PERSISTENT ORGANIC POLLUTANTS IN HUMANS AND WILDLIFE: EMERGING ISSUES FOR ENVIRONMENTAL AND PUBLIC HEALTH

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ABSTRACT
Persistent organic pollutants persevere in the environment for a long time, are toxic to humans and/or wildlife, and have a resilient propensity to bioaccumulate in the food chain. Due to its chemical stability, their lipid solubility, and its ubiquitous prevalence in environmental, these pollutants are disposed to long-range transport. The success of modern societies is in part based on extensive achievements of chemistry with a systematic development of products in medicine, agriculture, and in almost all manufacturing industry sectors and materials for daily use. Although, these chemicals unequivocally contribute to the quality of life for billions of human beings, however, the negative impacts to environment and health are an important issue for ostensible monitoring. Social and environmental benefits should not be ignored, in spite of economic forces.The recognition that prevention is the best method to mitigate the risk of diseases to public health related to the environment, mainly driven by technological development, becomes essential the individuation and quantification of toxicological endpoints for systematic monitoring of these emerging pollutants.
Keywords: Pollutants; Environmental health; Exposure; Public health.

RESUMO
Os poluentes orgânicos persistentes perseveram no ambiente por um longo tempo, são tóxicos para os seres humanos e / ou animais, e têm uma propensão resiliente a bioacumulação na cadeia alimentar. Devido à sua estabilidade química, a sua solubilidade lipídicae sua prevalência ubíqua no ambiente, estes poluentes são transportados a longa distância. O sucesso das sociedades modernas é, em parte, com base em extensas conquistas da química com um desenvolvimento sistemático de produtos em medicina, agricultura, e em quase todos os setores da indústria de manufatura e materiais para uso diário. Embora estes produtos químicos contribuam inequivocamente para a qualidade de vida de bilhões de seres humanos, no entanto, os impactos negativos ao meio ambiente e à saúde devem ser uma questão importante de monitoramento ostensivo. Interesses sociais e ambientais não devem ser desconsiderados, apesar das forças econômicas. O reconhecimento de que a prevenção é o melhor método para reduzir o risco de doenças para a saúde pública relacionados ao meio ambiente, impulsionado principalmente pelo desenvolvimento tecnológico, torna-se fundamental a individualização e quantificação de parâmetros toxicológicos para um monitoramento sistemático desses poluentes emergentes.
Palavras-chave: Poluentes; Saúde ambiental; Exposição; Saúde pública.

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INTRODUCTION

A Present time is marked with growing attention to environmental issues of persistent organic pollutants (POPs). POPs are defined as compounds with high toxicity, stability in environment, ability to migration in food chains and high bioaccumulation potential [1-6]. This create the necessity of strict criteria development for POPs emissions [7] and accumulation limits in the environment [8-10] and human body [2,3,11-13].

The success of modern societies is in part based on extensive achievements of chemistrywhere a systematic development of products occurs in medicine, agriculture, in almost all manufacturing industry sectors and materials for daily use [14]. Chemistry, in a general sense, contributes to the quality of life for billions of human beings [15]. However, the negative impacts to environment and to healthare an important issue of public concern[7]. Social and ecological interests should not be disregardedin spite of the economic forces.

Annual world production of chemicals has increased from around 7 million tonnes per year in the 1950s to 400 million tonnes in the last few years [16]. The number of commercially produced substances is not precisely known, although the upper possible limit is estimated to be about 100,000[17]. Related to the increasing production ofthe chemical industry, it is imperative to improve regulation of substancesthat have been proved or suspected to cause adverse effects to human and environmental health[3,11,13]. These substances were launched in the consumer market, domestic or industrial, with no restrictions or no knowledge of the environmental impacts of medium and long term[18,19]. Thus, we are in touch with a large number of substances whose effects are unknown [10]. Moreover, these substances may react with each other, generating new chemicals, which even less knowledge exists [20]. The existence of any additive and synergetic effects among these substances is real possibilities, while generating controversy, being widely investigated.

