and industrial chemicals were prohibited with no knowledge that dioxins were by-products of their manufacture and contaminants in their final formulations.

Dioxin releases to the environment in Western Europe and North America peaked in the 1960s and early 1970s.[42] This coincided with the highest production and use of DDT and other chlorinated pesticides and chemicals now known to have dioxins as by-products. For three decades, Germany, the U.S., Japan and other industrialized nations produced copious quantities of DDT[43,44] and other dioxin-contaminated pesticides.

During this era, these substances along with the as-yet unknown dioxins were applied liberally and often on food crops, pastures, forests, and surface waters; on farm animals, on and in homes; and, at times, directly on humans. At the same time, dioxin-enriched wastes from production of these chemicals were disposed of primarily by dumping in unlined pits, ponds and piles. As DDT and a host of other organochlorine pesticides and a few industrial chemicals, such as PCBs, were phased-out during the mid-1970s and 1980s, dioxin releases to the environment in Western Europe and North America began to fall.[45]

Production and use of some of these same pesticides and industrial chemicals as well as others that are known or suspected to have dioxins as by-products continues today in many regions of the world, primarily among the newly industrialized nations.

Production and use of some of these same pesticides and industrial chemicals as well as others that are known or suspected to have dioxins as by-products continues today in many regions of the world, primarily among the newly industrialized nations.

A whole new generation of dioxin-contaminated pesticides and chemicals emerged in the industrialized nations during the 1950s with the mass production of chlorophenols and their derivatives.[46] Three decades later, in 1985, the U.S. Environmental Protection Agency (USEPA) had identified the manufacture of chlorophenols as the most important dioxin source in the U.S.:[47]

> *"[P]rimary sources of PCDD [dioxin] contamination in the environment result from the manufacture of chlorophenols and their derivatives and the subsequent disposal of wastes from these industries."*

By 1997, the use and manufacture of chlorophenols were reportedly phased out in most European countries and in a few countries outside Europe.[48] In 1998, USEPA estimated the annual release of dioxins from the use of one chlorophenol – pentachlorophenol – as eight times greater than the combined releases from all other known dioxin sources.[49] In the European Union, manufacture and use of pentachlorophenol has been banned.[50]

Mass production of some chlorophenols has continued with little or no abatement. For example, 2,4-D has been produced for 50 years and is the most extensively used herbicide in the world.[51] This chlorophenol derivative is commonly believed to be free of dioxins. However, a recent study found dioxin levels ranging from 195 to 915 parts per trillion (ppt) TEQ in 2,4-D manufactured in the U.K. and used in the U.S.; 2,4-D produced in Russia; and 2,4-D manufactured in Western Europe and used in Palestine.[52] There is little or no information on the dioxin contents and fate of 2,4-D production wastes.

Besides chlorophenols, there are many other chlorinated chemicals that have been found to contain dioxins as contaminants and, consequently, can be assumed to have production wastes that are dioxin-enriched.

5.2 Materials Policies

Materials policies are primary measures that have one objective -- preventing dioxin formation. This is accomplished in one of two ways:

1) Materials substitution -- replacing a chlorine-containing material that serves some function by a chlorine-free material that can achieve that same purpose; and

2) Materials segregation -- preventing the entry of chlorine-containing material into a process in which the material serves no purpose but within which the material serves, in effect, as a dioxin source.

Materials Policies for Dioxin Source Elimination

- **Materials substitution -- replacing a chlorine-containing material that serves some function by a chlorine-free material that can achieve that same purpose; and**
- **Materials segregation -- preventing the entry of chlorine-containing material into a process in which the material serves no purpose but within which the material serves, in effect, as a dioxin source.**

As noted by UNEP, *"Normally, these measures are applied first to prevent formation of unwanted byproducts*." [53]

Such measures have been used and/or recommended for the elimination of some dioxin sources and for reducing dioxin releases from others. For example, the Protocol to the Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants (LRTAP) notes, *"The main control measures for PCDD/F emissions from waste incineration facilities are (a) Primary measures regarding incinerated wastes,…"* [54] Similarly in 1995, an advisory group for the U.K. Department of the Environment discussed the applicability of materials policies for thermal processes in general:[55]

> *"One of the more obvious primary ways of minimising TOMPS [toxic organic micropollutants, e.g., dioxins] in incinerators and in other thermal processes is to try to avoid (or reduce) TOMPS, their precursors or fundamental species (such as chlorine or bromine) being included in the feedstock."*

Ten years ago, USEPA outlined two kinds of materials policies to reduce dioxin releases from hospital waste incinerators. One is a proactive policy requiring hospitals to purchase and use products with the aim of controlling the composition of their wastes. The other is a more retroactive policy requiring chlorine-containing materials, such as PVC products, to be segregated from waste prior to incineration:[56]

> *"Plastics and metal-containing components of the waste, such as sharps, could be segregated: this could result in lower HCl, polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans, and trace metal emission rates. ... Another approach to possibly lowering HCl and PCDD/PCDF emission rates would be to have hospitals use low chlorine content plastics. This could be accomplished if the health care*

industry were to use plastics such as polyethylene and polystyrene in place of polyvinyl chloride, which contains over 45 weight percent chlorine."

In 1997, USEPA offered further support to such materials policies with the acknowledgment that *“[s]everal studies have identified strong correlations between chlorine content and CDD/CDF [dioxin] emissions during combustion tests.”* At the same time, the Agency also reaffirmed that PVC is a dioxin precursor.[57]

Materials policies have often been more or less voluntary responses to laws restricting dioxin releases and market forces. For example, increasingly stringent restrictions on dioxin releases have led some pulp and paper manufacturers to replace elemental chlorine as a bleaching agent with chlorine-free bleaching agents.

Dioxins in the exhaust gases of internal combustion engines in vehicles (e.g., autos, trucks, motor scooters, etc.) have been reduced, primarily in North America and Western Europe. This came about, in part, through materials policies such as the German policy that prohibits the use of chlorine-containing additives in gasoline.[58] However, such reductions have been an unintended benefit of the phase-out of leaded gasoline due to its role as a source of lead contamination not because it contains chlorinated additives that are, in effect, dioxin sources. The continued use of chlorinated additives in gasoline and oil for automobiles, motorcycles and motor scooters is, in all likelihood, a major dioxin source in some regions of the world.

