# Environmental Fate of Bioaccumulative and Persistent Substances – A Synopsis of Existing and Future Actions

# Destino ambiental de la bioacumulación y las sustancias persistentes - Una sinopsis de las acciones existentes y futuras

# Destino meio ambiental das substâncias Bioacumulativas e Persistentes – uma sinopse

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## Resumen

Cercada por los riesgos derivados de su gran progreso técnico, la sociedad del riesgo ve sorprendida la confianza en la ciencia y en los poderes públicos, en la proporción en que los accidentes se producen y los efectos secundarios son imposibles de anticipar y prevenir. Así, ganan preeminencia conceptos tales como seguridad química. La extensión que han alcanzado las nuevas tecnologías en el tiempo y el espacio hace imposible predecir todos sus efectos secundarios negativos, y es frente a esa incertidumbre que surge el principio de precaución. Los aspectos del medio ambiente y la salud relacionados con los contaminantes orgánicos persistentes (COPS) son un excelente ejemplo de la necesidad de la adoptar el principio de precaución, porque solo cuando la contaminación con estos contaminantes ha llegado a proporciones mundiales, es imposible de demostrar sus efectos nocivos para la salud humana y animal. Con el objetivo de reducir y eliminar algunos de los más peligrosos COPS, el Convenio fue firmado en Estocolmo en 2001, pero la falta de recursos financieros en los países en desarrollo y el poderoso *lobby* de las empresas multinacionales en la industria química podrían poner en peligro la aplicación de este importante tratado multilateral.



**Palabras clave autor**: contaminadores, salud ambiental, exposición, medición de riesgo, salud pública.

**Palabras clave descriptor:** salud ambiental, medición de riesgo, contaminantes.



## Abstract

Bordered by risks arising from their massive technical progress, the risk society sees surprised the confidence in the science and the public authorities in the proportion of accidents occur and side effects are impossible to be anticipated and prevented. Thus, gaining prominence concepts such as chemical safety. The extent that it has reached new technologies in time and space makes it impossible to predict all its negative side effects, and in front of that uncertainty, it is the precautionary principle. The environmental and health issues related to the Persistent Organic Pollutants (POPs) are an excellent example of the need for adoption of the precautionary principle, because only when the pollution with these contaminants have reached global proportions that it was impossible to prove its harmful effects to human and animal health. Aiming to reduce and eliminate some of the most dangerous POPs, the convention was signed in Stockholm in 2001, but the lack of financial resources in developing countries and the powerful lobby of multinational corporations in the chemical industry could jeopardize the implementation of this important multilateral treaty.



**Key words author**: pollutants, environmental health, exposure, risk assessment, public health.

**Key words plus:** environmental health, risk assessment, pollutants.


## Introduction

The success of modern societies is in part based on extensive achievements of chemistry. This statement has as base the mechanisms utilized in the modern world, where occurs a systematic development of products in medicine, agriculture, in almost all manufacturing sectors of industry and materials for everyday use. With it, chemistry contributes to the progress of the quality of life of billions of human beings. But, the price for these progresses to be paid by our environment seems to be more and more too high to the public. Goods and how they are created by the chemical industry today influence the environmental quality of tomorrow. The social and ecological interests should not be disregarded.

In analogous with the development of the chemical industry over the last decades, an increasing require has been recognised to normalize chemicals that have been proved or supposed to make unwanted, adverse effects on human health and the environment. The need for an improved chemicals regulation has lately, for a number of reasons, become increasingly imperative [1].

Among factors contributing to this urgency is the fact that the annual world production of chemicals has increased from around 7 million tonnes per year in the 1950s to 400 million tonnes today [2, 3]. The number of substances that are commercially produced today is not precisely known, but the upper possible limit should be close to the about 100,000 [4].

