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STUDY ON THE INTERLINKAGES BETWEEN THE CHEMICALS AND WASTE MULTILATERAL ENVIRONMENTAL AGREEMENTS AND BIODIVERSITY

Secreatariats of the Basel, Rotterdam and Stockholm Conventions and the Secretariat of the Minatmata Convention

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ABBREVIATIONS AND ACRONYMS

AMAP	Arctic Monitoring and Assessment Programme
ASGM	Artisanal and small-scale gold mining
BFR	Brominated Flame Retardant
CBD	Convention on Biological Diversity
CEE	Central and Eastern Europe
COP	Conference of the Parties
DDD /DDE	Metabolites of DDT
DDT	Dichlorodiphenyltrichloroethane
Deca-BDE	Deca-bromodiphenyl ether
dl-PCB	Dioxin-like PCB
EDCs	Endocrine Disrupting Chemicals
ESM	Environmentally Sound Management
FAO	Food and Agriculture Organization of the UN
GAPS	Global Atmospheric Passive Sampling
GEF	Global Environment Facility
GEMS	Global Environment Monitoring System
GMP	Global Monitoring Plan
HBCD	Hexabromocyclododecane
HCB	Hexachlorobenzene
HCBD	Hexacholorobutadiene
HCHs	Hexachlorocyclohexanes
Hg	Mercury
IFCS	Intergovernmental Forum on Chemical Safety
IMO	International Maritime Organization
IPBES	Intergovernmental Panel on Biodiversity and Ecosystem Services
LRT	Long-Range Transport
LRTAP	Long-Range Transboundary Air Pollution
MEA	Multilateral Environmental Agreement

MeHg	Methylmercury
NCP	Nature’s Contributions to People
OCs	Organochlorines
OCP	Organochlorine Pesticide
OECD	Organisation for Economic Co-operation and Development
OCP	Organochlorine pesticide
OHC	Organohalogenated Contaminant
OP	Organophosphate
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofuran
PCP	Pentachlorophenol
PeCBz	Pentachlorobenzene
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PIC	Prior Informed Consent
POPs	Persistent Organic Pollutants
PVC	Polyvinylchloride
SAICM	Strategic Approach to International Chemicals Management
SCCPs	Short-chain Chlorinated Paraffins
SDGs	Sustainable Development Goals
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UNITAR	United National Institute for Training and Research
WHO	World Health Organization

The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the 1998 Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade, the 2001 Stockholm Convention on Persistent Organic Pollutants, and the 2013 Minamata Convention on Mercury all aim at protecting human health and the environment from hazardous chemicals and wastes.

The preparation of this exploratory study was inspired by ongoing discussions of a post-2020 global biodiversity framework and illustrates the interlinkages between the work of the above four chemicals and waste conventions and the subjects preoccupying the Convention on Biological Diversity (CBD) and other biodiversity-related conventions, thereby positioning the four conventions to contribute to ongoing discussions and the implementation of the post-2020 global biodiversity framework, and future work of the CBD and other biodiversity-related instruments.

I. Key 'linkages' to global sustainable development processes

At the 2002 World Summit on Sustainable Development (WSSD) governments agreed to "achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment […].".

The Basel, Rotterdam, Stockholm and Minamata conventions contribute to this goal through their specific and individual legal mandates. In addition, the non-binding Strategic Approach to International Chemicals Management (SAICM), has also aimed at the 2020 goal by focusing on important chemicals and waste issues not covered by the above multilateral environmental agreements (MEAs), and is currently in the process of considering its beyond-2020 objectives, structure and targets. The United Nations Environment Assembly (UNEA), which is the governing body of the United Nations Environment Programme (UNEP), also provides leadership on chemicals issues and the interlinkages with other areas of UNEA and UNEP endeavours, such as biological diversity.

Despite these and other collective efforts, UNEP's 2019 Global Chemicals Outlook II concluded that the WSSD 2020 goal will not be achieved.

In 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, with 17 Sustainable Development Goals (SDGs). The Basel, Rotterdam, Stockholm and Minamata conventions are contributing to the achievement of a number of the SDGs adopted by the United Nations General Assembly in 2015 through the achievement of their own objectives, aided by their own internal strategic frameworks and effectiveness evaluations.

The sound management of chemicals and waste is an enabler to many of the SDGs, starting with SDG 12 on sustainable consumption and production. Of 196 targets and 30 indicators under the SDGs, around 69 targets and 91 related indicators have been cited to be relevant to chemicals and waste. The Implementation Plan of the UN Environment Assembly's Towards a Pollution-Free Planet aims to accelerate and scale up action to reduce pollution and to support countries in implementing the 2030 Agenda and achieving the SDGs through existing MEAs and other international initiatives.

In its 2019 Global Assessment Report on Biodiversity and Ecosystem Services, the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) noted that SDG Target 12.4 on waste management is an area likely to have many positive implications for nature and nature's contributions to people as well as a greater quality of life for all people. The report considered that waste, through its impacts on air and water quality, has negative impacts on wellbeing, especially in poor and vulnerable communities. This target relates closely to SDGs 6, 14, and 15, as well as aspects of SDGs 3 and 11, in terms of trends in pollution and its impacts on health and the environment.

The 1992 Convention on Biological Diversity (CBD) is part of a cluster of biodiversity-related MEAs that includes, among others, its Cartagena Protocol on Biosafety and Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. The CBD is now leading the preparation of a post-2020 global biodiversity framework, with targets for 2030, aimed at ultimately achieving its 2050 vision of Living in Harmony with Nature, as mandated by CBD COP decision 14/3.

This study outlines the specifics of the above four chemicals and waste conventions and how through regulations on chemicals and waste management they contribute to the conservation and sustainable use of biological diversity and the services provided by ecosystems, most recently called “nature’s contributions to people” (NCP) by IPBES in its 2019 Global Assessment Report.

II. Pollution one of the main drivers of biodiversity loss

Pollution is one of the main drivers of biodiversity loss. The Strategic Plan for Biodiversity 2011-2020, adopted under the CBD and acknowledged by other multilateral processes, includes a specific target on pollution. Aichi Biodiversity Target 8 calls for pollution, including from excess nutrients, to be brought to levels that are not detrimental to ecosystem function and biodiversity by 2020. While most of the reporting on this target has focused on excess nutrients, the study highlights other important pollutants regulated by the Basel, Rotterdam, Stockholm and Minamata conventions, whose management can result in improvements to the state of biological diversity and nature’s contributions to people. The most recent UN report on progress under the Aichi Targets, the Global Biodiversity Outlook 5 (GBO-5), concluded that this target has not been achieved.

Given the many benefits of chemicals to humanity, for example in consumer products, industry and medicine, it is not surprising that society is currently amid an intensification of the production, distribution and use of chemical-based products around the globe. The production, use and trade of chemicals is growing in all regions of the world, driven by global megatrends such as population and increasing consumption. Global sales in chemicals were worth approximately 3.5 trillion USD (including pesticides but excluding pharmaceuticals) in 2017 and chemicals production is expected to double in size between 2017 and 2030. However, hazardous chemicals and other pollutants (e.g. endocrine-disrupting chemicals and pharmaceutical pollutants) continue to be released in large quantities and are ubiquitous in humans and the environment. The global waste market has become a viable economic sector, estimated at USD $410 billion per year, from collection through to recycling—yet only about one-third of the world’s municipal solid waste is properly managed, and much of that is increasingly hazardous. Marine litter, including plastics and microplastics, is now found in all oceans, at all depths.

It is within this setting that the four conventions and their contributions to, and interlinkages with, biological diversity and nature’s contributions to people are investigated in this exploratory study.[1] The study also identifies challenges and emerging issues in the four subject areas below.

Mercury and Biodiversity

Mercury is a highly toxic heavy metal that poses a global threat to human health and the environment, persists in the environment and bioaccumulates and biomagnifies in the food chain. Together with its various compounds, it causes a range of severe health impacts, including damage to the central nervous system. Exposure to mercury occurs mainly through ingestion of fish and other marine species contaminated with methylmercury (MeHg), through inhalation of mercury vapour during occupational activities or spills, or through direct contact from mercury use. Mercury is transported around the globe through the environment, so its emission and release can affect human health and the environment even in remote locations. Once released, mercury persists in the environment where it circulates between air, water, sediments, soil and biota in various forms, and may not be removed from this cycle for a century or more. Furthermore, due to climate change, future releases of mercury from melting permafrost could be twice the amount contained in the rest of all soils, the atmosphere and the oceans combined.

[1] The BRS Secretariat and the Minamata Secretariat have also prepared a study on the interlinkages among chemicals and waste and climate change.

Although naturally-occurring in the Earth's crust, due to its unique properties it has also been used in or released from various products and processes for hundreds of years. Over two thousand tonnes of mercury are emitted into air annually from the top 17 anthropogenic sources, with almost 38% derived from artisanal and small-scale gold mining (ASGM), and this, along with emissions from stationary combustion of coal (e.g. coal-fired power plants), contributes 60% of emissions. Estimates of releases from the ASGM sector to land and water combined are 1220 tonnes worldwide, with other sources accounting for about 580 tonnes of releases to water, with 42% of that from waste treatment (including use and disposal of mercury-added products and the disposal of municipal wastewater), 41% from ore mining and processing, and 16% from the energy sector. ASGM activities are the single biggest source of mercury releases to soil and often take place in biodiverse and sensitive ecosystems around the world.

ASGM is on the rise and is practiced in many megadiverse countries, with many of the 15-20 million miners worldwide relying on mercury to process mined gold, with possible health, environmental and ecosystem impacts on approximately 100 million people in ASGM communities worldwide. Impacts of this type of mining on biological diversity occur directly through the clearing of forests to prepare mining sites, and where mercury is used to amalgamate gold ore, the subsequent burning off and emissions into the atmosphere are deposited in the environment, with related releases to soils and in tailings leaching into nearby streams and rivers, where much of the activities take place. In the Amazon Basin, for example, ASGM activities have been documented to lead to biodiversity loss and polluted fisheries, and a number of endemic or threatened freshwater fish may be at risk from ASGM activities. In many ASGM operations, the mercury that operators use to extract gold from ore comes through trade that violates national or international laws on the import, marketing or use of mercury. Food webs in many of the world's biomes and ecosystems have MeHg concentrations at levels of concern for ecological and human health. The UN's 2018 *Global Mercury Assessment* concludes that "mercury loads in aquatic food webs are at levels of concern for ecological and human health around the world." Many species of fish and wildlife are impacted by the adverse effects of Hg on their physiology, behaviour and reproductive success. Because of biomagnification of methylmercury, long-lived piscivorous or other top predatory animals in aquatic food chains are at greatest risks of elevated dietary methylmercury exposure (e.g. tuna). Tropical ecosystems appear to be particularly sensitive to elevated methylation rates and many such ecosystems are 'megadiverse', home to many of the world's most sensitive ecosystems containing numerous species.

Atmospheric, terrestrial, and oceanic pathways deliver methylmercury to Arctic environments, distant from the source of original emission or release. Levels of mercury, (along with polychlorinated biphenyls (PCBs)), remain a significant exposure concern for many Arctic biota, including polar bears, killer whales, pilot whales, seals, and various seabird, shorebird, and birds-of-prey species. The levels of these chemicals put these species at higher risk of immune, reproductive and/or carcinogenic effects. This is complicated by the fact that Arctic wildlife and fish are exposed to a complex cocktail of environmental contaminants in addition to mercury, including legacy persistent organic pollutants (POPs), emerging chemicals of concern, and other pollutants that in combination may act to increase the risk of biological effects. The added influence of environmental factors such as climate change, invasive alien species, emerging pathogens, and changes in food web dynamics, on top of existing chemical exposures, may significantly increase the risk of health effects and population impacts.

Ecosystem services/nature's contributions to people are affected by mercury in the environment. Apart from impacts on nature's ability to regulate air and water quality, there are impacts on foods that are grown in soil or harvested from fresh and marine waters, including foods that are part of a region's culture and identity, such as rice and fish. Moreover, indigenous peoples in many areas of the world but especially groups within the Amazonian region and Inuit from the Arctic are at increased risk of mercury exposure. Many from these communities are reliant upon traditional and locally caught foods such as fish and marine mammals not only for sustenance, but as a strong basis for their culture, spirituality, recreation, and economy.

The development of the Minamata Convention on Mercury was spurred on by recognition that the significant levels of mercury in the environment from human activities required international action. It is a legally binding convention that contains provisions that regulate anthropogenic activities throughout the entire life cycle of mercury, from its primary mining through its various uses to the management of mercury as waste and management of sites contaminated with mercury. The monitoring, scientific, implementation and evaluation work is overseen by the Conference of the Parties to the Convention. In addition, the UN Environment Programme has prepared the periodic

Global Mercury Assessments, including the 2018 assessment, which provides the most recent information available for the worldwide emissions to air, releases to water, and transport of mercury in atmospheric and aquatic environments.

Persistent Organic Pollutants (POPs) and Biodiversity

Persistent organic pollutants (POPs) are human-made chemicals that persist in the environment for long periods, become widely distributed geographically, bio-accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on the environment and human health. They have been shown to have impacts on ecosystems and biota at all levels of the food chain, and also affect nature's contributions to people.

POPs are found in the environment around the globe, including close to industrial and urban settings, but also in remote locations such as the Arctic and Pacific Ocean trenches at 7-10,000 metres below sea level. Primary sources of POPs are those with direct fluxes into the environment (such as the use of industrial chemicals or pesticides, or emissions from industrial processes) and secondary sources are already contaminated environmental compartments that can release POPs subsequent to their use or production. Climate change may affect emissions of POPs by enhancing volatilisation and re–volatilisation, and lead to increased atmospheric emissions especially in remote areas, such as Alpine lakes or the Arctic. Recent research shows that the global plastics crisis is exacerbated by POPs, which are both contained in, and absorbed by, plastics circulating in the world's oceans.

Effects of POPs on the environment have been observed in a range of ecosystems. POPs are having effects in freshwater ecosystems, such as lakes and rivers, the latter often contributing POPs to coastal marine environments. Mangroves have been shown to contain a suite of chemicals, including POPs, resulting in impacts on both plants and animal biota, as well as large-scale changes in diversity, or ecosystem structure, as vulnerable populations decline as a result of exposure to chemical pollutants. Aquatic biota, including aquatic vascular plants, seagrasses, algae and other water plants, fish, crabs and mussels, are being adulterated by POPs. Effects are also being found in terrestrial species and warrant further study.

Accumulation of POPs in marine mammals, such as Baltic seals, bottle-nosed and striped dolphins and killer whales, is associated with population declines. Levels of PCBs remain a significant exposure concern for many Arctic biota, including polar bears, killer whales, pilot whales, seals and various seabird, shorebird, and birds-of-prey species. The levels of these chemicals put these species at higher risk of immune, reproductive and/or carcinogenic effects. PCB-mediated effects on reproduction and immune function may threaten the long-term viability of over 50% of the world's killer whale populations. Contaminant exposure is one of the largest threats to polar bears after loss of sea ice habitat due to climate change.

Nature's contributions to people, such as the regulation of air quality, water quality (including groundwater), coastal protection, and the formation, protection and decontamination of soils are affected by the presence of POPs. The provision of materials such as food, including for indigenous peoples in the Arctic, who are reliant on subsistence harvests as part of a traditional diet, are affected. They and others around the world are also deprived of nature's non-material contributions such as recreation, aesthetic enjoyment of nature, learning, and spiritual and social-cohesion experiences.

The 2001 Stockholm Convention on Persistent Organic Pollutants contains provisions on the prohibition and/or elimination of the production and use, import and export of listed POPs (initially 12 at time of adoption, with 30 chemicals now regulated). The Convention also regulates POPs such as dioxins and furans that are unintentionally released during industrial processes, by requiring the use of best available techniques and the promotion of best environmental practices for preventing releases of POPs into the environment. The Convention also regulates the management of POPs wastes at both the domestic level and when subject to transboundary movements, where their movement is governed by the Basel Convention. New chemicals can be added to the Convention through a process based on examination of proposals by the Persistent Organic Pollutants Review Committee, which makes recommendations to the Conference of the Parties for listing and related controls. Proposed chemicals are assessed against a number of criteria, including their impact on biodiversity. The Conference of the Parties also oversees the global monitoring, implementation and evaluation work of the Convention.

Primary emissions of the first 12 POPs listed to the Stockholm Convention (legacy POPs) are declining, and concentrations measured in air and in human populations have declined and continue to decline or remain at low levels due to restrictions on POPs that predated the Stockholm Convention and are now incorporated in it. For the POPs listed since the Convention's entry into force in 2004, such as certain brominated diphenyl ethers (BDEs) and perfluorooctane sulfonic acid (PFOS), concentrations in air are beginning to show decreases, although in a few instances, increasing and/or stable levels are observed. Based on limited data from only two regions, the levels of brominated diphenyl ethers (BDEs) and perfluorooctane sulfonic acid (PFOS) seem to be gradually declining in human tissues, but information regarding changes over time is very limited. Temporal trend information for PFOS in water is also very limited. However, where it is available, some data shows detectable concentrations of PFOS and perfluorooctanoic acid (PFOA) in nearly every region studied. Remobilization of regulated chemicals continues to be a problem, and for some chemicals e.g. PCB, PBDEs and other new POPs, emissions continue from stockpiles, continued product usage and waste disposal/dismantling/recycling practices.

Pesticides and Biodiversity

Pesticide use is a well-documented threat to birdlife, with bird populations having declined 20-25% since pre-agricultural times with one of the major causes being pesticides. Pesticide poisoning is currently the greatest threat to the Andean condor, and bald eagle populations in the USA that declined in part because of exposure to DDT.

By affecting insects and pollinators, pesticides may impact a wide range of ecosystem services. For example, while animal pollination directly affects the yield and/or quality of about 75 per cent of global food crop types, pollinators are important beyond agriculture and food production, as they and their habitats provide ecological, cultural, financial, health, human, and social values. For example, nearly 90 per cent of wild tropical flowering plant species and 78% of those in temperate zones depend, at least in part, on the transfer of pollen by animals. Pollination also maintains genetic diversity in wild plants. Pollinators also contribute directly to medicines, biofuels, fibres, construction materials, musical instruments, arts and crafts, recreational activities, and as sources of inspiration for art, music, literature, religion, traditions, technology and education, including for many indigenous people.

Declines in pollinator diversity are expected to continue globally, with adverse effects on pollinators having direct effects on agricultural yields and food supplies. Currently, 16.5% of vertebrate pollinators are threatened with global extinction, rising to 30% for island species. Pesticides are one of the drivers of this decline in addition to changes in land-use and management intensity, use of herbicides in conjunction with genetically modified crops, invasive alien species, pollinator management and pathogens, and climate change-induced range shifts--threatening both managed and wild pollinators and the services they provide.

The present scale of use of systemic insecticides such as fipronil and the neonicotinoids (one third of the sales globally of insecticides) has resulted in widespread contamination of agricultural soils, freshwater resources, wetlands, non-target vegetation, and estuarine and coastal marine ecosystems. The combination of prophylactic use, persistence, mobility, systemic properties and chronic toxicity is predicted to result in substantial impacts on biodiversity and ecosystem functioning. Fipronil and neonicotinoids are the pesticides most frequently cited as affecting pollinators, which are suffering a decline globally. Neonicotinoids have been shown to significantly reduce the reproductive capacity of male honeybees (drones), and exposed bumble bee colonies experienced a significantly reduced growth rate and suffered an 85% reduction in the production of new queens. Neonicotinoids are a significant factor in the decline of mayflies, a food chain foundational species, because they are extremely vulnerable to pesticide impacts even at very low exposure levels. Due to these facts this study focuses in part on these pesticides. This does not imply that other pesticides might not have similar negative impacts on biodiversity.

In terrestrial ecosystems, insecticides and herbicides can contaminate air, soil, water, and vegetation, including non-target organisms such as birds, fish, beneficial insects, and non-target plants. Pesticide exposure has been suggested as a contributing factor in monarch butterfly declines in the western United States. Declines in terrestrial insect abundances observed in North America and Europe of approximately 10% per decade between 1960 and 2005 were linked to pesticide use and land use changes. Flying insects in protected areas in Germany were shown to have declined by more than 75 per cent during the previous 27 years, with agricultural intensification, including pesticide use, as a plausible explanation.

Pesticide use has been linked to a reduction in aquatic plants, reduced fish egg production, and high mortality and reduced growth in amphibians. If pesticides are misused or overused, they can poison agricultural soil, reduce its resilience, and interfere with natural nutrient cycles. The diversity and functions of soil invertebrates and microorganisms are known to be affected by the use of herbicides and pesticides. Negative impacts on soil biodiversity may impact on current and future food security. Glyphosate and its degradation product AMPA[2], have accumulated in the environment and could potentially contribute to some antibiotic resistance in bacteria, such as penicillin. However, the mechanism for this resistance is not clear and further research is required, including on how this relates to the emergence of animal, human and plant diseases. Stockpiles of banned and/or obsolete pesticides have accumulated over the decades in developing countries and economies in transition, leaving a legacy of polluted soil.

Freshwater species combine to provide a wide range of critical services for humans, such as flood protection, water filtration, carbon sequestration, nutrient cycling and the provision of fish and other protein. These services are jeopardized by water pollution, including pesticide run-off. Soil biodiversity, which is affected by pesticides, is not only key to sustaining food production and other ecosystem services, but also to detoxifying polluted soils, suppressing soil-borne diseases and contributing to the nutritional quality of food.

Agriculture is a major land use covering approximately 37.5% of the planet's global land area. While the agricultural sector provides several obvious benefits to people, large-scale agriculture also puts significant pressure on biodiversity. This occurs mainly through changing land use to agriculture, certain agricultural practices and through adverse impacts of input-intensive agriculture involving pesticides and fertilizers, particularly for aquatic and soil ecosystems. Globally about one-third of all land is moderately to highly degraded due to erosion, salinization, compaction, acidification and chemical pollution of the soil, with contamination of soils with pesticide residues a major concern in intensive crop-production systems. Pollution from within agricultural production systems and beyond, including pesticides, plastics and heavy metals, urban effluent and excess nutrients, is a major cause of the decline in many populations of many important species of associated biodiversity.

Today, pesticide production is a multi-billion-dollar industry and production is steadily moving from the OECD to transitional and developing countries, and global sales have increased dramatically (USD 50 billion in 2019), although pesticide use by unit of agricultural area has remained stable. China is both the number one consumer and producer of pesticides. Consumption is next largest by the US, Brazil, Argentina and Mexico, with use increasing in a number of upper middle-income and lower middle-income countries experiencing greater growth in intensity of pesticide use.

Herbicides account for most of global pesticide use, with glyphosates used with certain genetically engineered crops (not currently regulated by either of the Rotterdam or Stockholm conventions) the largest-volume herbicides in use today. Glyphosates have been used extensively over the last several decades because it was assumed their impacts were minimal, but because they are being intensively applied, leaving increasing environmental and plant residues, questions are now being raised about their environmental and human health impacts.

Occupational exposure for farm workers results in adverse health effects, including from poisoning due to excessive exposure or inappropriate use. Trade in unidentified, fake, obsolete and banned chemicals occurs in licit and illicit markets and can contribute to such exposure. Other major routes of human and environmental exposure to pesticides are through food and water intake (e.g. pesticide residues). In addition to being regulated under the Stockholm Convention, a large number of pesticides (e.g. DDT) and industrial chemicals are regulated by the Rotterdam Convention's prior informed consent procedure.

The 1998 Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade grew out of the recognition of the dramatic growth in chemical production and trade during the previous three decades, which raised concerns about the potential risks posed by hazardous chemicals and pesticides. Countries lacking adequate infrastructure to monitor the import and use of these chemicals are particularly vulnerable. The Convention's Annex III lists pesticides and industrial chemicals that are subject to its prior informed consent procedure, which involves the provision of information to Parties through a decision guidance document about listed chemicals to facilitate the making of informed import decisions. All Parties are required to take appropriate measures to ensure that exporters within their jurisdiction comply with the decisions, among other things. The listing process involves consideration by a Chemical Review Committee, which makes listing recommendations for pesticides and industrial chemicals to the Conference of the Parties for decisions that

[2] **Aminomethylphosphonic acid** (AMPA) is one of the primary degradation products of the herbicide glyphosate.

are made on a consensus basis. Developing countries or countries with economies in transition experiencing problems with severely hazardous pesticide formulations under conditions of use in their territory may also propose these for inclusion in Annex III. Chemicals proposed for listing are assessed against a number of criteria, including their impact on biodiversity.

Hazardous Wastes and Other Wastes and Biodiversity

Today, humans extract more from the Earth and produce more waste than ever before. The best estimate of the global amount of municipal solid waste is around 2.1 billion tonnes per year with at least 33 per cent of that amount not managed in an environmentally sound manner. As the proportion of discarded chemically intensive products increases, municipal wastes are becoming hazardous wastes. Overall, hazardous waste generation increased by 50% between 2007 and 2015, mainly due to growth in countries with lower-middle and higher-middle income. The total amount of hazardous waste generated was estimated to be 390-94 million MT in 2015. Waste, through its impacts on air and water quality, has negative impacts on wellbeing, especially in poor and vulnerable communities.

Electrical and electronic waste (e-waste) is one of the fastest-growing waste streams due to consumer demand, perceived and planned obsolescence and rapid changes in technology, among other things. In 2019, it was estimated that 53.6 million tonnes (Mt) were generated globally, up by 9.2 Mt since 2014, and is expected to grow to 74.7 Mt by 2030. The e-waste pollution problem disproportionately affects developing countries, where electronic devices are often disposed of in a non-environmentally sound manner, often compounded by the fact that such wastes are not all domestically generated. About 7-20% of e-waste generated in high-income countries is either refurbished products that are shipped to low-or middle-income countries as second-hand products, or illegally exported under the guise of reuse when the product has no lifespan left. Exports of e-waste to lower-income countries in South East Asia and Africa are a concern because, although this provides income to a very large informal waste recycling sector in countries such as China, India, Ghana and Nigeria, the workers and those living in e-waste communities are subject to exposure from the toxic chemicals and metals in e-waste. Despite the valuable raw materials in e-waste (e.g. copper, gold, silver), there is only about a 20% recycling rate, partly due to product design, with the fate of about 80% of e-waste being uncertain. This poses a problem because e-waste also contains hazardous materials like lead, mercury, cadmium, nickel, beryllium, zinc and persistent organic pollutants like flame retardants or those found in product fluids, lubricants and coolants.

Open dumping is the most common method of hazardous waste disposal in developing countries and means that many hazardous wastes and other wastes are not being managed in an environmentally sound manner as provided by the Basel Convention and its technical guidelines. Waste dumps and informal recycling are major sources of pollution in many countries, and toxic wastes, including e-waste, accumulates in such dumps. Roughly 33 per cent of the world's solid waste ends up in open dumpsites. Forty-eight of the world's 50 biggest active dumpsites are in developing countries and pose a serious threat to human health and the environment, affecting the daily lives of approximately 64 million people. Uncontrolled disposal of municipal solid waste leads to severe and various environmental and social impacts: heavy metals pollution in water, soil, and plants; open burning causing polluting emissions; waste picking within open dump sites posing serious health risks to people; and release of municipal solid waste in water bodies augmenting global marine litter. Open burning is common in many low-income countries and releases large amounts of hazardous substances to the environment, making dumps a major global source of some substances of high concern such as dioxins and furans and mercury.

Plastics, another area of global concern, are ubiquitous in aquatic, atmospheric, and terrestrial ecosystems. Global plastic production was 359 million tonnes in 2018 and expected to double by 2050, with about 8 million tonnes of it ending up in the oceans. COVID-19 has resulted in a resurgence in single use plastics. Three-quarters of all marine debris is plastic, a persistent and potentially hazardous pollutant, which fragments into microplastics that can be taken up by a wide range of marine organisms. There are more than 800 marine and coastal species affected by marine debris through ingestion, entanglement, ghost fishing and dispersal by rafting, as well as habitat effects. 100% of marine turtle species, up to 66% of marine mammal species, and 50% of seabird species are affected by entanglement or ingestion of plastics from the ocean.

Marine plastic debris is made of chemicals, including POPs, but it also accumulates contaminants like POPs and can transport them long range. Macro- and micro-plastics can also transport invasive alien species, including harmful algal blooms, pathogens, and non-native species, with at least 300 species known to disperse by rafting on debris, which can form a new habitat. Pathogen dispersal via "microbial rafting," increases the likelihood of disease outbreaks which is highest in tropical regions. The generation of microplastic wastes may also be fueling the spread of antibiotic resistance.

Much less studied are the impacts of plastics on terrestrial species, although it is notable that a critically endangered species, the California condor, had reduced nestling survival due to ingestion of junk including plastic debris, threatening the re-establishment of a viable breeding population. Microplastics in the soil have a detrimental ecological impact on soil macro- and microbiota and are a major route for transferring toxic chemical pollutants, heavy metals and pesticides into the human food chain. There is a growing body of evidence that microplastics interact with terrestrial organisms that mediate essential ecosystem services and functions, such as soil dwelling invertebrates, terrestrial fungi and plant-pollinators, thus suggesting that microplastic pollution might represent an emerging global change threat to terrestrial ecosystems. One study estimated that the full implementation of all commitments to date would reduce plastic waste entering the environment by only around 7%. Nature's contributions to people such as food provision and freshwater/groundwater regulation are affected as a result of non-environmentally sound management of hazardous and other wastes. Marine debris in general damages fisheries and aquaculture, marine transport, shipbuilding and marine tourism. Microplastics that co-pollute the marine environment with metal, antibiotics, and human pathogens pose an emerging health threat globally, threatening humans who ingest marine-derived foods. Pollution from major dump sites with hazardous wastes leach into rivers, which can affect both freshwater and coastal marine fisheries and recreational activities. The regulation of air and water quality are affected due to open burning and large open dumpsites. Nature's ability to contribute to the formation, protection and decontamination of soils are affected due to soil pollution.

Awakening environmental awareness and corresponding tightening of environmental regulations in the industrialized world in the 1970s and 1980s led to increasing public resistance to the disposal of hazardous wastes and an escalation of disposal costs, causing some operators to seek cheap disposal options for hazardous wastes in Eastern Europe and the developing world. There, environmental awareness was much less developed, and regulations and enforcement mechanisms were lacking. It was against this background that the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was negotiated to combat the "toxic waste trade".