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Table 5: Materials policies that have been formally incorporated, recommended or proposed for dioxin abatement programs
A 1996 report from the Intergovernmental Forum on Chemical Safety (IFCS) concluded that it was appropriate and important to consider materials policies in developing strategies to minimize and/or eliminate releases of both the polychlorinated and polybrominated dioxins and furans;[59]
The Governing Council of the United Nations Environmental Programme adopted the recommendations of the IFCS report on Feb. 7, 1997, as part of the process of achieving a global, legally binding agreement to eliminate or reduce dioxins and other persistent organic pollutants in the global environment;[60]
On November 22, 1996, the American Public Health Association adopted a resolution urging health care facilities and suppliers to reduce or eliminate their use of PVC and other chlorinated plastics that are currently disposed of in medical waste incinerators;[61]
The Central Pollution Control Board of India ruled in July 1996 that polyvinyl chloride (PVC) can no longer be burned in medical waste incinerators;[62]
In 1994, the International Joint Commission (IJC) between the U.S. and Canada recommended that *“...the Parties ... alter production processes and feedstock chemicals so that dioxin, furan and hexachlorobenzene no longer result as byproducts”* and *“... develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks and that the means of reducing or eliminating other uses be examined.”* [a] This followed the IJC’s 1992 conclusion: *"We know that when chlorine is used as a feedstock in a manufacturing process, one cannot necessarily predict or control which chlorinated organics will result and in what quantity. Accordingly, the Commission concludes that the use of chlorine and its compounds should be avoided in the manufacturing process."*[63]
In 1992, the German Federal Government enacted a prohibition against using chlorinated and brominated compounds as petrol additives to reduce dioxin release via car exhausts.[64]

6.0 PVC: One of the World's Largest and Most Widespread Dioxin Sources

Materials policies are perhaps most important in the case of PVC. PVC and dioxins are inextricably linked. Dioxins are created during the manufacture of PVC and dioxins are created whenever and wherever PVC is burned.

6.1 PVC Manufacture as a Dioxin Source

Industry sources have described dioxin formation as unavoidable during at least one of the processes of PVC manufacture.[65] Dioxins have been found in the major PVC precursor, ethylene dichloride (EDC).[66] Dioxins are found in EDC/vinyl chloride monomer (VCM) production wastes at very high levels[67] and have also been detected in some samples of PVC at low levels.[68,69] Moreover, one of the dioxins has been identified as a biomarker of exposure for those who work in EDC/VCM production.[70]

Table 6: PVC Production Chain and Global Dioxin Output

The PVC production chain includes the three organochlorines that are, among all the organochlorines, produced in the greatest quantities: [71]

- 1,2-Dichloroethane, or ethylene dichloride (EDC): Ninety-five percent of EDC is pyrolyzed to produce vinyl chloride monomer;
- Vinyl chloride monomer (VCM): Ninety-nine percent of VCM is polymerized to produce polyvinyl chloride: and
- Polyvinyl chloride (PVC): Global production of PVC, or "vinyl", was estimated at 22 million metric tons in 1996,[72]as compared to 12.8 million metric tons in 1988.[73]

Making the very conservative assumption that all EDC/VCM facilities in the world are designed, equipped and operated like those in Germany (including German-standard high temperature incinerators for waste treatment), dioxin releases from global production of PVC can be calculated to range from 3 to 30 gramsTEQ per year released to air; 3 to 993 grams TEQ per year released to water; and 12,040 grams TEQ per year released in catalyst residues. These calculations are based on emission factors presented in the 1997 European Dioxin Inventory [74]

PVC manufacture can make significant contributions to dioxin loadings in the air, water and soil at the local level. The largest concentration of PVC manufacturing facilities in the world is in the southern United States in the states of Louisiana and Texas. Despite assurances by USEPA and PVC manufacturers, residents in many of the communities surrounding these plants are highly concerned about potential dioxin exposure. Their concerns are supported by a recent study that found extraordinarily high dioxin levels in the blood of some residents of one such community, Mossville, Louisiana. High levels of dioxins as well as PCBs and hexachlorobenzene were also found in soils and sediments of bays and estuaries near some of the nearby PVC manufacturing facilities.[75]

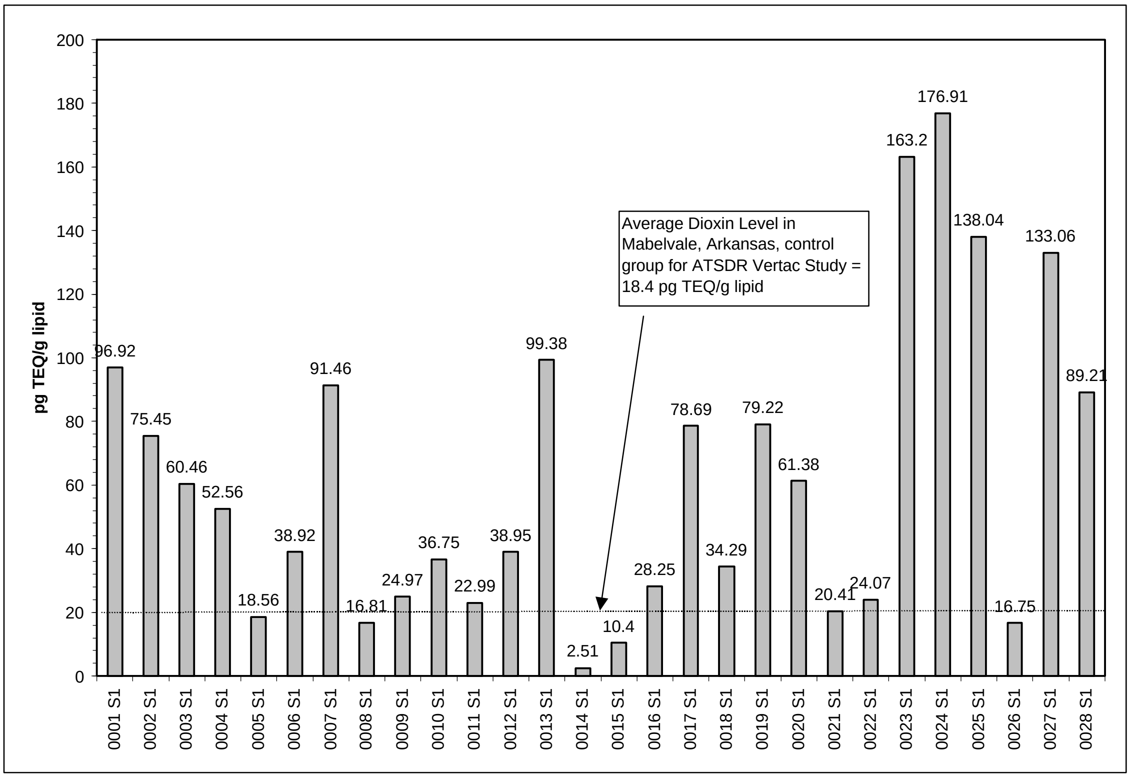

Figure 2: Dioxin Concentrations in Blood Lipids of 28 Individuals from Mossville, Louisiana.