Mounting evidence of damage to human health and the environment has focused the attention of the international community on a category of substances referred to as Persistent Organic Pollutants (POPs). POPs are pesticides, industrial chemicals or unwanted by-products of industrial processes or combustion. They are characterized by persistence – the ability to resist degradation in various media (air, water, sediments, and organisms); bio-accumulation – the ability to accumulate in living tissues at levels higher than those in the surrounding environment; and potential for long range transport – the potential to travel great distances from the source of release through various media (air, water, and migratory species). Because of these properties, POPs can be found throughout the world, including in areas far from their original source. The harm these chemical substances can cause to humans and animals includes disruption of the endocrine system, suppression of the immune system, reproductive dysfunction, and developmental abnormalities. Organisms at the top of food chains such as predatory birds, marine mammals, and humans absorb the greatest concentrations of POPs [3, 5-7].

Furthermore, once in the environment they do not degrade, instead they recycle and partition between the major environmental media, being an environmental concern since toxic effects do not disappear and the control is difficult [7]. In addition, they have low aqueous but high lipid/organic solubilities which result in their bioaccumulation in lipoids tissues and in their biomagnification through foodchains [8]. Even at low concentrations they are toxic to humans and wildlife, with suspected effects including carcinogenesis, immune dysfunction, neurobiological disorders and reproductive and endocrine disruption [9].

This article is proposed to provide an overview of today's regulation of POPs, management and strengthening of the regulatory and intuitional arrangements for long term control of POPs and other toxic substances in line with the requirements of the Stockholm Convention and other related conventions and protocols. It will also address the question of whether proven toxicity is a necessary prerequisite, before regulatory action is decided upon against these chemicals.

## Methods

The aim of the literature search was to identify all studies that analyzed the distribution of concentrations of persistent organic pollutants in a representative sample of the general population. All countries and regions worldwide were eligible for inclusion. Articles published in the academic literature were as eligible as reports from governmental and nongovernmental organizations. It was searched in Medline/PubMed and in other abstracting, indexing and citation databases like ScienceDirect, Scopus, ISI / Thomson's, SciELO and Blackwell's Synergy. Searches were based on combinations of the following terms: "persistent organic pollutants", "POPs", "persistent toxic substances", "PTS", "PTSs", "persistent toxic pollutants", "persistent toxic residues", "environmental pollutants/toxicity/prevention and control", "environmental exposure/adverse effects", "general population", "hydrocarbons, chlorinated", "insecticides/blood", "pesticides", "pesticide residues", "human biomonitoring", "environmental monitoring", "human samples", "representative sample", "Stockholm Treaty", "reports", "serum", "blood", "adipose tissue", or "breast milk".

Specific chemical names were also used in conjunction with previous terms (e.g., dioxins, dichlorodiphenyltrichloroethane, dichlorodiphenyldichloroethane, polychlorinated biphenyls, hexachlorobenzene, hexachlorocyclohexane). Both printed and electronic media were searched; we hence looked for reports in the web pages of environmental and health ministries and agencies, related organizations, and surveillance programs of many countries and institutions worldwide. Although some studies analyzed POPs concentrations on substantial numbers of people, studies were excluded if their population was mainly occupationally exposed, had suffered an accident and or was some other specific population that did not stand as representative of the general population. Also outside the scope of the paper fell etiologic studies on POP effects, even though some of them provide useful estimates of concentrations in the population.

## Chemical pollution: Effects in health and environment

As distinguished, health is defined in the World Health Organization's Constitution [10] as *a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*. Also according to the WHO [11], *environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial processes in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially adversely affect the health of present and future generations.*

Chemicals that resist degradation in the environment, bioaccumulate in body tissues of organisms and demonstrate inherent toxicity to organisms in the environment or humans are of special concern when taking into account chemical impacts on the environment and human health. As these substances stay in the environment for a long time and are easily taken up by organisms, there is a risk of long-term adverse effects in environmental organisms and ecosystems and also in humans (table 1).