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes and other wastes. It covers a wide range of wastes defined as "hazardous wastes" based on their origin and/or composition and their characteristics—including mercury, POPs, and pesticide wastes--as well as two types of wastes defined as "other wastes" --household waste and incinerator ash. At its 2019 meeting, the Conference of the Parties amended three annexes to the Convention in relation to plastic waste, with the new entries coming into effect on January 1, 2021. Within the Convention are embedded obligations in relation to the prevention and minimization of the generation of hazardous and other wastes as well as in relation to their environmentally sound waste management (ESM), with thirty technical guidelines developed to provide ESM guidance for priority waste streams. For permitted transboundary movements, the prior informed consent scheme of the Convention requires that before an export may take place, the authorities of the State of export notify the authorities of the prospective States of import and transit, providing them with detailed information on the intended movement, which can only proceed if and when all States concerned give their written consent. Each transboundary movement must be accompanied by a movement document, which must be signed each time the shipment changes hands, to allow for tracking of each shipment from point of generation until point of environmentally sound disposal. The Conference of the Parties oversees the work of the Open-ended Working Group and the Implementation and Compliance Committee, as well as numerous small intersessional working groups, and is currently undertaking a review of progress under its 2011-2020 strategic framework.

III. Conclusions from the exploratory study on interlinkages betweenchemicals and wastes and biodiversity

1. Pollution is one of the key drivers of biodiversity loss. Chemicals and wastes are ubiquitous in the environment and found in all parts of the globe, and global production and distribution of chemicals-based products continues to increase. The Basel, Rotterdam, Stockholm and Minamata conventions address some of the most significant chemicals and waste pollution that has been identified over the last several decades and are thus contributing to the conservation and sustainable use of biological diversity.

2. Mercury is persistent in the environment, and while some emissions are naturally-occurring (e.g. rock weathering), anthropogenic emissions are increasing, polluting the air, freshwater and oceans, with severe consequences for human health and the environment, particularly biodiversity (e.g. mercury bioaccumulation in biota). Artisanal and small-scale gold mining (ASGM) is the biggest polluter to air, lands and waters, often fed by the illegal trade in mercury. Significant re-volatilization is expected to occur due to melting permafrost, snow and ice as a result of climate change.

3. POPs are human-made chemicals that are persistent in the environment and are found around the globe in air, water and soil. While the concentrations of legacy POPs continue to decline or remain at low levels, emissions from PCBs continue and along with DDT continue to be found in biota, the former associated with population declines in killer whales. For POPs listed after 2004, concentrations in air are beginning to show decreases, although in some instances increasing and/or stable levels are observed, but information is lacking for human tissues and other media. Re-volatilization continues to occur, including for legacy POPs such as PCBs, and more is expected due to climate change. Large remaining stockpiles of obsolete pesticides and PCBs remain an issue.

4. There needs to be a reduction in nature's exposure to pesticides. Global food security is under threat due to the threats to bees, other pollinators, and the deterioration in soil ecosystems, partly due to pesticides. Agricultural runoff, including pesticides, is a major source of water pollution and contaminant of groundwater aquifers. The impacts of certain high-use pesticides on nature need monitoring and action (e.g. glyphosate, neonicotinoids). The illegal trade in pesticides continues to add to human and environmental exposure.

5. Mismanagement of hazardous wastes in large waste dumps around the world--including e-waste, mercury waste, POPs waste and pesticide waste--is resulting in serious impacts on biological diversity and ecosystem services as well as the health of millions of people, particularly those involved in the informal recycling sector and their communities, and those living near those dumps due to open burning and other releases. The transboundary movement of e-wastes to poorer countries lacking recycling infrastructure continues to add to the environmental impacts of such wastes, although all countries are having difficulties properly managing the volume and complexity of e-waste. The volume of e-waste is expected to continue to grow and needs proactive measures globally to manage it.

6. Plastics, the production of which is expected to double by 2050, have demonstrated impacts on marine species through entanglement, ingestion, contamination, and transport/rafting (including the spread of antibiotic resistance, pathogens and POPs), but may also pose a serious threat to terrestrial ecosystems, including soils. Concerted proactive actions are needed at the international level to address this rapidly growing menace.

7. Mercury, POPs, pesticides and hazardous and other wastes (e.g. plastics) are negatively impacting soil biodiversity around the world. Soils are one of the main global reservoirs of biodiversity with more than 40 per cent of living organisms in terrestrial ecosystems associated directly with soils during their life cycle.

8. Transformation of key polluting sectors in developing countries, such as ASGM and informal e-waste recycling, can provide major benefits for biodiversity and ecosystem services, as well as the human health of workers and their communities, while promoting significant economic sectors and contributing to a circular economy.

9. Nature's contributions to people and ecosystems world-wide are impacted by mercury, POPs, pesticides and hazardous and other wastes as they impede nature's ability to regulate air and freshwater quality, soils and organisms, create and maintain habitat, and they reduce pollination and seed dispersal services. These pollutants also affect services such as the provision of food and feed, materials and assistance, and genetic diversity. They affect non-material contributions of particular importance to indigenous peoples around the world, including those regarding the consumption of traditional foods that also support spiritual and religious identity, as well as experiences with nature that contribute to social cohesion, recreation, learning and inspiration.

10. High levels of contamination are found in countries or regions that are megadiverse (e.g. ASGM using mercury), from mercury, POPs, pesticides and hazardous and other wastes, as well as in vulnerable ecosystems like the Arctic, and in locations close to intense industrial activity, often in urban centres. These pose particular challenges for biological diversity and ecosystem services, as well as for human health.

11. Of particular concern is the impact of mercury, POPs, pesticides and hazardous and other wastes in combination with other chemicals, and other natural and anthropogenic stressors--such as climate change, hunting pressure, invasive alien species, emerging pathogens, and changes in food web dynamics--which are having an impact on biodiversity, ecosystem services and human health. Further emphasis in research is needed to enhance understanding on mixtures and cumulative effects, including from long-term low-dose exposures, and how to address them. Risk assessment for pesticides needs improvement, for example, by focusing on high use, ubiquitous pesticides, and on the formulated products rather than just the active ingredient, and by placing a greater emphasis on post-approval monitoring.

12. Climate change is a key factor amplifying the effects of chemicals but is also expected to contribute to the continued re-volatilization of both mercury and POPs, which are persistent in the environment and can cycle between environmental compartments for extended periods of time. Melting permafrost and ice are expected to release significant quantities of both mercury and POPs into the environment.

13. Environmental monitoring for POPs and mercury needs to be improved and consistent in all regions of the world so that the risks to human health and the environment can be fully understood in all regions. Although discussion of the possibility of a broader science platform for chemicals and hazardous wastes is under consideration as part of the ongoing beyond-2020 discussions--the equivalent of the IPCC for climate and IPBES for biodiversity—the current convention processes for environmental monitoring and examining effectiveness are extremely valuable.

14. Illegal trade in mercury, POPs, pesticides and hazardous and other wastes (particularly e-waste) continue to exacerbate both environmental and human health risks, often in poorer countries with limited infrastructure to combat it.

15. Many species are evolving rapidly as they adapt to human drivers of change, including some changes – such as resistance to antibiotics and pesticides – that pose serious risks for society. Close monitoring of such developments is required. Similarly, new technologies that could reduce pesticide use, such as gene drives, require careful assessment due to their potentially irreversible impacts if released into the

environment. Reduction of pesticide use, rather than the search for alternatives to current pesticides, can be achieved through alternative techniques, such as integrated pest management practices and agroecological farming.

Building on the Interlinkages Study

1. In mapping the interlinkages between chemicals and wastes and biological diversity, this exploratory study reflects that environmental challenges and their solutions are inter-related, complex and shared. This exploratory study provides a baseline for future work and collaboration between conventions in different spheres and within them. To achieve the 2050 vision of the Convention on Biological Diversity (CBD) through its post-2020 global biodiversity framework and its 2030 pollution target, the significant ongoing contributions of the Basel, Rotterdam, Stockholm and Minamata conventions need to be fully harnessed. Conversely, knowledge and insights garnered through collaboration with the CBD and related protocols and conventions can benefit the work of the four global chemical and waste conventions.

2. As the international community finalizes and implements the post-2020 global biodiversity framework, collaboration between the four chemicals and waste conventions and the biodiversity-related conventions can provide ongoing refinements to the targets and indicators on pollution as they relate to mercury, POPs, pesticides and hazardous and other wastes. This is particularly important as the 2020 GBO-5 concluded that CBD Aichi pollution Target 8 was not achieved.

3. Target 8 did not reference the significant chemicals and waste biodiversity-related issues addressed under the four conventions, and information in this study and the ongoing work of the four conventions can contribute to achieving the CBD's 2030 pollution target. Their ongoing work includes national reporting, environmental monitoring, and treaty effectiveness and strategic framework evaluations where biodiversity considerations could be increasingly integrated, along with efforts to contribute to the 2030 SDGs, which this study highlights as a point at which chemicals/waste and biodiversity issues also converge.

4. More specifically, whether or not the 2030 biodiversity pollution target is drafted to reflect priority pollutants/chemicals such as mercury and other heavy metals, POPs, pesticides, wastes (including plastics) this study provides baseline information about key interlinkages that can serve the four conventions' governing bodies to consider the detailed contributions they could make to the refinement and implementation of the CBD's 2030 pollution target and indicators going forward. Examples could include specific targets related to mercury air emission reductions, reduction of concentrations of POPs in environmental media, enhanced focus of the Rotterdam Convention on neonicotinoids and glyphosate pesticides, the enhancement of legislative implementation of the Basel Convention's plastic waste amendments, or decisions on international cooperation and coordination that build these inter-convention connections (e.g. forwarding this study to the CBD Conference of the Parties, or working on common areas of concern such as ASGM).

5. This study also highlights that current research on and regulation of chemicals in the environment tends to take a simplistic view and does not account for the complexity of the real world, including how to differentiate and quantify the effects of multiple stressors on ecosystems and how to improve risk assessment of such stressors (including at different levels of biological organization) to enhance predictability. Enhanced and focused collaboration between the chemicals and waste conventions and those related to biodiversity provides an opportunity for each to share their pressure points and complexities and mobilize limited resources towards prioritized solutions that benefit both. Collaboration on ASGM, plastics, e-waste, pesticides and pollinators, illegal trade, the sharing of monitoring data and scientific research, along with shared communications and messaging, could produce significant benefits to both the biodiversity and chemicals and wastes worlds.

6. Each of these worlds can also alert the other to emerging issues of concern and key developments. This study has identified UNEP's Assessment Report on Issues of Concern for UNEA-5, which consists of an assessment of eight emerging policy issues and other issues of concern under SAICM (e.g. nanomaterials, e-waste) and 11 issues with emerging evidence of risks identified by GCO-II, and identified possible contributions of the four MEAs to addressing those issues (see Annex 6). It also identified the ongoing SAICM intersessional process as it shapes the beyond-2020 framework on chemicals and wastes and how this relates to the four chemicals and waste conventions.

7. Ultimately, this exploratory study identifies a significant number of areas of convergence between chemicals/wastes and biodiversity and suggests the need to resolve challenges in these areas of convergence in a manner that better reflects the interconnectedness within our natural environment.

Study on the Interlinkages between the chemicals and waste multilateral environmental agreements and biodiversity

I. Purpose

The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the 1998 Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade, the 2001 Stockholm Convention on Persistent Organic Pollutants, and the 2013 Minamata Convention on Mercury all aim at protecting human health and the environment from hazardous chemicals and wastes.

This exploratory study outlines the scope of coverage of the four conventions of the chemicals and waste multilateral environment agreements (MEAs) cluster and assesses the inter-relationship of those conventions with the subjects preoccupying the MEAs of the biodiversity cluster.[3] It is intended to show how environmentally sound management of chemicals and wastes contributes to biological diversity and the delivery of ecosystem services, and conversely, how not managing chemicals and wastes in an environmentally sound manner negatively impacts them.[4] This study has been inspired by ongoing discussions on the post-2020 global biodiversity framework being negotiated under the 1992 Convention on Biological Diversity (CBD)[5], and helps position the four conventions to contribute to those discussions and the implementation of the post-2020 global biodiversity framework, and future work of the CBD and other biodiversity-related instruments. This includes the CBD's 2000 Cartagena Protocol on Biosafety and 2010 Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization.

The scientific information in this report was developed through four strategies. The first was to undertake a literature review of key subjects requested by the BRS and Minamata Secretariats using science databases, focusing on more recent studies, and meta-studies where available. The second was to take existing UN (GEO-6 2019 and GCO II 2019) and other authoritative reports (e.g. IPBES, AMAP) and reflect their findings within the key subjects. The third was to do an internet scan to verify that no major studies or issues were missed, and this resulted in the identification of further studies (e.g. monarch butterflies). The fourth strategy involved further searches to follow up on points raised by the first three strategies and to reflect new studies in the key subject areas that were published during the course of writing this report. Except where web links are provided, all studies are available at the BRS and Minamata Secretariats.

II. Introduction

We stand now where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road — the one less traveled by — offers our last, our only chance to reach a destination that assures the preservation of the earth.

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[3] The full list is on page 19 below.

[4] September 30, 2020 is the cut-off date for data in this study, although in the final edit some factual changes were reflected. This report has been prepared in parallel with a related report prepared by the BRS and Minamata Secretariats on chemicals and waste and climate change.

[5] https://www.cbd.int/conferences/post2020.

-- *Rachel Carson, Silent Spring (1962)*

A. The chemicals and waste MEAs and the 2020 target

At the 2002 World Summit on Sustainable Development, governments agreed to "achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment […]".[6]

Contributing to this effort are a series of binding treaties on chemicals and hazardous wastes at the global level[7]. The 2013 Minamata Convention on Mercury, which addresses the complete lifecycle of mercury, was developed in response to high levels of mercury in the atmosphere and elsewhere in the environment resulting from human activities, which has resulted in harm to both human health and the environment, due to the toxic, persistent, bioaccumulative and long-range transport characteristics of this chemical. The 2001 Stockholm Convention on Persistent Organic Pollutants focuses on the elimination or restriction of a group of chemicals known as persistent organic pollutants (POPs), such as PCBs, DDT and flame retardants, that are toxic to humans and the environment, are persistent in the environment, bioaccumulate in the food chain, and can travel long distances from their point of origin to remote and formerly pristine environments. The 1998 Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade provides Parties with information about listed industrial chemicals and pesticides, and provides a mechanism through which Parties can make informed decisions to accept or not imports of chemicals, coupled with obligations on exporting Parties to respect decisions of importing Parties, including refusals or imposition of conditions of import. The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal addresses the transboundary movements of the end of the lifecycle of chemicals, including e-waste, mercury, POPs, pesticides and other chemical wastes, and was recently amended to help address global concerns around plastic waste. Although not studied here, the Montreal Protocol on Ozone-Depleting Substances has been highly successful in remediating damage to the ozone layer and thus providing benefits to biodiversity and ecosystem services.[8] Such legally binding approaches at the global level are essential to addressing the most critical and complex pollution challenges and are

[6]Plan of Implementation of the World Summit on Sustainable Development, paragraphhttps://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf 23: https://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf

[7] Although there are a number regional agreements that contribute to the minimization of impacts of chemicals and wastes on the environment, such as the regional seas agreements, the focus of this study is on the four cited global agreements.

[8] The production of this exploratory study did not include the Ozone Secretariat. The Montreal Protocol successfully regulates a narrow suite of chemicals that directly impact the ozone layer, thus protecting all life on Earth from damaging UV radiation, as well reducing climate warming as some of the regulated chemicals are greenhouse gases. The focus of this study is those chemicals and wastes covered by the four Conventions, which directly impact biota. For a recent report on the environmental effects of ozone depletion, see Bernhard et al., Environmental effects of stratospheric ozone depletion, UV radiation and interactions with climate change: UNEP Environmental Effects Assessment Panel, update 2019, Photochem.Photobiol. Sci., 2020, **19**, 542.

notable successes. [UNEP, Towards a Pollution-Free Planet 2017; GCO II 2019; GMA 2018] The four conventions discussed here are highly regulatory conventions that require implementation at the national level.

The 2006 voluntary Strategic Approach to International Chemicals Management (SAICM) built upon the 2020 timeline and has addressed a number of issues which were not addressed by the existing chemicals and waste MEAs, such as lead in paints, chemicals in products, and environmentally persistent pharmaceutical pollutants. [9] An intersessional process is underway to prepare recommendations regarding SAICM and the sound management of chemicals and waste beyond 2020.[10]

The United Nations Environment Assembly (UNEA), the governing body of the United Nations Environment Programme (UNEP), with a universal membership, meets biennially to set priorities for global environmental policies and develop international environmental law. Through its ministerial declarations and resolutions, the Assembly provides leadership, catalyzes intergovernmental action on the environment, and contributes to the implementation of the UN 2030 Agenda for Sustainable Development and can be an important forum to foster

2006 Strategic Approach to International Chemicals Management (SAICM)

What: SAICM is a policy framework to promote chemical safety around the world.

Objective: Sound Management of chemicals throughout their life cycle so that by the year 2020, chemicals are produced and used in ways that minimize significant adverse impacts on the environment and human health.

Components: Dubai Declaration on International Chemicals Management; Overarching Policy Strategy; Global Plan of Action

Governance: The International Converence on Chemicals Management (ICCM), which, among other things, evaluates the implementation of SAICM with a view to reviewing progress against the 2020 target; Open-ended Working Group (OEWG): as subsidiary body of the ICCM to consider the implementation , development and enhancement of SAICM, including discussion of emerging policy issues, inclusion of new activites in the Global Plan of Action, and consideration of initiatives related to achieving the 2020 goal; Bureau of the ICCM serves as the Bureau of the OEWG; the Secretariat services the foregoing and is overseen by UNEP.

Emerging Policy Issues: Lead in paint; chemicals in products; hazardous substances within the life cycle of electrical and electronic products; chemicals in products; nanotechnology and manufactured nanomaterials; endocrine-disrupting chemicals; environmentally persistent pharmaceutical pollutants; perfluorinated chemicals and the transition to safer alternatives; highly hazardous pesticides.

Beyond 2020: Strategic Approach and sound management of chemicals and waste beyond 2020—the Intersessional Process: This process aims to prepare recommendations regarding the Strategic Approach and the sound management of chemicals and waste beyond 2020. Three meetings have been held to date and the fourth meeting, to have been held in March 2020, has been postponed due to COVID-19. Documents for this session, including a compilation of recommendations as well as targets prepared by the Technical Working Group on targets, indicators and milestones, are available at: http://www.saicm.org/Beyond2020/IntersessionalProcess/FourthIntersessionalmeeting/tabid/8226/language/en-US/Default.aspx

Box 1: 2006 Strategic Approach to International Chemicals Management (SAICM)

dialogue and cooperation among MEAs. Numerous resolutions on the sound management of chemicals and wastes[11]

[9] http://www.saicm.org/. For the full list of emerging policy issues and other issues of concern, and progress thereon see: http://www.saicm.org/Implementation/EmergingPolicyIssues/tabid/5524/language/en-US/Default.aspx
[10] http://www.saicm.org/Beyond2020/IntersessionalProcess/tabid/5500/language/en-US/Default.aspx
[11] Resolutions 1/5, 2/7, and 4/8, for example: https://environmentassembly.unenvironment.org/unea4

illustrate this role, as does its resolution 3/2 on Pollution mitigation by mainstreaming biodiversity into key sectors.[12]

Despite the collective efforts of both binding[13] and non-binding regimes, including a number of successes and ongoing progress, and the efforts of UNEA, UNEP's 2019 Global Chemicals Outlook II concluded that the 2020 goal will not be achieved. [GCO II 2019]

2020 is thus an important reference year in the environmental world, both for assessing progress and for launching new frameworks for assessing progress. The Basel Convention's strategic framework ended in 2020 with the preparation of a final evaluation report being prepared for its Conference of the Parties (COP) in 2021. The Stockholm Convention Conference of the Parties in 2021 is expected to launch the next cycle to evaluate its effectiveness, and work is underway in the Minamata Convention on Mercury on its first effectiveness evaluation, with its governing body also meeting in 2021 to make further progress on this and other issues. 2020 is also a key year in the Minamata Convention after which products listed in Part I of Annex A are not allowed to be manufactured, imported or exported. A compliance mechanism adopted by the Rotterdam Convention COP in 2019 in a new annex to the Convention, with election of a first committee and initiation of its work in 2021, is expected to enhance that Convention's effectiveness.

Sustainable Development Goal 12:

Ensure sustainable consumption and production patterns

Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.

Target 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

Box 2: A Key SDG target for the chemicals and waste conventions

The 17 Sustainable Development Goals (SDGs) were adopted by all United Nations member states in 2015 as part of the 2030 Agenda for Sustainable Development, which set out a 15-year plan to achieve the Goals. They are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. While progress has been made in a number of areas, 2020 needs to usher in a decade of ambitious action to deliver the Goals by 2030.[14] The chemicals and waste conventions are now focusing on contributing to the achievement of a number of the 2030 Sustainable Development Goals adopted by the United Nations General Assembly in 2015 through the achievement of their own objectives.[15] The Implementation Plan of UNEP's Towards a Pollution-Free Planet was approved by UNEA-4, and aims at contributing to implementation of the SDGs by focusing on pollution. It describes UNEP subprogrammes that address pollution, including these four conventions, and notes that action on pollution contributes to healthy ecosystems, which protect biodiversity. Part VI of this study outlines in more detail the specific contributions that ongoing implementation of the four Conventions can make to the SDGs of relevance to biological diversity.

This study also references assessments that have been prepared on chemicals and wastes that will contribute to the UNEP Global Assessments Synthesis Report in the lead up to the Stockholm + 50 activities in 2022.

[12] http://wedocs.unep.org/bitstream/handle/20.500.11822/31017/k1800174.english.pdf?sequence=3&isAllowed=y
[13] There are other binding regimes that address chemicals and waste issues such as the global 1996 Protocol to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, the regional hazardous waste treaties, and UNEP regional seas agreements not detailed here.
[14] The Sustainable Development Goals, including those relevant to biodiversity, can be referenced here: https://sdgs.un.org/goals.
[15] References to the SDGs can also be found on the BRS website: http://www.brsmeas.org/Implementation/SustainableDevelopmentGoals/Overview/tabid/8490/language/en-US/Default.aspx and the Minamata website: http://www.mercuryconvention.org/Implementation/SDG/tabid/8150/language/en-US/Default.aspx

There have been an increasing number of recent discussions on the contribution that the Minamata, Stockholm, Rotterdam, and Basel conventions make to the protection of biological diversity and how strong chemicals and waste management benefits biological diversity.[16] This report outlines the specifics of what these four global treaties address and how they contribute to biological diversity and the services provided by ecosystems. Although each treaty focuses on both environmental and human health impacts of these chemicals and wastes, this report focuses on biodiversity and ecosystem service impacts.

B. The biodiversity cluster of MEAs

The biodiversity cluster of MEAs consists of the Convention on Biological Diversity (and its Cartagena Protocol on Biosafety and Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization), together with the following biodiversity-related conventions: the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention on Wetlands), the 1972 UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage, the International Treaty on Plant Genetic Resources for Food and Agriculture, the Convention on Migratory Species of Wild Animals (CMS), the International Convention for the Regulation of Whaling, and the International Plant Protection Convention. These are the eight conventions (and two Protocols) whose secretariats are members of the Liaison Group of Biodiversity-related Conventions.

Like the chemicals and waste conventions' attention to evaluation of progress in achieving their respective objectives, an ongoing process has been organized by the CBD for the preparation of a post-2020 global biodiversity framework towards the 2050 vision of "Living in Harmony with Nature"as a follow-up to the Strategic Plan for Biodiversity 2011-2020.[17] An extensive process of consultations and meetings has been launched to develop the post-2020 global biodiversity framework with this vision in mind.

Living in Harmony with Nature

By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.

Box 3: The CBD 2050 Vision

This report uses the term "biological diversity" as it is defined in the Convention on Biological Diversity, that is, the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.[18]

Similarly, "ecosystem" is understood as defined under the Convention: a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.[19]

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) used the concept of "nature's contributions to people" (NCP) in its 2019 Global Assessment Report on Biodiversity and Ecosystem Services, which builds on the concept of ecosystem services and shares many similarities with that framework. Some differences are that NCP emphasizes the central role that culture plays in defining NCP and the distinction between potential and realized NCP. Realized NCP emphasizes the integration of inputs from humans and nature to

[16] For example, see the 2019 Trondheim Conference on Biodiversity, highlighting discussions on biodiversity for the post-2020 framework, including on chemicals and wastes: https://trondheimconference.org/assets/Files/TC9%20Conference%20Report/Co-chairs-report-31-July-2019-revised.pdf; the Consultation Workshop of Biodiversity-related Conventions on the Post-2020 Global Biodiversity Framework, https://www.cbd.int/meetings/BRC-WS-2019-01 and in the SAICM International Process, a Special Event was held at the third meeting on Biodiversity Linkages, which included a perspective from the Minamata and BRS Secretariats: http://www.saicm.org/Portals/12/Documents/meetings/IP3/InSession/UNEP_SpecialEventBiodiversityLinkages.pdf.
[17] https://www.cbd.int/conferences/post2020.
[18] Article 2.
[19] *Ibid.*

co-produce NCP (e.g. a productive marine ecosystem may provide fish, but without boats and nets, food for human consumption is not possible). NCP highlights how changes in nature can have a profound impact on people's quality of life, and is defined to include both positive and negative contributions to good quality of life for which nature is a vital, but not necessarily the sole, contributing factor. [IPBES 2019, chapter 2.3] Because this is a new concept, this report uses the term when characterizing nature's contributions (see Figure 1 below), but also refers to ecosystem services, as studies referred to have used that terminology.

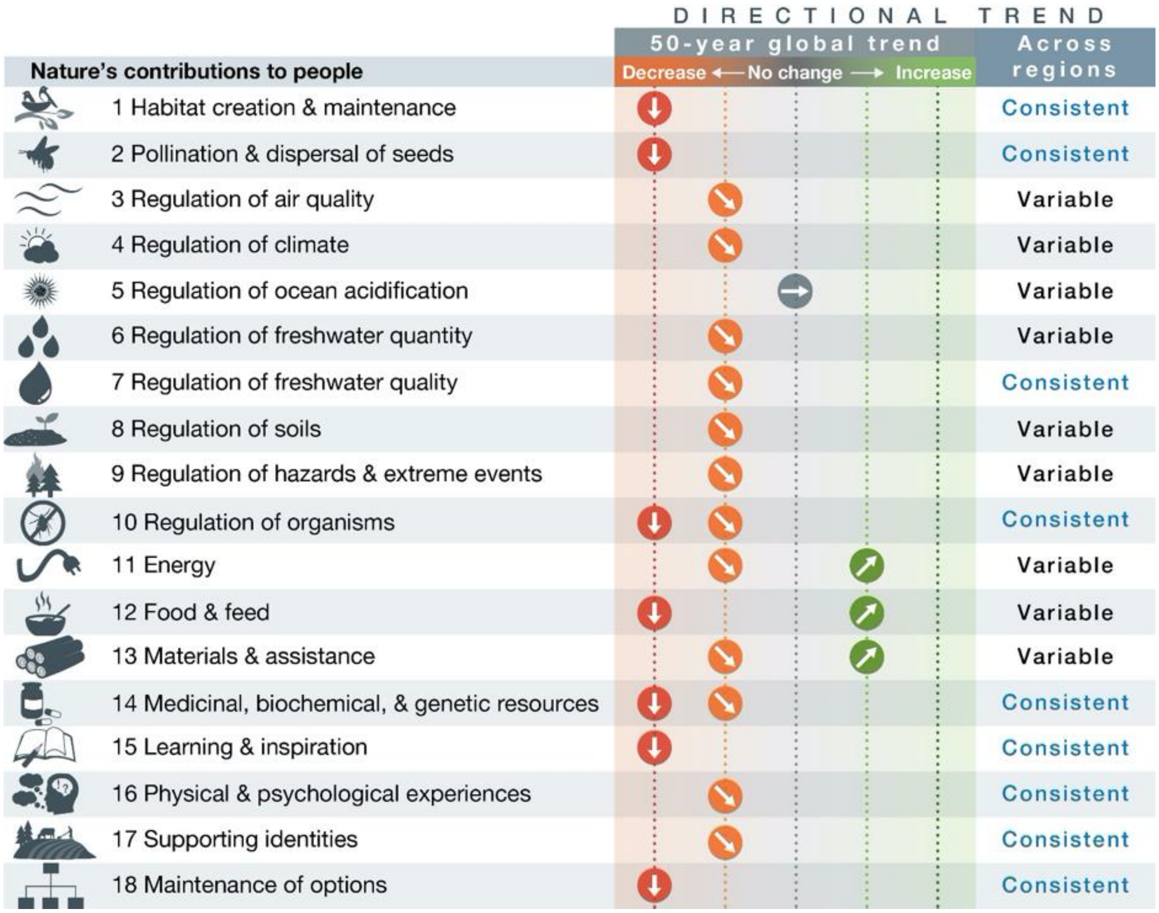

Figure 1 - *Global 50-year trends in the capacity of nature to sustain contributions to a good quality of life, showing a decline for 14 of the 18 categories of nature's contributions to people analyzed (Source: IPBES, 2019).*

C. Pollution as a main driver of biodiversity loss

Pollution is one of the five main direct drivers of biodiversity loss, along with changes in land and sea use, direct exploitation of organisms, climate change, and invasive alien species. [GBO-5 2020; IPBES 2019] IPBES includes in "changes in land and sea use" what others call "habitat loss, fragmentation and degradation," considered to be the most prominent driver of biodiversity loss globally, as confirmed in Figure 2 below. [WWF Living Planet Report 2018] Many types of air, water and soil pollution are increasing with negative impacts for nature. For example, marine plastic pollution has increased tenfold since 1980, affecting at least 267 species, including 86% of marine turtles, 44 % of seabirds and 43% of marine mammals [IPBES 2019] and 46% of the species on the IUCN Red List of Threatened Species have been impacted by ghost fishing gear [GBO-5 2020]. Greenhouse gas emissions, untreated urban and rural waste, pollutants from industrial, mining and agricultural activities, oil spills and toxic dumping have had strong negative effects on soil, freshwater and marine water quality and on the global atmosphere. [IPBES 2019] Pollution continues to drive species toward extinction according to the Red List Index (Impacts of Pollution). [GBO-5 2020] Pollution is one of the direct drivers of change in wetland ecosystems, which are critical to human livelihoods and sustainable development, and yet have declined by 35% since 1970. Water quality has worsened in almost all rivers in Latin America, Africa and Asia and projected to escalate, with major threats being untreated wastewater, industrial waste, agricultural runoff (including pesticides), erosion and changes in sediment. Plastics in oceans have huge impacts in coastal waters and add to the list of threats to wetlands. [Ramsar 2018] The relative impact of pollution may be higher or lower depending upon the ecosystem, including the interaction among the various threats to the ecosystem. [IPBES 2019; Dudgeon, 2006; Collen, 2014]

The Biodiversity Convention's Aichi Target 8 is most relevant for this study: "By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity." With a view to future development of a revised Target 8, it is noteworthy that the term 'pollution' is very general and that excess nutrients are the only type of pollution highlighted. The recent Global Biodiversity Outlook-5 (GBO-5 2020) assesses progress under this target as not having been achieved (see Box 4) and highlights a number of examples that help prove the point. The report notes the Minamata, Stockholm, Rotterdam and Basel conventions' contributions towards targeting particular sources of pollution. [GBO-5 2020]

GBO-5 Assessment of Progress under Aichi Target 8

Pollution, including from excess nutrients, pesticides, plastics and other waste, continues to be a major driver of biodiversity loss. Despite increasing efforts to improve the use of fertilizers, nutrient levels continue to be detrimental to ecosystem function and biodiversity. Plastic pollution is accumulating in the oceans, with severe impacts on marine ecosystems, and in other ecosystems with still largely unknown implications. Actions taken in many countries to minimize plastic waste have not been sufficient to reduce this source of pollution. The target has not been achieved (medium confidence).