Mossville, Louisiana is a global dioxin hotspot. PVC manufacturing facilities in other parts of the world have created similar dioxin hotspots. For example, the Venice Lagoon in Italy is contaminated by dioxins from PVC manufacturing and other industries[76,77] and has also been designated by Greenpeace as a global dioxin hotspot.

6.2 PVC: A Material Dioxin Source

PVC is a dioxin precursor. As USEPA noted in 1997, *"[t]he chlorinated precursors [of dioxins] include … polyvinyl chloride (PVC)."*[78] This means that wherever PVC is subjected to certain conditions, such as those during combustion (e.g., waste incinerators, open burning of household and construction, landfill fires, and accidental fires involving vehicles, homes and buildings, PVC stockpiles, etc.), dioxins will be formed. In such circumstances, PVC is, in effect, the dioxin source.

PVC is the primary source of the chlorine available for dioxin formation in the materials burned in municipal and medical waste incinerators, trash fires, landfill fires, some secondary metal smelters, accidental fires, vehicle fires, etc.

PVC is the primary source of the chlorine available for dioxin formation in the materials burned in municipal and medical waste incinerators, trash fires, landfill fires, some secondary metal smelters, accidental fires, vehicle fires, etc. Under these conditions, PVC can be considered the single largest contributor to the global dioxin burden.

Dioxins are created when …
pure PVC resin is brought to a high temperature or burned alone.[79,80,81]
PVC products, such as vinyl gloves and other medical devices, are burned.[82,83]
PVC is burned in open fires with wood[84]and vegetation.[85]
PVC-coated cables are burned.[86]
household wastes containing PVC are burned in open barrels.[87]
PVC is burned in accidental fires, such as those involving homes, businesses and industrial facilities.[88,89,90,91]

6.2.1 PVC and Dioxin Releases from Incinerators

PVC is used for a wide range of products such as packaging, toys, hospital products, school and office supplies, automobile trim and undercoatings, electrical wire coatings, home furnishings, water and sewer pipes, building materials, etc. These PVC products have an expected useful life after reaching the consumer that ranges from one day to fifty years. At the end of their useful life, however, these products become waste and are often burned. They are burned in highly controlled incinerators, poorly controlled incinerators, open waste dumps, backyards, barrels, etc. Because they are so widespread, PVC products, in many parts of the world, become dioxin sources in every accidental building, vehicle fire, dump and landfill fire, etc.

Despite years of effort and billions of dollars in improvements to incinerators and their pollution control systems, municipal waste incinerators remain, as a group, the largest source of dioxin releases to the air in most industrialized countries.

The amount of dioxin generated and released when PVC is burned varies depending on a broad range of factors. For example, a modern, state-of-the-art incinerator that is well operated will produce less total dioxin output for a given quantity of PVC input than a poorly controlled incinerator.

Construction of a moderate-sized municipal waste incinerator built to German standards is now estimated to cost about US$500 million, two-thirds of which is devoted to pollution control equipment.[92]

Despite years of effort and billions of dollars in improvements to incinerators and their pollution control systems, municipal waste incinerators remain, as a group, the largest source of dioxin releases to the air in most industrialized countries.[93,94] For example, municipal and/or medical waste incinerators contribute the greatest share of dioxin releases to air in Canada, Belgium, Denmark, France, Italy, and the U.K.[95,96]

In municipal and medical wastes, PVC contributes the majority of the chlorine available for dioxin formation. In the early 1990s, municipal solid waste in Denmark was estimated to contain approximately 0.6-0.7 percent PVC, which contributed about 67 percent of total chlorine input to incinerators at that time.[97]The PVC content in such wastes is undoubtedly higher now. For example, data presented in a recent study of European municipal waste shows that PVC contributes 97 percent of the chlorine in municipal waste sent to landfills.[98] In other countries, the PVC content of municipal waste may be considerably higher. For example, municipal solid waste in Japan is reported to contain an average of 12.2 percent PVC, with a maximum of 25.3 percent.[99] In Israel, plastics account for over one-third of waste by volume and about 14 percent by weight.[100]

In addition, studies by USEPA, the U.S. Department of Energy and other scientists have found that chlorine in the form of chlorinated organic compounds is more readily available for dioxin formation than chlorine present as common salt (sodium chloride) or other inorganic salts. [101,102,103,104,105] This suggests that materials policies focusing on PVC and other chlorinated organic materials will be particularly effective in curtailing dioxin formation and release.

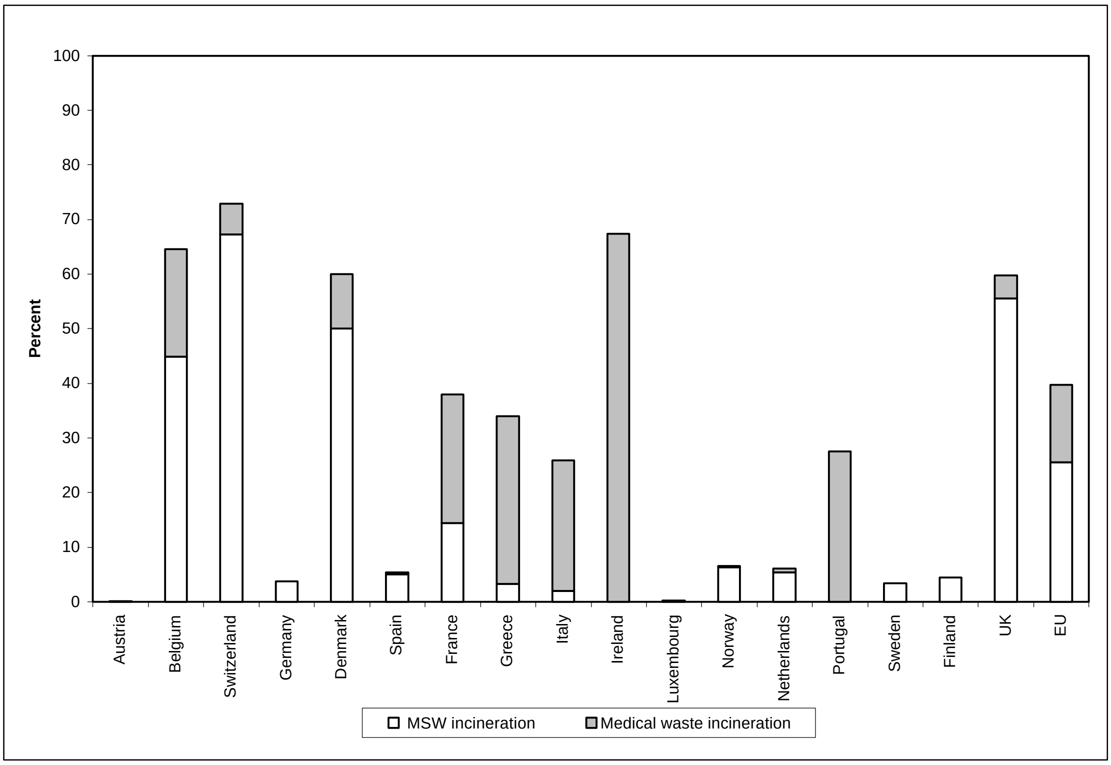

Figure 3: Contribution of Municipal and Medical Waste Incinerators to Total Dioxin Releases to Air in Selected Countries[106,107]