Emergent chemical concerns are specially related with POPs, because in this category are included all of the toxins that resist degradation, persist in the environment, bioaccumulate as they pass through a food web, and pose significant health threats to organisms which may ingest them [12, 6]. Additionally in the air-water interface, which accounts about the 70% of the Earth surface, take place many vital processes that determine the role of the oceans as a sink and as a reservoir of POPs. However the interpretation of these processes encounters difficulties because of the lack of measurements in the remote oceanic areas, and the lack of understanding of

**Table 1.**
**Criteria for identification of POPs**

| Property | Criteria for definition as POP | |
|---|---|---|
| Potential for LRAT | Vapour pressure < 1000 Pa | and |
| | Half-life in air > 2 days | or |
| | Presence of the substance in remote regions | |
| Persistence | Half-life in water > 2 months | or |
| | Half-life in soil > 6 months | or |
| | Half-life in sediments > 6 months | |
| Bioaccumulation | $\log k_{ow} > 5$ ($k_{ow}$: partition coefficient octanol-water) | or |
| | BCF > 5000 (BCF: Bioconcentration factor) | or |
| | Evidence of high toxicity | |

*LRAT: long range atmospheric transport

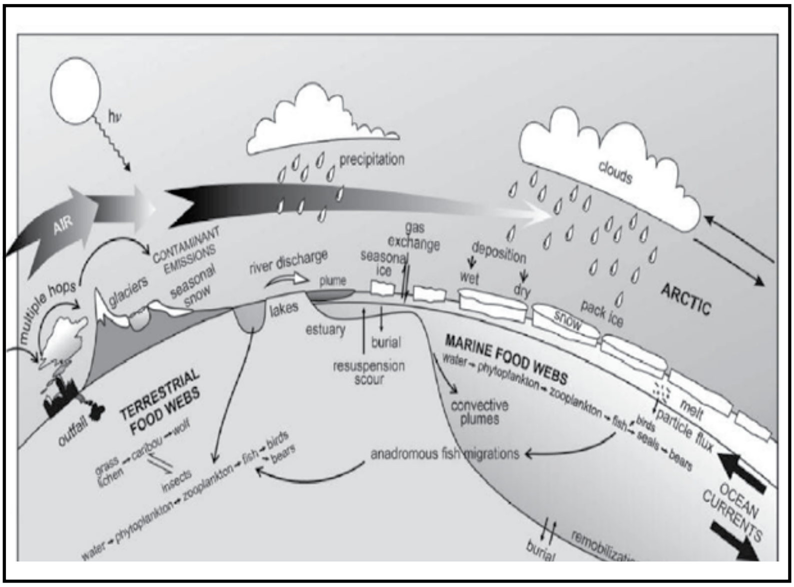
Source: based on Zarkera & Kerrb [1].

the dominant mechanisms at different spatial and temporal scales.

They have been detected in all the environmental compartments, even in remote areas like open ocean and polar regions, where POPs have been never manufactured or used [13]. In that way, atmospheric transport has been suggested as the main route dispersing these semivolatile compounds thousands of km away from industrialized and densely populated areas [9]. POPs, also termed by Persistent Bioaccumulable Toxic chemicals (PBTs), are bioaccumulable compounds of prolonged environmental persistence and susceptible to long-range atmospheric transport (figure 1).

Uptake and retention of essential nutrients, including vitamins, minerals and amino acids,

**Figure 1.**
**Schematic drawing showing major transfers of POPs in the environment**




Source: based on Rice [6].

occur through bioaccumulation pathways; however, when harmful chemicals enter these pathways and are accumulated in an organism, death or other effects on reproduction or growth may result. For example, a predator must consume many food items in its lifetime, and because POPs tend to become concentrated in animal fats, predators usually accumulate more POPs than are present in their prey. This process is repeated at each successive stage of the food chain, with higher predators consuming increasingly tainted prey.

Within pollutants class, those considered the most dangerous - are the dirty dozen - that the United Nations Environment Program - UNEP- aims to regulate internationally under the Stockholm Convention are: PCBs, dioxins, furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene and heptachlor [14]. Most of these chemicals are pesticides; others are industrial by-products, flame retardants or additives in consumer products like plastics. All have been widely banned or restricted for more than twenty years and yet all appear ubiquitously in the environment (table 2).