Box 4: GBO-5 Assessment of Progress under Aichi Target 8

This study highlights these and other areas where pollution from chemicals and hazardous waste is impacting biodiversity, where they are addressed by the four chemicals and waste conventions—and where they are not.

In its overall assessment of progress on all of the Aichi Targets, GBO-5 predicts that on our current trajectory, biodiversity and the services it provides will continue to decline, jeopardizing the achievement of the Sustainable Development Goals. If the status quo continues, this trend is projected to continue until 2050 and beyond, due to "the increasing impacts of land and sea use change, overexploitation, climate change, pollution and invasive alien species." [GBO-5 2020]

The necessary actions that together could take the world to achieving the 2050 Vision for Biodiversity include taking effective steps to address all remaining drivers of biodiversity loss, including pollution, invasive alien species, and the unsustainable exploitation of biodiversity especially in marine and inland water ecosystems. Actions to combat pollution are noted among the eight transitions required to achieve the 2050 Vision in the interface between human activity, human well-being and nature. [GBO-5 2020]

On September 30, 2020, a global summit on biodiversity was convened by the President of the United Nations General Assembly,[20] with the theme of "Urgent action on biodiversity for sustainable development". At the summit many countries renewed their pledge for the realization of the 2050 vision through a wide reiteration of commitment to preserve land and marine ecosystems, reduce pollution, increase climate mitigation and adaptation, fight land degradation and halt biodiversity loss. Because chronically contaminant-disturbed biological communities may be at greater risk from subsequent influences of global climate change due to genetic adaptation resulting in reductions to genetic diversity at the population level, predictions of climate change impacts on biodiversity can be improved by incorporating assessment of species' vulnerability due to current and future contaminant exposure. [Moe et al., 2013] In this vein, a number of the studies referenced here illustrate the complex interactions between climate change and the chemicals and hazardous waste pollution canvassed in this study.

[20] In accordance with the General Assembly resolution 74/269 and decision 74/562.

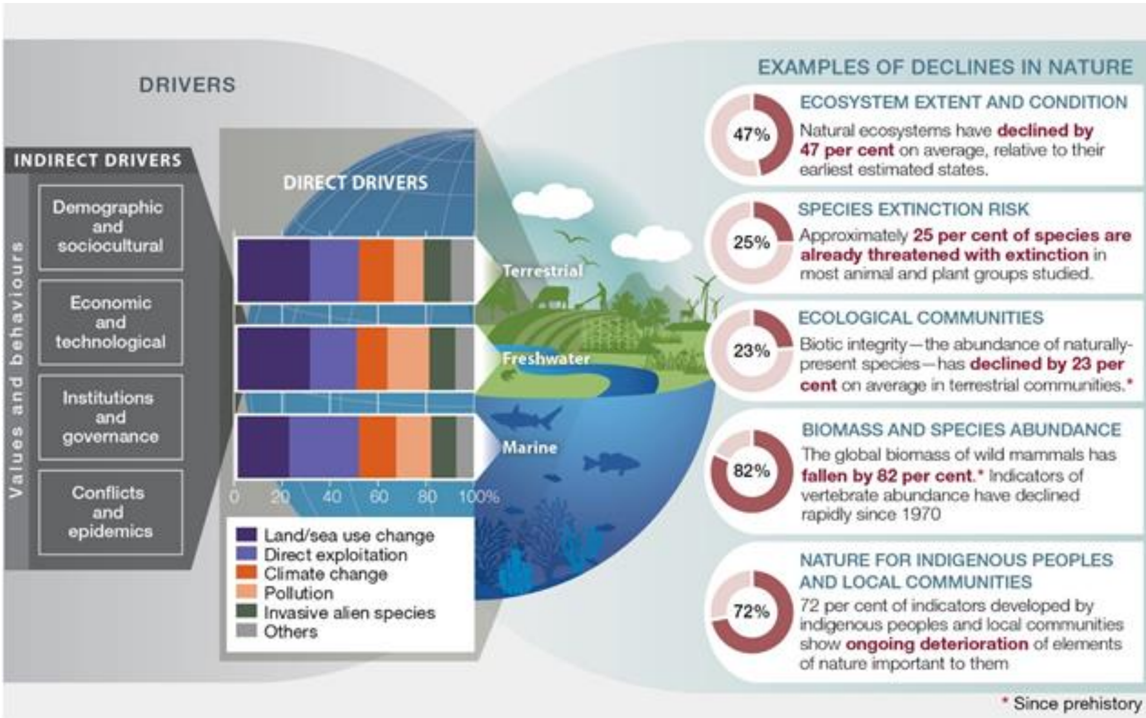

Figure 2- *Drivers of biodiversity loss (Source: IPBES, 2019).*

D. The state of chemicals and wastes globally

Chemicals provide substantial benefits to humanity, such as their use as flame retardants in consumer products, the use of mercury in batteries, fertilisers, herbicides and pesticides to enhance crop yields, and pharmaceuticals to improve human well-being. It is therefore not surprising that there is an increasing global production and distribution of novel entities (e.g. synthetic organic pollutants, agricultural inputs, genetically modified organisms, nanomaterials and micro-plastics) as well as heavy metals mobilized by human activities, that have been generally linked to disruptions/disturbances in earth systems -- freshwater, marine, terrestrial ecosystems, biogeographical cycling, and ozone depletion. [Steffen et al., 2015] Despite their many benefits, the pollution associated with chemicals poses a global problem because toxic substances can spread to the remote parts of the planet, including to water systems worldwide. [GEO-6] These have important implications for nature and people, as they can exist for a very long time, and their effects are potentially irreversible. [IPBES 2019]

We are living in the most chemical-intensive era in human history and the production of new chemicals surpasses the capacity to fully assess their potential adverse impacts on human health and ecosystems. [GEO-6 2019] The production, use and trade of chemicals is growing in all regions of the world, driven by global megatrends. In 2018, the total number of industrial chemicals in commerce globally was estimated at 40-60,000, with 6000 of these constituting 99% of the total. The size of the global chemical industry was roughly USD 3.5 trillion in 2017, (over $5 trillion including pharmaceuticals) and is projected to double by 2030. Consumption and production are rapidly increasing in emerging economies. Projected growth will be highest in Asia, with China estimated to account for almost 50 per cent of global sales by 2030. High growth rates are also expected in Africa and the Middle East. Global supply chains, and the trade of chemicals and products, are becoming increasingly complex. [GCO II 2019]

Per capita consumption of chemicals is increasing steadily and growth in chemical use will outstrip population growth until at least 2030. This reinforces the need to decouple material use from economic growth, enhance resource- and eco-efficiency, advance sustainable materials management, and prioritize source reduction, reuse and recycling. [GCO II 2019]

Hazardous chemicals and other pollutants (e.g. plastic waste and pharmaceutical pollutants) continue to be released into the environment in large quantities. They are ubiquitous in humans and the environment and are accumulating in material stocks and products, highlighting the need to avoid future legacies through sustainable materials management and circular business models. Large amounts of chemicals are released during production, and from products and wastes, illustrating that resources are not being used efficiently. [GCO II 2019] Over 54% of the global population lives in urban areas, which poses challenges regarding hazardous chemicals and wastes and their impacts on people and the environment, such as air pollution, inadequate waste and wastewater management and degradation of the water supply. [GEO-6 2019]

Human activities have increased total atmospheric mercury concentrations by about 450% above natural levels. Reductions in mercury emissions and resulting declines in atmospheric concentrations may take some time to show up as reductions of mercury concentrations in biota, as methylmercury will continue to be produced from legacy mercury previously deposited into soils, sediments and aquatic systems. [GMA 2018]

The global waste market has become a viable economic sector, estimated at USD $410 billion per year, from collection through to recycling. [GEO-6 2019] Only 9 per cent of global material resources are recycled and only 9% of the 6.3 billion metric tons of plastic waste generated up to 2015 has been recycled, while 12 per cent was incinerated and 79% disposed in landfills or in the environment. [GCO II 2019]

Not only do chemicals add to the global burden of disease, where risks are particularly high for vulnerable populations such as artisanal and small-scale gold miners, chemical pollution threatens biota and ecosystem functions around the world, [GCO II 2019] from mangroves and tropical rivers, to highly urbanized settings, to fragile ecosystems like the Arctic. The studies which follow highlight further complexities regarding the impacts of multiple chemical stressors on biological diversity and ecosystems, as well as additional other environmental stressors, such as climate change. [AMAP 2018][21]

III. The Chemicals and Waste Conventions: Protecting the Environment and Human Health from Chemicals and Wastes of Global Concern

A. Minamata Convention on Mercury

Mercury is a highly toxic heavy metal that poses a global threat to human health and the environment. Although naturally occurring in the Earth's crust, due to its unique properties it has also been used in or released from various products and processes for hundreds of years. Mercury is transported around the globe through the environment, so its emissions and releases can affect human health and environment even in remote locations, such as the Arctic.[22] Once released, mercury persists in the environment where it circulates between air, water, sediments, soil and biota in various forms, and may not be removed from this cycle for a century or more. Levels of mercury in the atmosphere are considered a significant source of air pollution. [GCO II 2019]

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[21] Although Aichi Target 8 includes pollution from nutrients like nitrogen and phosphorous, which result in eutrophication that is very harmful to biological diversity, because none of the four treaties in the chemicals and waste cluster directly address nutrients, they will not be taken up here other than in passing where studies referred to have addressed them along with pollutants addressed by the four treaties.

[22] http://mercuryconvention.org/Portals/11/documents/Awareness%20raising/FACT%20SHEETS/Minamata%20Convention%20on%20Mercury%20at%20a%20glance_COP1%202017.pdf.

An assessment completed by UNEP in 2003 found that there was sufficient evidence of significant global adverse impacts from mercury and its compounds to warrant further international action to reduce the risks to human health and the environment from their release. Subsequent international discussions involved both binding and voluntary options for action, which resulted in both the voluntary UNEP Global Mercury Partnership, and the launch of negotiations on a binding treaty in 2009. The treaty was adopted and opened for signature in 2013. It entered into force on August 16, 2017 and has 124 Parties[23]. The most recent UNEP Global Mercury Assessment was released in 2018.

The Minamata Convention is named after the place in Japan where, in the mid-20th century, mercury-tainted industrial wastewater from an acetaldehyde plant[1] poisoned thousands of people living near Minamata Bay, leading to severe neurological conditions that worsen over an affected persons' lifetime and became known as "Minamata disease". This was in fact, methylmercury poisoning from the consumption of contaminated fish and shellfish that was the local food supply. In children born to mothers exposed to the methylmercury, serious disturbances in mental and motor developments were observed in all cases. [Ekino et al., 2007]

The objective of the Minamata Convention is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

The Convention is regulatory in nature and requires specific implementation at the national level. In support of its objective, the Convention contains provisions that relate to the entire life cycle of mercury, including controls and reductions across a range of products, processes and industries where mercury is used, released or emitted. The Convention also addresses the primary mining of mercury, mercury trade, mercury interim storage, mercury waste and its disposal, and the management of sites contaminated with mercury. More specifically:

- Controls on mercury supply sources and trade (Article 3): No new primary mercury mines; closure of active mines within 15 years of entry into force for a Party, restrictions on trade in elemental mercury

- Phase-out and phase-down of mercury use in products (Articles 4 and 6, Annex A): to address mercury in products such as measuring devices (including thermometers), electrical switches (including thermostats), relays, measuring and control equipment, energy-efficient fluorescent light bulbs, batteries, cosmetics, pesticides and dental amalgam

- Phase-out and phase-down of mercury use in processes (Articles 5 and 6, Annex B): addresses industrial processes using mercury: mercury chlor-alkali plants, acetaldehyde production in which mercury or mercury compounds are used as a catalyst, vinyl chloride monomer for polyvinyl chloride (PVC) production, sodium or potassium methylate or ethylate processes, and the production of polyurethane elastomers.

- Controls on artisanal and small-scale gold mining (ASGM) where mercury is used (Article 7, Annex C): Parties with ASGM activities that are more than insignificant must develop and implement a national action plan and submit this to the Secretariat within three years of entry into force of the Convention for it

- Controls on air emissions (Article 8 and Annex D): Requirements for new and existing Annex D sources, with new sources requiring the use of BAT and BEP within five years of entry into force of the Convention for the Party (or emission limit values that are consistent with BAT). Annex D lists the most problematic sources (apart from ASGM): coal-fired power plants, coal-fired industrial boilers, smelting/roasting in non-ferrous metals production, waste incineration facilities, cement clinker production facilities

- Controls on releases to land and water (Article 9): Parties to identify relevant point source categories and take measures to control releases from them

[23] As of October 14, 2020. The latest numbers can be found at: http://mercuryconvention.org/Countries.

- Storage, waste and contaminated sites (Articles 10, 11 and 12): environmentally sound interim storage for allowed uses; environmentally sound management of domestic mercury wastes, with transboundary movements of mercury waste subject to the Basel Convention; development of strategies for identifying contaminated sites and guidance on management of contaminated sites

- Research, development and monitoring (Article 19)

The Convention requires each Party to report on its implementation of the Convention (Article 21) and established an Implementation and Compliance Committee to examine both individual and systemic issues of non-compliance (Article 15).

The Convention also requires all Parties to report on a regular basis on the measures they are implemting and their experinces of their effectiveness (Article 21). These national reports form the basis of tracking progress made in implementing the Convention and forms a key set of information to facilitate the work of the Implementation and Compliance Committee.

The Convention also has a requirement to undertake periodic evaluations of whether the Convention is effective in achieving its objective (Article 22), using data from Articles 15, 21 and global monitoring data. Apart from the overall evaluation of effectiveness, the Convention has other requirements for the review of individual articles and annexes to help ensure a dynamic treaty.[24]

To further support Parties, the Convention has a financial mechanism, which includes the Global Environment Facility, and the Specific International Programme to support capacity-building and technical assistance (Article 13), administered by the Conference of the Parties. The Convention also addresses the provision of capacity building, technical assistance and technology transfer (Article 14).

The Convention establishes a governing body, the Conference of the Parties, which meets regularly to oversee implementation of the Convention and keep it timely and relevant, supported by a UNEP secretariat.

The regulatory value of the Minamata Convention on Mercury has already been acknowledged in numerous scientific reports and studies. [GCO II 2019; GMA 2018] The Convention has 124 Parties.[25]

B. Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that persist in the environment for long periods, become widely distributed geographically, bio-accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on the environment or human health.

In the environment, persistent organic pollutants (POPs) have been shown to have impacts on ecosystems and biota at all levels of the food chain, thus affecting nature's contribution to peoples. Exposure to POPs by humans can lead to serious health effects including certain cancers, birth defects, dysfunctional immune and reproductive systems, greater susceptibility to disease and damage to the central and peripheral nervous systems.

Concerns about POPs arose as early as the 1980s in research undertaken in the Arctic countries where such chemicals were found in both indigenous peoples and the environment despite the fact that they had never been used in the region. Arctic countries began addressing the problem through the UN ECE's Convention on Long-range Transboundary Air Pollution (LRTAP) and the 1991 establishment of the Arctic Monitoring and Assessment Programme (AMAP), to further the science and the regional policy response to these chemicals, which were eventually proven to travel long distances and descend into the Arctic environment, where they bioaccumulated and

[24] Articles 3.13, 4.2, 4.8, and 5.10.
[25] As of October 14, 2020.

biomagnified in the food chain. Regional scientific and policy responses were developed through the mid-1990s, resulting in the development by 1998 of the regional Aarhus Protocol on POPs to the LRTAP Convention. [Stone, 2015]

Also becoming concerned that POPs posed major and increasing threats to human health and the environment, in May 1995 the Governing Council of UNEP requested[26] that an international assessment process be undertaken of an initial list of 12 POPs and that the Intergovernmental Forum on Chemical Safety (IFCS) develop recommendations on international action for consideration by UNEP Governing Council and the World Health Assembly no later than 1997. In June 1996, IFCS concluded that available information was sufficient to demonstrate that international action, including a global legally binding instrument, was required to minimize the risks from the 12 POPs through measures to reduce and/or eliminate their emissions or discharges. Given their long-range transport, it was understood that no one government acting alone could protect its citizens or its environment from POPs. [Buccini, in Downie & Fenge 2003]

In February 1997, the UNEP Governing Council[27] invited UNEP to convene intergovernmental negotiating committee (INC), with a mandate to prepare an international legally binding instrument for implementing international action initially beginning with the 12 POPs (originally called 'the dirty dozen' and now known as 'legacy' POPs). The treaty was negotiated in five rounds between June 1998 and December 2000 and requires its parties to take measures to eliminate or reduce the release of POPs into the environment.

The Convention was adopted and opened for signature at a Conference of Plenipotentiaries held from 22 to 23 May 2001 in Stockholm, Sweden, and entered into force on 17 May 2004. It now has 183 Parties.[28]

POPs consist of intentionally-produced industrial chemicals used in various applications, pesticides used in agricultural or public health applications and chemicals generated unintentionally as a result of incomplete combustion and/or chemical reactions. Twelve chemicals with well-known POPs characteristics were initially listed in the Stockholm Convention (in the box above). In general, these 'legacy' POPs were first produced and/or used several decades ago, their persistence, bioaccumulative properties and potential for long-range transport are well studied, and they have been globally banned or restricted since 2004. In 2009, nine more substances were added to the Convention[29]. Since that time, at each meeting of its governing body, at least one new chemical has been added to the Convention, with the Convention now regulating 30 chemicals, some of which are listed for elimination/restriction as well as control of unintentional releases.[30] Of these, 15 have pesticide use.

The Dirty Dozen 'Legacy' POPs

Aldrin: pesticide, Annex A
Chlordane: pesticide, Annex A
Dichlorodiphenyltrichloroethane (DDT): pesticide, Annex B
Dieldrin: pesticide, Annex A
Endrin: pesticide, Annex A
Heptachlor: pesticide, Annex A
Hexachlorobenzene (HCB): pesticide (Annex A) unintentional by-product emission (Annex C)
Mirex: pesticide, Annex A
Toxaphene: pesticide, Annex A
Polychlorinated biphenyls (PCB): industrial chemical (Annex A), unintentional by-product emission (Annex C)
Polychlorinated dibenzo-p-dioxins (PCDD): unintentional by-product emission (Annex C)
Polychlorinated dibenzofurans (PCDF): unintentional by-product emission (Annex C)

Box 3: The 12 chemicals listed in the 2001 Stockholm Convention

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[26] Decision 18/32
[27] Decision 19/13C.
[28] As of September 15, 2020. http://chm.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx.
[29] **Added at COP-4 in 2009**: chlordecone, gamma-hexachlorocyclohexane (γ-HCH, lindane) and by-products of lindane [alpha-hexachlorocyclohexane (α -HCH) and beta-hexachlorocyclohexane (β -HCH)], tetra- and pentabromodiphenyl ethers (PBDEs), hexa- and heptabromodiphenyl ethers (PBDEs), hexabromobiphenyl, perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F), pentachlorobenzene (PeCB).
[30] The full list according to each subsequent Conference of the Parties: **Added at COP-5, in 2011**: endosulfan. **Added at COP-6 in 2013**: hexabromocyclododecane (HBCD). **Added at COP-7 in 2015**: hexachlorobutadiene (HCB); Pentachlorophenol (PCP) and its salts and esters; polychlorinated naphthalenes (PCN). **Added at COP-8 in 2017:** decabromodiphenyl ether (deca-BDE); short-chain chlorinated paraffins (SCCP). **Added at COP-9 in 2019:** perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds, including any substances that degrade to PFOA. Under consideration currently by the POPs Review Committee are methoxychlor and dechlorane plus; perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds has been recommended for consideration by the Conference of the Parties at its 10th meeting in 2021.

Key provisions of the Convention require each party to:

- Prohibit and/or eliminate the production and use, as well as the import and export, of the intentionally produced POPs that are listed in Annex A to the Convention (Article 3). Annex A allows for the registration of time-limited specific exemptions for the production or use of listed POPs, in accordance with that Annex and Article 4. The import and export of chemicals listed in Annex A can take place under specific restrictive conditions, as set out in paragraph 2 of Article 3.

- Restrict the production and use, as well as the import and export, of the intentionally produced POPs that are listed in Annex B to the Convention (Article 3). Annex B allows for the registration of acceptable purposes for the production and use of the listed POPs, in accordance with that Annex, and for the registration of time-limited specific exemptions for the production and use of the listed POPs, in accordance with that Annex and Article 4. The import and export of chemicals listed in Annex B can take place under specific restrictive conditions, as set out in paragraph 2 of Article 3.

- Reduce or eliminate releases from unintentionally produced POPs that are listed in Annex C to the Convention (Article 5), sometimes referred to as by-product emissions. The Convention requires the use of best available techniques and promotes best environmental practices for preventing releases of POPs into the environment.

- Ensure that stockpiles and wastes consisting of, containing or contaminated with POPs are managed safely and in an environmentally sound manner (Article 6). The Convention requires that such stockpiles and wastes be identified and managed to reduce or eliminate POPs releases from these sources. The Convention also requires that wastes containing POPs are transported across international boundaries taking into account relevant international rules, standards and guidelines, such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The governing bodies of the Stockholm and Basel Conventions cooperate to ensure that technical guidelines are developed for any newly listed POP to help ensure the environmentally sound disposal of wastes containing that POPs. Parties are to endeavour to develop appropriate strategies for identifying sites contaminated by listed chemicals, and when remediating such sites to do so in an environmentally sound manner.

2. Parties with regulatory and assessement schemes have obligations to regulate with the aim of preventing the production and use of new POPs (Article 3(3)). Parties can also propose that a chemical be added to the Convention for elimination or restriction (Article 8). The Convention provides detailed procedures for the listing of new POPs in Annexes A, B and/or C. A Committee composed of experts in chemical assessment or management - the Persistent Organic Pollutants Review Committee- was established under the Convention to examine proposals for the listing of chemicals, in accordance with the process set out in Article 8 and the criteria and information requirements specified in Annexes D, E and F of the Convention, and meets at least once a year. Environmental and human health considerations are important throughout the listing process. For example, when endosulfan was listed in Annex A for elimination, the supporting document for the risk management evaluation pursuant to Annex F noted: “It should first be confirmed that the alternatives do not have POPs properties…. Pollinator management is a relevant issue if endosulfan will be replaced by alternatives.…Furthermore, the alternative should not possess hazardous properties such as mutagenicity, carcinogenicity, reproductive and developmental toxicity, endocrine disruption, immune suppression, neurotoxicity. Consideration should also be given to the exposure situation under actual conditions of use by workers, farmers and consumers.”[31]

Criteria for a POP under Annex D of the Stockholm Convention

Persistence

Bio-accumulation

Potential for long-range environmental transport

Adverse effects on human health or the environment

Box 4: Criteria for a POP under Annex D of the Stockholm Convention

[31] UNEP/POPS/POPRC.6/INF/12.

3. Other provisions of the Convention relate to the development of national implementation plans (Article 7), information exchange (Article 9), public information, awareness and education (Article 10), research, development and monitoring (Article 11), technical assistance (Article 12), financial resources and mechanisms (Article 13), reporting (Article 15), and non-compliance (Article 17). No compliance mechanism has been agreed to date, despite longstanding efforts to arrive at a consensus mechanism.

4. The first Effectiveness Evaluation Committee reported in 2017, which examined the effectiveness of the Convention in achieving its objectives (Article 16). A Global Monitoring Plan for POPs is an important component of the effectiveness evaluation of the Stockholm Convention and provides a harmonized organization framework for the collection of comparable monitoring data on the presence of POPs from all regions, in order to identify changes in their concentrations over time, as well as on regional and global environmental transport.

The Convention is serviced by the joint secretariat for the Basel, Rotterdam and Stockholm Conventions. Its governing body is a Conference of the Parties, which oversees the implementation of the Convention and evaluates its overall effectiveness. This includes amending the Convention to add new chemicals identified as having POPs characteristics and to tighten controls.[32]

C. Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade

The dramatic growth in chemical production and trade during the past three decades has raised concerns about the potential risks posed by hazardous chemicals and pesticides. Countries lacking adequate infrastructure to monitor the import and use of these chemicals are particularly vulnerable.

In response to these concerns, UNEP and the Food and Agriculture Organization of the United Nations (FAO) developed and promoted voluntary information exchange programmes in the mid-1980s. FAO launched the International Code of Conduct on the Distribution and Use of Pesticides in 1985 and UNEP established the London Guidelines for the Exchange of Information on Chemicals in International Trade in 1987. In 1989, the two organizations jointly introduced the voluntary Prior Informed Consent (PIC) procedure into these two instruments. Together, these instruments helped to ensure that governments had the necessary information to enable them to assess the risks of hazardous chemicals and to take informed decisions on their future import.

Seeing the need for mandatory controls, officials attending the United Nations Conference on Environment and Development held in 1992 in Brazil (Rio Earth Summit) adopted Chapter 19 of Agenda 21, which called for a legally binding instrument on the voluntary PIC procedure by the year 2000. Consequently, the FAO Council (in 1994) and the UNEP Governing Council (in 1995) mandated their Executive Heads to launch negotiations, which were completed two years in advance of the deadline set at Rio. The text of the Rotterdam Convention was adopted on 10 September 1998 by a Conference of Plenipotentiaries in Rotterdam, the Netherlands. The Convention entered into force on 24 February 2004, and now has 163 Parties[33].

The importance of UNEP and FAO continuing to work together is reflected in the fact that the FAO (in Rome) shares the hosting of the secretariat with UNEP and contributes to the core Secretariat functions in conjunction with the BRS Secretariat functions in Geneva as they relate to implementation of the Rotterdam Convention. FAO takes the lead on all technical matters related to pesticides and severely hazardous pesticide formulations.

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[32] For example, the number of exemptions and acceptable purposes for PFOS were reduced by amendment in 2019 at the 9th Meeting of the Conference of the Parties, Decision SC-9/4.

[33] As of September 15, 2020. For an up-to-date list of Parties, see: http://www.pic.int/Countries/Statusofratifications/tabid/1072/language/en-US/Default.aspx.

The technical work is delivered in close cooperation with the Pesticide Management Team in FAO, regarding in particular the building of capacity in Parties for the lifecycle management of pesticides in the context of the International Code of Conduct on Pesticide Management. The Rome office links the implementation of FAO's highly hazardous pesticide strategy and application of less hazardous alternatives to these pesticides with support to Parties in notifying any final regulatory actions taken, as required under the Convention. Work on pesticides is further leveraged through cooperation with a network of technical staff in five Regional Offices and nine Sub-regional Offices and in synergy with the Basel and Stockholm Conventions.

The objectives of the Convention are:

- to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm;
- to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.

The Convention creates legally binding obligations for the implementation of the Prior Informed Consent (PIC) procedure. It built on the voluntary PIC procedure which ceased on 24 February 2006.

The Convention covers pesticides and industrial chemicals that have been banned or severely restricted for health or environmental reasons by Parties and which have been notified by Parties for inclusion in the PIC procedure. One notification from each of two specified regions triggers consideration of addition of a chemical to Annex III of the Convention. In addition, Parties that are developing countries and countries with economies in transition can make proposals for so-called severely hazardous pesticide formulations that pose problems under conditions of use. In such cases, a proposal from one country is sufficient to trigger discussions for inclusion in Annex III.

This paper addresses industrial chemicals mainly in the context of POPs, since many of the industrial chemicals listed in Annex III to the Rotterdam Convention are POPs, such as various BDEs, PFOS, PBB, PCB, PCT, and SCCP. Two industrial chemicals listed on Annex III that have not been listed as POPs under the Stockholm Convention are asbestos and tributyltin compounds. For the former, five forms are listed, except for chrysotile asbestos, which is still under consideration by the Conference of the Parties, and other forms of asbestos are not addressed here due to concerns primarily being focused on human health impacts. Tributyltins were initially listed as pesticides, and later have been listed in Annex III also as industrial chemicals and are mentioned in this paper under the pesticides section.[34]

The Chemical Review Committee, which normally meets annually, is a subsidiary body established under the Rotterdam Convention to review notifications of final regulatory actions of chemicals and proposals to list severely hazardous pesticide formulations according to the criteria set out by the Convention in Annexes II and IV respectively and make recommendations to the Conference of the Parties for whether to list such chemicals in Annex III. The criteria to be applied include consideration of information related to impacts on the environment.

At the time the Conference of the Parties decides by consensus to include a chemical in Annex III it also adopts a "decision guidance document" (DGD) containing information concerning the chemical and the regulatory decisions to ban or severely restrict the chemical for health or environmental reasons, which is circulated to all Parties. There is a total of 52 chemicals listed in Annex III, 35 pesticides (including 3 severely hazardous pesticide formulations), 16 industrial chemicals, and 1 chemical in both the pesticide and the industrial chemical categories.[35]

Parties have nine months to prepare a response concerning the future import of the chemical (Article 10). The response can consist of either a final decision (to allow import of the chemical, not to allow import, or to allow

[34] Their use on ships is regulated by the International Convention on the Control of Harmful Anti-fouling Systems on Ships, which was adopted in 2001 and entered into force in 2008: http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Pages/Default.aspx.
[35] As of its 2019 Conference of the Parties, with the next scheduled for July 2021.

import subject to specified conditions) or an interim response (interim decision to consent to import with or without conditions or not to consent; statement that a final decision is under active consideration; request for further information; request Secretariat for assistance in evaluating the chemical). Decisions by an importing country must be trade neutral (that is, decisions must apply equally to domestic production for domestic use as well as to imports from any source).