Numerous studies with laboratory- and pilot-scale combustors[108,109,110,111,112,113,114,115,116,117] and full-scale incinerators[118,119,120,121,122,123,124] have found that, when other factors are held constant, increasing chlorine input to an incinerator or other combustion system increases dioxin formation and release.[125] In 1997, the U.S. Environmental Protection Agency acknowledged, *"Several studies have identified strong correlations between chlorine content and CDD/CDF* [dioxin] *emissions during combustion tests."*[126] More specifically, scientists studying a full-scale municipal waste incinerator in Germany listed *"excluding PVC"* as one of the measures that were effective in reducing dioxin formation.[127]

Despite all of this scientific evidence, the relationship between chlorine input, particularly that from PVC, to incinerators and their dioxin emissions has been a matter of controversy for at least two decades. Some of the contributing factors are as follows:

1) Maintaining the constant operating conditions and feed content necessary to obtain unequivocal results from full-scale incinerators is virtually impossible;

2) In studies with full-scale incinerators, scientists have often assumed that the relationship between chlorine input and dioxin output can be determined by comparing chlorine input and a small, highly manipulated slipstream of the dioxin output – stack emissions. For example, when eleven municipal solid waste incinerators in Germany were studied, dioxins in stack emissions accounted for less than 12 percent of total dioxin output.[128] In another, more recent study in Japan, data show stack emissions account for 0.05 to 0.0004 percent of total dioxin output of a municipal waste incinerator.[129]

6.2.2 PVC and Dioxins from Open Burning, Landfill Fires and Accidental Fires

In the most recent inventory of U.S. dioxin sources, USEPA presented preliminary estimates of dioxin releases to air that show open burning of household wastes and accidental landfill fires to be large contributors to air releases of dioxins.[130]As shown in Figure 4, PVC is, in effect, the primary dioxin source for more than 80 percent of total dioxin releases to air in the U.S. (open burning, municipal waste incinerators, accidental landfill fires, medical waste incinerators, and copper smelters).

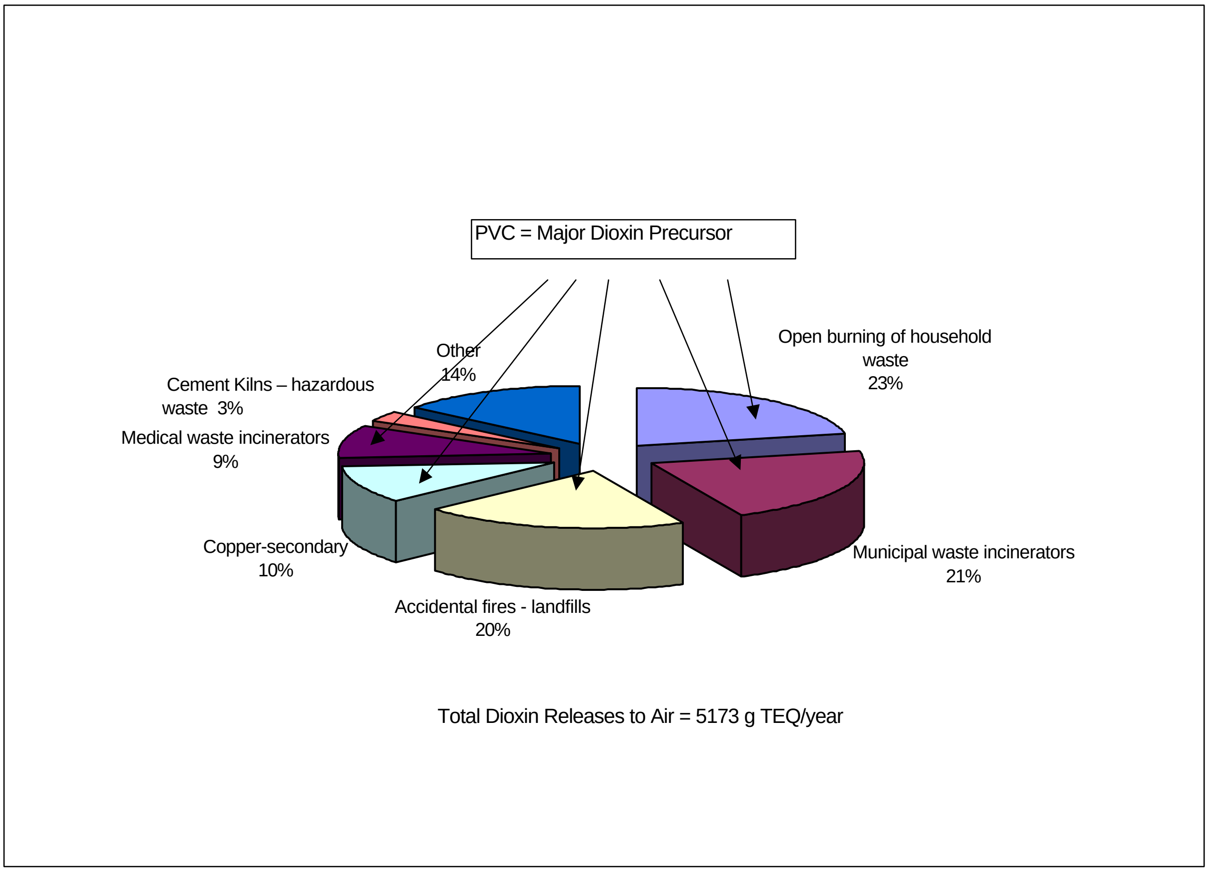

Figure 4: U.S. Dioxin Releases to Air from Major Sources, derived from USEPA (1998)

As mentioned earlier, a recent study shows that PVC contributes 97 percent of the chlorine in the wastes in European landfills.[131]

Open burning is so common as to be accepted practice in many regions of the world. In some of these same regions, plastics (particularly PVC) are an increasingly large share of domestic waste. For example, because of increased use of drinking water and milk packaged in disposable plastic containers, domestic waste in Abu Dhabi, U.A.E., and in Qatar contains 12-15 percent plastics. This can be compared to the 2-3 percent of plastics in domestic waste in the U.S. and U.K.[132]

Open burning of waste is also a common practice in industrialized nations, such as the U.S. According to USEPA's estimates, about 21 million people in the U.S. are burning about 8 million metric tons of household waste in pile or barrels in their backyards each year.[133] A recent USEPA study indicates that PVC materials are the major effective source of the dioxins released into the air during open burning of household waste.[134] As shown in Figure 4, open burning of household waste may account for a portion of total releases that is as large as that from municipal waste incinerators or medical waste incinerators.