Many chemical substances of natural or anthropogenic origin are suspected or known to be endocrine disruptors, also considered POPS, which can influence the endocrine system of life[21]. These chemicals in its variety encompassing many classes as drugs, pesticides, compounds used in the plastics industry and in consumer products, industrial by-products and pollutants, and even some naturally

produced botanical chemicals[22-25]. Some are pervasive[26,27], widely dispersed in the environment[27] and may bio-accumulate[29-32]. All people, in general, are exposed to chemicals with estrogenic effects in their everyday life[21,31], because endocrine disrupting chemicals are found in low doses in thousands of products[28]. Among others, endocrine disruptors commonly detected in human analysis include dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), bisphenol A (BPA), polybrominateddiphenyl ethers (PBDEs), and a variety of phthalates[33].

The possibility that some chemicals may disrupt the endocrine system in humans and animals has receivedconsiderable attention in the scientific and public community. These disruptions can cause cancerous tumors, birth defects, and other developmental disorders[34]. As shown in figure 1, endocrine disruptors, specifically, may cause learning disabilities, severe attention deficit disorder, cognitive and brain development problems; deformations of the body; breast cancer, prostate cancer, thyroid and other cancers; and sexual development problems such as feminizing of males or masculine effects on females[28,33-35].

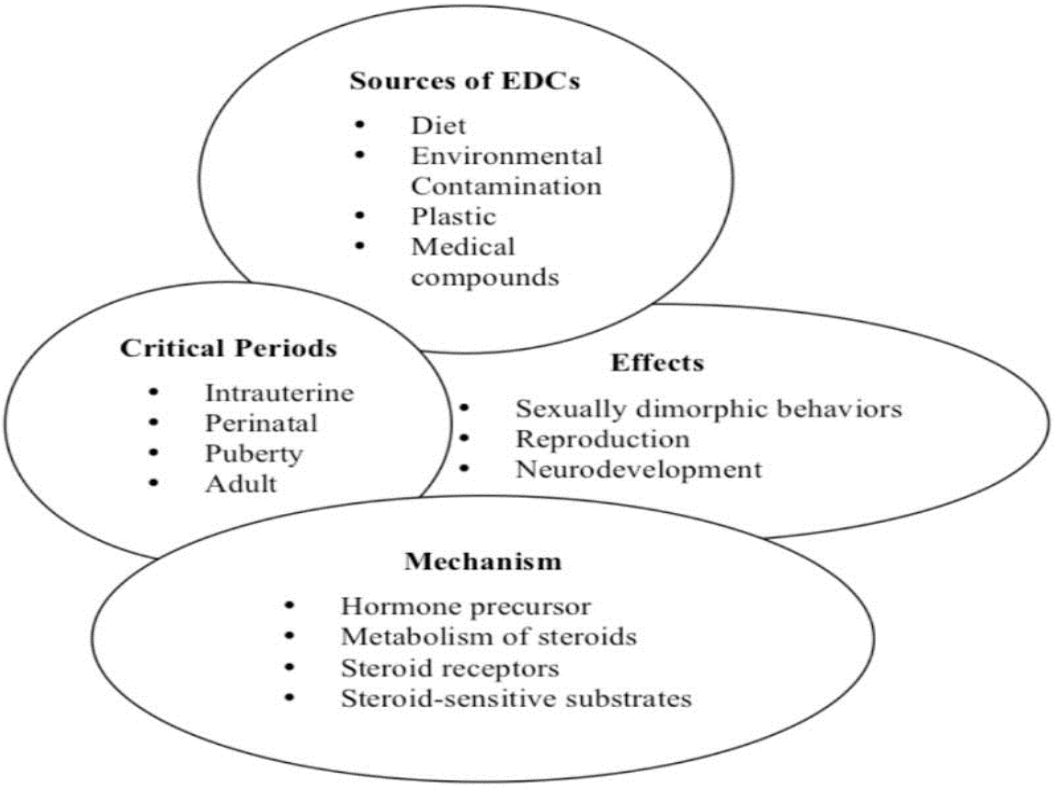

Figure 1. Endocrine disrupters (EDCs): a schematic diagram denoting sources, effects, critical periods, and mechanisms of actions[28].

This article is proposed to provide an overview of today's regulation of POPs management in accordance to the requirements of the Stockholm Convention.POPOS' levels in the environment were discussed with the objective to demonstrate the importance of monitoring generate data in order to control and minimize the environment contamination and the health impacts to humans. It will also address the question of whether proven toxicity is a necessary prerequisite, before regulatory action is decided against these chemicals.