The import decisions are circulated to all Parties and all Parties are obligated under the Convention to take appropriate measures to ensure that exporters within their jurisdiction comply with the decisions.

The Convention promotes the exchange of information on a very broad range of chemicals. It does so through:

- the requirement for a Party to inform other Parties of each national ban or severe restriction of a chemical;
- the possibility for a Party that is a developing country or a country with an economy in transition to inform other Parties that it is experiencing problems caused by a severely hazardous pesticide formulation under conditions of use in its territory;
- the requirement for a Party that plans to export a chemical that is banned or severely restricted for use within its territory, to inform the importing Party that such export will take place, before the first shipment and annually thereafter;
- the requirement for an exporting Party, when exporting chemicals that are to be used for occupational purposes, to ensure that an up-to-date safety data sheet is sent to the importer; and
- labeling requirements for exports of chemicals included in the PIC procedure, as well as for other chemicals that are banned or severely restricted in the exporting country.

The Rotterdam Convention also facilitates information exchange among Parties regarding regulatory and management practices that promote the safer use of pesticides and the development and use of safer alternatives and techniques to control pests and regulate plant growth. The Convention also assists Parties to reduce risks from highly hazardous pesticides and provides the necessary guidance and technical assistance for sound pesticides management, including the identification of safer alternatives. Information on alternatives is contained in guidance documents developed by the CRC, and Parties that have notified of national bans or restrictions also provide information on alternatives in the relevant form. The Secretariat, by means of technical assistance activities, then further supports Parties in identifying other sources of information on safe alternatives.[36]

At its 2019 meeting of the Conference of the Parties, a new annex VII was added to the Convention to establish a compliance committee. The amendment enters into force on November 6, 2020, and it is expected that the fifteen-member Committee will be elected at the 2021 Conference of the Parties.

D. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal

Awakening environmental awareness and corresponding tightening of environmental regulations in the industrialized world in the 1970s and 1980s had led to increasing public resistance to the disposal of hazardous wastes – in accordance with what became known as the NIMBY (Not In My Back Yard) syndrome – and to an escalation of disposal costs. This in turn led some operators to seek cheap disposal options for hazardous wastes in Eastern Europe and the developing world, where environmental awareness was much less developed, and regulations and enforcement mechanisms were lacking. It was against this background that the Basel Convention was negotiated in the late 1980s, and its thrust was to combat the "toxic trade", as it was termed. The Convention

[36] For more information:
http://www.pic.int/Implementation/Pesticides/Alternativestohazardouspesticides/tabid/8078/language/en-US/Default.aspx.

was adopted on 22 March 1989, pre-dating the negotiation and adoption of the Convention on Biological Diversity. It entered into force in 1992 and has 188 Parties.[37]

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous and other wastes. Its scope of application covers a wide range of wastes defined as "hazardous wastes" based on their origin and/or composition and their characteristics, as well as two types of wastes defined as "other wastes" - household waste and incinerator ash. At its 2019 Conference of the Parties, Annex II was amended to add plastic waste, along with consequential amendments in Annexes VIII and IX[38]. These new entries came into effect on January 1, 2021 and bind all Parties who have not notified the Depositary that they were unable to accept to them.[39]

The provisions of the Convention center around the following principal aims:

- the reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous and other wastes, wherever the place of disposal;
- the restriction of transboundary movements of hazardous and other wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and
- a regulatory system applying to cases where transboundary movements are permissible.

[37] As of September 15, 2020. For an up to date list of Parties, see: http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx

[38] The amendment to Annex VIII, adding new entry A3210, clarifies the scope of plastic wastes presumed to be hazardous and therefore subject to the prior informed consent (PIC) procedure. The amendment to Annex IX, new entry B3011, clarifies the types of plastic wastes presumed not to be hazardous and as such not subject to the PIC procedure. The wastes listed in entry B3011 include: a group of cured resins, non-halogenated and fluorinated polymers, provided the waste is destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes; mixtures of plastic wastes consisting of polyethylene (PE), polypropylene (PP) or polyethylene terephthalate (PET) provided they are destined for separate recycling of each material and in an environmentally sound manner, and almost free from contamination and other types of wastes. The third amendment is the insertion of a new entry Y48 in Annex II which covers plastic waste, including mixtures of such wastes unless these are hazardous (as they would fall under A3210) or presumed to not be hazardous (as they would fall under B3011), which will also be subject to the PIC procedure.

[39] As of that date, Turkey is the only Party to whom the amendments do not apply.

Key Basel Convention Technical Guidelines on Hazardous Wastes and Other Wastes

- **General POPs Guidelines**
- **POP Pesticides**
- **PBDEs**
- **Unintentionally-produced POPs (including dioxins and furans)**
- **PCBs, PCTs, PCNs or PBBs, including HBB**
- **DDT**
- **Hexachlorobutadiene (HCBD)**
- **Short-chain chlorinated paraffins (SCCPs)**
- **Pentachlorophenol and its salts and esters (PCP)**
- **Hexabromocyclododecane (HBCD)**
- **Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF)**
- **Electrical and electronic waste and used electrical and electronic equipment in particular regarding the distinction between waste and non-waste under the Basel Convention**
- **Mercury**
- **Plastic Wastes (being updated)**

Box 5: Key Basel Technical Guidelines

The first aim is addressed through a number of general provisions requiring Parties to observe the fundamental principles of environmentally sound waste management (article 4). A number of prohibitions are designed to attain the second aim: hazardous wastes and other wastes may not be exported to Antarctica, to a State not party to the Basel Convention, or to a party having banned the import of hazardous wastes (article 4). Parties may, however, enter into bilateral or multilateral agreements on hazardous and other wastes management with other parties or with non-parties, provided that such agreements are "no less environmentally sound" than the Basel Convention (article 11). In all cases where transboundary movement is not, in principle, prohibited, it may take place only if the principles of environmentally sound management (ESM) are observed and if it is carried out in accordance with the Convention's control system. What constitutes environmentally sound management is different depending on the waste stream, and the Conference of the Parties has developed 30 technical guidelines over the last thirty years which provide advice to Parties on a range of options for environmentally sound disposal of particular waste streams (e.g. mercury, POPs, e-waste, waste pesticides, plastics).

The control system is the cornerstone of the Basel Convention as originally adopted. Based on the concept of prior informed consent (PIC), it requires that, before an export may take place, the authorities of the State of export notify the authorities of the prospective States of import and transit, providing them with detailed information on the intended movement. The movement may only proceed if and when all States concerned have given their written consent (articles 6 and 7). Each transboundary movement must be accompanied by a manifest – called a "movement document"-- which must be signed each time the shipment changes hands, to allow for tracking of each shipment from point of generation until point of environmentally sound disposal, with a certificate of disposal required to be sent to the Party of export when disposal is complete. In the event of a transboundary movement of hazardous or other wastes having been carried out illegally, i.e. in contravention of the provisions of articles 6 and 7, or when it cannot be completed as foreseen, the Convention attributes responsibility to one or more of the States involved, and imposes the duty to ensure environmentally sound disposal, either by re-import into the State of export or otherwise environmentally sound disposal (articles 8 and 9).

It should be noted, however, that pursuant to an amendment adopted in 1995 that entered into force in 2019 – the Ban Amendment - each Party that is a member of the OECD, the EC or Liechtenstein and that expressed consent to be bound by the amendment is to prohibit all transboundary movements of hazardous wastes[40] to other States.[41]

The technical guidelines inform judgments about ESM in the context of a transboundary movement, or pursuant to the Convention's general obligation about proper domestic waste management in an environmentally sound

[40] All hazardous wastes are concerned when the movement is destined for Annex IV A disposal operations (final disposal operations), while only hazardous wastes under Article 1 paragraph 1 (a) of the Convention are concerned when destined for Annex IV B disposal operations (recovery operations)
[41] As of September 30, 2020 there are 99 Parties to this amendment: http://www.basel.int/Countries/StatusofRatifications/BanAmendment/tabid/1344/Default.aspx.

manner.[42] For example in the context of the recent amendments to the Convention on plastics wastes, the 2002 technical guidelines on plastic wastes are currently being updated to facilitate implementation of the amendments, including clarifying what is considered environmentally sound recycling of plastic waste. Work is also being conducted within the broader context of the review of Annexes I and III to the Convention to determine whether any additional constituents or characteristics in relation to plastic wastes should be added to Annexes I or III of the Convention. Complementary work is underway to provide guidance to Parties on how to develop an inventory of plastic wastes. Finally, a Plastic Waste Partnership was established to provide a global platform to bring together countries from all over the world, working with stakeholders, to promote the environmentally sound management of plastic waste and prevent and/or minimize its generation.

The Convention also provides for the establishment of regional or sub-regional centres for training and technology transfers regarding the management of hazardous wastes and other wastes and the minimization of their generation to cater to the specific needs of different regions and subregions (article 14). Fourteen such centres have been established that carry out training and capacity-building activities in the regions.

The Convention has a longstanding Implementation and Compliance Committee, which examines both individual cases, and systemic issues of, non-compliance. Progress under the Convention's Strategic Framework of 2011-2020 is the subject of an ongoing review that will be presented to the 2021 Conference of the Parties, which is the governing body of the Convention and is serviced by the BRS secretariat.

The Conference of the Parties also adopted a Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal in 1999, but it has not yet entered into force.

IV. Key linkages between the chemicals and waste issues under the Minamata, Basel, Stockholm and Rotterdam conventions and impacts on and benefits for biological diversity

Challenges in assessing impacts of chemicals and hazardous and other wastes on biodiversity:

- causal relationships between exposures and effects are often difficult to establish [GCO II 2019]
- linking cause and effect is often further complicated by multiple chemical stressors and/or multiple environmental stressors [AMAP 2018]

Box 6: Challenges in assessing impacts of chemicals and hazardous wastes on biodiversity

A. Mercury and biodiversity

(i) Mercury in the environment generally

1. In general

[42] Article 4.2.c.

Mercury, together with its various compounds, can cause a range of severe human health impacts, including damage to the central nervous system, thyroid, kidneys, lungs, immune system, eyes, gums and skin. Victims may suffer memory loss or language impairment, and the damage to the brain cannot be reversed. There is no known safe exposure level for elemental mercury in humans, and effects can be seen even at very low levels. Fetuses, newborn babies and children are amongst the most vulnerable and sensitive to the adverse effects of mercury. Exposure to mercury occurs mainly through ingestion of fish and other marine species contaminated with methylmercury (MeHg), its most toxic and bioaccumulative form. People may also be exposed to elemental or inorganic mercury through inhalation of mercury vapour during occupational activities or spills or through direct contact from mercury use.

The total amount of mercury currently in the environment comes from a mixture of sources: historical anthropogenic releases to air, land and oceans; historical natural inputs; and current anthropogenic and natural releases. Mercury in the air can be transported long distances from where it was emitted, and deposited onto land/soils, waters and plants. It can be re-volatilized into the air, transported by water or taken up into the food web.[43] Because it is persistent in the environment, it is only over the course of centuries or longer that it is removed from this global cycle through burial in ocean or lake sediments and subsurface soils. [GMA 2018] In general, climate effects will alter future mercury concentrations across many ecosystems, such as marine, subarctic and temperate lakes, temperate estuarine ecosystems and terrestrial ecosystems, although the specific impacts on biota are still unknown. [GMA 2018]

Natural sources (rock weathering, forest fires, volcanic eruptions or geothermal activities) account for only about 10 percent of annual emissions to the atmosphere, while human activities have increased total atmospheric mercury concentrations to about 450% above natural levels.[44] As of 2015, there are about 2500+/-500 tonnes/year emitted into the atmosphere annually from such activities.

When mercury is emitted to the atmosphere or deposited to land and water, it is still in inorganic form. However, once in the water (freshwater or oceans) and sediments, inorganic mercury can be transformed into methylmercury (MeHg) through microbial action and is far more toxic than inorganic forms, and it bioaccumulates and biomagnifies in the food web. [Hosseini, 2013] Methylmercury is a potent neurotoxin that can cause physiological, neurological, behavioural, reproductive, and survival harm to fish and wildlife. It can bioaccumulate and readily biomagnifies, increasing in concentration as it moves up the food web, such that top predators may have concentrations ten million times higher or more than the concentrations found in the area's water. [GMA 2018]

Because methylation occurs in aquatic systems, aquatic animals are generally more exposed to, and have higher concentrations of, mercury than land animals. Biotic exposure varies widely and is linked to a variety of factors, such as trophic level,[45] lifespan, latitude and sensitivity of an ecosystem to mercury input. Tropical ecosystems appear to be sensitive to elevated methylation rates. Many tropical ecosystems are 'megadiverse', home to many of the world's most sensitive ecosystems containing numerous species.[46] [GMA 2018]

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[43] It is important to note that the estimates of emission from the Earth's surface and re-emission from previously deposited mercury remains very uncertain, with a range of error comparable to the total anthropogenic emission of mercury. [GMA 2018]

[44] Key message 5, p. 5, Global Mercury Assessment. https://wedocs.unep.org/bitstream/handle/20.500.11822/27579/GMA2018.pdf?sequence=1&isAllowed=y. The 2018 assessment utilized 2015 inventory data.

[45] Hierarchical level in an ecosystem food web and whether they constitute primary producers, or primary, secondary, or tertiary consumers. https://sciencing.com/trophic-levels-rain-forests-8732158.html

[46] For example, 17 of the top megadiverse countries in the world, which account for 60-70% of the earth's biodiversity, joined forces in 2002 to form the Group of Like-Minded Megadiverse Countries for purposes of consultation and cooperation for the negotiation of the Nagoya Protocol on access to and benefits from genetic resources: Bolivia, Brazil, China, Colombia, Costa Rica, Democratic Republic of Congo, Ecuador, India, Indonesia, Kenya, Madagascar, Malaysia, Mexico, Peru, Philippines, South Africa, and Venezuela. https://www.euston96.com/en/megadiverse-countries/ . The USA and Australia are also considered mega-diverse countries but were not part of the negotiating group.

Hg concentrations in the oceans have quadrupled over the last 600 years. One model predicts that over those centuries half of emitted anthropogenic mercury has accumulated in the oceans and marine sediments, 50 per cent of which remains in the oceans. Of that amount, 36 per cent is in sea water and the rest in ocean sediments. Of the other 50% of "all-time cumulative anthropogenic emissions," 2% remains in the atmosphere with 48% held in soils. [Zhang et al., 2014]

All models predict that the clearance rates of Hg from ocean basins will be slow relative to the rate of anthropogenic emission reductions in the future, taking many decades to centuries, depending on the specific ocean basin as well as the trajectory of emission controls. Even at current global emission levels, seawater and marine food chain mercury levels are "likely to substantially increase over time" due to slow clearance of legacy mercury from the world's oceans, coupled with the release of legacy anthropogenic mercury from soil into rivers and re-volatilized into the air. [GMA 2018; Sunderland & Selin, 2013] While reductions in anthropogenic emissions and releases of inorganic mercury will ultimately reduce methylmercury concentrations in biota in the long-term, short-term trends may instead reflect local environmental conditions. [GMA 2018]

2. Mercury emissions are increasing, polluting the air, freshwater and oceans, with severe consequences for human health and the environment, particularly biodiversity (e.g. mercury bioaccumulation). [GEO-6]Emissions to air

Of the 2220 tonnes of mercury emitted annually from the top seventeen anthropogenic sources, almost 38% is derived from artisanal and small-scale gold mining (ASGM), and this, along with emissions from stationary combustion of coal (e.g. coal-fired power plants), contributes 60% of emissions. Other key sources are metal smelting and roasting, cement production, chlor-alkali production, and waste disposal of products, [GMA 2018] which are regulated by the Minamata Convention.

Estimated global emissions for 2015 are 20% higher than they were for updated 2010 emissions. While there have been modest reductions during that period in North America and Europe, these have been offset by increases, primarily in Asia, which is responsible for 49% of the 2015 global emissions, and these are mostly related to energy production and industrial processes. In Latin America (18%) and sub-Saharan Africa (16%), ASGM is the major contributor to those levels. While emissions from this sector are transported globally, the most significant deposition occurs closer to emission sources and thus largely impacts South America, equatorial Africa, and East and Southeast Asia [GMA 2018]—all areas of the world with megadiverse countries and important ecosystems (see Annex 2 for a table linking ASGM and megadiverse countries). In fact, South America, Sub-Saharan Africa and East and Southeast Asia are responsible for 96% of all ASGM emissions. [GMA 2018]

Artisanal and Small-scale gold mining (ASGM)

How many miners world-wide?

There are approximately 15 to 20 million miners including 4-5 million women and children, in approximately 70 (mostly lower-income and often mega-diverse countries) worldwide, in this rapidly growing sector. (Not all operations use mercury.)

How many people live in ASGM communities worldwide?

There are potentially 100 million people living in ASGM communities.

Economic importance:

20-25% of the world's gold is produced by ASGM.

How does mercury enter the environment during ASGM?

Gold is extracted from ore through the use of elemental mercury to form an amalgam, which is then heated to vaporize the mercury and separate the gold. Mercury is also released to soils and nearby waters.

Global emissions and releases:

2200 tonnes annually (38% of anthropogenic emissions).

1220 tonnes annually released to land and waters. ASGM is responsible for the largest releases of mercury to the soil of any sector globally.

Other significant impacts:
Deforestation, Nature's Contributions to People (e.g. habitat creation and maintenance, food and feed, supporting identities)

Sources: [UNEP, 2012; GMA 2018, Global Mercury Partnership, Esdaile and Chalker 2018, GCO II 2019]

Box 7: Artisanal and Small-scale Gold Mining (ASGM)

In many ASGM operations, the mercury that operators use to extract gold from ore comes through trade that violates national or international laws on the import, marketing or use of mercury. It is estimated that half of all mercury used in ASGM is traded illegally, and for some countries using it for ASGM the use of illegal mercury is nearly 100 per cent. There is currently an estimated value of illegally traded mercury in the range of US $100–215 million annually. [UNEP and GRID-Arendal 2020]

3. As noted earlier, these emissions result in deposition in land and water, some of which turns into methylmercury, the most toxic form for biota. Releases to water and land

The 2018 GMA produced a new global inventory of primary anthropogenic mercury releases to aquatic systems based on estimates. Estimates of releases from the ASGM sector to land and water combined are 1220 tonnes worldwide, with other sources accounting for about 580 tonnes of releases to water, with 42% of that from waste treatment (including use and disposal of mercury-added products and the disposal of municipal wastewater), 41% from ore mining and processing (production of copper, lead, zinc, aluminium, mercury and large-scale gold production) and 16% from the energy sector. Municipal sewage contributes about 25% of the 42%, which is expected to reduce as the 2020 phase-out of products under the Minamata Convention occurs. Mercury-added products are on the decline, but in the 2015 inventory are a major source of releases. [GMA 2018]

In many low-income countries, 80-90% of municipal sewage enters coastal zones untreated. Such sewage often contains heavy metals, including mercury, as well as POPs. [GCO II 2019]

In addition to direct releases to water, some of the above sources contribute mercury to land, general waste and sector-specific storage, which can be equally or more important for the global mercury cycle. For example, large-scale gold mining is estimated to put 2700 tonnes of mercury into soils each year, 45 times more than it releases directly to water. Releases to land and soil become a potential secondary source of release to water and re-emissions to air. [GMA 2018]

In addition to losses occurring during gold ore amalgamation, large quantities of mercury are accumulating in soils and sediments around ASGM sites over time, which can be remobilised and enter aquatic systems. Fifty-three percent of all releases to land or water from ASGM are from South America, 36% from East and South-east Asia and 8% from Sub-Saharan Africa. [GMA 2018] From all sources combined, East and Southeast Asia contribute the most to the global release inventory, at almost 50%. ASGM is also responsible for the largest releases of mercury to soil of any sector globally. [GCO II 2019; Esdaile & Chaler 2018]

Two major contributors to the Indo-Pacific region's MeHg burden are ASGM activities and emissions from coal-fired power plants, which provide both atmospheric deposition and releases into watersheds ending up in estuaries, which generally comprise mangrove wetlands and associated seasonally-flooded forest areas known for their ability to capture and methylate mercury. [GMA 2018]

In South America, small-scale gold mining in Brazil, Bolivia, Venezuela, and Ecuador is a major source of Hg, with major mining sites located in the Amazon Basin, where 70% of the mercury used at the ASGM site ends up in atmosphere, with 30% in tailings. That released to the atmosphere oxidizes very quickly in the tropical atmosphere with resultant high atmospheric deposition rates. Cycling is then affected by the soil conditions (where re-emission can occur) and methylation in aquatic ecosystems. [De Lacerda 2003]

ASGM is the single largest source of release to water, either directly or through remobilization, the exact proportions of which remain unknown. Because operations are often located on riverbanks, approximately 50% of the mercury released into terrestrial systems by ASGM is directly discharged into streams. Many countries with the highest ASGM activity and Hg releases are located in regions susceptible to soil erosion, including Colombia, Indonesia, the Philippines, Brazil, Guyana, Vietnam, Papua New Guinea, French Guiana, Suriname and Malaysia. Together these countries contribute more than 36% of global annual releases to terrestrial compartments from ASGM. Most of them are considered megadiverse. Similarly, in a number of African countries contaminated tailings are discharged directly into waterways. [Kocman et al 2017; de Souza Hacon et al., 2020]

4. Leaching of mercury and other toxic chemicals into groundwater from a Superfund site located 750 feet from the City of Miami's main aquifer has been an issue since at least 1981, although actions have been taken over the years to try to ameliorate the situation. A 2014 Environmental Protection Agency report warned that increased flooding could push toxins from Superfund sites into the groundwater table. Miami is already experiencing increased flooding attributed to climate change, which exacerbates the risk.[47] [Bloomberg Businessweek 2018]

Soil, Sediments, Wastewater Sludge

Legacy soil pollution therefore impacts local communities and food supplies, biodiversity and fragile ecosystems. [GCO II 2019] Soils worldwide have been damaged by mining, agriculture and industrial wastes that contain heavy metals, including lead, cadmium, chromium, mercury and copper. Heavy metals damage soil quality and reduce the number of microorganisms that are critical to soil fertility. [GCO II 2019] As noted above, about 48% of historic anthropogenic mercury emissions are now considered to be stored in the Earth's soils.

ASGM is the sector contributing the largest amount of mercury to soils. For example, artisanal gold mining in Senegal, which has intensified over the last two decades, has contaminated soils close to mining sites with elemental Hg; surface soil erosion may lead it to downstream ecosystems where it methylates. In mined river and pond areas, there is high MeHg. Hg contamination of river sediments decreases away from mining sites, but due to particulate transport, levels of MeHg in the water increases further away from the site. [Niane et al., 2019]

In French Guiana, ASGM activities increased total Hg in sediments by 78%, with up to 70% of that from liquid Hg used in ASGM, while the rest came from ASGM-driven erosion of Hg-rich soils into the river. [Goix et al., 2019] Hg levels in water and soil are elevated in areas downstream of ASGM. [Diringer et al., 2015]

Heavy metals, including Hg, can accumulate in sediments through adsorption, precipitation/coprecipitation, and biological effects, acting as sinks. As a result, heavy metal content (concentration) in sediments is far greater than in the overlying water column. Sediments can become a source of heavy metals like mercury when environmental and/or physicochemical conditions change (i.e. pH, temperature, dissolved oxygen), and the heavy metals are released from the sediments into the overlying water column, where they are likely to transform (i.e. Hg into methylmercury) and transfer through the food web (bioaccumulate and biomagnify). [Peng et al., 2018]

Sediment is a vital habitat for aquatic and marine life in coastal ecosystems and reflects the long-term history of development in a coastal area. A study of 52 selected coastal sites in twenty countries on six continents concluded that heavy metal pollution in sediments is widespread [Qian et al., 2015] and serious heavy metal quantities (Cd and Hg) have been found in Chinese river sediments. [Peng et al., 2018]

[47] https://www.bloomberg.com/news/features/2018-08-29/miami-s-other-water-problem. This article describes how a Superfund site for previous industrial activity leaching mercury, arsenic, cyanide, nickel, lead, cadmium, chromium, choloroform and oil into groundwater is located 750 feet away from Miami's primary groundwater supply, a risk now enhanced by climate change, expected sea level rise and already increased flooding. This citation is not provided to prove that this site is a substantial contributor of mercury pollution, but to illustrate that historical industrial activity in developed countries can also pose problems today.

(ii) Impacts on Biological Diversity

1. Biodiversity and biota generally

Ecotoxicology tries to understand and predict effects of chemicals on natural communities under realistic exposure conditions. At the **organism level**, the response can be: acute toxicity causing mortality, chronically accumulating damage ultimately causing death, sub lethal impairment of various aspects of physiology and morphology, sub lethal behavioral effects. At the **population level**, the response could be: size and dynamics (e.g. birth and death rates), a reduction or increase in the natural flow of numbers (e.g. sex ratio). At the **community level** the response could be about species diversity or predator/ relationship etc. At the **ecosystem level**, this could constitute changes in nutrient cycling rates and patters of nutrient flow, physicochemical conditions, and the like.

[Bhat, 2013]

Box 8: Ecotoxicology

There is extensive literature on mercury concentrations in biota, the main route of exposure being methylmercury, which comprises 95% of the total mercury in tissue commonly sampled. Food webs in many of the world's biomes and ecosystems have MeHg concentrations at levels of concern for ecological and human health. [GMA 2018] While this paper focuses on impacts on biodiversity, the issue of human health is also relevant where mercury impacts nature's ability to provide traditional ecosystem services such as provisioning, culture, regulation and support services.

There are **MeHg "hotspots" around the world** where biota have above average MeHg body burdens with potential significant human and ecological health impacts. These are linked to both contaminated sites and to ecosystems that are particularly sensitive to such inputs. [GMA 2018] The factors affecting MeHg accumulation in biota are diverse. [GMA 2018]

The 2018 *Global Mercury Assessment* concludes that "mercury loads in **aquatic food webs** are at levels of concern for ecological and human health around the world." [GMA 2018; GCO II 2019] Mercury is a neurotoxic heavy metal that can impair physiology, neurology, behavior, reproduction, and survival in fish, wildlife, and humans. [Provencher, 2016]

Methylmercury produced in upper oceans has been shown to accumulate in **deep Mariana Trench fauna**, suggesting that anthropogenic mercury released at the Earth's surface is much more pervasive across deep oceans than was previously thought. [Sun et al., 2020]

Under the Minamata Convention[48], bioindicators of noted relevance for human health and the environment are fish, sea turtles, birds, and marine mammals.

Many species of fish and wildlife are impacted by the adverse effects of Hg on their physiology, behavior and reproductive success [Dietz et al., 2019; Scheuhammer et al., 2015; Provencher, 2016; Ackerman et al., 2016; Evers, 2018]. Some are considered high profile species and are included by IUCN on their Red List of Threatened Species or listed as threatened or endangered by national governments. [GMA 2018] Absorption of heavy metals, especially the uptake of methylmercury, has been shown to cause toxicity, neurological damage, behavioural changes, renal failure, hyperactivation of dermal cells surrounding gills and death in aquatic animals. [Zeitoun & Mehana, 2014]

Because of biomagnification of methylmercury, long-lived piscivorous or other **top predatory animals in aquatic food chains** are at greatest risks of elevated dietary methylmercury exposure, and ecologically relevant MeHg exposures can cause significant behavioral, physiological, immunological, neurochemical, reproductive, and histological changes. For some wild piscivorous bird species, reproduction impairment is demonstrated at ecologically relevant levels of Hg contamination. [Scheuhammer et al., 2007]

Various species of **porpoise, dolphin and beaked whale** have high Hg body burdens, as well as marine mammals foraging at lower depths in the mesopelagic zone, such as the **northern elephant seal**. [Peterson 2015; Peterson 2018] Mercury contamination of oceans is prevalent worldwide and methylmercury concentrations are increasing

[48] Art. 19.1.b.

more rapidly in the mesopelagic zone (200–1000 m) than in surface waters. Furthermore, as mercury concentrations in the world's oceans are projected to increase for decades or even centuries, even if anthropogenic mercury emissions are halted, [Sunderland & Mason, 2007] this furthers the risk of mercury exposure to predators foraging within the mesopelagic zone and those in the northeast Pacific Ocean may be at high risk for mercury bioaccumulation. [Peterson 2015; Peterson 2018]

The Amazon and Orinoco basins, where mercury has been released from ASGM since Colonial times along with natural sources, are home to the highest diversity of **river dolphins** on the planet. As active top predators with high feeding requirements and extended longevity, among other factors, these river dolphins are susceptible to exposure and ultimately accumulation of contaminants such as mercury. River dolphins are a keystone species and among the most threatened cetaceans on the planet. Four taxa of river dolphins were found to have high concentrations of total mercury in muscle tissue, which exacerbates the conservation status of these aquatic mammals, suffering from other stressors such as climate change, and pointing to the need to reduce the use of mercury through transboundary cooperation pursuant to the Minamata Convention on Mercury. In addition, ancestral fish-eating societies face an imminent health threat. [Mosquera-Guerra et al., 2019]

Those **species foraging at pelagic habitats** have higher MeHg burdens, like **sharks**, than species foraging in benthic habitats. Although most sharks have a dietary uptake beyond the level that affects reproduction in freshwater fish, it is unclear whether these are related to population declines. Of 14 shark genera with published muscle Hg concentrations, average levels exceed advisory levels in 71% of genera. [GMA 2018]

Similarly, **seabirds** biomagnify high levels of methylmercury, and due to their range, can reveal differences in levels of contamination between different ocean basins. [GMA 2018] Due to their foraging strategies, behavioral ecologies and life-history traits, they generally have elevated body burdens of Hg which can reduce their reproductive capacity and affect the ability to sustain populations over time. Those feeding on crustaceans show lower levels of mercury than those feeding on fish; similarly those foraging at epi-pelagic rather than mesopelagic levels have lower levels of mercury. Seabirds, such as albatrosses, at the highest trophic levels with a regular dietary intake of MeHg, are at risk of MeHg toxicity associated with potential long-term population declines, which could be exacerbated by other perturbations such as climate change. [Goutte et al., 2014] There have been concerns about the impact of mercury on the **ivory gull**, which is increasingly rare. [GMA 2018] Elevated mercury levels in **petrels** in New Zealand might be linked to reduced reproductive success and reported declines in breeding populations, and also pose a risk to the customary harvest of chicks by Māori, with resultant human health implications. [Lyver et al., 2017]

> "Although the risk-assessment approach used for wildlife often emphasizes sustainability of wildlife "populations" rather than the health of individuals, conserving habitat quality is also a major consideration. Environmental Hg contamination results in degradation of Hg-sensitive aquatic ecosystems, because inorganic Hg is methylated, rapidly enters the food web, and biomagnifies to potentially toxic concentrations in fish and their predators."
>
> [Scheuhammer et al., 2007]

Box 9: Risk Assessment for Wildlife

For **birds of prey,** certain **osprey and eagle species** that have a near global distribution have been commonly monitored for contaminants. Some studies have shown that raptors generally reflect the level of MeHg exposure found in the food web associated with the nesting territory, that piscivorous raptors have the highest concentrations of Hg, and those specializing in bird prey have higher levels than those species targeting small mammals. A study of bald eagles in the USA Great Lakes ecosystem found that 14-27% of those sampled had Hg at concentrations associated with subclinical neurological damage. Hg levels in **raptorial birds** have been found to be elevated in areas located close to ASGM operations. [Markham & Sangermano 2018]

Many species of **landbirds** are at elevated risk of mercury exposure. Some species of invertivore-feeding birds have higher Hg concentrations in tissue than avian piscivores within the same ecosystem. They may also be more sensitive to MeHg, resulting in a higher likelihood of adverse impacts on reproductive success. Recent research suggests that certain species of **songbirds** are more at risk, depending on their foraging behaviour and breeding habitats. Those that breed in wetlands, including rice fields, are at the highest risk of Hg exposure, especially species that feed on predaceous arthropods such as spiders. Studies also show possible impacts on reproductive success and impacts on migration behaviour. [GMA 2018]

Spiders often serve as an important trophic level link for MeHg to terrestrial wildlife as predators of emerging aquatic insects and then serving as prey for terrestrial wildlife such as birds and lizards. High MeHg concentrations in spiders show that MeHg transfer in adult aquatic insects is an overlooked but potentially significant pathway of MeHg bioaccumulation in terrestrial food webs. [Chaves-Ulloa et al., 2016]

Mercury pollution has been related to decreases in food consumption and body size and increases in mortality of **amphibians** and their larvae [Bergeron et al., 2011; Burke et al., 2010; Todd et al., 2012]

In fathead **minnows** exposed to dietary MeHg at environmentally relevant concentrations, circulating sex hormones were suppressed in both sexes, leading to decreased fecundity in females and altered reproductive behavior in males, resulting in adverse effects on reproductive success. [Drevnick & Sandheinrich, 2003]

Wastewater **sludge deposition** on agricultural fields often contains heavy metals, resulting in adverse ecological effects, such as: localizing in plant roots, inhibiting enzymatic processes, and resulting in reduced growth and root damage; bioaccumulation in higher trophic levels up the food chain. [Manzetti & Van der Spoel, 2015]

2. Mercury Hotspot: ASGM activities and related contaminated sites

There is considerable literature on the impacts of mercury on biota and soils from ASGM activities, which, as noted in Annex 2, are often undertaken in countries which are home to particularly high numbers of species of plants and animals. Deforestation is also a major environmental concern at such sites. [Towards a Pollution-free Planet] [Markham & Sangermano, 2018] For example, 32% of deforestation in Suriname is caused by gold mining, some of which is practised in biodiversity protected areas. 95% of Suriname is forested, making it the 2nd most forested country in the world, [Amazon Conservation Team, 2015] housing unique species such as the blue poison dart frog. Mercury pollution from artisanal gold mining compromises food chains and biodiversity [Esdaile & Chalker, 2018; Markham & Sangermano 2018] and also human health. [Kahhat et al 2019; Marrugo-Negrete et al., 2019; Gibb & O'Leary, 2014] In Brazil, COVID-19 is fuelling an increase in ASGM, due to surging unemployment, coupled with extremely high gold prices and lax enforcement. People are travelling from all over the country to hundreds of illegal mining sites for economic reasons, but it has resulted in devastating impacts on the rainforest, including protected indigenous lands, [Washington Post, 2020] highlighting the tensions between the economic and environmental dimensions of ASGM.