In addition, PVC is the predominant dioxin source in accidental fires involving homes and other buildings as well as vehicles.[135,136,137,138] PVC has also been recognized as contributing to dioxin releases from household stoves.[139]Accidental fires involving stockpiles of PVC have released substantial quantities of dioxins to the air in Canada, Germany, and other countries.[140,141] For example, Canadian officials estimated that about 13 grams TEQ of dioxins were released to the air during a 1997 warehouse fire in which 200 to 400 tonnes of PVC were burned.[142] No estimates are available yet for another PVC stockpile fire at another Canadian warehouse in 1999.

6.2.3 PVC and Dioxin Release from Metal Smelting

Large quantities of dioxins are formed and released to the environment during secondary metals recovery. In secondary copper smelting, the major effective dioxin source is PVC insulation on copper wire.

As USEPA noted, *"Some of the scrap materials contain chlorinated plastics such as polyvinyl chloride (PVC). CDD/CDF* [dioxins] *are produced as the plastic and other combustible materials are combusted in the blast furnace."*

For secondary lead smelters, the Agency concluded, *"The primary source of CDD/CDF* [dioxins] *at secondary lead smelters is PVC used as separators in lead-acid batteries."* In addition, USEPA reported that a Swedish study of Iron and steel scrap metal processing found, *"The largest* [dioxin] *emissions were observed during charging of scrap metal containing PVC plastics."* [143]

7.0 Global and National Estimates of Dioxin Releases

Despite decades of research and massive expenditures, no nations, not even those with the most long-standing and sophisticated programs, have robust inventories of dioxin releases to the environment within their borders. The mass of dioxins deposited onto the Earth's surface is estimated to be about 20 times greater than air emissions from known sources.[144]

There are no national or global estimates of the mass of dioxins already deposited in products or in existing reservoirs -- surface soils, freshwater and marine sediments, landfills, salt mines, road beds, etc. And there are no national or global estimates of the annual rates at which dioxins are being released in new products and added to these reservoirs.

7.1 Dioxin Releases to Air

Global dioxin fallout – the amount of dioxins deposited onto the surface of the planet -- has been estimated at 18,700 to 59,500 kilograms of total dioxins per year, with the larger number described as the *"more probable value"*. [145] This is equivalent to about 1,000 kilograms TEQ per year, using the UNEP conversion factor.[146] In 1990, global dioxin emissions to air from nine major source categories were estimated at 3,000 kilograms per year total dioxins,[147] or approximately 50 kilograms TEQ per year. More recently, UNEP estimated dioxin emissions to air of 10.5 kilograms TEQ per year from known sources in 11 European nations, Australia, Canada, Japan, and the U.S.[148]

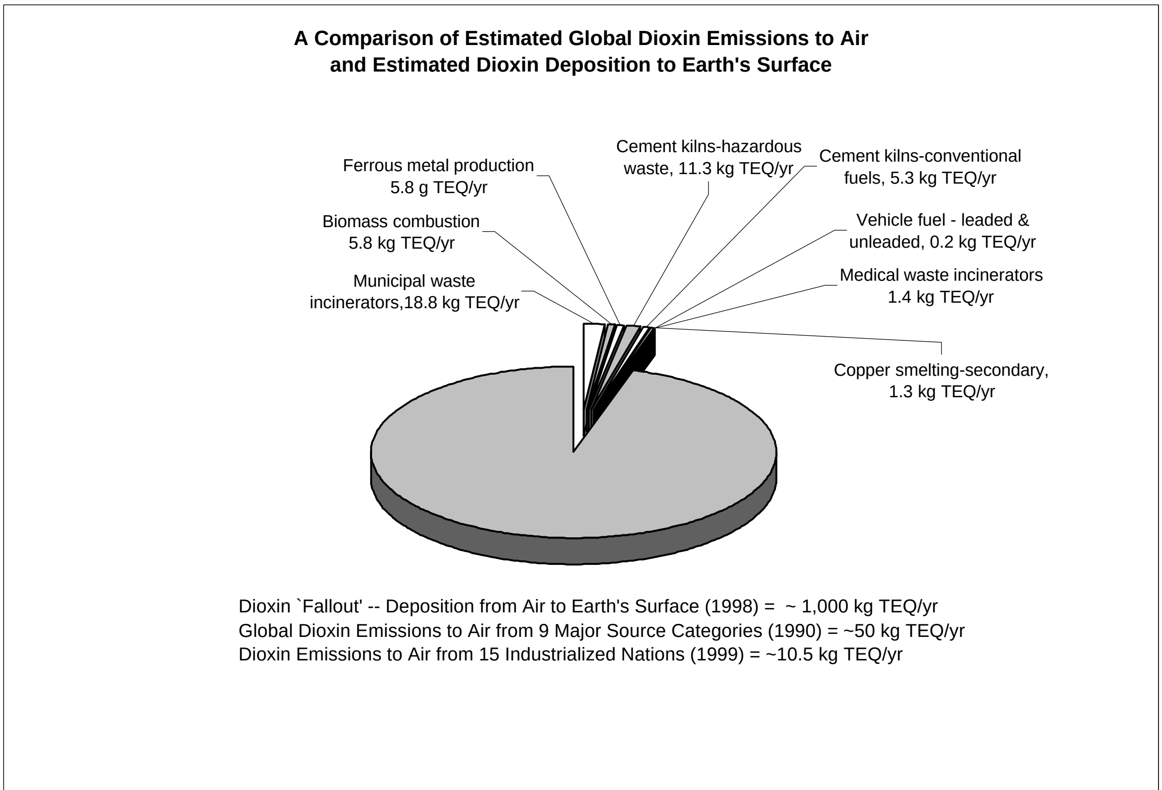

Figure 5: Estimated Global Dioxin Emissions to Air and Estimated Dioxin Deposition to Earth's Surface, (as derived from Brzuzy and Hites (1996); Eisenberg et al. (1998); and UNEP (1999).