METHODS

The aim of the literature search was to identify all studies that analyzed the concentrations of POPsdistribution in a representative sample of the general population. All countries and regions worldwide were eligible for inclusion. Articles published in the academic literature were eligible as, for example, reports from Governmental and Nongovernmental Organizations, that 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

POPs concentrate in the human body and in eco-systems and can cause serious long-term health effects[1,6]. They can most severely impact those who work or live where POPs are used or produced and who are directly exposed through inhalation, dermal contact and ingestion[36]. The main human exposure pathway to POPs, however, is from general environmental exposure to POPs that is caused by eating fish, meat and dairy products that have been contaminated by POPs in the environment[37].

The water resources quality is perhaps currently the most discussed topic when it comes to environmental preservation, since aquatic ecosystems have been suffering changes worldwide in most cases irreversible. Such changes are often associated with human activities such as deforestation, release of industrial and domestic effluents, and even the use of pesticides in agricultural fields, which is one of sources that most contributes to the reduction of environmental quality [38]. According to Botelho et al.[39], currently, based on the data from National Health Surveillance Agency40, Brazil is one of the major pesticide consumers in the world and has the largest market for these products with 107 companies authorized to register this compounds, responding for 16% of the world market. According to the sales in Brazil, only in 2010, the industry negotiated 342,590 tons of active ingredients and it is clear that this number is increasing in recent years (figure 2).

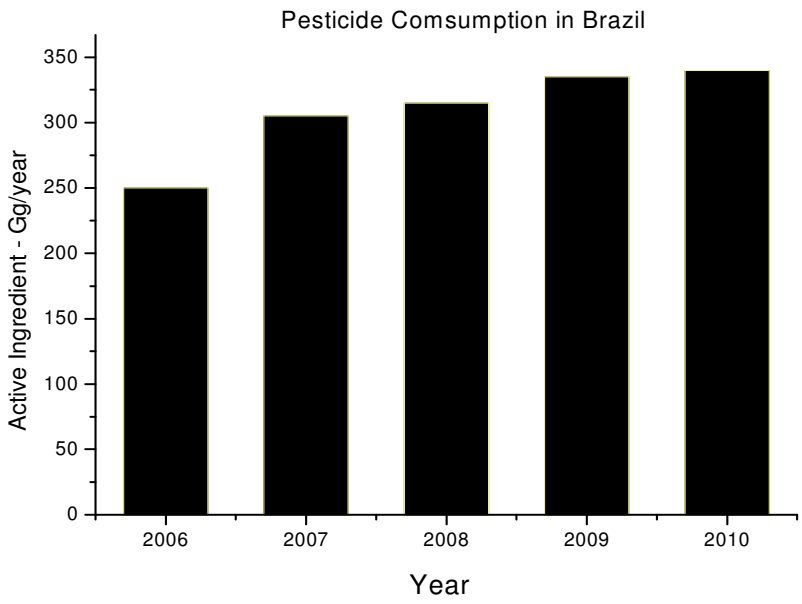

Figure 2. Pesticide consumption in Brazil, in gig grams of active ingredient, in the period of 2006 – 2010[39].

Few countries extensively monitor the POPs content of their food supply, and most never do[41]. Even POPs pesticides that have been banned for decades show up consistently in food5. A healthy inhabitant needs a healthy environment. Even though humans have been conscious of this vital relationship, there has still been a propensity to separate these two fields: to study health issues disregarding environmental factors.However, poor environmental quality is responsible for up to 30% of all preventable illness[42].

As notable, health is defined by the World Health Organization (WHO) Constitutionas a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity[43]. According to the WHO[44], environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial processes. In addition, it refers to the theory and practice of assessing, correcting, controlling, and preventing environmentalfactors that potentially can adversely affect health of the present and future generations. On the other hand, environmental health is poorly defined, hardly ever quantified and valued: the higher the anthropogenic influencesto the environment, the closer the relationship between health and environment[7,11,12].

In the last twenty years, emergent chemical concerns are specially related to

POPs since they are considered to pose significant health threats to organisms by exposure [45]. POPs can enter the water bodies principally by wet and dry precipitation, urban and agricultural runoff, domestic and industrial effluents [46]. Effluents are considered the only source to aquatic environment that can be controlled by wastewater treatment plants.Additionally,many vital processes take place in the air-water interface and determine the role of the oceans as a sink and a reservoir of POPs. This interfaceis estimated to be around 70% of the earth surface.However, the interpretation of these processes encounters difficulties mainly due to the lack of measurements in the remote oceanic areas, and complete understanding of the dominant mechanisms at different spatial and temporal scales.