## Safety trends: Pollutants Risk Assessment

Some worry that current practices and legal frameworks are not adequate to protect against pollutants exposition, with are being spread in many places. Today we are facing with preoccupations inserted in the environmental context which had as base the environmental assessment and their guidelines, where is possible detach, especially, the sustainable development and of the precautionary principle [15], that were transformed in essential tools and support for environmental analyses.

The regulation of chemicals is usually preceded by the process of risk assessment, where the potential hazard of a chemical is regarded in relation to its estimated, possible exposure to man and to the environment. The resulting regulation may range from various degrees of risk management to prohibition of use. The regulation of a chemical is partly dependent on its toxic properties, as can be determined by test systems designed to identify such effects [8, 9]. Today, a limited number of POPs have been regulated to varying degrees, but doubts have been raised about the sufficiency of current risk assessment practices in appointing which individual chemicals need to be restricted.

Pereira [16] suggested that the use of persistent and bioaccumulating chemicals should be generally restricted, because when problems are identified exposure cannot be easily reduced by discontinuing production, and discontinuation of their production and use will not alleviate the situation for a long time for those already exposed. The requirement of knowledge of toxicity of POPs impedes the possibility to take precautionary action. Complements detaching that knowledge of the possible toxicity of PB chemicals may be restricted both by limitations in the existing test systems addressing toxic effects, considering only toxic mechanisms known today, and by the scarcity of toxicity data for a large number of chemicals, since it is not possible to completely absolve a substance from possible toxic effects. There is always a residual risk of e.g.: (i) overlooked and unforeseeable effects, (ii) effects in a more sensitive system than that studied, (iii) additive effects, (iv) synergistic effects, and (v) chronic low-dose effects.

Taking in account the imminent danger with bioaccumulative and persistent substances, becomes clear be is essential that environmental risk assessment studies be conducted,

**Table 2.**
**Priority and potential POP candidates**

| Banned substances in the Stockholm convention | Banned substances in LRTAP POPs protocol | Potential candidates[1] | Other dossier in progress |
|---|---|---|---|
| Aldrin | DDT | Hexachlorobutadiene (Netherlands) | Dicofol (Netherlands) |
| Chlordane | DDT in Dicofol | Pentabromodiphenyl ether (Finland/Sweden) | Short-chain Chlorinated parafines (Canada) |
| Toxaphene | Heptachlor | Pentachlorobenzene (Netherlands) | Pentachlorophenol (Poland) |
| Dieldrin | Lindane | Polychlorinated naphthalenes (Netherlands) | |
| Endrin | Polychlorinated Terphenyls | | |
| Heptachlor | Ugilec | | |
| Mirex | | | |
| PCBs | | | |
| HCBs | | | |
| PCDD/Fs | | | |
| DDT | | | |

[1] Rapporteur countries are given in brackets

Source: Based on Zarkera & Kerrb [1].

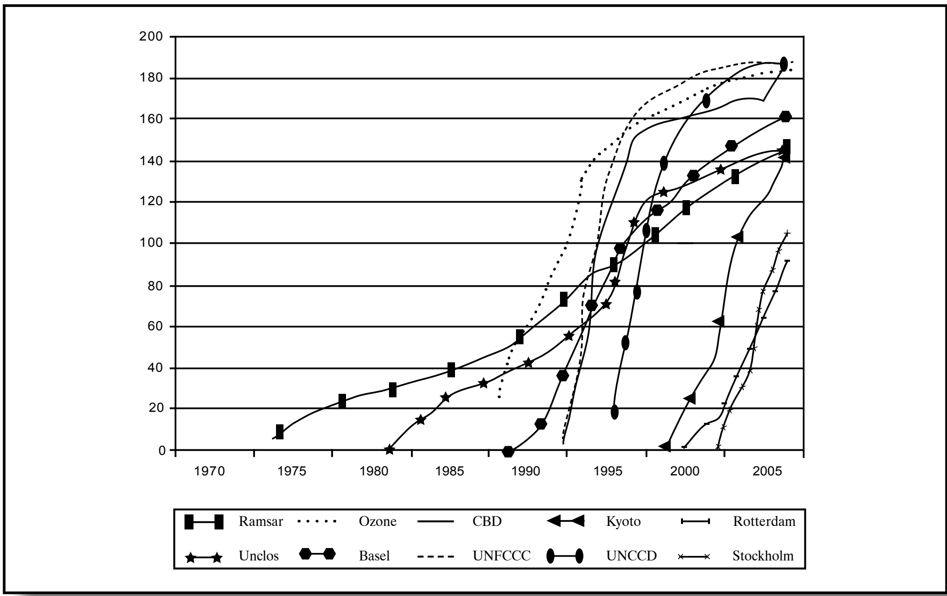
with protocols and methodologies agreed on at national and international levels. These questions that are denoted in *figure 2* which expresses a consolidate of many environmental agreements in the last thirty years.