The geographic extent of gold mining operations increased in the Peruvian Amazon by 400% between 1999 and 2012, with widely practiced extraction techniques using mercury leading to **biodiversity loss, logging and polluted fisheries**. [Asner et al 2013] In particular, mercury emissions have been found to affect **algal growth, crustacean health, fish growth, brain function, reproduction, amphibian larval health** and survival. Mercury bio-accumulates in **fish**, which then pose a threat to those species eating fish, including humans. Harm to such predators is important because many mining sites are located in highly bio-diverse regions such as the Amazon rainforest. [Esdaile & Chalker, 2018] For example, with almost 2,200 recognized species of fish, the Amazon Basin is the most diverse in terms of fish fauna with speculation that there are many more species yet to be discovered. Several endemic or threatened freshwater fish may be at risk in the Amazon Basin from ASGM activities. [Markham & Sangermano, 2018]

Waste from mining activities has been found to be one of the most important sources of water contamination for Peruvian **amphibians**, with some areas of high vulnerability over 25 km from an identified mining area, with high land vulnerability largely concentrated around rivers. [Catenazzi & von May 2014] [Markham & Sangermano 2018] A recent reassessment of Peruvian amphibians identified habitat loss as the main threat, with pollution from mining operations in the category of "other threats". However, the **Harlequin frog**, a highly threatened species on the IUCN Red List, is primarily threatened by stream mining operations/heavy metal pollution and chytridiomycosis. [Jarvis et al., 2015].

A Colombian floodplain that previously had mercury reported in water, plankton, fish, aquatic plants, and sediments as a result of ASGM activity, was subsequently found to have high mercury concentrations in tissues of **caiman lizards**, a predator species in tropical ecosystems. There was a highly significant correlation found between Hg and DNA damage in sampled tissues that could possibly influence vital functions such as reproduction of the species and the ecological niche that it represents within the ecosystem. It was further concluded that the impacts from ASGM "likely extend" to the rest of the species inhabiting the ecosystems, and humans who consume their meat. [Marrugo-Negrete et al., 2019]

Artisanal gold mining in Senegal, which has intensified over the last two decades, has contaminated soils close to mining sites and aquatic ecosystems through runoff, where it methylates, with possible long-term impacts on the aquatic ecosystem, including **plankton, shellfish, and fish.** [Niane et al., 2019]

3. Sensitive environments: the Arctic

Atmospheric, terrestrial, and oceanic pathways deliver methylmercury to Arctic environments, typically quite distant from the source of original emission or release. As part of the 2018 AMAP assessment, risks of Hg health effects were estimated for geographically widespread populations of Arctic mammals and birds. This analysis identified a number of species as being at a particularly high risk of adverse health effects or population impacts.

Despite global initiatives to limit human activities producing mercury and restrict the production of legacy chemicals such as POPs, levels in some Arctic apex predator species remain elevated and may no longer be declining in response to restrictions in use. Levels of mercury, and more importantly, polychlorinated biphenyls (PCBs), remain a significant exposure concern for many Arctic biota, including **polar bears, killer whales, pilot whales, seals, and various seabird, shorebird, and birds-of-prey species.** The levels of these chemicals put these species at higher risk of immune, reproductive and/or carcinogenic effects. [AMAP 2018]

This is complicated by the fact that Arctic **wildlife and fish** are exposed to a complex cocktail of environmental contaminants including legacy POPs, emerging chemicals of Arctic concern, mercury, and other pollutants that, in combination may act to increase the risk of biological effects. The impact of contaminant exposure in Arctic biota needs to be considered in combination with other natural and anthropogenic stressors, such as climate change, hunting pressure, invasive alien species, emerging pathogens, and changes in food web dynamics. The added influence of these environmental factors, on top of existing chemical exposures, may significantly increase the risk of health effects and population impacts. [AMAP 2018] For example, increased temperatures increase the bioavailability of methylmercury, increasing metal toxicity in periphyton. [Val et al., 2016]

As apex predators of the Arctic, **polar bears** continue to exhibit levels of mercury that put them at a high to severe risk for reproductive and other adverse health effects. Additionally, being long-lived predators that produce few offspring, polar bears may be at greater risk of population declines through exposure to endocrine disrupting chemicals and are expected to be greatly impacted by the effects of climate change due to the projections of sea-ice loss, and decline in access to their main prey, the ringed seal. [AMAP 2018]

Many Arctic species have been identified as being at high risk for Hg-mediated health effects, including **pilot whales, killer whales, narwhals, and hooded seals, polar bears, and seabirds.** [Dietz et al 2019] Fish and wildlife are exposed to the contaminant primarily through the food chain, resulting in higher concentrations found in higher trophic species, especially **ringed seals, belugas, and polar bears.** [Braune et al., 2015] Hg levels in Arctic **beluga** fall within the range of exposures that elicited in vitro immune suppression. [Frouin et al., 2012]

In the Arctic, **toothed whales and some seals** are the marine mammals of greatest concern for human and ecological health and toothed whales appear to be one of the most vulnerable groups of marine mammals to the dietary uptake of methylmercury. [GMA 2018] Mercury concentrations associated with subclinical neurochemical effects are found regularly in brain tissues from these species and are of concern for ecosystem health. [Dietz et al., 2013] [Krey et al., 2015]

Among affected **fish species**, are lake trout and burbot in Great Slave Lake where concentrations have increased between 1992 and 2012; [Evans et al., 2013] sculpins were found to have increased liver necrosis, vacuolated hepatocytes and gill lesions linked to increasing Hg concentrations [Sonne et al., 2014c] and landlocked Arctic char in the Canadian Arctic have been found to be relatively high in contaminants, especially mercury, [Swanson et al., 2011] with a more recent study concluding that 30% of landlocked Arctic char populations in Northern Canada and Greenland had concentrations of Hg that exceeded those known to cause toxicity in fish. [Barst 2018]

The Arctic is populated with numerous and diverse **marine and terrestrial bird species**, many of which serve as important subsistence foods for indigenous communities. Many different Arctic bird populations, spanning multiple species – including **gulls, guillemots and murres**--at various locations were found to be at a high to severe risk for health impacts from either PCB or Hg exposure, prompting concern for both population viability and human health impacts. [AMAP 2018]. Increased methylHg concentrations have been linked to decreased survival of eggs in **thick billed murres** and **Arctic terns**. [Braune et al., 2011] Even sublethal levels of trace metals from the environment may be associated with reduced reproductive outputs in **eider ducks**. [Provencher, 2016]

Loons are piscivores that breed on freshwater ponds and lakes in temperate and Arctic ecosystems of the Northern Hemisphere and winter in marine ecosystems, with parts of some populations overwintering on freshwater lakes. Loons have been used as bioindicators for several decades, in both their breeding and wintering areas. Large species that are obligate piscivores have some of the highest average Hg body burden in birds in the world, and the effects of mercury on reproductive success have been well-established. Even small declines in adult survival can have significant implications for population demographics due to the low annual productivity, delayed sexual maturity, and long-life expectancy. [Burgess & Meyer, 2008; Evers et al., 2011; Depew 2012]

(iii) Impacts on nature's contributions to people

This section provides examples from around the globe of concerns about mercury pollution affecting nature's ability to provide services that people have come to rely upon: materials such as food and genetic resources; non-material contributions of consuming traditional foods that support spiritual and religious identity, learning and inspiration; and the regulation of soil and freshwater quality and habitat creation and maintenance. (See Figure 1, above, on Nature's Contributions to People)

Mercury pollution from ASGM around the world is a growing problem. A review of 60 studies conducted in 19 communities in South America, Asia, and Africa demonstrated that ASGM workers and their families were exposed to dangerous levels of Hg vapor, but workers, their families and residents of nearby and downstream communities were all consuming fish heavily contaminated with methylmercury. [Gibb & O'Leary, 2014] Fish consumption and location of residence are significant risk factors for elevated Hg levels, with households in mining zones at increased risk. [Ashe, 2012] Human health issues arise from ingestion of rice planted near ASGM activities. [Liu et al., 2018] Impacts on soil noted earlier, and below in emerging issues, implicate nature's regulation of the formation and long-term maintenance of soils.

Moreover, indigenous peoples in many areas of the world (but especially groups within the Amazonian region and Inuit from the Arctic) are at increased risk of mercury exposure.[49] Many from these communities are reliant upon traditional and locally-caught foods such as fish and marine mammals not only for sustenance, but as a strong basis for the culture, spirituality, recreation, and economy of many of their communities. Therefore, contamination of food by Hg has been characterized as an issue of environmental justice. [GMA 2018] The Lancet Commission on Pollution observed that pollution of rivers, lakes and oceans from human activities can have 'catastrophic effects' on freshwater and marine ecosystems that result in the collapse of fisheries and diminished livelihoods of indigenous and other populations who rely on fish as a major food source. [Landrigan, et al., 2017]

The major river basins of South America support a large freshwater fishery, providing livelihoods for small-scale fishers as well as commercial fisheries. [Barletta et al., 2010.] In the remote interior regions, indigenous communities are highly dependent on freshwater resources for subsistence, and for those with a high level of fish consumption the risk of MeHg exposure can be equally high, particularly in ASGM 'hotspots'. Where these and other Hg point sources are connected with river floodplain habitats, with daily seasonal water fluctuations, they can be subject to elevated methylation rates. [GMA 2018] In Suriname, 70-80% of households of Maroon peoples obtain regular income from family members working in gold mines. Whereas 32% of Suriname generally has suffered deforestation due to gold mining, including artisanal mining, in Maroon lands 45% of deforestation is caused by such mining. Further, fish from the Saramacca River south of the capital are no longer considered safe to eat as a result of mercury absorption. [Amazon Conservation Team, 2015]

The environmental impacts of gold mining in the Peruvian Amazon include deforestation, soil erosion, and mercury contamination, which is released into water systems, soil, vegetation and the air. This has contaminated the **local**

[49] These concerns have been reflected in the preamble of the Convention.

food supply, including fish, wildlife, fruits, nuts and vegetables. Since 2009, studies have found high mercury levels in many species of **fish**, particularly in large catfish, which are a staple diet of the local people. It has been estimated that roughly two thirds of the approximately 120,000 residents of the region have been affected, many of them young children, who are the most vulnerable to mercury toxicity. Fish from mining-impacted water had twice the levels of Hg as those from pristine waters; mercury is biomagnified because levels are significantly higher in the carnivore fish higher up the food chain. [Thomas, 2019]

The Brazilian part of the Amazon is facing similar challenges with mercury contamination from ASGM, with the **fish consumed by local communities** found to contain levels of mercury exceeding World Health Organization safe limit in 28.7% of fish samples (although all 428 fish sampled had detectable levels of mercury), with a higher prevalence in inland zones. The local preference for carnivorous fish species presents a serious health risk, particularly for communities (and children) near inland rivers. The risks are high enough to justify proposing limits of 200 g of some fish per week, with others to be consumed only once per month, which compromises indigenous cultural traditions. [de Souza Hacon et al., 2020]

ASGM sources in Africa are concentrated in South Africa, the East African Rift Valley and West Africa, with ASGM being responsible for about 70% of emissions on the African continent. In Africa, **subsistence and commercial fisheries** are important to food and economic security, contributing up to 70% of animal protein consumption [GMA, 2018], and although Hg concentrations in fish from uncontaminated lakes has been quite low, levels of monitoring have been low. Much higher levels of MeHg are found where aquatic ecosystems are impacted by ASGM, such as in Ghana, Tanzania and South Africa, where fish in such lakes have metal contaminants, including mercury at levels of concern for human consumption. In a study on sediments, water and fish in four regions associated with ASGM in Cote D'Ivoire, methylmercury was found in sediment and **local fish** populations. Mercury and methylmercury were elevated at locations close to gold mining activities. Mercury concentrations in fish populations were high enough to be a human health concern, thus extending impacts beyond ASGM communities. [Mason et al., 2019]

In Indonesia, there is an extensive artisanal gold-mining sector, estimated to provide 20 tonnes of gold (out of 127 tonnes of gold) annually, that has increased since 2000. ASGM has been conducted alongside farming, which is dominated by rice production, where mercury levels have exceeded government standards. High concentrations of mercury were found in miners and their families living nearby, with workers showing symptoms of mercury exposure in less than five years. ASGM miners are moving away from amalgamation to a process of cyanidation, which if done properly is less dangerous for workers, but still produces tailings that contain mercury, which can harm the environment. To achieve environmentally sustainable ASGM, it is recommended that it be formalized. [Krisnayanti 2018]

In its 2018 report, AMAP noted that, "The high contaminant levels observed in some Arctic wildlife could pose a concern for the health of indigenous communities reliant on subsistence harvests as part of a traditional diet." Studies show that in the Arctic, Hg levels in birds and marine mammals have increased ten-fold over the last 150 years, with an annual increase of 1-4%. Indigenous peoples rely on biota for sustenance that are higher up the food chain with longer lifespans and high levels of MeHg, such as **narwhal, beluga, pilot whale and ringed seal** [GMA 2018; Dietz et al., 2013; Scheuhammer et al., 2015]

In the Aleutian Islands of Alaska, Aleuts and subsistence hunters are facing such challenges with marine birds. [GMA 2018] Both **marine and terrestrial bird species** important as subsistence foods for indigenous communities have been found to be at a high to severe risk for health impacts from either PCB or Hg exposure, prompting concern for both population viability and human health impacts. [AMAP 2018]. 30% of landlocked arctic char populations in Northern Canada and Greenland had concentrations of Hg that exceeded those known to cause toxicity in fish. [Barst 2018] Arctic char and lake trout can represent up to 35% of human Hg intake in the Canadian Arctic, and Arctic char and lake trout are the second most frequently consumed traditionally harvested food (after caribou) in most Inuit regions of Canada. [Van Oostdam, 2003]

A case study on the global oceans examined the issue of **tuna**, as it is one of the most important global sources of seafood, with commercial harvests totaling 5 million tonnes in 2014, worth an estimated USD 42.21 billion. Whether the levels in tuna exceed health advisories depends on the size of the species, location in geographic Hg hotspots (e.g. eastern and northern Pacific Ocean), whether the tuna is canned or fresh (canned have lower concentrations) and farmed or wild (farmed have less accumulation in muscle). [GMA 2018] For yellowfin tuna and common dolphinfish caught in the eastern Pacific Ocean off Ecuador, mercury was found in muscular and liver tissue in half the samples at levels exceeding limits considered safe for consumption by the EU. [Arajuo & Cedeno-Macias, 2016].

Many **sharks, skates and rays** have muscle mercury concentrations well above the World Health Organization (WHO) health advisory levels. Species within the **mackerel and ground sharks** generally have elevated body burdens, which is concerning because many of these species are already threatened with extinction from over-fishing, and their meat is consumed globally. [GMA 2018]

Important socio-cultural benefits of harvesting and using traditional foods

Fosters an essential part of the culture

A way to practice and teach spirituality

Keeps people in tune with nature

Provides intergenerational education about nature

Fosters survival skills

Contributes to physical fitness/health, as a favourite outdoor recreation activity

Provides people with healthy food and fosters food preparation skills

Favours sharing in the community

Fosters personal attributes like humility, pride, confidence and patience

Brings respect from others

From Kuhnlein et al., 2003, in Fenge and Downey, *Northern Lights Against POPs*

Box 10: Important socio-cultural benefits of harvesting and using traditional foods

Mercury body burdens in **billfishes** such as marlin and swordfish are among the highest known for marine fish, and swordfish, for example, are an extremely important commercial fish for small island developing states, such as the Seychelles. Their ability to market these internationally has become difficult due to the mercury levels which can exceed those acceptable to their trading partners, with the result that there has been an attempt to switch the domestic fishing fleet to tuna, despite the fact that tuna populations in the Indian Ocean are in decline, and this is not a long-term solution. [GMA 2018] **Pilot whales** are still harvested by some SIDS such as the Faroe Islands and St Vincent and the Grenadines and their elevated levels of Hg are a human health concern.

In temperate lakes across Fennoscandia,[50] data collected over the past 50 years for over 3000 lakes and rivers illustrates that Hg concentrations in the south (below 60) are generally higher than in the north, with over 40% of the lakes containing **fish** with muscle Hg concentrations exceeding the WHO/FAO limit of .5ppm widely used as a trigger for human consumption safety. [GMA 2018]

[50] Finland, Norway, Sweden, and the Kola Peninsula in the Russian Federation.

A reduction in height of rice plants growing in soil contaminated with Hg has been shown, and plants growing on such soils show a general reduction in growth, performance and yield. [Chibuike & Obiora 2014] Human health issues arise from ingestion of rice planted near ASGM activities [Liu et al., 2018]

The Nura River in Kazakhstan underwent remediation activities, as mercury in the river had become associated with millions of tonnes of power station fly ash, forming a highly contaminated silt that dispersed over the floodplain during spring floods, resulting in unsafe levels of mercury contamination in river sediment, floodplain soils and fish, loss of clean water, fish and agricultural land; potential mercury-related health impacts in adults and children; and the potential for further dispersion of mercury loaded sediments to accumulate in Ramsar wetlands, with risks to endangered wildlife. [IPEN 2016]

Heavy metals such as mercury contribute to the spread of antimicrobial resistance because they increase the selection for antibiotic resistance genes among bacteria. [Wales & Davies 2015; Singer et al. 2016; GCO II 2019]

(iv) Challenges and emerging issues

Many of the studies noted above have suggested specific areas for future research to better understand the complexities of the mercury cycle and its impacts on biological diversity and ecosystem services. This section highlights several of the broader challenges and emerging issues of concern with assessing mercury impacts on biodiversity and ecosystem services.

- ***Multi-chemical exposures require improved risk evaluation:*** There is a need for improved predictions of contaminant-related risks to Arctic biota through methods that account for the combined toxicity of real-world, complex, multi-chemical exposures and for these to be considered in combination with other natural and anthropogenic stressors. Arctic wildlife and fish are exposed to a complex cocktail of environmental contaminants including legacy POPs, emerging chemicals of Arctic concern, mercury, and other pollutants that, in combination may act to increase the risk of biological effects. Yet, most of the data and methods currently used to predict potential health impacts to Arctic biota are based on single-chemical exposures. In order to improve the accuracy of risk evaluations, a better understanding of impacts of real-world, multi-chemical exposures is needed. New experimental approaches and targeted research involving complex contaminant exposures are required to address this need. [AMAP 2018] There is a need for cross-disciplinary studies that include observations of indigenous knowledge holders, environmental data, and the development of new tools, such as computer models, to integrate data collected from the field into a larger, holistic picture of Arctic wildlife health. [AMAP 2018]

- ***Climate change impacts and other environmental stressors amplify mercury impacts*:** The impact of contaminant exposure in Arctic biota needs to be considered in combination with other natural and anthropogenic stressors, such as climate change, hunting pressure, invasive alien species, emerging pathogens, and changes in food web dynamics. The added influence of these environmental factors, on top of existing chemical exposures, may significantly increase the risk of health effects and population impacts. [AMAP 2018] The interlinkages between human toxicity, freshwater ecotoxicity and climate change have been identified in the context of alluvial gold mining activities in the Peruvian Amazon rainforest. [Kahhat et al., 2019] Climate change-contaminant interactions may alter the bioaccumulation of two priority contaminant classes: the fat-soluble POPs, and MeHg. These interactions include phenomena deemed to be either climate change dominant (where climate change increases contaminant exposure) or contaminant dominant (where contaminant presence leads to an increase in climate change susceptibility) [Alava et al., 2017]

In general, climate effects will alter future mercury concentrations across many ecosystems, such as marine, sub-Arctic and temperate lakes, temperate estuarine ecosystems and terrestrial ecosystems. Specific effects of climate change include enhanced air-seawater exchange, melting of polar ice caps and glaciers, increased thawing of permafrost, and changes in estuarine sulfur biogeochemistry, but how these landscape processes relate to changes in biotic Hg exposure is relatively unknown. [GMA 2018] A July 2020 study predicts that all but a few high-Arctic polar bear populations could be extinct by 2100, and although moderate emissions mitigation will prolong persistence, it is unlikely to prevent some extirpations within the 21st century. [Molnar et al., 2020] The combined impact of such effects with mercury or POPs impacts, discussed below, are an important consideration for future research and policy development. [AMAP 2018]

Given that climate change could cause much of the Arctic permafrost to thaw over the next century, the mercury stored in the permafrost will likely be transported from the soil via streams, rivers, biological vectors, and the atmosphere. This could potentially have far-reaching impacts on terrestrial and aquatic species through bioaccumulation or microbial conversion to methylmercury. [Sutherland et al., 2019] A recent study estimates that the entire Northern Hemisphere permafrost region contains twice as much natural mercury as the rest of all soils, the atmosphere and oceans combined. With melting permafrost (due to climate change), the impact of meHg released into environment will depend on how quickly temperatures warm, how much permafrost thaws, how much is released into the food chain, and after impacts on Arctic peoples and wildlife, where the mercury will travel and be deposited on the rest of the planet. [Schuster et al., 2018] [National Geographic UK, 2018]

- ***Transforming the ASGM sector*:** ASGM continues to be the sector emitting the most mercury to the atmosphere and releasing the most to land and waters, particularly in biodiversity hotspots, with significant impacts on the environment, nature's contributions to people and human health. The Convention addresses this issue through the use of national action plans which are required to include national objectives and reduction targets and actions to eliminate the most damaging practices involving mercury. These efforts are supported by the Global Environment Facility and other donors.[51] The Global Environment Facility (GEF), which operates the financial mechanism for both the Convention on Biological Diversity and the Minamata Convention on Mercury, held the implementation launch in 2019 of the GEF PlanetGold Programme, led by UNEP and implemented with a range of other partners, and aims at assisting eight countries[52], a number of which can be characterized as megadiverse, to replace mercury with cleaner techniques, as well as improve access to finance and facilitate formalization of the sector. More countries need this type of encouragement and assistance if impacts on biological diversity from the ASGM sector are going to be substantially reduced. Furthermore, there is a need throughout the global supply chain (merchants, refineries, luxury suppliers) to press for "cleaner gold".[53] Parties to the Minamata Convention need to fully implement the Convention's trade provisions at the national level and improve monitoring and reporting of mercury stocks and movements to reduce the amount of illegal mercury supporting ASGM. The legalization and regulation of ASGM as part of the formal economy is likely needed to transition to mercury-free ASGM. [UNEP and GRID-Arendal 2020]

- ***Improving monitoring efforts, including on biota:*** While there are some parts of the world that have been studied in great detail, such as the Arctic, other parts of the world are still developing their monitoring capabilities[54] The Minamata Convention requires Parties to cooperate to develop and improve geographically representative monitoring and modelling of levels of mercury and mercury compounds in environmental media, as well as collect and exchange information among themselves, and provide it to their publics. For human exposure, for which data at the moment is limited, studies using the WHO protocol for assessment of prenatal exposure to methylmercury are recommended to fill the data gaps and obtain a global picture, along with reminding Parties to facilitate the exchange of relevant epidemiological information as required under the Convention. There is a large amount of published data available on mercury levels in biota, as well as unpublished data that has been collected for government and commercial purposes. Further work is required to gather all currently available, globally representative biota mercury data, and assess its relevance, comparability and harmonization. This process has been

[51] See the report of the Third Meeting of the Conference of the Parties to the Minamata Convention on Mercury for a full list of groups: http://mercuryconvention.org/Portals/11/documents/meetings/COP3/English/UNEP-MC-COP-3-23-Report-EN.pdf at paragraphs 180 and following.
[52] https://www.planetgold.org. Burkina Faso, Colombia, Guyana, Indonesia, Kenya, Mongolia, Peru and the Philippines are currently part of the project.
[53] The planetGOLD vision is: a clean global supply of gold from small-scale miners.
[54] For example, in the development of the framework for effectiveness evaluation, some of the gaps in global monitoring coverage were identified: UNEP/MC/COP.3/14/Add.1, Report of the ad hoc technical expert group for effectiveness evaluation: proposed framework for the effectiveness evaluation of the Minamata Convention on Mercury, Appendix I, Technical information on monitoring.

started with the Global Biotic Mercury Synthesis (GBMS[55] dataset, used in the 2018 Global Mercury Assessment), which will allow for better identifying geographic and taxonomic data gaps.[56]

B. Persistent Organic Pollutants (POPs) and biodiversity

(i) POPs in the environment generally

POPs are industrial chemicals and pesticides that are toxic, persistent in the environment, bioaccumulate in the food web and are subject to long-range transport.

After emission or release, chemical pollutants can concentrate in air, surface and groundwater, soils, sediments and in living organisms, including people. Such concentrations tend to be higher near the point of release and to decrease with distance due to dilution, chemical transformations and microbial or chemical degradation. [GCO II 2019] A chemical's persistence in the environment is a key determinant of its fate, and long-range transport via atmospheric or surface water currents can distribute chemicals far from their original source of emission or release.

Global POPs distribution is affected by factors such as temperature, wind speed, and precipitation. In particular, climate change may affect emissions of POPs by enhancing volatilisation and re–volatilisation [Hung et al., 2005], and lead to increased atmospheric emissions especially in remote areas, such as Alpine lakes or the Arctic. [Teran et al., 2012] POPs are also frequently carried by water currents, moving contaminants long distances from their source. [Farrington & Takada, 2014] Compared with the mass of POPs transported globally, the contribution of migratory species has generally been found to be substantially smaller than that of air or ocean currents, but can become the predominant pathway for contaminants in many circumstances.[57] [Blais et al., 2007]

POPs inputs in the environment can be divided into primary and secondary sources. Primary sources are those with direct fluxes into the environment (such as the use of industrial chemicals or pesticides, or emissions from industrial processes) and secondary sources are already contaminated environmental compartments that can release POPs subsequent to their use or production [Hung et al., 2010; UNEP/AMAP, 2011].

Apart from Alpine snow or ice or Arctic ice, other relevant secondary sources acting as POPs reservoirs are soil, vegetation, water bodies and sediments, with net re-emission from these media triggered by declining atmospheric concentrations and controlled mainly by temperature and biogeochemical processes. [Nizzetto et al., 2010] The oceans are an important sink for POPs [Farrington & Takada, 2014], covering 71 percent of the Earth's surface and containing 97% of the Earth's water.[58] Controls of primary emissions from production and use may not always be reflected in expected reductions of atmospheric concentrations due to these secondary sources, and once primary sources are eliminated, secondary sources will become dominant. This also means that biogeochemical factors, including those related to the global mass balance of carbon (and related changes in climate), will be the main drivers controlling the distribution, depletion/degradation and the extent of human and wildlife exposure to these POPs in the environment. [Nizzetto et al., 2010]

Primary emissions of most of the POPs first listed under the Stockholm Convention ("the dirty dozen" or "legacy" POPS) are declining. Monitoring results indicate that regulations targeting POPs are succeeding in reducing levels of POPs in humans and the environment. For the original POPs listed in 2004 under the Convention, concentrations measured in air and in human populations have declined and continue to decline or remain at low levels due to restrictions on POPs that predated the Stockholm Convention and are now incorporated in it. [SC EE, 2017][59]

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[55] For more information, see http://www.briloon.org/uploads/BRI_Documents/Mercury_Center/Publications/For%20Web%20GBMS%20Booklet%202018%20.pdf.