What are Persistent Organic Pollutants (POPs) and how it can affect human and environmental health?

POPs can be found far away from industrialized and densely populated areas, throughout the world due, to the potential for long range transport –potential to travel great distances from the source of release through various media (air, water, and migratory species). In that way, atmospheric transport has been suggested as the main dispersing route for these semi volatile compounds [5]. They have been detected in all environmental compartments, even in remote areas such as the open ocean and polar regions, where POPs have been never manufactured or used [2]. In addition, they have low aqueous but high lipid/organic solubility which results in high bioaccumulation in lipids – the ability to accumulate in living tissues at levels higher than those in the surrounding environment - and biomagnification through food chains[6,20,47].

Studies of how individual POPs disrupt ecosystems are difficult because eco-systems and wildlife are generally exposed to multiple POPs at the same time. The effects caused by a given POP may vary according to the animal species, age and gender and the level, extent and duration of exposure. The effect of exposure on an individual organism is also critically influenced by the timing of the exposure relative to the organism's life cycle. There may also be a time delay between exposure and onset of effects. Abnormalities may occur in the second or third generation offspring.

Ecosystem balance can also be negatively impacted by POPs. For example

when POPs pesticides are used, they not only kill the organisms for which they are intended, but also kill beneficial insects, birds, fish and other organisms as well [39]. Extensive pesticide use creates resistance, leading to altered ecological equilibrium and threatens wildlife habitat and the survival of endangered species, for example, amphibians, pacific salmon, sea turtles and bald eagles[48].

POPs are pesticides, industrial chemicals or unwanted by-products of industrial processes or combustion.They are characterized by persistence – the ability to resist biological and physical-chemical degradation in air, water, sediments and organisms[1,11]; once in the environment they recycle and partition between the major environmental media occurs (figure 3).

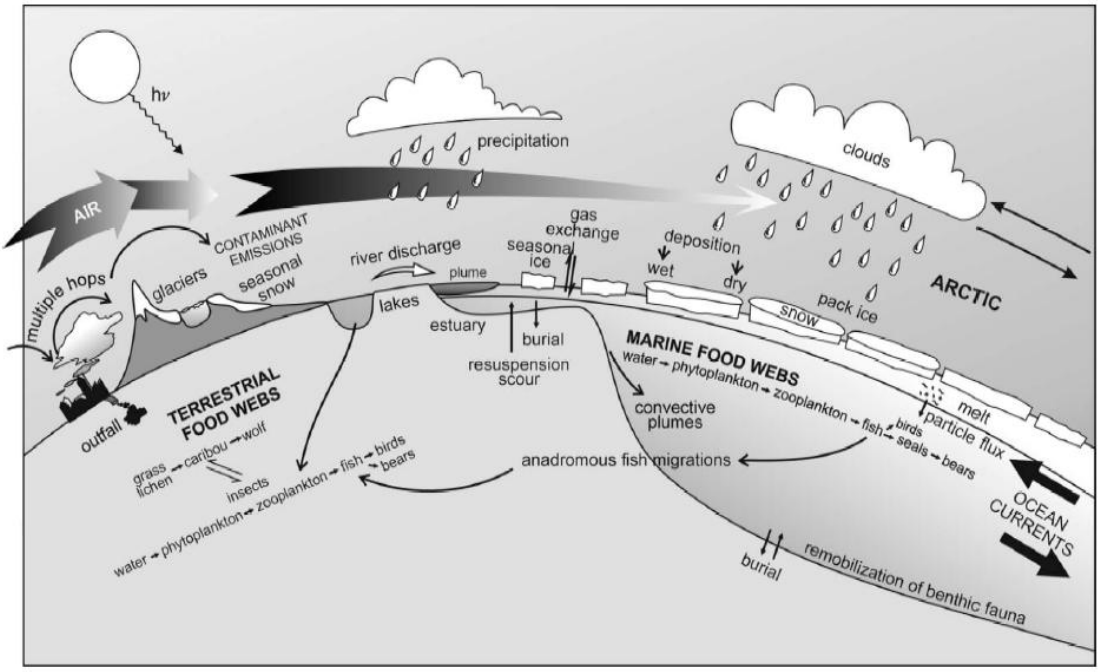

Figure 3. Major transfer pathways of POPs in the environment[2].