Obviously a substantial gap still exists between estimated deposition and air emissions of dioxins. National dioxin inventories are still incomplete and estimated releases are highly uncertain even in those nations that have devoted many years and enormous resources to such efforts, as noted in the European Dioxin Inventory:[149]

> *"The knowledge on PCDD/F emissions in the European countries certainly has been improved during the last decade. However, the annual emission freights being assessed by national and international investigations appear to be far away from being complete. The European PCDD/F air emissions reported in national dioxin inventories cover only 50% - or even less- of the emission estimate obtained in the present study. It should be stressed that this estimate was made only for emission sources yet identified, thus the situation might be worse if the existence of unknown sources is taken into account."*

These comments suggest at least two potential explanations for the disparity between atmospheric fallout of dioxins and dioxin emissions to the air:

- All major sources are not yet identified:
  - Diffuse sources, such as open burning of wastes, landfill fires, etc., remain largely unaddressed in the dioxin inventories of many of the industrialized countries.
  - Magnesium production is another potentially very rich dioxin source that has received little attention. Based on dioxin emission factors for a Canadian magnesium facility, [150] dioxin releases from global magnesium production of about 300,000 metric tons per year can be estimated as about 0.6 g TEQ per year in process stack gases; 9-42 g TEQ per year through volatilization from waste pits and piles; 90-42 g TEQ per year to landfill; and 2,900-8,700 g TEQ in off-site transfers.
  - Dioxin releases in products have received little attention, although USEPA estimated dioxin releases to air through pentachlorophenol use as some nine times greater than the sum of all other dioxin releases to air in the U.S.[151]
- Releases from identified sources are underestimated:
  - The standard technique for measuring dioxin air emissions in stack gases underestimates average emissions by a factor of *"30 to 50"* according to a recent European study.[152]
  - The authors of the European Dioxin Inventory drew attention to the likelihood that dioxin air emissions from residential wood stoves in Europe are underestimated: *"The extent of co-combustion of household wastes is almost unknown and should be assessed … since this practice may influence considerably the PCDD/F emissions from stoves and fireplaces."* [153]

7.2 Dioxin Releases to Water and Land

The authors of the European Dioxin Inventory note that dioxin releases to land are thought to *"exceed… atmospheric emissions by far."* [153] Nonetheless, little if any information on dioxin releases to land, water or products is given in the UNEP dioxin inventory or the European Dioxin Inventory.

Those nations with the most long-standing and advanced dioxin abatement programs, primarily those in Western Europe and North America, have little information on the sources and extent of such dioxin releases.[154]

USEPA has concluded, *"Volatilization and particle resuspension from environmental reservoirs are probably important contributors to global distribution."*[155]

In discussing releases to land, the authors of the European Union dioxin inventory caution, "*[E]ven if the transfer rate of dioxins and furans from these reservoirs [so-called secondary sources, for example dioxins disposed of with wastes and sludges] into the food chain might be low this pathway must not be ignored."* [156]

8.0 Dioxin and Human Health: Why Reduction Will Not Suffice

World Health Organization (WHO) experts re-evaluated the tolerable daily intake (TDI) for dioxins and dioxinlike chemicals in 1998 and made a marked downward adjustment in WHO's tolerable daily intake: [157]

> *"The consultation recognized that subtle effects might already be occurring in the general population in developed countries at current background levels of exposure to dioxins and dioxin-like compounds. It therefore recommended that every effort should be made to reduce exposure to the lower end of this range [1-4 pg/kg bw/day]."*

Results of at least three studies released following re-evaluation of the TDI support WHO experts in their suspicion that effects are occurring at present in the general population:

- Scientists in Japan reported in one study that *"our study suggests that exposure to background levels of the highly toxic organochlorine compounds [dioxins] through the breast milk influences the human neonatal immune system."* [158]
- In a second study, scientists report that *"exposure to background levels of the highly toxic organochlorine chemicals through the breast milk may cause some effects on thyroid hormone status…"*[159]
- In a study of the teeth of breastfed children, Finnish scientists found, *"Defects were clearly associated with the total exposure to toxic dioxins and furans."* Noting that the *"high frequency of hypomineralised dental defects among normal children may be a sign of exposure to PCDD/Fs [dioxins],"* they proposed that such defects *"may be the best available indicator of dioxin exposure."*[160]

These and other studies also suggest that, to afford adequate protection for the nursing infant, not to mention the developing fetus, the TDI may need to be adjusted downward considerably further. As suggested by the daily intake values in Table 1, lowering dioxin levels in mothers' milk so that nursing infants ingest no more than 1 pg TEQ/kg bw/day of dioxins means a TDI for women of about 0.02 pg TEQ/kg bw/day. This is surprisingly close to *USEPA's* current *"virtually safe dose"*[161] for cancer risk of 0.006 pg TEQ/kg bw/day[162] as well as the proposed 0.01 pg TEQ/kg bw/day.[163]

8.1 Cancer and Other Effects in Exposed Adults

Cancer has been the traditional benchmark for triggering action to prevent or reduce chemical exposures. And, in 1997, the International Agency for Research on Cancer (IARC) classified one of the 210 dioxins and furans, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), as *"carcinogenic to humans."* Other dioxins were said to be *"not classifiable as to their carcinogenicity to humans."* [164]

Studies of humans who have had extraordinary dioxin exposures during adulthood *"show that dioxins produce … an increase in all cancers…"* [165] In addition, dioxin exposures can lead to *"developmental effects, chloracne … and may also alter immune and endocrine function."*[166] Other responses to dioxin exposure include tumor promotion,[167] decreased testosterone[168] and altered glucose homeostasis.[169] The reasons for such a diverse range of effects are explained as follows:[170]

"The appropriate way to view dioxin is as a modulator of growth and development. … Dioxin appears to perturb normal homeostasis and hormonal balance leading to alterations in proliferation and differentiation. In the adult, such changes may lead to cancer, immunosuppression, chloracne, and endometriosis."

8.2 Exposure of the Fetus, Nursing Infant and Child

For all but perhaps the eldest of the world's people and certainly for the infants and children of today, dioxin exposure began at conception. It is during earliest development – the prenatal period, from conception through birth -- that dioxin exposure is highest and the effects are most insidious:[171]

"… [P]renatal dioxin/PCB exposure can cause growth deficits, motor dysfunction, neurodevelopmental disabilities, learning problems and hearing disorders in humans. … PCBs and dioxins are present in background exposed mothers and their infants at concentrations that might be toxicologically relevant. These chemicals may interfere with endogenously produced hormones, neurotransmitters and growth factors and may change the course of prenatal human development. Cognitive and neuromotor changes, differences in immune response, reduced birthweight, microgenitalism, reduced fertility and change in the male/female ratio may all be associated with human prenatal PCB/dioxin exposure."