[56] *Ibid.*, at para 40.

[57] This does not include the species that "raft" on plastics, discussed below in the section on plastic wastes. See Annex D of the Convention for the POPs criteria, including such long-range transport. These have been referenced at Box 4 of this study.

[58] https://oceanservice.noaa.gov/facts/oceanwater.html

[59] The monitoring data in the 2017 Effectiveness Evaluation was synthesized from the Second Global Monitoring Report.

In regions with sufficient data to evaluate changes over time, levels of legacy POPs such as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF), polychlorinated biphenyls (PCB), and DDT/DDE9, including their transformation products, have generally declined in human tissues. Unintentional releases of dioxins and furans have increased the most in the Asia-Pacific Region and decreased the most in the Western Europe and Others region. [SC EE, 2017] In other media, there are clear declines in legacy POPs from the 1970s until 2000 and few changes thereafter.

India is the sole remaining producer of DDT, producing approximately 3400 tonnes per year. In the years preceding the 2017 Effectiveness Evaluation, India was responsible for 96-97% of global use (about 3,000 tonnes per year), while usage in Sub-Saharan Africa was estimated to be less than 100 tonnes per year. [SC EE 2017] For purposes of the Stockholm Convention's second global monitoring report (GMP-2), the highest levels in human tissue were found in tropical and sub-tropical countries: Côte d'Ivoire, Ethiopia, Hong Kong SAR, Uganda, Mali, Mauritius, Haiti, Solomon Islands, Sudan and Tajikistan, and the presence of the metabolite DDE suggests this may be due to past use for malaria control and in African countries may be due to contamination from obsolete stockpiles. [GCO II 2019; EE 2017; SC GMP-2, 2017]

A high level of detection of legacy POPs in a terrestrial ecosystem demonstrates the ubiquitous nature of such POPs in the environment. [Fremlin et al., 2020] Despite the significant decreases of some POPs since the 1980s the ubiquitous presence of mixtures of relatively low levels of a numerous multiplicity of POPs also gives reasons for concern. [SC GMP-2, 2017]

For the POPs listed since 2004, concentrations in air are beginning to show decreases, although in a few instances, increasing and/or stable levels are observed. Based on studies available from the Western Europe and Others Group and from Asia Pacific, the levels of brominated diphenyl ethers (BDEs) and perfluorooctane sulfonic acid (PFOS) seem to be gradually declining in human tissues, but information regarding changes over time is very limited. Temporal trend information for PFOS in water is also very limited and precludes robust assessment of trends at the current time. [SC EE, 2017]

For some chemicals, e.g. PCB, PBDEs and other new POPs, emissions continue from stockpiles, continued product usage and waste disposal/dismantling/ recycling practices. [SC GMP-2, 2017] A recent study notes that trends are less positive for polybrominated diphenyl ethers (PBDEs), HCB and PCBs, due in part to their remobilization. [Hung et al., 2016]

There are declining trends for PBDEs across the globe, but monitoring in the Arctic has revealed uncertain trends for other flame-retardant chemicals, with some studies showing they are now being detected at concentrations comparable to those found in urban air, while organophosphate-based flame retardants (PFRs) are being detected at higher concentrations than PBDEs. [GCO II 2019] During the last two decades, concentrations of many legacy POPs have declined, although concentrations of PCBs and chlordanes have remained relatively high in wildlife tissues. [AMAP 2016] A recent global analysis of passive air samples suggests that in general concentrations of PBDEs have *not* declined since global regulatory measures were implemented. However, it did confirm that alternative flame retardants (organophosphate esters (OPEs) and novel flame retardants) have increased in production and OPEs are now being found at levels more elevated than for PBDEs, have similar POP-like properties of persistence and long-range transport and are more difficult to assess in environmental samples, producing a "hydra-effect". [Rauert et al., 2018]

Although there has been extensive research and monitoring in the Arctic for decades, POPs are found around the globe, including close to industrial and urban settings. Geographical distribution of DDT, PCBs, PBDEs and HCH in the Asia-Pacific region identified hotspots of POPs contamination in the region, with PBDE used in flame retardants and some electronic devices with the potential to adversely affect biological populations. It also identified open dumping sites for municipal waste as sources for many chemical contaminants as these sites were linked to degraded environment and adverse impact on human health (e.g. dioxins in breast milk). DDT was highest in China, and HCH highest in India (high levels of HCH reflect use of insecticides in certain crop production), with PCBs highest in Hong Kong and Korea (while previous studies showed the highest concentrations in Japan; this shift suggests that sources of PCB contamination have expanded); PBDEs were relatively widespread in the Asia-Pacific region. Because they are structurally similar to PCB and DDT, it is highly likely their persistence, distribution, and ecological impacts will have similar consequences. [Tanabe & Minh, 2009]

Chemical pollutants occur in freshwater bodies around the world, including surface waters [Stehle and Schulz, 2015; Muir and Lohmann, 2013], groundwater [Lapworth et al. 2012], glaciers [Ferrario et al 2017], river basins [Malaj et al., 2014], lakes/reservoirs, estuaries and coastal waters. [SC GMP-2, 2017]

PFOS and its precursors are more hydrophilic[60] and are more suitable to be monitored in water rather than in air, and in human blood rather than in human milk. [SC GMP-2, 2017] A large number of studies report concentrations of PFOS in rivers, lakes/reservoirs, estuaries and coastal waters in the northern hemisphere nations of the WEOG and Asia-Pacific regions. Monitoring of PFOS in water has been initiated on pilot basis in the Africa and CEE regions. No information is currently available from GRULAC. [SC GMP-2, 2017] Endocrine-disrupting chemicals (a number of which are POPs) are of particular concern as they are now widely distributed through the freshwater system on all continents. [GEO-6 2019]

Spatial trends of PFOS in ocean waters are relatively well studied with measurements of surface waters in all oceans as well as in some deep basins. Compared to freshwaters and estuaries, open ocean concentrations of PFOS are very low, with the highest levels found in the eastern Atlantic off of France and Portugal carried on water currents from Europe, with elevated concentrations off the coast of Brazil possibly for a similar reason. [SC GMP-2, 2017]

A 2014 study provided strong evidence that the ecological integrity and consequently biodiversity of over half the water bodies on the European continent are threatened by chemicals. In the first risk assessment of organic chemicals on a continental scale, via 4000 European monitoring sites, of 223 chemicals monitored, pesticides, brominated flame retardants (BFRs), tributyltin and polycyclic aromatic hydrocarbons were the most common contributors to chemical risk. Increasing chemical risk was associated with deterioration in the quality status of fish and invertebrate communities, indicating that chemical pollution is a large-scale environmental problem impacting ecosystem health. [Malaj et al., 2014]

A survey of river water samples in 41 cities in 15 countries found detectable concentrations of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in nearly every region studied [Kunacheva et al., 2012]. In addition to river contamination, many studies in Western Europe and the Asia-Pacific region report concentrations of PFOS in lakes/reservoirs, estuaries and coastal waters. [SC GMP-2, 2017]

Sediments of both ocean and freshwater ecosystems store and concentrate chemicals, including POPs. For example, deca-BDE concentrations in the sediments of the North American Great Lakes were found to double every 3-5 years in Lake Michigan and approximately every 7 years in Lake Ontario. [Yang et al., 2012] However, in Adriatic Sea sediments, due to regulation at the national level of PCBs in the late 1970s, sediments show a 40-80% reduction in national peak levels of PCBs. [Combi et al., 2016] [GCO II 2019] Two estuary areas of central Vietnam were examined for organochlorine pesticides (including DDT), PCBs and PBDEs, revealing that concentrations of PCBs, PBDEs, and endosulfan compounds were generally higher than those of the remaining OCPs. While the highest PCB concentrations were from sediment layers dated to the 1970s, there are increasing PCB residues in shallower layers that may relate to strong recent industrialization and urbanization in Vietnam. PBDEs are increasing in shallower depths, suggesting substantial use and ongoing releases in recent years. [Tham et al., 2020]

Oceans act as sinks for PCBs, DDT, and PAHs in three ways: they are ingested/absorbed by biota; adsorb onto sediments in the ocean floor; or are adsorbed onto particulates[61] floating in the water column/on the water surface. The response time of the near-shore coastal environment to legacy POPs such as PCBs and DDT indicates that these POPs will persist in such ecosystems for many decades, if not a century or more. Similar concerns exist for chemicals such as PBDEs [Ross, 2009]. The deep ocean appears to act as a sink for such chemicals on time scales of a century or longer, including indications of horizontal transport from the continental shelf and slope areas to the deep ocean. Although it is clear that deep ocean fish are contaminated with POPs, deep ocean ecosystems are much less sampled and understood. [Farrington & Takada, 2014]

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[60] That form an ionic or hydrogen bond with a water molecule.
[61] This can be either natural particulates, or micro-plastics, as will be seen in the section on plastic wastes.

Nevertheless, it has recently been found that PCB concentrations in amphipods in the Mariana and Kermadec Trenches of the Pacific Ocean (at 7-10,000 metres below sea level) were at “extraordinary levels,” for example, 50 times more contaminated than crabs from paddy fields fed by one of the most polluted rivers in China. PBDEs were not found at such high levels but were comparable to estuarine sediments from New Zealand’s North Island, illustrating that PBDEs are present in the trenches at comparable or higher levels than in coastal waters. It was concluded that the most likely explanation for such results was long range oceanic and atmospheric transport and association with particulate matter and carrion-falls sinking through the water column. [Jamieson et al., 2017]
Ice in the Arctic is a sink for legacy POPs and other atmospheric pollutants such as mercury. In the Arctic, legacy POPs have been declining over the past two decades and are reaching steady state. [AMAP 2018] However, as noted above, chemicals more recently added to the Stockholm Convention show a more mixed pattern with some decreasing and others not. Certain organochlorine pesticides regulated under the Stockholm Convention have been found in Himalayan glaciers. [GCO II 2019]

Climate change, manifested as widespread loss of ice cover in the Arctic and thawing of permafrost, alter the cycling and fate of POPs, releasing POPs from environmental reservoirs (ice and soil) and increasing POPs availability to wildlife. [Ma et al., 2016] Climate studies have indicated that with the melting of Arctic sea ice, these former POPs reservoirs are expected to release these chemicals back into the environment with the possibility of up to a fourfold increase in the oceans even after production and use of such chemicals have been phased out. [Wöhrnschimmel et al., 2013]

Compared to metals, metalloids and radionuclides, the global footprint of soils highly contaminated by organic contaminants is smaller than for other pollutants, with contamination of the food chain localized around industrial or urban centres. [Rodriguez 2018 FAO soil report]. Nevertheless, soils throughout the world are contaminated by a wide range of chemicals, including POPs such as PFOA and PFOS in soils in Asia, and pesticides such as DDT and endosulfan in Africa. PBDEs are commonly detected in surface soils, including in Antarctica and the northern polar regions. PCBs, PBDEs and dioxins and furans have been found in soils near informal e-waste recycling sites in China and India. [GCO II 2019] Pollution by POPs could be expected to be significant in dump sites of developing Asian countries, considering their poor management of municipal wastes and extensive use of such chemicals in the past but in general not enough is known about the state of soils in developing countries. [Minh et al., 2006 and Fiedler et al., 2013, in Rodriguez 2018 FAO soil report]

(ii) Impacts of POPs on biodiversity, including biota

Concentrations of many manufactured chemicals build up in wildlife and increase as they move up food chains, where bioaccumulation results in the highest concentrations occurring in animals at the highest levels of the food web. [GCO II 2019; Muir et al., 1988]

Exposure to chemical contamination reduces the long-term viability of **biological populations** by changing the DNA sequence (mutation process) that is passed on to offspring. [Bhat, 2013] Chemical contamination can cause population reduction through both heritable and non-genetic modes of toxicity, and although the original damage is at the molecular level, there are emergent effects at the level of populations, such as the **loss of genetic diversity**, that are not predictable based solely on the knowledge of a chemical’s toxicity mechanism. Although several factors are involved in loss of biodiversity, chemical contamination has been implicated in the decline or disappearance of many populations (e.g. bald eagle, peregrine falcon). [Bickham, 2000]

> Both mutagenic and non-mutagenic chemicals can impact reproductive success, which can lead to **decreased genetic diversity**, which can ultimately lead to reduced fitness and extirpation of the population (i.e. **biodiversity loss**).
>
> [Bickham, 2000]

Box 11: How chemicals result in biodiversity loss

Pollution caused by persistent organohalogen compounds like POPs has become increasingly important because of their historical use in large quantities, which has resulted in numerous negative impacts such as environmental deterioration and health effects on wildlife. [Tanabe & Minh, 2009] In **wildlife**, high or prolonged exposure to certain chemicals leads to reproductive, immunological and neurological damage or even death. Many surfactants and heavy metals are toxic to aquatic organisms. Dioxins and PCBs adversely affect reproduction in turtles and some birds, correlating with smaller and more fragile eggs. PCB exposure has been implicated in the suppression of immune systems in seals and other marine mammals, contributing to mass die-offs in Europe in the late 1980s. Studies of sea turtles have found high levels of other perfluorinated compounds, which weaken the immune system and result in greater vulnerability to opportunistic infections. [GCO II 2019]

Updated time trends of POPs in **biota from marine and freshwater ecosystems across the Arctic region** showed downward trends in legacy POPs over the past few decades, including PCBs, while newer/POPs in commerce show a more mixed pattern of trends. However, while PCBs peaked in the 1970s and had a rapid decrease thereafter, they are now in a slower period of decline. There were increases in BDE and PFOS until the mid-2000s and then decreases in concentrations, attributed to national and international regulatory action, and some voluntary action. Some Arctic biota appears to have responded fairly quickly to these declines. HBCDD, listed under the Stockholm Convention in 2013, was the only compound showing an increasing trend. Further long-chain perfluroalkyl carboxylic acids (PFCA) have been reported to be on the increase in Arctic biota, but PFOA, the main PFCA, was only listed to the Stockholm Convention in 2019 and will be monitored in the next round of the Global Monitoring Programme. While some trends in Arctic biota seem to be a direct response to changes in emission levels, multiple factors can affect the accumulation of POPs in Arctic biota, such as climate changes affecting sea ice coverage, ice and permafrost sinks, wildlife migration patterns and distribution, and changes in feeding habits. [Rigét et al., 2019]

Although there is a substantial body of research on impacts of POPs in the Arctic, other less-studied ecosystems in the world face challenges from POPs. **Mangroves** are ecologically important tropical ecosystems that house a diverse array of species, a number that are at a high risk of extinction. Chemical pollution from solid waste, sewage discharge, atmospheric deposition, and import from other water bodies was found to be a significant contributor to the degradation of mangrove ecosystems. A suite of chemical pollutants (trace metals, PAHs, POPs, but also emerging contaminants (e.g. pharmaceutical and personal care products, endocrine disruptors, current-use pesticides, brominated flame retardants) were found in water, sediments and biota of mangrove systems, resulting in: a reduction in photosynthesis, growth, and biomass of mangrove plants; endocrine disruption, enzymatic inhibition, behavioural changes, mortality, and embryonic malformations in large benthic species and fish; and large-scale changes in diversity, or ecosystem structure, as vulnerable populations decline as a result of exposure to chemical pollutants. [Bayen 2012]

Riverine ecosystems in Bangladesh experienced lethal concentrations of POPs such as DDT, HCH, HCB, PCB and heptachlor in aquatic species where **aquatic biota**, including aquatic vascular plants, seagrasses, algae and other water plants, fish, crabs and mussels, are being adulterated by POPs. The fatty tissues of aquatic species are more sensitive to POPs, which can be bioaccumulated and transferred to the food cycle. Fish have been found to have DDT and heptachlor at "destructive and lethal" levels. Groundwater, a cheap and available source of drinking water, is being contaminated in places where it is connected to surface water, and better monitoring is urgently needed. [Islam et al., 2018].

Embryonic and larval marine medaka fish exposed to (PFOS) and benzo(a)pyrenes that had adsorbed onto microplastics exhibited reduced growth, increased developmental anomalies and abnormal behaviour, appearing more embryotoxic when spiked on microplastics than when alone in seawater, suggesting a relevant pollutant transfer (without ingestion) that should be taken into account in future risk assessments of microplastics. [Le Bihanic et al., 2020][62]

A study of POPs levels in **tilapia** on four lakes in Tanzania showed that concentrations of organopesticides, PCBs, PBDEs and HBCD were found in pooled samples of tilapia muscle from Lakes Victoria, Tanganyika, Nyasa and Babati, with levels of DDT and PCB significantly higher in tilapia from Lake Tanganyika. While concentrations were permissible for human consumption, the study pointed out that the fish are an important food source for local people and are at risk from overfishing. This, coupled with the pesticide pollution, could have impacts on decreasing both number and variety. [Polder et al., 2014] Another study in Tanzania comparing wild fish to farmed fish to determine presence of organochlorine pesticides, PCBs and brominated flame retardants, showed that showed that DDTs were the primary POP found in both farmed and wild milkfish and mullets, but over 500 times higher in the wild milkfish than the farmed. PCBs and PBDEs were low and in varying ranges in both the milkfish and mullets. While these fish, despite all having some level of POPs, were fit for human consumption, the reported levels may

[62] More on POPs and plastics below.

pose ecological and fish health risk and threaten biodiversity. Concerns were raised for increased regulation and monitoring due to the increasing levels of aquaculture in Tanzania. [Mwakalapa et al., 2018]

Concentrations of POPs in some fish are declining, but unevenly. For example, in the Canadian Arctic, concentrations of PFASs in landlocked **freshwater fish** are declining while some benthic species such as **burbot** show increasing trends in some regions. [AMAP 2016] concentrations of PCBs are declining in the great Lakes, but the levels of BDEs and DDT varies in fish in the different Great Lakes. [GCO II 2019]

Sustained and elevated PCB burdens in European **bottle-nose dolphins, striped dolphin and killer whales** have resulted in populations that are either very small, or show evidence of major and long-term declines or a significant contraction of range, even though it was not possible to directly and causally link high PCB exposures to cetacean population declines. [Jepson et al., 2016] POPs exposure levels (dl-PCBs, PBDEs, and PCDD/Fs) in **striped dolphins** in the Mediterranean, which are a serious conservation concern, have not declined in recent years despite international regulation, due to the fact that bioaccumulation and long-term persistence leave these chemicals available in the environment. Toxicological and risk assessment studies on this sentinel species may provide an early indication of potential adverse health effects on Mediterranean ecosystems. [Capanni et al., 2020]

Population-level effects on seals in the Baltic have resulted from POPs exposure affecting reproductive systems and survival through immune suppression and endocrine disruption. [Sonne et al., 2020] In harbour seals, contaminant exposure from PAHs, PCBs, PCDDs and PCDFs has been linked to immune suppression, diminished T-cell function and delayed antibody response. [Ross et al., 1996] Exposure to contaminant mixtures resulted in effects on the immune systems of seals. [Desforges et al., 2017] Exposure to POPs is the main causal factor of impaired reproduction, immunosuppression, and chronic infections in **Baltic grey seals**. [Bergman 2007; Desforges et al., 2016; Jepson et al., 2016] Exposure to PCBs negatively correlated to free thyroxine in **Baltic seal pups:** changes in thyroid hormone balance can affect reproductive success, growth, thermoregulation, and immune function. [Gabrielsen et al., 2011] In **Baltic harbour seals**, bone mineral density increased with increasing PCB concentration, but was not indicative of better quality or stronger bones, but rather an indication of impaired bone quality, with increased risk of fractures, osteoporosis, and reduced mandibular functioning. [Lind et al., 2003] Exposure to dioxins induced oxidative stress in **Baikal seals** [Hirakawa et al., 2011] and oxidative stress, iron ion homeostasis and inflammatory responses resulted from exposure to PCBs. [Nomiyama et al., 2014]

Accumulation of POPs in marine mammals is associated with **population declines**. A temporal trend analysis of concentration of POPs regulated by the Stockholm Convention in the blubber of **finless porpoises** revealed that concentrations of PCB, DDT, HCB and PBDE significantly reduced in 2010 compared to 2003, suggesting the effectiveness of domestic and global regulatory actions addressing POPs. However, between 2010-2015, concentrations stabilized and there were no significant POPs reductions, which is likely related to the long-term persistence of POPs in marine environments. Of the latter group of porpoises studied, 10% exceeded the PCB threshold and 27% exceeded the DDT threshold associated with endocrine disruption and immunotoxicity in harbour seals, while 17% exceeded the threshold for DDT associated with mass mortality due to epizootic disease in harbour seals. [Jeong et al., 2020]

Despite global initiatives to restrict the production of PCBs (e.g. the Stockholm Convention), levels of mercury and more importantly, PCBs, remain a significant exposure concern for many Arctic biota, including **polar bears, killer whales, pilot whales, seals and various seabird, shorebird, and birds-of-prey species**. The levels of these chemicals put these species at higher risk of immune, reproductive and/or carcinogenic effects. [AMAP, 2018]

Marine mammals are exposed to the highest levels of environmental contaminants worldwide, including POPs and heavy metals, with PCBs and mercury most often reported. Such exposure leads to systemic suppression of immune function, which is tied to reproductive and endocrine systems, with potential costs for fitness and ultimately **population growth**. Exposure to immunotoxic contaminants may have significant **population level consequences** as a contributing factor to infectious disease outbreaks in wildlife. [Desforges, 2016] PCBs and other organochlorines remain the top contaminant threat to marine mammal populations around the world. PCB-induced immuno-suppression has been postulated to play a role in facilitating the emergence, and exacerbating the severity and mortality of, infectious diseases in marine mammals [Ross, 2002], confirmed by a recent study using blubber-derived chemical cocktails of PCB, organochlorine pesticides, PBDEs and other brominated flame retardants to illustrate a more relevant risk evaluation of complex and ubiquitous multiple-chemical exposures that marine mammals are exposed to in their environment. [Desforges et al., 2017]

A recent comprehensive follow-up study to the 2010 comprehensive AMAP study on exposure to major classes of persistent halogenated organic contaminants (i.e. PCBs, DDT, CHLs, HCHs, PBDEs, HBCDs, PFSAs, PFCAs) in **Arctic marine and terrestrial mammals, birds, and fish species** from both single contaminants and mixtures found overall that there were differences in impacts across phyla, species, populations and regions of the Arctic. For example, findings on the potential for PCB-mediated effects on the immune and endocrine systems of **killer whales** support previous findings from [Jepson et al., 2016] who concluded that highly contaminated killer whale populations at lower latitudes (the UK, Ireland, Canary Islands and Gibraltar) have little to no known reproductive capacity and are at risk of extinction. [Dietz et al., 2019] (Earlier studies had pointed out the effects of PCB exposure on killer whales, where they were linked to increased mortality and reduced reproductive success, but with a lack of clarity about population-level consequences.) [Buckman et al., 2011] Based on PCBs being the dominant contributor, killer whales were found to be the marine mammal most at risk, along with transient Pacific killer whales just south of the Arctic region. Long-finned **pilot whales** from the Faroe Islands also had large groups with numbers indicating a risk of PCB-mediated health effects. [Dietz et al., 2019]

Another recent study reports **killer whales** to be the most highly contaminated mammals in the world from PCBs. Killer whales near industrialized regions at lower latitudes and those feeding at higher trophic levels regardless of location were found to be at high risk of PCB population collapse over a 100-year simulation period based on current blubber PCB levels. PCB-mediated effects on reproduction and immune function may threaten the long-term viability of over 50% of world's killer whale populations. The results highlight the vulnerability of killer whale populations to the persistent threat of PCBs, with many of these populations already listed under various national threatened species programs despite the ban on PCBs more than 30 years ago. Given that PCB levels have stopped declining in many marine mammal populations, the current status of global PCB remediation efforts are obviously not sufficient to protect most wild killer whale populations. [Desforges, 2018] The 2017 Stockholm Convention effectiveness evaluation pointed out that the 2025 and 2028 deadlines under the Convention regarding PCBs are not likely to be met by most Parties.[63]

POPs exposure is a key indicator of the health of killer whales in the North Pacific, with concentrations of POPs (including PCBs and DDT) in **killer whales of the North Pacific** exceeding concentrations that indicate high risk for negative biological effects. [Atkinson et al., 2019] Elevated POPs (PCB, DDT and PBDE) contaminant concentrations were linked to immunosuppression, increased susceptibility to disease, elevated risk of cancer, nervous system dysfunction, skeletal abnormalities, endocrine disruption, reproductive impairments, and premature birth. The detrimental biological effects are heightened by a mixture of contaminants and may hinder recovery of the resident killer whale population. [Mongillo et al., 2012; Mongillo et al., 2016; Ross et al., 2000]

Moderate levels of PCB exposure significantly reduced hepatic vitamin A and E levels in **belugas** from the Western Canadian Arctic. Those vitamins are essential nutrients for development, reproduction and immunological health and must be obtained through diet. Given their importance, the results emphasize the potential risk of population level effects, which may be compounded by a rapidly changing Arctic climate. [Desforges et al., 2013] Subsequently, contaminant exposure from PCBs, PBDEs, mercury and other metals was found to be systemically suppressing immune function in bottle-nosed **dolphins, seals and beluga whales**. As the immune system is tied to reproductive and endocrine systems, such immune effects may ultimately extend to costs for fitness, reproduction and population growth. [Desforges et al., 2016] [Dietz et al., 2019] found that **beluga and ringed seals** did not seem to be at risk of being detrimentally affected by PCB exposure on its own.

For marine birds, PCBs were only of concern in **glaucous gulls** in Norway (moderate risk), although interpretation of these effects at the population level remains a challenge. On the other hand, several populations of **birds of prey**, such as the white-tailed eagle, the gyrfalcon and the peregrine falcon, seem to be at risk of PCB-mediated biological health effects. Further study is required, including the establishment of concentration thresholds for individual compounds as well as for realistic cocktail mixtures that in fact indicate biologically relevant health effects for specific species and subpopulations. [Dietz et al., 2019] Exposure to POPs was linked to a negative association of components of coloration, an indication of reduced breeding condition, in female **kittiwakes.** [Blévin et al., 2014]

Increased numbers in populations were found in **otters, grey seals and sea eagles** from Sweden after concentrations of PCB and DDT reduced over time due to bans at the national level, providing evidence that PCBs and DDT have

[63] UNEP/POPS/COP.8/22/Add.1, at paragraph 48.

had strong negative effects on the reproduction and population levels of these species. [Roos et al., 2012]

Contaminant exposure is one of the largest threats to **polar bears** after loss of sea ice habitat due to climate change. In a comprehensive recent review of publications on polar bear ecotoxicology, it was found that legacy POPs --PCBs, OCPs (including DDTs, chlordanes, hexachlorocyclohexane, and hexachlorobenzene) and PFOS--are still the main compounds commonly found in polar bear populations, along with high levels of PFASs, currently in use.[64] Concentrations of legacy POPs that have been banned for decades in most parts of the world have generally declined in polar bears. POPs contaminant exposure disrupts circulating levels of thyroid hormones and lipid metabolism, alters neurochemistry, and reduces immune function. [Routti et al., 2019] Polar bears from Eastern Greenland showed PCBs at high levels of concern. [Dietz et al., 2019]

Legacy and new halogenated POPs in **polar bears** were analyzed from a contamination hotspot in Hudson Bay, Canada, where 210 of 295 legacy and new POPs were present in Hudson Bay polar bear fat or liver tissue collected in 2013-14. PCBs, chlordanes (CHLs), and PFOS were the dominant contaminants in fat and liver samples, with the first two reducing slowly, and PFOS decreasingly rapidly, attributed to global regulation. Endosulfans and hexabromocyclododecane (HBCD) were detectable in samples from 2007–2008 but not from 2013–2014, which is consistent with their global regulation (listed in 2011 and 2013, respectively). Polychlorinated naphthalenes (PCNs) (listed in 2015) were consistently detected at relatively high concentrations compared to other Arctic wildlife (but relatively low compared to other legacy POPs); short chain chlorinated paraffins (SCCPs) are a major contributor to the overall POPs burden with concentrations comparable to other legacy POPs, but were only listed under the Stockholm Convention in 2017. The study also illustrates that polar bears in Hudson Bay are exposed to an increasingly complex cocktail of POPs. [Letcher et al., 2018] High levels of PFOS measured in polar bears have been linked to carcinogenic effects. [Dietz et al., 2015]

Exposure to 'naturally occurring' contaminant mixtures (cocktail made from killer whale and polar bear adipose tissue of OHCs) affects immune responses in **cetaceans, seals, and polar bears. [**Desforges et al., 2017] Exposure to PCBs is linked to reproductive failure in polar bears [Letcher et al 2010; Dietz et al., 2015; Gilmore et al., 2015]. Exposure to PCB and OCP are linked to decreases in concentration of circulating thyroid hormones in polar bears. (Changes in thyroid hormone balance can affect reproductive success, growth, thermoregulation, and immune function). [Bourgeon et al., 2017] Exposure to OHCs might alter plasma cortisol concentrations[65] in polar bears, thus inhibiting physiological processes in a manner that may endanger the animal's health. [Oskam et al 2004; Bechshoft et al., 2012b]

High levels of DDT, PCBs, and chlordanes were detected in **Greenland sharks in** Canadian waters, a "near threatened" species on the IUCN Red List and an upper trophic level organism, despite DDT having been banned for three decades at the time of the study. [Fisk et al., 2002] A subsequent study confirmed that high levels of concentrations of non-dioxin-like PCBs were from feeding on high-trophic level species like seals, rather than being related to size or age of the shark, and the levels were higher than in the earlier study, possibly due to a higher level of contamination in the European Arctic. Overall, concentrations of dioxins and furans and dioxin-like PCBs in Greenland shark muscle and liver were measured for the first time, finding high concentrations in the same range or higher compared to other Arctic marine species found with levels exceeding those recommended for fish consumption, but the general impact on the health and reproduction of the Greenland shark is not known. [Strid et al., 2007]

A study analyzing a **terrestrial food web** for PCBs, OCPs, PBDEs and brominated flame retardants (BFRs) found that 83 of 85 contaminants were detected within at least 1 trophic level; 30 contaminants were detected in greater than 60% of species groups in the food web; and many contaminants were detected at high concentrations, particularly in apex predators (urban Cooper's hawk). This illustrates a similar pattern of widespread contamination and trophic transfer as in aquatic environments and illustrates that legacy POPs remain prevalent and continue to biomagnify in both terrestrial and aquatic ecosystems. For emergent POPs such as PBDEs, there was higher biomagnification in the urban Cooper's hawk than in terrestrial mammals in the Arctic found by [Morris et al., 2018], highlighting the need for more studies in terrestrial ecosystems. Although in this situation the

[64] Listed under Annex A of the Stockholm Convention (elimination) in 2019.