## Discussion and Conclusion

In many countries POPs are still used for agricultural and disease vector control, as well as for industrial purposes. There are countless facts that take us to affirm that, in these countries the stockpiles of obsolete POPs create significant problems that are compounded by municipal-waste burning on open sites. When this waste is burned at low temperatures, it produces significant quantities of polychlorinated dioxins and related chemicals. Recent surveys indicate that such activities lead to local, regional and widespread global contamination. Studies show that alarming levels of POPs are present in the environment as well as in human beings.

Many of the existing methods for the measurement of POPs, in particular dioxins and furans, are highly technical and relatively expensive, involving sophisticated instruments and special chemicals. Because laboratories in developing countries often do not have the required equipment, they often find it difficult to detect and measure these chemicals in their environment. The high cost of analysis is another significant barrier to routine monitoring. Moreover, because many of the pollutants are present in ultra-low levels in the environmental samples, large number of samples must often be collected, parti-

**Figure 2.**
**Multilateral Environmental Agreements, Follow-Up from 1970–2005**




Source: calculation of the author, 2007

cularly from the marine environment. This means that the pollutants are also difficult to quantify.

According to Scott [17], there are two views of the relationship between health and development, each correct but each also very different. One view is that life expectancy improves with increases in per capita income. The other is that economic growth is helped by improvements in public health. Two examples may suffice to emphasize the importance of improvements in health to development: (i) the decline in mortality over the past century, and (ii) the contrast between the rich and poor countries.

One of the greatest events of human history had a variety of causes: improvements in nutrition, public health, and personal hygiene, decontamination of foot and water, improved housing, and advances in technology. The contrast between the rich and poor countries today is striking, but so is the contrast between the rich countries today and these same countries one-to-two centuries before. Of course, poor countries today have an advantage over the rich countries of yesterday: the availability of technologies like vaccines, antibiotics, and drugs, not to mention knowledge of the causes of disease. But the ecological circumstances of poor countries today are very different, and as we shall see, the challenge is not just to bring the technologies developed for the rich countries to the aid of the poor.

In contrast to ordinary development assistance, the supply of global public goods yields benefits both to developing and industrialized countries. If industrialized countries gain enough from a public good, they may be willing to finance its supply for their own benefit, even though doing so also aids developing countries [18].

It is increasingly outdated and unacceptable to think that humanity has to choose between economic growth and environmental protection. Without environmental security, economic growth is not sustainable. Advanced engineering, management concepts, and a better educated market are making it profitable to synergistically further economic growth and a healthy environment. Environmental security continues to move up on national, regional, and international agendas due to increasing scientific evidence of climate change, extreme weather events, the number and intensity of natural disasters, pollution, potentials for pandemics, and nuclear-biological-chemical threats.

The challenges confronting humanity are increasingly transnational, transdisciplinary, and transinstitutional. They cannot be fully addressed by any government or institution acting alone. They require collaborative action among governments, international organizations, corporations, universities, Non-governmental Organizations, and individuals. Global futures research should draw on all these sources and not be too attached to any one of them. It is imperial the maintenance of the life.

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