The extent of fetal exposure is determined by the body burden accumulated by the mother prior to conception. Dioxins pass from mother to fetus through the placental barrier. Also, during the latter stages of the pregnancy, the fetus can swallow and absorb dioxins in the amniotic fluid. The greatest risk of dioxin-induced major structural anomalies is during the first nine weeks of the pregnancy, while major defects in the central nervous system are most likely to occur during the first 16 weeks.[172]

Newborn infants are exposed to larger amounts of dioxins through breastfeeding than in any other post-birth stage of life (see Table 1). A new mother excretes from 20-80 percent of her dioxin body burden in her breast milk.[173,174] The nursing infant absorbs the dioxins in her breast milk with 95 percent efficiency so that the infant's dioxin body burden increases with the duration of breast feeding.[175,176,177]

During the period from conception to early infancy, the perinatal period, dioxins and PCBs affect the development of the central nervous system, the immune system, the reproductive system, and the endocrine system, as shown in Table 7.[178]

Table 7: Effects of Perinatal Exposure to Dioxins and PCBs
Central nervous system
Delayed cognitive development, mildly disordered behavior, and increased activity in children of mothers who were accidentally exposed to extraordinary levels of dioxins/PCBs.
Deficits in autonomic maturity and reflexes, less preference for a novel stimulus, and defects in short term memory in children whose mothers were exposed to background levels of PCBs and dioxins.
Delayed motor development, hypotonia and hyporeflexia in children exposed to background levels.
Increased hypotonia, lower psychomotor developmental indices, less optimal neurological condition, and lower cognitive scores in children whose mothers were exposed to background levels.
Immune system
More frequent occurrence of bronchitis, upper respiratory infections and ear infections among children whose mothers had extraordinary prenatal exposure.
More frequent ear infections and altered levels of certain cells that have roles in warding off diseases in Inuit infants whose mothers had elevated exposure through their diet of traditional foods.
Altered levels of certain cells involved in resisting diseases among children whose mothers had background exposures.
Growth, sexual development and reproductive health
Fewer boy children were born to couples in which both parents had high dioxin exposures during the seven-year period following a large dioxin release at a chemical manufacturing facility.
Lower weight at birth and continued diminished height and weight at school age among children whose mothers had extraordinarily exposure.
Reduced penis length among boys who were conceived in the earliest years after their mothers had extraordinary exposure.
Altered birthweight and gestational age among infants of mothers who had occupational exposure to PCBs.
Lower birthweight and smaller head circumference among infants of mothers whose diets included fish from the Great Lakes.
Lower birthweight and slower postnatal growth until 3 months of age among infants whose mothers had background exposure.
Thyroid function
Subtle alterations in levels of thyroid hormones in pregnant mothers and their infants exposed to background levels of PCBs and dioxins.

These and other effects that have been found in infants and children exposed to now common `background’ levels of dioxins and those exposed both to “background” and extraordinary levels of dioxins are shown in Table 8. In the Yu-Cheng incident, people in Taiwan consumed rice oil contaminated with dioxins and PCBs during 1978-79.

Table 8: Epidemiological Studies of Human Infants and Children Exposed Perinatally to Dioxins and PCBs		
Effects	Type of Exposure	
	Extraordinary	Environmental
Low birth weight[179,180,181]	Yu-Cheng incident	U.S., Lake Michigan fish consumers Sweden, Baltic Sea fish consumers
Lower weight at 4 years[182]		U.S., Lake Michigan fish consumers
Reduced head circumference[183,184]		U.S., Lake Michigan fish consumers Sweden, Baltic Sea fish consumers
Hyperpigmentation[185]	Yu-Cheng incident	
Increased skin infections[186]	Yu-Cheng incident	
Increased respiratory infections[187]	Yu-Cheng incident	
Neurological dysfunction[188]	Yu-Cheng incident	
Natal teeth[189]	Yu-Cheng incident	
Decreased penis length[190]	Yu-Cheng incident	
Hypotony[191,192]	Yu-Cheng incident	The Netherlands, Dutch Healthy Infant Study The Netherlands, Zaanstreek study
Hyperactivity[193]	Yu-Cheng incident	
Lower mean intelligence quotients[194,195]	Yu-Cheng incident	U.S., Lake Michigan fish consumers
Altered latencies and amplitudes of auditory event-related potentials[196]	Yu-Cheng incident	
Motoric immaturity (5 months to 11 years of age)[197,198]		U.S., Lake Michigan fish consumers
Hypoactive reflexes[199,200]		U.S., Lake Michigan fish consumers
Reduced memory[201,202]		U.S., Lake Michigan fish consumers
Reduced cognitive function[203,204]		U.S., Lake Michigan fish consumers
Low neurological optimality score[205]		The Netherlands, Dutch Healthy Infant Study
Enhanced neuromotor maturation[206]		The Netherlands, Dutch Healthy Infant Study
Higher reflexes[207]		The Netherlands, Dutch Healthy Infant Study
Alterations in thyroid hormone levels[208,209,210]		The Netherlands, Dutch Healthy Infant Study The Netherlands, Zaanstreek study, Japan
Hypomineralization defects of permanent teeth[211]		Finland, study of breast-fed children
Immunopathy - atopic dermatitis[212]		Japan

Table 9: Dioxins in Breast Milk in Selected Nations				
	pg TEQ/g fat			
	Range of averages	Approximate overall average	Approximate year of sampling	Source
Albania	3.8-4.8	4.3	1992-1993	213
	10.7-10.9	11.9	1992-1993	214
	20.8-34.4	27.2	1992-1993	215
Austria	10.8-20.9	16.9	1992-1993	216
Belgium	8.4-13.5	11.0	1992-1993	217
Czech Republic	12.1-18.4	15.2	1992-1993	218
Denmark	15.2-17.1	16.2	1992-1993	219
Finland	12.0-21.5	16.8	1992-1993	220
Germany	16.5-29.3	22.9	1992-1993	221
Hungary	7.8-8.5	8.2	1992-1993	222
Japan	17.5	17.6	1992-1993	223
Japan		16.2	~1998	224
Japan				
Primapara		17.1	1994-1996	225
Multipara		12.8	1994-1996	226
Lithuania	13.3-16.6	14.8	1992-1993	227
The Netherlands	23.5-30.2	26.8	1992-1993	228
Norway	9.3-12.5	10.6	1992-1993	229
Pakistan	3.9	3.9	1992-1993	230
Russia	5.9-15.2	10.6	1992-1993	231
Slovak Republic	12.6-15.1	13.8	1992-1993	232
Spain	19.4-25.5	22.4	1992-1993	233
Ukraine	11.0-13.3	12.2	1992-1993	234
United Kingdom	15.2-17.9	16.6	1992-1993	235
United Kingdom	21-24	22	1993-1994	236
France, limits for cow milk and dairy -for large consumption -for trade -action level		 <1 5 3		237
Belgium, limit for cow's milk		5		238
Netherlands, limit for cow's milk		6		239