[65] Such concentrations indicate that a polar bear is undergoing stress, as cortisol is a blood-borne stress hormone. https://polarbearsinternational.org/research/see-our-projects/cortisol-studies/

biomagnification and POP exposure levels were generally below threshold concentrations that would affect population stability, further understanding is needed of commercial chemicals currently in use and how they behave in both terrestrial and aquatic environments. [Fremlin et al., 2020]

Global reviews of PBDE contamination in **birds** have revealed that concentrations of PBDE are generally higher in terrestrial birds than in freshwater or marine birds, and that concentrations in terrestrial birds – particularly of the chemical mixture deca-bromodiphenyl ether (deca-BDE) – were highest in North America and China [Chen and Hale 2010; Law et al., 2014, in GCO II 2019].

Population-level effects from POPs exposure on **white-tailed eagles** in the Baltic affected reproductive systems and survival through immune suppression and endocrine disruption. [Sonne et al., 2020] A causal correlation was found between increased concentrations of PCB and DDT and decreased/reduced reproductive success (due to eggshell thinning) in **white-tailed eagles.** [Ross et al., 2012; Bergman, 1999]

Greenland sled dogs, a top Arctic predator, have been used to determine impacts of POPs on apex predators. Even at low levels of exposure to POPs (DDT and PBDE through food consumption e.g. whale blubber) physiological levels of Vitamins A and E were reduced. Vitamin metabolism disruption produced by complex mixtures of naturally-occurring organohalogen contaminants is important in both wildlife and humans. [Kirkegaard, et al., 2010] OHC exposure through food was linked to disruption of blood steroid (androgen, estrogen, and progesterone) concentrations in sled dogs. Environmental exposure to OHC elicits endocrine disrupting effects on hormone homeostasis that control important processes, such as growth and reproduction. [Sonne et al., 2014]

(iii) Impacts on nature's contributions to people

This section provides a range of examples where traditional ecosystem services/nature's contributions to people, are affected. Regulation of air quality, water quality, and the formation, protection and decontamination of soils, the provision of materials such as food, or non-material contributions (such as recreation, aesthetic enjoyment of nature, learning, or the basis of spiritual and social-cohesion experiences), are all impacted by POPs.

Chemical pollution threatens a range of ecosystem services. [GCO II 2019] For example, the majority of streams and rivers in Europe are ecologically impaired or threatened with high losses in biodiversity, which compromise the future provision of vital contributions from nature, such as **clean drinking water** and **recreation**. [Malaj et al., 2014]

Mangroves perform ecologically valuable services to nearby populations, such as providing **food resources, employment and generation of income (tourism, fisheries) and stabilizing coastlines**. They are also one of the most threatened ecosystems from threats such as chemical pollution, which was found to be a significant contributor to the degradation of mangrove ecosystems. [Bayen, 2012]

Studies of PCBs in **dietary fish and seafood** in Asia show the potential health effects, including possible lifetime cancer risk, of such exposures. Coastal residents in Bangladesh are exposed to levels of PCBs through **seafood** consumption at sufficient levels to cause severe health risks, including dioxin-like toxic effects. [Habibullah-Al-Mamun et al., 2018] While these risks crossed all socio-economic groups, slum dwellers in Hyderabad, India had the highest lifetime cancer risks in that city from ingestion of **fish** from both freshwater and marine species, although the latter contained the most PCBs. [Ahmed et al., 2016]

High contaminant levels in wildlife can be a particular concern for the health of indigenous communities in the Arctic reliant on subsistence harvests as part of a traditional diet [AMAP, 2018] which affects both **provisioning** and **cultural ecosystem services**. [Kuhnlein et al., in Downie and Fenge; Watt-Cloutier 2016]

Concentrations of dioxins and furans and dioxin-like PCBs in Greenland shark muscle and liver found high concentrations in the same range or higher compared to other Arctic marine species found with levels exceeding those recommended for fish consumption. Although the Greenland shark is not used to any great extent for human consumption, the muscle tissue is part of the **traditional diet** in Iceland. [Strid et al., 2007]

A study documented numerous other studies outlining how POPs are affecting ecosystem services by contaminating the global **food supply** through pesticides and/or other POPs being found in fruits and vegetables, fish and seafood, whales and many of the foods eaten by indigenous peoples in northern regions of the world. Bangladesh is a riverine country, with aquatic biota contaminated by POPs, including aquatic vascular plants, seagrasses, algae and other water plants, as well as fish, crabs and mussels, which can be bioaccumulated and transferred to the **food cycle**. [Islam et al., 2018]

Groundwater in Bangladesh, a cheap and available source of drinking water, is being **contaminated** in places where it is connected to surface water, and better monitoring is urgently needed. High levels of DDT found in meat in Ghana, highlights particular **concerns for developing countries** where economic development is putting people in danger. [Islam et al., 2018].

A recent study in Tanzania **comparing wild fish to farmed fish** to determine presence of organochlorine pesticides, PCBs and brominated flame retardants showed that while these fish were fit for human consumption, the reported levels (500 times higher in wild fish) may pose ecological and fish health risk and threaten biodiversity. Concerns were raised for increased regulation and monitoring due to the increasing levels of aquaculture in Tanzania. [Mwakalapa et al., 2018]

The fertilization effects of applying sewage sludge plus the contamination of wildlife habitats results in the "intoxification" of food chains, including the transfer of pollutants from species to species, reduction of reproductive potential and other long-term effects on biodiversity. When used in **agriculture**, it also has adverse effects on human health. [Manzetti & Van der Spoel, 2015]

(iv) Challenges and emerging issues

- ***Chemical intensification of the global economy:*** The last several decades have seen increasing global production and distribution of chemical-based products that have been generally linked to disruptions/disturbances in earth systems -- freshwater, marine, terrestrial ecosystems, biogeographical cycling, and ozone depletion [Steffen et al., 2015] While production of chemicals is projected to grow in each region, annual growth rates are highest in regions with developing and emerging economies, particularly in Asia-Pacific, Africa and the Middle East. International trade in chemicals has been increasing rapidly, and in 2017 had a global value of USD 748 billion. [GCO II 2019]

- ***'New' pollutants, some of which are POPs, are not easily removed by current wastewater treatment technologies and are of emerging concern:*** these include flame retardants, pesticides, certain veterinary and human pharmaceuticals, antimicrobial disinfectants, detergent metabolites and microplastics. [UNEP Assessment Report on Issues of Concern 2020] Endocrine-disrupting chemicals, a number of which are POPs, are of particular concern as they are now widely distributed through the freshwater system on all continents [GEO-6 2019] and some endocrine-disrupting pharmaceuticals have been shown to have adverse effects on wildlife at very low concentrations, such as feminizing of male fish, preventing reproduction or triggering population collapse. [GCO II 2019]

- ***Improved risk evaluations are needed to account for mixtures/chemical cocktails:*** Despite the significant decreases of some POPs since the 1980s, the ubiquitous presence of mixtures of relatively low levels of a numerous multiplicity of POPs gives reasons for concern, and strategies should be considered for making better connections between POPs monitoring and toxicity tests for the assessment of long-term effects of mixtures in the environment. [SC GMP-2, 2017] Arctic fish and wildlife are exposed to a complex cocktail of contaminants that includes legacy POPs, chemicals of emerging Arctic concern (e.g. PBDE), mercury and other pollutants, that may act in combination to increase the risk of biological effects. As most research currently focuses on exposure from single chemicals, future research needs to undertake risk evaluations based on real-world multiple-chemical exposures. [AMAP 2018; Desforges et al., 2017; Van den Brink et al., 2018; Letcher et al., 2018]

- ***Finding safe alternatives to POPs chemicals:*** it is challenging to find alternatives to POPs, which have been useful to humanity in a number of ways but are now understood to pose risks that outweigh their benefits. As noted by [Fremlin et al., 2020], a 'hydra effect' is produced when replacement chemicals are equally or more dangerous to human health and the environment and more costly and difficult to evaluate. Replacement flame retardants for BDEs cannot be monitored as a group, so need to be handled individually, adding to the risk assessment costs. As more commercial chemicals are introduced into the global market, there is a need to understand their impacts in both aquatic and terrestrial ecosystems. [Fremlin et al., 2020] Additional efforts are needed for work on alternatives under the Stockholm Convention to avoid the creation of new POPs as set out in paragraph 3 of Article 3,[66] through the identification of alternatives at the time of listing that are to be assessed and screened against Annex D POPs criteria, with the goal of discouraging research and development in such alternatives. [SC EE 2017]

- ***Policymakers need to be aware of the combined effects of multiple stressors, including other drivers of biodiversity loss:*** the impact of contaminant exposure in Arctic biota needs to be considered in conjunction with other natural and anthropogenic stressors, including climate change, hunting pressure, invasive alien species, emerging pathogens, and changes in food web dynamics. [AMAP, 2018; Van den Brink et al., 2018] Cumulative exposure to multiple stressors -- i.e. pollutants from different point sources and non-chemical stressors -- can enhance the vulnerability of a population to chemical toxicants [Solomon et al., 2016] In freshwater ecosystems, three processes predominantly threaten freshwater species: habitat loss/degradation, water pollution and over-exploitation, but analysis is complicated by complex interactions between the threat drivers, and the relative importance of such drivers vary among taxa. For example, 98% of threatened crabs and 74% of threatened fish were at risk due to pollution, while over-exploitation was a greater threat to crayfish and reptiles. [Collen et al., 2014] In a study of threats to global freshwater biodiversity, threats of overexploitation, water pollution, flow modification, destruction or degradation of habitat and invasion by exotic species were considered, with their combined and interacting influences, to result in population declines and range reduction of freshwater biodiversity worldwide, further complicated by prevalent global changes such as nutrient overloading and climate change. Solutions require balancing conservation and human needs into account, and a mixture of strategies will be needed to protect freshwater biodiversity in the long term. [Dudgeon et al., 2006] Numerous natural and anthropogenic factors: climate change, invasive alien species, pathogens, changes in trophic interactions (i.e. predator prey relationships) can influence exposure to and effect of contaminants [Jenssen et al., 2015] To achieve the Sustainable Development Goals, there needs to be a shift in the current research process. [Van den Brink et al., 2018]

- ***Climate as an additional stressor:*** Climate change is expected to alter patterns of human economic activity and the associated emissions of chemicals, and the transport and fate of POPs. [SC GMP-2, 2017; Wöhrnschimmel et al., 2013] Climate change and exposure to endocrine-disrupting chemicals, some of which are POPs, are two of the most serious threats to biodiversity and ecosystems. [Jenssen, 2006] The release, distribution and degradation of POPs into the environment are highly dependent on environmental conditions, among which climate change and increasing climate variability have the potential to affect POPs contamination via changes in emissions sources, transport processes and pathways, and routes of degradation. Several of the effects of climate change could enhance the toxic effects of POPs on wildlife and increase disease risks and species vulnerability. [UNEP/AMAP, 2011] New approaches that approximate 'real-world' exposures are needed to more accurately predict and anticipate population-and ecosystem-level effects in a rapidly changing Arctic. [AMAP 2018]

  Climate change-contaminant interactions may alter the bioaccumulation of POPs and include phenomena deemed to be either climate change dominant (where climate change increases contaminant exposure) or contaminant dominant (where contaminant presence leads to an increase in climate change susceptibility) [Alava et al., 2017] With the intensification of global warming, an increase in POP concentrations have

[66] Each Party that has one or more regulatory and assessment schemes for new pesticides or new industrial chemicals shall take measures to regulate with the aim of preventing the production and use of new pesticides or new industrial chemicals which, taking into consideration the criteria in paragraph 1 of Annex D, exhibit the characteristics of persistent organic pollutants.

been found in the environment as they are released from environmental reservoirs -- soil, water, and ice. [Nizetto et al., 2010]

- ***POPs exacerbate the global plastics crisis*** (plastics are treated in more detail in the wastes section): apart from the chemicals used in the production of plastics, including PBDEs, it is widely accepted that **plastic debris accumulates contaminants, including POPs**. POPs can accumulate on plastic debris at concentrations up to 6 orders of magnitude greater than ambient water. [Ogata et al., 2009] **Plastic debris,** coupled with ocean currents, **contributes to long range transport of POPs.** For example, PCBs have greater affinity for plastic debris than organic carbon and are more likely to accumulate on marine plastic debris. Paired with oceanic currents, this increases the potential/likelihood that plastic debris contributes to long range transport of PCBs to the Arctic. [Zarfl & Matties, 2010] **Marine plastic debris, unlike sediments, remains bioavailable to the marine food chain:** marine plastic debris tends to adsorb POPs (PCBs, DDT) and PAHs out of the water column in a manner similar to the adsorption of pollutants on particles in sediments, but unlike sediments, these particles remain accessible for ingestion providing another path for entry into the marine food chain and are linked to adverse physical and physiological effects when ingested by marine biota. [Rios et al., 2010] **Plastics plus the POPs they contain result in greater adverse effects on marine species:** fish exposed to a mix of pollutants sorbed onto polyethylene (including POPs and metals) suffered adverse effects from liver toxicity, glycogen depletion, lipidosis, cellular death, tumor promotion [Rochman et al., 2013b] as well as changes in gene expression resulting in endocrine disruption and abnormal growth of germ cells from gonads [Rochman et al., 2014c]. In both studies, adverse effects were observed with plastic only, but were greater with plastic plus pollutants. Chemicals may transfer into lower trophic levels via ingestion and biomagnify as they transfer to higher trophic levels. [Bergmann et al., 2015] [Rochman et al., 2013a]

- ***Need to improve monitoring capability in all regions in all media****:* Through the Stockholm Convention's Global Monitoring Plan, it is evident that although monitoring capabilities around the world have improved over time, there still needs to be improvement in order to ensure that POPs levels are accurately measured in all regions of the world. [SC GMP-2, 2017] The 2017 effectiveness evaluation report recommended that the global monitoring plan should be sustained in the long term to support the evaluation of the Convention's effectiveness, and that monitoring should be enhanced in developing country Parties, including at the regional level, to advance national and regional capacities. [SC EE 2017]

  Long time series monitoring data of legacy POPs in air, human matrices and other media are available from Asia and the Pacific, Central and Eastern Europe (CEE) and Western Europe and Others Group (WEOG), while information on changes in concentrations over time is very limited in Africa and in Latin American and Caribbean Group (GRULAC). Information on changes over time in concentrations of the newly listed POPs is still limited for all. Temporal trend information for PFOS in water is currently very limited. Differences in sampling locations and in detection limits currently preclude any robust assessment of trends of PFOS concentrations in water. [SC GMP-2, 2017]

C. Pesticides and biodiversity

(i) Pesticides in the environment generally

The Stockholm Convention regulates a number of pesticides that possess POPs characteristics outlined earlier (e.g. DDT) that have impacts on biodiversity and will not be repeated here. A broader range of pesticides beyond POPs pesticides are regulated under the Rotterdam Convention's prior informed consent procedure, or if not so regulated, could be eligible for listing under the Convention. As noted earlier, the Rotterdam Convention also works to promote alternatives to harmful pesticides and works closely with the FAO in this regard. The manufacture, import or export of mercury in pesticides is not allowed after 2020 under the Minamata Convention on Mercury.[67]

Agriculture is a major land use covering approximately 37.5% of the planet's global land area. While the agricultural sector provides a number of benefits to people, including ecosystem services, large-scale agriculture also puts significant pressure on biodiversity, mainly through changing land use to agriculture and through adverse impacts of input-intensive agriculture involving pesticides and fertilizers. While fertilizers are not addressed here as they are not covered by the Basel, Minamata, Rotterdam or Stockholm conventions, fertilizers contribute to nitrogen deposition, which is also an important driver of biodiversity loss [Sud, 2020] under the general rubric of pollution [IPBES 2019], including in the CBD's Aichi Target 8. In that context, the overapplication of pesticides is an important part of the equation, particularly for aquatic and soil ecosystems.

Globally about one-third of all land is moderately to highly degraded due to erosion, salinization, compaction, acidification and chemical pollution of the soil, with contamination of soils with pesticide residues a major concern in intensive crop-production systems. [FAO BFA 2019] Pollution from within agricultural production systems and beyond, including pesticides, plastics and heavy metals, urban effluent and excess nutrients, is a major cause of the decline in many populations of many important species of associated biodiversity. [FAO BFA 2019; FAO 2018]

Pesticide Facts

- Used in agriculture, which covers 37.5% of the planet
- 1/3 of all land moderately to highly degraded, including by pesticides
- Global sales of pesticides were USD 50 billion in 2019
- Herbicides account for 80% of global pesticide use
- Glyphosate, mainly used in combination with genetically modified crops in particular, is the largest-volume herbicide in use today
- Systemic insecticides such as neonicotinoids and fipronil account for 1/3 of global insecticide sales

Box 12: Pesticide Facts

The main reason for the use of pesticides is the reduction of the negative impacts of pests, such as insects, diseases and weeds on crop yields, estimated in the 1990s to account for 40 per cent of the world's losses. [Chandler et al., 2011] Since then, the intensive use of pesticides, alongside improved management practices, has helped increase crop yields by nearly 70 per cent in Europe and 100 per cent in the United States. However, pesticide use has also created an almost universal human and environmental exposure to agricultural chemicals, with well-reported effects among those experiencing acute, chronic and cocktail/combined effects exposure [Towards a Pollution-Free Planet, 2017; Alleva et.al., 2018; Kim et.al. 2017] with little evidence of additional productivity gain. [van der Sluijs et al., 2015] The use of pesticides and fertilizers has caused widespread adverse impacts on soils and ecosystems [Carvalho, 2017].

Today, pesticide production (including insecticides, herbicides, fungicides and plant regulators) is a multi-billion-dollar industry and production is steadily moving from the OECD to transitional and developing countries, and global sales have increased dramatically (to USD 50 billion in 2019). Herbicides account for 80% of pesticide use. [GCO II 2019]. Until about 1945, inorganic compounds were used at low levels of intensity to control pests such as insects, plant diseases and weeds. Subsequently, farmers widely used organic chemical compounds as insecticides, starting with the highly toxic and persistent organochlorines (e.g. DDT). As the dangers of these chemicals became known and they were banned in a number of countries, they were replaced by shorter-lived organophosphate products that do not accumulate in the food chain. However, it has become clear that even these chemicals can cause considerable harm to the environment. While developed countries have taken these off the market over time, there remains use around the world of the older chemicals, plus many of those (e.g. DDT) continue to persist in the environment. [FAO 2018] Today the newer pesticides used in developed countries tend to be less toxic to humans and the environment and require fewer

[67] Article 4, Annex A. Products subject to Article 4, paragraph 1 include: pesticides, biocides and topical antiseptics. After 2020 the manufacture, import or export of these products is not allowed unless an exemption is claimed according to the provisions of Article 6. As an alternative to Article 4, paragraph 1, a Party may indicate at the time of ratification that it will implement different measures or strategies for products listed in Part I of Annex A if certain conditions are met. As of September 15, 2020, only the United States of America has made such a notification, in which it indicates that all registrations for mercury-containing pesticides and as a biocide in paint were cancelled by 1995, it is unlawful to market topical antiseptics containing mercury, and there was no evidence of exports of these three products at the time of notification.

applications to be effective. [FAO 2018] The average quantity of pesticides used per hectare remained stable between 2010 and 2017, having grown significantly during the previous two decades. Nevertheless, pollution from pesticide use remains at a level that has a detrimental impact on biodiversity. [GBO-5 2020]

About 500 pesticides are used for mass application, some of which are highly toxic to the environment [Zhang, Jiang and Ou, 2011]. China is both the number one consumer and producer of pesticides. Consumption is next largest by the US, Brazil, Argentina and Mexico, with use increasing in a number of upper middle-income and lower middle-income countries experiencing greater growth in intensity of pesticide use. [FAO 2018] Pesticide use is found to increase more than proportionately with agricultural intensification. It has been estimated that on average for every 1% increase in crop output per hectare, there is a 1.8% increase in pesticide use per hectare and that few high-income countries, where intensity is highest, have managed to decrease pesticide use intensity. There is also very rapid growth in the intensity of pesticide use for several middle-income countries such as Brazil, Mexico, Uruguay, Cameroon, Malaysia and Thailand. [Schreinemachers & Tipraqsa, 2012].

Because of their current scale of use and impacts on biological diversity, two types of pesticides are of particular importance for this study, although this doesn’t mean that other pesticides might not have similar negative impacts. The present scale of use of systemic insecticides such as fipronil and the neonicotinoids (one third of the sales globally of insecticides, not regulated by either the Stockholm or Rotterdam conventions) [Simon-Delso et al., 2014] has resulted in widespread contamination of agricultural soils, freshwater resources, wetlands, non-target vegetation, and estuarine and coastal marine ecosystems. Many organisms in these habitats are being subjected to repeated doses of these insecticides. The combination of prophylactic use, persistence, mobility, systemic properties and chronic toxicity is predicted to result in substantial impacts on biodiversity and ecosystem functioning and needs to be more fully considered by regulatory agencies. [van der Sluijs et al., 2015]

Glyphosates (not regulated by either the Stockholm or Rotterdam conventions), increasinglyused over the last 25 years in combination with the development of certain herbicide-tolerant genetically engineered crops, are the largest-volume herbicides in use today [GCO II 2019] and are being intensively applied, leaving increasing environmental and plant residues. [Van Bruggen et al., 2018] Globally, glyphosate is ubiquitous in surface wasters and croplands. [UNEP International Assessment Report on Issues of Concern 2020] Questions have been raised about their environmental and human health impacts. [Benbrook et al., 2018] While national risk assessments have reached different conclusions about the human health risks of glyphosate, assessments of environmental impacts are in agreement that glyphosate poses potential risks to non-target terrestrial and aquatic plants (e.g. from off-field spray drift) but that risks to non-target plants would be low provided risk mitigation measures are implemented. Studies on human exposure are limited but there is some evidence to suggest that glyphosate levels in the environment and some foodstuffs in some regions may be worrisome. [UNEP International Assessment Report on Issues of Concern 2020].

Occupational exposure for farm workers can result in adverse health effects, including acute toxicity, cancers, reproductive disorders and depression. [Siddoo-Atwal 2019; Kim, Ko & Lee 2013; GCO II 2019] Globally, it is estimated that at least 1 million people are unintentionally poisoned every year by excessive exposure and inappropriate use of pesticides, with health effects on all. [UNEP GCO 2013] Some of this relates to lack of awareness among vendors, local famers, rural communities and private landowners about the health and environmental risk associated with pesticides, particularly those traded illicitly. [UNEP and GRID-Arendal 2020]

Trade in unidentified, fake, obsolete and banned chemicals occurs in licit and illicit markets and can contribute to such exposure. This is due to a combination of factors but in all cases the ongoing demand and an economic interest in illegal production and trade are the main drivers of illicit pesticide markets. Determining the scale of illegal trade is challenging because data sources are limited, and official statistics only give part of the picture. However, the following are known: (a) Annual revenue losses of €1.3 billion in the legitimate pesticides industry in the European Union is attributable to counterfeit pesticides, (b) It is estimated that 30 per cent of the pesticides sold in developing countries are substandard, and (c) Illegal pesticide trade in India represents about 25 per cent of the value of pesticides used in that country. [UNEP and GRID-Arendal 2020]

Apart from occupational exposure, major routes of human and environmental exposure to pesticides are through food and water intake (e.g. pesticide residues). For children, prolonged low-level exposure to pesticides may induce birth defects, asthma, cancer and neurological alterations. [Schwartz et al., 2015; Eskenazi et al. 2014; Raanan et al.

2015; Roberts and Karr 2012]. Women are also particularly vulnerable due to occupational roles applying pesticides and for physiological reasons (e.g. more body fat), especially true for indigenous populations in the Arctic. However, the long-term exposure impacts for human well-being and biodiversity and ecosystems are still to be fully assessed. [Towards a Pollution-Free Planet, 2017]

1. Impacts on aquatic ecosystems and biota

Pollution from pesticide use remains at a level that has a detrimental impact on biodiversity. [GBO-5 2020] Agricultural production is the primary source of surface water pollution globally. [GCO II 2019] In many higher-income countries and most lower-income ones, pollution from agriculture exceeds that from municipal and industrial discharges, with farming and food processing generating 40 per cent of water pollution in higher-income countries and 54 per cent in lower-income countries [UNESCO 2009 in GCO II 2019]. Eutrophication and toxic pollution are major sources of water quality degradation and [WWF 2018] pesticides are a primary pollutant for both freshwater and marine waters, especially coastal waters. [Towards a Pollution-Free Planet, 2017] Pesticides are the most impactful pollutant in freshwater systems, and in ocean systems, organochlorine compounds from pesticides and industrial chemicals. [Knapp et al., 2017] Surface water pollution resulting from current agricultural insecticide use constitutes an excessive threat to aquatic biodiversity. [Stehle &Schulz, 2015] The increasing contamination of freshwater systems with pathogens and chemical pollutants, including nutrients, is a major global threat to aquatic biodiversity. [Collen et al., 2014]

Herbicides, insecticides, fungicides and bactericides applied directly in fields can drift or wash off soil into nearby surface water or leach and percolate to lower soil layers and groundwater. Groundwater pollution resulting from chemical discharges remains significant. Despite considerable progress globally in reducing discharges of chemical pollutants to aquifers and water collection basins, pesticides, industrial chemicals and household chemicals continue to affect the quality of regional groundwater in many areas. [GCO II 2019]

Fresh water makes up only 0.01% of the world's water and approximately 0.8% of the Earth's surface, but supports at least 100,000 species out of approximately 1.8 million – almost 6% of all described species. Inland waters and freshwater biodiversity constitute a valuable natural resource in economic, cultural, aesthetic, scientific and educational terms. Fresh waters are experiencing declines in biodiversity far greater than those in the most affected terrestrial ecosystems. These declines seem to be especially serious in some tropical latitudes, and particularly affect large fishes and other vertebrates. Threats to global freshwater biodiversity are: overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species. Their combined and interacting influences on biodiversity are now worldwide, and are exacerbated further by global-scale environmental changes such as nitrogen deposition and climate change. [Dudgeon et al., 2006; Collen et al., 2014]

Rivers are the chief source of renewable water supply for humans and freshwater ecosystems. Nearly 80% (in 2000) of the world's population lives in areas where either the human water security or biodiversity threat exceeds the 75th percentile and in such areas, water resource development (engineering works) and pollution are dominant contributing themes to threats for both human water security and biodiversity. 65% of global river discharge and the aquatic habitat supported by this water is under moderate to high threat. At least 10,000-20,000 freshwater species are extinct or at risk. [Vörösmarty et al., 2010]

The ecological integrity and consequently biodiversity of over half the water bodies on the European continent are threatened by chemicals, including pesticides, brominated flame retardants, tributyltin and polycyclic aromatic hydrocarbons, with pesticides the largest contributor to chemical risk. Herbicides were responsible for most of the exceedances of acute risk thresholds in algae, whereas insecticides accounted for most of the exceedances for invertebrates and fish. Increasing chemical risk was associated with deterioration in the quality status of fish and invertebrate communities, indicating that chemical pollution is a large-scale environmental problem impacting ecosystem health. [Malaj et al., 2014] A comprehensive risk assessment of Swiss rivers showed that herbicides and insecticides dominate the risk in Swiss surface waters and exceedances of critical concentrations were found in all catchments. [Moschet et al., 2014]

The risks posed by a particular pesticide to fresh and marine waters depends on the pesticide's physico-chemical properties of the active ingredients, contaminants and additives in the formulated product, as well as any metabolite/degradate/transformation product formed during chemical, microbial or photochemical degradation of active ingredients. [FAO 2018] For example, neonicotinoid and fipronil systemic insecticides are water soluble and can leach into freshwater and marine systems. Neonicotinoid insecticides are toxic to most arthropods and invertebrates, while fipronil is toxic to fish and some bird species. [van Lexmond et al., 2015; IPBES 2016]

A pesticide's capacity to harm fish and aquatic animals is largely a function of its (1) toxicity, (2) exposure time, (3) dose rate and (4) persistence (fate and behaviour) in the environment. [Helfrich et al., 2009] Streams with higher average pesticide concentrations have been associated with lower taxonomic richness, suggesting that the losses in taxonomic diversity (particularly for taxa particularly vulnerable to pesticides) related to pesticide contamination. Pesticides caused statistically significant effects on both the species and family richness, with losses in taxa up to 42% of the recorded taxonomic pools. This may mean that pesticides must be reprioritized as a driver of biodiversity loss because pesticide use is not decreasing and due to climate change is expected to increase. [Beketov et al., 2013] Measured pesticide levels in **one-sided livebearer fish** found in waterways in Argentina's agricultural district found 17 different pesticides in fish tissue, with 81% of fish tested having at least one pesticide. Evidence suggests that pesticides end up in freshwater systems due to leaching through soil and surface runoff and can accumulate in wild fish and impact their health and energetics. [Brodeur et al., 2017]

Insects provide important services such as pollination and decomposition, as well as playing a key role in food chains. Increases in freshwater insect abundances have been observed in North America and Europe, with approximately 10% per decade (between 1960 and 2005). Researchers linked these increases to improvements in agricultural practices that resulted in improved water quality. [van Klink et al., 2020]

The decline of many populations of **invertebrates**, due mostly to the widespread presence of waterborne residues and the extreme chronic toxicity of neonicotinoids, is affecting the structure and function of aquatic ecosystems. Consequently, vertebrates that depend on insects and other aquatic invertebrates as their sole or main food resource are being affected. Declines of **insectivore bird species** are quite evident, but many other terrestrial and amphibian species may be at risk. [Sánchez-Bayo et al., 2016]

Seawater quality and marine and coastal biodiversity all around the world are also seriously affected by pollution. [FAO BFA 2019] Coastal pollution is one of the many threats facing coral reefs. For example, the Great Barrier Reef off the coast of Australia is seriously affected by nutrient and pesticide runoff from sugar-cane farming and other types of agriculture. [Queensland Government, 2017] Many inshore reefs are exposed to agricultural runoff, increasing nutrients, sediments, and pesticide levels, which is linked to increased macroalgal cover and decreased octocoral diversity. [Fabricius & De'ath, 2004]

Booster biocides, introduced as a substitute for tributyltin (now listed under Annex III of the Rotterdam Convention as industrial chemicals and as pesticides), are broad-spectrum antifoulants, which can disrupt local marine habitats such as **coral reefs and seagrass beds**, and disturb organisms at the base of the food chain. As with many other pesticides, they are persistent and pervasive. Herbicides have also been reported to reduce the reproductive output of reef-building corals. [Cantin, Negri & Willis 2007] Organotins have been identified by UNEP as an emerging issue of concern for human health and the environment, with about 76% used in the PVC industry and another 20% used as biocides and pesticides. [UNEP Assessment Report on Issues of Concern 2020] The herbicide triazine from aquaculture effluents had contaminated a tropical coastal coral reef area in China, and although the levels were below levels where acute toxic effects were expected, chronic exposures of sensitive species to low concentrations have not been studied, nor the combined effect of other stressors such as climate change. [Dsikowitzky et al., 2020] A range of biocides have been used to replace tributyltin and are in use in aquaculture operations, and in general marine aquatic species from algae to crustaceans to fish are sensitive to all of these biocides, so it is important to develop environmentally-friendly non-stick coatings that work in nets and ropes used in aquaculture. [Amara et al., 2018]

Ecosystem functioning underpins nature's contributions upon which humans rely and yet the direct threat of chemical stressors to ecosystem functioning has been largely overlooked, although much research has been done on the major diversity losses associated with toxic chemicals. A recent review of studies of chemical contaminants, including herbicides, in mostly temperate marine ecosystems, found that a wide range of chemicals had the general effect of reducing productivity and increasing respiration levels in wildlife, but also suggested that contaminants may alter the ecosystem functions that underpin critical services to human society. Up to 70% of the studies reviewed found a decrease in the gross primary production of ecosystems due to contamination caused not only by increased mortality, but also effects on physiological functions. [Johnston et al., 2015].