Considering environmental and health problems, the scientific community has been giving special attention to POPs and it is an excellent example of the adoption of chemical safety. Due to their persistence and capacity to accumulate in living organisms and cause health impacts, an international treaty was established to control these substances in order to minimize/eliminate their release to the environment[16]. The environmental management and control of POPs is addressed at a global level through the Stockholm Convention. This international treaty aims to protect environment and human health from adverse effects associated with

exposure to persistent organic pollutants. The Stockholm Convention is a multilateral environmental agreement that establishes the commitment of signatory Parties to protect human health and the environmental from the risks posed by POPs. 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 [49]. 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 1).

Table 1. Priority and potential POP candidates

Banned substances in the Stockholm convention	**Banned substances in LRTAP POPs protocol**	**Potential candidates[#]**	**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			

Source: Stockholm Convention, 2009[49] *Rapporteur countries are given in brackets*

Based on the risk profile, taking into account its long-range environmental transport, other chemicals that is likely to lead a significant adverse human health and/or environmental effects can also be considered as a POP and global action is warranted.Pentabromodiphenyl ether, chlordecone, hexabromodiphenyl, lindane, perfluorooctanesulfonate, octabromodiphenyl ether, pentachlorobenzene, alpha- and beta- hexachlorocyclohexane are the newly reviewed chemicals to be included in the list of the Convention. Short chained chlorinated paraffins, endosulphan and hexabromocyclododecane are still under review♦. Some characteristics are inherent to each substance and essential to be considered as a POP (table 2).

Table 2. Criteria for the 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: Zarkera & Kerrb modified [14].

Safety trends: Pollutants risk assessment

The current practices and legal frameworks are not always adequate to protect the populations against exposure to chemical substances due to their wide distribution in the environment.There is a clear need to evaluate a large numbers of potentially toxic chemicals in the environmental context as base for the environmental assessment and their guidelines, in accordance to the sustainable development and the precautionary principle, essential tools for environmental analyses [13].

The regulation of chemicals is usually preceded by the process of risk assessment, where the potential hazard of a chemical is related to its estimated potency of exposure to man and impacts to the environment. The resulting regulation

♦ http://chm.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/language/en-US/Default.aspx

may range from various degrees of risk management even though to its prohibition of use. The regulation of a chemical is partly dependent to its toxic properties, as determined by many toxicological tests designed to identify such effects [5,50]. Today, a limited number of POPs have been regulated, but doubts are raised about the sufficiency of risk assessment practices in appointing which individual chemicals need to be restricted.

Pereira [3] suggested that the use of persistent and bioaccumulating chemicals should be generally restricted.Identified exposure cannot be easily reduced by only discontinuing the production or use. It will not exclude the burden of those already exposed for a long time. The requirement of knowledge of toxicity of POPs impedes the possibility to take precautionary action. The possible toxicity of PB chemicals may be restricted both by the limitations in the existing test systems addressing toxic effects, that considers only the known toxic mechanisms, and also by the scarcity of toxicity data for the major number of chemicals, since it is not possible to completely absolve a substance from its 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 ofbioaccumulative and persistent substances, it becomes clear that environmental risk assessment studies should be conducted, with protocols and methodologies agreed on national and international levels.

CONCLUSION

Many countries, which are parties to the Stockholm Convention, have established a foundation for chemicals management through regulatory instruments that support compliance with Convention obligations. The current legal framework for POPs, at the national level, will need to be reviewed to addresses adequately the obligations resulting of listing new POPs. If necessary, this framework will need to be updated and appropriate develop policy instruments, including non-regulatory approaches.

In many countries, POPs are still used for agricultural and disease vector

control. In these countries, the stockpiles of obsolete POPs create significant problems to environmental health. Additionally, municipal-waste burning on open sites can be considered anotherexample. When waste is burned at low temperatures, it produces significant quantities of polychlorinated dioxins and related chemicals. Such activities lead to local, regional and widespread global contamination.

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 of this, 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 analysis cost is a 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, particularly from the marine environment. This means that the pollutants are also difficult to quantify.

There are two points of viewon the relationship between health and development, each correct but 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 be adequate 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 food 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 have the advantage over the rich countries of yesterday: the availability of technologies like vaccines, antibiotics, and drugs, not to mention knowledge of disease causes. Nevertheless, 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, 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

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.Maintenance of life is imperative.

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