As shown in Table 9 and Figure 6, dioxin levels in human milk vary both within and among countries. There is also evidence that dioxin levels in human milk have decreased substantially in most of the industrialized nations where such data are more commonly collected.[240] Nonetheless, in the nations of Western Europe, where efforts to reduce dioxin releases have been ongoing for one or more decades, dioxin levels in mothers' milk are still far higher than the levels allowed in cows' milk.

For example, in both the Netherlands and Belgium, dioxins in mothers' milk are from four to five times higher than the limits for cows' milk.

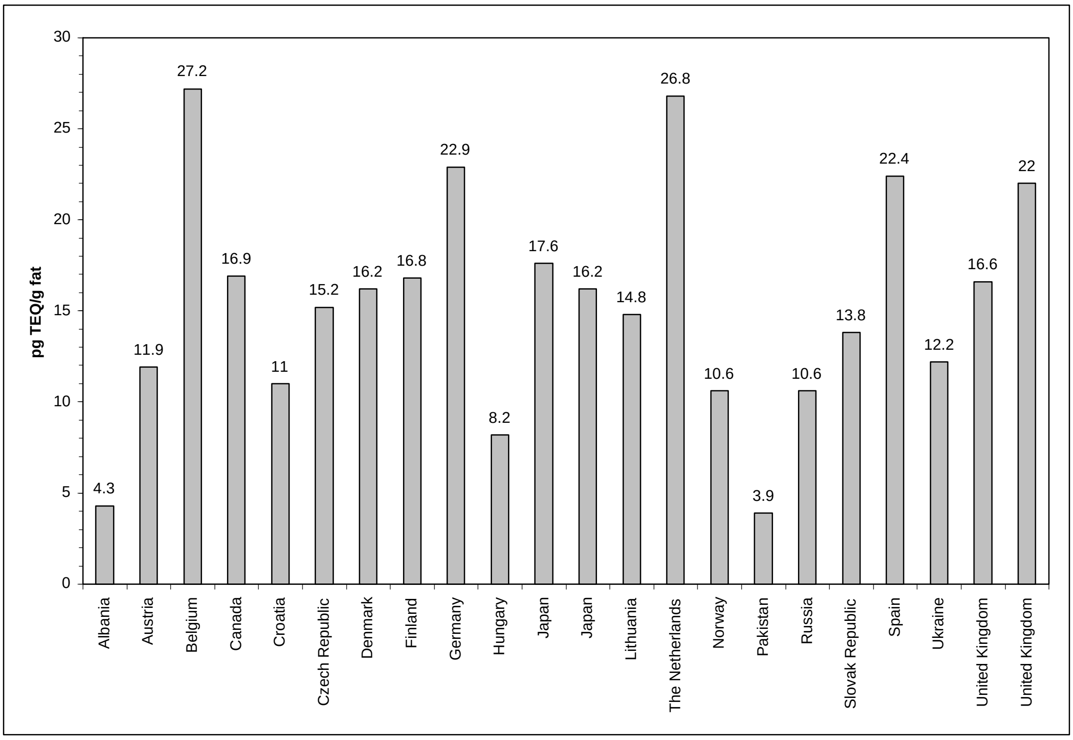

Figure 6: Dioxins in Breast Milk in Selected Countries

Breast milk is the first food for most infants and the preferred first food for all infants. The rights of mothers to breast feed and the rights of infants to be breastfed must not be jeopardized.

The fact that a mother's breast milk is contaminated with dioxins is clear evidence that her infant was exposed to dioxins before birth. There are no means for preventing such prenatal exposure other than the elimination of dioxin sources.

Numerous studies have found that the benefits of breastfeeding seem to outweigh the negative effects of exposure to dioxins at so-called background levels.[241,242,243,244,245,246] However, no mother should ever be forced to choose between the benefits of breastfeeding and adding further to the toxic insult her infant endured before its birth.

It is also important to note that elevated dioxin exposure is not limited to the fetus and nursing infant. Children also have higher dioxin exposure in comparison to adults.[247] A detailed analysis in the Netherlands found that, in ordinary modern life, dioxin exposures for children do not fall to those of adults until around the age of 20.[248] This is particularly important since development of the brain, lungs and reproductive system continues until sexual maturity is reached at about age 12.[249]

9.0 Conclusions

Greenpeace agrees with the WHO that the level of dioxins in the world's population must be reduced to the lowest levels achievable.

Greenpeace and many other public interest organizations regard the elimination of dioxins and other POPs as an imperative. The global treaty will be effective and meaningful only if it establishes as its overarching objective the elimination of all persistent organic pollutants of global concern.

For POPs that are deliberately produced, elimination means a long-term commitment to end all production, use and trade of these chemicals and to destroy properly all remaining stocks, stockpiles and reservoirs.

For dioxins and other POPs that are generated as unintentional by-products, elimination means crafting and implementing policies that prevent the introduction of new dioxin sources and actions that prevent dioxins from being generated – in preference to measures that only reduce dioxin releases and do not advance elimination as the goal.

The success of the treaty depends greatly on the resources that national governments are willing to allocate to solving the global dioxin problem. In each nation, dioxin sources must be identified and addressed at the same time that steps are being taken to prevent the introduction of new sources.

Further releases from dioxin hotspots and reservoirs must be prevented. The contaminated soils, sediments and other materials must be treated using technologies that will destroy the dioxins with effectively 100 percent efficiency, with no generation of new by-products that are persistent and bioaccumulative, and with complete containment of all residues for assay and reprocessing if necessary.

Substantial financial and other assistance will be necessary to develop and carry out national programs of action. Moreover the results of such programs may not come quickly. Even a well-designed, well-funded plan will require a substantial period to achieve a real and stable solution.

The chemical revolution of the last century has damaged, perhaps irrevocably, future generations. Therefore the nations now negotiating the POPs treaty must face these challenges and have the vision to choose to eliminate dioxins at the source at the beginning of the new century.

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