Pesticide use has been linked to a reduction in aquatic (non-target) plants and the reduction of oxygen availability in aquatic environments (indirect effects for aquatic animals). Repeated exposure to certain pesticides can result in sublethal effects on aquatic animals such as reduced **fish egg production** and hatching, nest and brood abandonment, lower resistance to disease, decreased body weight, hormonal changes and reduced avoidance of predators, resulting overall in reduced survival and lowered population abundance. [Helfrich et al., 2009]

Pesticides are toxic to some fish species and glyphosate can cause high mortality in some **tadpoles and juvenile frogs** [Relyea 2005] and has been shown to cause mortality in tadpoles of induced wood and leopard frogs when no predators are present. [Relyea 2012] Low concentrations of malathion interacted with the presence of predators to affect an entire aquatic community, by causing a large decrease in zooplankton, an increase in phytoplankton, and a decrease in periphyton that impacted the growth of the **leopard frog tadpoles**. [Relyea & Hoverman 2008] Contamination from the herbicide atrazine causes ovary development within testes of male frogs [Mahmood et al. 2016] and results in reduced immune functioning in fish and amphibians. [Rohr & McCoy 2010] Mixtures of glyphosate and cypermethrin-based pesticides were linked to greater toxicity to **tadpoles** of the common South American toad than either pesticide on its own. [Brodeur et al., 2014]

Neonicotinoids are a significant factor in the decline of **mayflies**, a food chain foundational species, because they are extremely vulnerable to pesticide impacts even at very low exposure levels. From 2015 to 2019 the reduction of mayflies in the Western Lake Erie Basin went down by 84% and in the Upper Mississippi River there was a decrease between 2012 and 2019 of 52%. [Stepanian et al., 2020]

Alachlor, listed under the Rotterdam Convention, is one of the most widely used herbicides and can remain in agricultural soils and wastewater, but the toxicity of alachlor to marine life has been rarely studied. In the case of the marine **dinoflagellate**[68] *Prorocentrum minimum*, alachlor may affect microalgal photosystem function, causing severe physiological damage to the cells, and even cell death. [Kim et al. 2020]

2. Impacts on soil communities

Soil organisms drive processes that produce food, purify soil and water, and preserve both human well-being and the health of the biosphere. Soil biodiversity is defined as the variety of life below ground: soils are one of the main global reservoirs of biodiversity with more than 40 per cent of living organisms in terrestrial ecosystems associated directly with soils during their life cycle. [SBSTTA 2020] Soils provide ecosystem services such as the provision of food and fibres, water quality, biodiversity conservation, and ecoysystem supporting services such as nutrient cycling and soil structure formation. [FAO Soils Report 2020]

Soil pollution is one of the main threats affecting soils globally and the ecosystem services they provide. [Rodríguez Eugenio, McLaughlin and Pennock 2018]. Excessive use of fertilizers and pesticides have exacerbated land and soil degradation and erosion. [IPBES 2019] Soils throughout the world are contaminated by a broad range of hazardous chemicals such as PFOS and PFOA, heavy metals, dioxins and furans, and hazardous pesticides, and legacy soil pollution threatens local communities and food supplies, biodiversity and fragile ecosystems. Total fertilizer and pesticide applications to soil are increasing, but application rates are decreasing. [GCO II 2019] Nevertheless, contaminants represent only one aspect of the anthropogenic pressure to which an ecosystem may be exposed (such as land use change, other agricultural practices), making it difficult to attribute changes to ecosystem structure and function to the effects of contaminants alone. Further, the understanding of long-term effects of exposure is hindered by the lack of methods to assess soil community change over extended time-scales. The major threats to soil biodiversity are caused by human-induced changes and the negative impacts can be amplified by the synergistic and additive effects that might occur among such threats. [FAO Soils Report 2020]

[68] One-celled aquatic organisms that are an important component of phytoplankton in all but the colder seas and an important link in the food chain: https://www.britannica.com/science/dinoflagellate

The main anthropogenic sources of soil pollution are the chemicals used in or produced as byproducts of industrial activities, domestic, livestock and municipal wastes (including wastewater), agrochemicals, and petroleum-derived products. Conventional applications of pesticides and fertilizers in agriculture result in direct releases of pesticides to soil. [Rodríguez Eugenio, McLaughlin and Pennock 2018] If pesticides are misused or overused, they can poison agricultural soil, reduce its resilience, and interfere with natural nutrient cycles.

The diversity and functions of soil invertebrates and micro-organisms are known to be affected by the use of herbicides and pesticides. [FAO BFA 2018] Agricultural intensification, which includes increased use of pesticides and chemical fertilizers, is known to negatively affect soil biodiversity, which in turn may impact on current and future food security. [El Mujtar et al., 2019] It (1) reduces the diversity of species associated soil communities, making food webs (soil communities) less diverse, and (2) reduces the heterogeneity of taxa, leaving species that are less genetically diverse, possibly affecting the long-term viability of populations, as they are more susceptible to pathogens, disease, and less able to adapt as a community to environmental changes. [Tsiafouli et al., 2015] Soil biota are indispensable to sustaining plant and animal/human life as soil communities play essential roles in processes such as nutrient uptake by plants, formation of soil organic matter, carbon/nutrient cycling and soil formation and regeneration: services that are essential to the sustainable functioning (including resilience) of natural and managed ecosystems. [El Mujtar et al., 2019] For example, pesticide contamination disrupts nitrogen fixation process in soil [Lang & Cai 2009], and the severe loss of soil biodiversity increased insecticide uptake by a pakchoi crop. [Zhang et al., 2017]

Neonicotinoids are linked to earthworm toxicity, [Goulson 2013] as pesticides produce neurotoxic effects in earthworms, [Shreck et al., 2008] and reduced their surface casting activity and reproduction. [Gaupp-Berghausen et al., 2015]

However, the processes involved are complex and a lot of uncertainty remains as to how particular substances, and combinations of substances, affect particular organisms, and how these effects are influenced by environmental factors and by other management practices. For example, while the herbicide glyphosate may increase soil microbial activity, this may be either beneficial or detrimental towards plant growth and soil quality, as the soil ecosystem is extremely complex, containing many thousands of different species of bacteria, protozoa and fungi, as well as micro- and macrofauna. [Wolmarans & Swart 2014; Wołejko et al., 2020; Sanchez-Moreno et al., 2015]

Stockpiles of banned pesticides kept in poorly maintained facilities across Sub-Saharan Africa, for example, have left a legacy of polluted soil. Virtually every developing country or economy in transition has stockpiles of obsolete pesticides that have accumulated over several decades. [Blankespoor et al., 2009][69]

3. Impacts on other terrestrial ecosystems

Insecticides and herbicides can contaminate air, soil, water, and vegetation. Additionally, pesticides can be toxic to a range of **non-target organisms** including birds, fish, beneficial insects, and non-target **plants.** [Aktar et al., 2009] [Gaba et al., 2016] There is a compelling body of evidence that the use of systemic insecticides neonicotinoids and fipronil in cultivated systems is affecting non-agricultural lands and wild biodiversity, including pollinators and other beneficial organisms. [van Lexmond et al 2015]

Sixty-four different pesticide residues were found in all milkweed samples tested, the main food for monarch butterflies, in monarch breeding grounds in California, sometimes at levels harmful to monarchs or other insects. Chlorantraniliprole was found in lethal concentrations to monarchs in 25% of all samples. The results suggest that pesticide exposure could be a contributing factor to monarch declines in the western United States. [Halsch et al., 2020] Neonicotinoids, the most widely used insecticide in the world, have been associated with the decline of butterflies. [Forister et al., 2016]

The continuous application of pesticides can deplete **insect and microorganism** populations, generating pesticide-resistant pests and adversely affecting predator-prey relationships. [GCO II 2019] A recent study found that the population of flying insects in protected areas in Germany has declined by more than 75 per cent during the previous 27 years, with agricultural intensification, including pesticide usage, as a plausible explanation. Loss of insect

[69] See the section on hazardous wastes for more details on sources of contaminated soils more generally.

diversity and abundance could have cascading effects on food webs and jeopardize ecosystem services. [Hallmann et al., 2017]

Populations of beneficial insects other than bees, such as **beetles**, can experience significant decline through the use of insecticides. [Mahmood et al., 2016] Declines in terrestrial **insect** abundances were observed in North America and Europe, with approximately 10% per decade (between 1960 and 2005). Researchers link these declines to land use changes and pesticide use. [van Klink et al., 2020] Insect species richness and trap catches were generally higher in peach orchards with less insecticide application. The magnitude of adverse effects might be greater for herbicide application than for insecticide application. [Sonoda et al., 2011]

Exposure to clothianidin coated corn seeds (nearly all US corn seed is coated in this way) reduced abundances of non-target minute **pirate bugs** by 66%, **lady beetles** by 45%, **ants** by 43%, **ground beetles** and larvae by 31%, and **rove beetles** by 44% during the first four weeks of corn growth stages. By contrast, certain other groups like leafhoppers exhibited significantly higher abundances. Although there was some recovery towards the later corn growth stages, likely due to the decreasing clothianidin in the plants as they grew, and while the insecticide suppressed multiple herbivores, none were a danger to corn, thus suggesting that the pest suppression benefits of clothianidin did not justify the non-target impacts. [Disque et al., 2018]

The taxonomic and functional group diversity of **arthropods** in 19 rice fields of Northern Vietnam were decreased by increased numbers of pesticide applications, while land cover heterogeneity increased both diversity measures, suggesting that rice agroecosystems can be made more sustainable by increasing landscape heterogeneity and reducing pesticide use to help maintain higher levels of biodiversity. [Sattler et al., 2020]

Pesticide use is a well-documented threat to **birdlife**, either directly through ingestion [Hallman et al., 2014] or indirectly through the removal of flora around agricultural fields that birds rely on [FAO BFA 2018], or the fauna in soils (e.g. earthworms), including in the case of **predators and raptors**. Bird populations have declined 20-25% since pre-agricultural times with one of the major causes being pesticides. [Mahmood et al. 2016] Apart from affecting bees and other pollinators (see below), neonicotinoids are potentially deadly for granivorous **birds and mammals.** [van Lexmond et al., 2015] Ingestion of high dose (recommended application rate) of imidacloprid, a neonicotinoid pesticide, by **partridges** killed all partridges, with a faster rate in females. The lower (20%) dose resulted in reduced levels of plasma glucose, magnesium, and lactate dehydrogenase; reduced clutch size; delayed first egg lay; depressed immune response in chicks. [Lopez-Antia et al 2015] Pesticide poisoning (mostly carbofuran, listed in Annex III of the Rotterdam Convention) is currently the greatest threat to the **Andean condor**, with poisonings affecting adult condors more than immature ones, with alarming levels that could lead to extinction. [Pacheco et al., 2020] **Bald eagle** populations in the USA declined in part because of exposure to DDT. [US Fish & Wildlife Service, 2019; Carson 1962]

4. Impacts specific to pollinators

Bees, other pollinators and our soils – all critical for global food security – are under increasing threat. [WWF 2018; Potts et al., 2016; Gill et al., 2016; Carvalho 2017]. Adverse effects on pollinators, in turn, have direct effects on agricultural yields and food supplies [GCO II 2019; Moffat et al. 2015; Straub et al. 2016]. Declines in pollinator diversity have been recorded and are expected to continue globally. Currently, 16.5% of vertebrate pollinators are threatened with global extinction, rising to 30% for island species [IPBES 2016; Potts et al. 2016], and declines in bee diversity over the last century have been recorded in industrialized regions of the world, particularly northwestern Europe and eastern North America. [GCO II 2019]

The vast majority of pollinator species are wild, including more than 20,000 species of bees, some species of flies, butterflies, moths, wasps, beetles, thrips, birds, bats and other vertebrates. A few species of bees are widely managed, including the western and eastern honeybee. [IPBES 2016]

Several anthropogenic drivers are threatening the abundance, diversity and health of wild and managed pollinators and the services they provide to wild plants and crops: changes in land-use and management intensity; pesticides; use of herbicides in conjunction with genetically modified crops; pollinator management and pathogens; invasive alien species; and climate change-induced range shifts. Interactions between drivers may increase their overall impact. The risks from pesticides are from a combination of toxicity and level of exposure. Most of the research to date has been under controlled experimental conditions, where a broad range of lethal or sublethal effects on pollinators have been found. However, there are few true field studies, and there is much more to learn, such as whether sublethal effects scale up to the colony or population level especially in the longer term, and the potentially synergistic and long-term impacts of pesticide mixtures. Methods to reduce risks to pollinators of pesticides include decreasing levels of non-target toxicity and reducing exposure by, among other things, providing 'viable alternatives to conventional high-chemicals-input systems.' [Potts et al., 2016] [IPBES 2016]

Although the IPBES 2016 assessment concluded that for three neonicotinoids (imidacloprid, clothianidin and thiamethoxam) evidence was established but incomplete for their impacts on wild pollinator survival and production at actual field exposure, due to more recent in-depth risk assessments carried out in Canada, the EU and the US, a more recent assessment concludes that these compounds may result in high risks for bees in specific realistic scenarios, including risks at the colony level. Current levels of exposure to the three compounds may also result in significant impacts on other wildlife including birds, mammals and aquatic organisms—all measured or estimated under specific realistc scenarios. [UNEP Assessment Report on Issues of Concern 2020].

The predominant use of neonicotinoids and fipronil is as a seed dressing, whereby the active ingredient is applied prophylactically to seeds before sowing and is then absorbed by the growing plant and spreads throughout the plant tissues, hence protecting all parts of the crop [Simon-Delso et al. 2014]. Both neonicotinoids and fipronil exhibit extremely high toxicity to most arthropods and a lower toxicity to vertebrates (although fipronil exhibits high acute toxicity to fish and some bird species). Neonicotinoids are persistent in soils, can build up environmental concentrations, and are likely to be substantially impacting soil invertebrates, possibly interfering with their ability to maintain soil structure and cycle nutrients. They affect bees and other pollinators and are potentially deadly for granivorous birds and mammals with lower doses leading to a range or symptoms including lethargy, reduced fecundity and impaired immune function. [van Lexmond et al., 2015]

There have been significant losses of honeybees and associated 'pollinator service providers' over the past few decades. [Lee et al., 2015] [Oldroyd, 2007] [Woodcock et al., 2016] Neonicotinoids significantly reduce the reproductive capacity of male honeybees (drones) through reduced lifespan, reduced sperm viability, and reduced living sperm quantity by 39%. [Straub et al., 2016] Chronic exposure to neonicotinoids increases neuronal vulnerability to mitochondrial dysfunction in the bumblebee, resulting in colonies suffering a deficit in their foraging ability (e.g. olfactory learning or navigation) and failing to grow as strongly as control colonies. [Moffat et al., 2015]

Bumble bee colonies were exposed in the laboratory to field-realistic levels of the neonicotinoid imidacloprid, then allowed to develop naturally under field conditions. Treated colonies had a significantly reduced growth rate and suffered an 85% reduction in production of new queens compared with control colonies. Given the scale of use of neonicotinoids, they may be having a considerable negative impact on wild bumble bee populations across the developed world, noting the importance of bumbles in pollinating wildflowers and crops. [Whitehorn et al., 2012]

Wild bee and butterfly genera are exposed to and are potentially bioaccumulating a wide variety of pesticides in addition to neonicotinoids, even in conservation areas, with bumblebee queens containing fungicides, herbicides and insecticide degradates. [Main et al., 2020] Although neonicotinoid insecticides are usually the main referenced pesticide concern for pollinators, a recent study concluded that exposure of bees to glyphosate can perturb their beneficial gut microbiota and increases susceptibility to infection by opportunistic pathogens, potentially affecting bee health and their effectiveness as pollinators. [Motta et al., 2018]]

(ii) Impacts on nature's contributions to people, including pollination and seed dispersal

The use of agricultural chemicals and pesticides is driven by unsustainable lifestyles and consumption patterns, agricultural subsidies, and the expansion of monocultures. This poses risks to ecosystem services such as **litter breakdown and nutrient cycling, food production, genetic diversity, biological pest control, and pollination**. A recent example of this is the use of neonicotinoids, which have been linked to losses of bee colonies in various countries. Pending further treatment, residual agrochemicals on food products can also directly expose people through their diet. [Towards a Pollution-Free Planet, 2017] By affecting insects and pollinators, pesticides may impact a wide range of ecosystem services. [GCO II 2019] Animal pollination plays a vital role in nature. [IPBES 2016]

Animal pollination directly affects the yield and/or quality of about 75 per cent of global food crop types, such as most fruits, seeds and nuts and some of the most important cash crops such as coffee, cocoa and almonds. While only an estimated 5–8% of global crop production relies directly on pollination, this is a fourfold increase over the last 50 years, with pollinator-dependence higher in countries growing cash crops such as coffee, almonds, cocoa, soybeans or rapeseed at large scales. Such crops also account for the approximately 30% expansion in global agriculture. Animal-pollinated crops often have higher sales prices and animal pollination services enhance global crop output by an additional US $235–577 billion annually (on the basis of 2009 market prices and production and inflated to 2015 USD). Pollinator loss will likely have a larger impact on human health in areas with micronutrient deficiencies, such as Southeast Asia, where 50% of the production of plant-derived sources of vitamin A requires biotic pollination. User groups around the world vary greatly in their capacity to compensate the loss of pollinator-dependent food with other nutritious foods. [Potts et al., 2016; IPBES 2016, 2019]

There is a wide diversity of **values linked to pollinators beyond agriculture and food production**. Pollinators and their habitats provide ecological, cultural, financial, health, human, and social values. [SBSTTA 2018] For example, nearly 90 per cent of wild tropical flowering plant species and 78% of those in temperate zones depend, at least in part, on the transfer of pollen by animals. [Potts et al., 2016; IPBES 2016, 2019; Ollerton et al., 2011] Pollination also maintains genetic diversity in wild plants [Kearns et al., 1998] and increases yield of cultivated crops. [Gill et al., 2016] More than half of all plant species rely on biotic pollination. These plants are critical for the continued functioning of ecosystems as they provide food, habitats and other resources for a wide range of species. This includes mangroves, which provide important services such as preventing coastal erosion, supporting fisheries, protecting from flood and salt intrusion, providing wood fuel and timber, as well as habitat and food provision for bees and many other species. Another example are tropical forests, as they contain a high number of species requiring biotic pollination, and contribute to climate regulation, provision of wild meat, regulate malaria and other diseases, and provide fruits and seeds that support many other species in the forest. [SBSTTA 2018]

Beyond food provisioning, pollinators contribute directly to **medicines, biofuels** (e.g. canola and palm oil), **fibres** (e.g. cotton and linen), **construction materials** (timbers), **musical instruments, arts and crafts, recreational activities, and as sources of inspiration** for art, music, literature, religion, traditions, technology and education, [IPBES 2016] including for many indigenous people. [SBSTTA 2018]

Bees provided a **contaminant bio-sampling service** via a bee-proof, in-hive passive sampler, where pesticides and related contaminants adsorbed onto a polystyrene strip, detecting 40 different pesticide residues. [Murcia-Morales et al., 2020]

While there is a benefit to focusing on ecosystem services such as pollination to help preserve pollinators, these benefits should not be overplayed because in fact there are a limited number of pollinator species contributing most of the pollination, yet other species are worth preserving on a moral and ecological basis. [Kleijn et al., 2015]

Value of pollinators beyond agriculture and food production

- Pollinate 90% of wild tropical flowering plants and 78% of temperate
- Maintain genetic diversity in wild plants
- Pollinate plants that serve was food, habitats and other resources for many species (e.g. mangroves and tropical forests)
- Pollinators contribute directly to:
    - Medicines
    - Biofuels
    - Fibres
    - Construction materials
    - Musical instruments
    - Arts and crafts
    - Recreational activities
    - Contaminant bio-sampling
- Inspiration, including for indigenous people, for:
    - Art
    - Music
    - Literature
    - Religion
    - Traditions
    - Technology
    - Education

Box 13: Value of Pollinators

Large-scale use of systemic insecticides has significant adverse impacts on nature's contributions such as **decomposition, nutrient cycling, soil respiration and invertebrate populations** valued by humans. Adverse effects were noted among earthworms, which fulfil functions that are important for soil fertility, insect pollinators important for plant and crop production, and several freshwater taxa involved in aquatic nutrient cycling. Most microbes and fish do not appear to be sensitive under normal exposure scenarios. [GCO II 2019] [Chagnon et al., 2015]

Ecosystems play a vital role in reducing quantities of pollutants in air, water and soil. **Pollution-regulating services** provided by ecosystems greatly alleviate the harmful effects of pollution on human health. Managing and restoring ecosystems can consequently enhance the provision of pollution regulation across rural as well as urban landscapes. Efficient agriculture techniques, organic farming, and integrated landscape management can significantly reduce pesticide and nutrient run-off into groundwater and surface water, and limit ammonia emissions. [Towards a Pollution-Free Planet, 2017]

Freshwater species combine to provide a wide range of critical services for humans, such as **flood protection, water filtration, carbon sequestration, nutrient cycling and the provision of fish and other protein**. These services are jeopardized by water pollution, including pesticide run-off, where in one study 98% of threatened crabs and 74% of threatened fish were at risk from water pollution. [Collen, 2014]

Soil biodiversity, which is affected by pesticides, is not only key to sustaining food production and other ecosystem services, but also to detoxifying polluted soils, suppressing soil-borne diseases and contributing to the nutritional quality of food. [WWF 2018] Soil ecosystem services consist of: **supporting services:** carbon & nutrient cycling; soil (structure) formation and primary production; **regulating services**: water and climate regulation, greenhouse gas mitigation, pest and disease control, decontamination and remediation; **provisioning services:** nutritious food, clean water, fiber, wood and fuels, medicine and pharmaceuticals. [El Mujtar et al., 2019]

(iii) Challenges and emerging issues

- ***Multiple drivers, including pesticides, affect species and ecosystems:*** while in some contexts, pesticides can have significant impacts on their own, many studies have pointed out that there are often multiple drivers that may interact to heighten risk and, ultimately, impacts. Such drivers can include land-use change, invasive alien species, and climate change. More interdisciplinary understanding of these linkages is required to appreciate which ecosystems are most at risk. [Potts et al., 2016; Dudgeon et al., 2006; Collen et al., 2014; Beketov et al., 2014] For example, under a projected climate scenario of 2.8°C for the period 2090-2099 from a baseline temperature period 1980-1999, there was a related prediction of increased application of, and aquatic exposure to, insecticides. [Kattwinkel et al., 2011] The combined effects of toxicant exposure and global climate change requires ecotoxicologists to predict how these joint effects measured at the individual level will be manifested at the population or community level. [Moe et al., 2013]

- ***Despite progress, significant challenges remain in understanding mixture effects and long-term, low-dose exposures [GCO II 2019]:*** the toxicological effects experienced as a result of exposures from mixtures of chemicals may differ significantly from laboratory-studies on the effects of individual chemicals. [GCO II 2019] For example, a study of the effects of five common pesticides mixed together, as opposed to individually, demonstrated an effect greater than a simple additive effect on the brain enzymes of endangered Pacific salmon; several combinations of organophosphates were lethal at concentrations that were sublethal in single-chemical trials. [Laetz et al., 2009] Before chemicals are placed on the market, their active ingredients are tested individually, and depending on the regulatory framework also a representative formulated product might be tested. However, farmers might use several formulated products together and evidence shows that some of the most common of such mixtures increase the toxicity of all active ingredients. [Brodeur et al., 2014; FAO BFA 2018]

- ***There needs to be a reduction in nature's exposure to pesticides:*** While there are still many questions about the precise effects of pesticide exposure on flora and fauna, and the precise interactions of the numerous drivers behind changes to biological diversity, the reduction in nature's exposure to pesticides should be a focus of national and international efforts. Rigorous risk assessment of pesticide ingredients and subsequent regulation at the national level, reduction of pesticide use through integrated pest management practices and better application practices, better education of farmers, national risk reduction goals, and research on alternatives to high-chemical input systems could all contribute. [Potts et al., 2016] A recent United Nations Report calls for the redesign of agricultural systems through agroecological and other innovative approaches to enhance productivity while minimizing negative impacts on biodiversity. Increasing the productivity and sustainability of agriculture is an essential element of reducing and reversing biodiversity decline. 'Sustainable intensification' comprises a range of methods to achieve these objectives, including by improving the efficiency of use of inputs of pesticides. [GBO-5 2020]

There is a need for worldwide improvements to current pesticide regulations and agricultural pesticide application practices and for intensified research efforts on the presence and effects of pesticides under real-world conditions. [Stehle and Schulz, 2015]

- The changing pattern of disease and insect pest scenarios due to climate change has warranted the need for improved novel agricultural practices and use of eco-friendly approaches for sustainable crop production. While the effects of climate change are multidimensional and will vary between species, it is critical to revisit the efficacy of current chemical, physical and biological control tactics under climate change, including pest-resistant cultivars, and to include future climate scenarios in all research aimed at developing new tools and strategies. [Chattopadhyay et al., in Peshin 2019] ***Rapid species evolution must be monitored:*** As they adapt to human drivers of change, some changes – such as resistance to antibiotics and pesticides –pose serious risks for society, which evolutionary-aware policy decisions and strategies can mitigate. For instance, the rapid evolution of antibiotic resistance in many bacterial pathogens, and the rapid evolution of pesticide-resistance in many crop pests, have been identified as major threats to human wellbeing. [World Economic Forum 2018; IPBES 2019] Species vary in their ability to adapt to environmental change. Pathogens, pests, and cancers generally evolve quickly to changing environmental conditions. Conversely, wild populations, crops, and livestock are generally slower at adapting to environmental changes. [Carroll et al., 2014]
- Control of mosquitoes has been severely hampered by their evolution of pesticide-resistance – leading to the development of control strategies that are evolution-resistant [Read et al., 2009] or that also make use of evolution: for instance, 'gene drive' technology[70] can cause the rapid evolution of phenotypes that have much lower (rather than higher) fitness, and thus may disrupt mosquito reproduction or malarial transmission [Eckhoff et al. 2016]. To date, research on living modified organisms with engineered gene drives has remained limited to laboratories, contained environments and population modelling. However, some applications are close to being released in trials. Because gene drives can alter entire species and be irreversible, a major concern is the development of appropriate regulation and risk assessment to minimize the chances of unintended consequences to the species or ecosystem. [Conklin, 2019][71] Similarly, gene editing applications may reduce the use of farm chemicals or require the use of less land, which could have positive or negative impacts for biodiversity. Differences in approach are illustrated by the US Department of Agriculture, which has elected not to regulate the use of gene editing in plants, whereasthe European Court of Justice has ruled that gene-edited crops should be subject to the same regulations that apply to genetically modified organisms. [Sutherland et al., 2019]***Examining the adequacy of risk assessment of pesticides:*** Risk assessment must consider more than just the western honeybee when measuring the risks of pesticides. [Potts et al., 2016] Risk assessment needs to place greater emphasis on post-approval monitoring, rather than on the pre-market testing and risk assessment, as this produces the data needed to refine risk assessments. There is also a need to focus risk assessment on the formulated pesticide products (e.g. Roundup) rather than the active ingredient (e.g. glyphosate) in order to achieve real-world results. Risks arising from the use of formulated pesticides like Roundup often exceed those produced from regulatory risk assessments based on data derived from studies on nearly 100% pure active ingredients like glyphosate. There has also been a failure to manage the collective impact of pest management tactics, pesticides and Bt toxins on food safety, human health

[70] Gene drives involve genetic elements that pass from parents to an unusually high number of their offspring, spreading quickly through their populations. Gene drives occur naturally but can also be engineered. In recent years such efforts were ehnahced by the introduction of CRISPR gene editing, which makes it easy to insert genetic material into specific spots on chromosomes: by Cynthia H. Collins, Scientific American, September 14, 2018. https://www.scientificamerican.com/article/gene-drive1/. For further research in this area, see: CBD/SBSTTA/24/INF/7, List of Bibliographic References on Engineered Gene Drives and Living Modified Fish (2020): https://www.cbd.int/doc/c/09c9/ee86/55bb912d6fc32982fcf4d8d2/sbstta-24-inf-07-en.pdf.
[71] This is being studied under the Convention on Biological Diversity at this time, particularly at the upcoming 24th Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, including on risk assessment. See: https://www.cbd.int/doc/c/f22d/a5d7/850597e99231b7d0dd194c7f/cp-ra-ahteg-2020-01-04-en.pdf.

and the environment. [Benbrook et al., 2018] The problems associated with the large scale and intensive use of glyphosate are more encompassing than originally anticipated by the regulatory agencies. A recent study suggests that the use of glyphosate could potentially contribute to some antibiotic resistance in bacteria, such as penicillin. However, the mechanism for this resistance is not clear and further research is required, including on how this relates to the emergence of animal, human and plant diseases. [Van Bruggen et al., 2018; Huhn 2018] A recent study on soils recommends that science-based risk assessment needs to be developed, enhanced and implemented on a regular basis, considering field-realistic exposures and longer-term effects, for veterinary drugs (e.g. antibiotics), pesticides and pesticide-coated seeds, pollutants, biocides and other contaminants to inform risk management decisions, to limit or minimize pollution and to promote the judicious application of veterinary drugs, fertilizers and pesticides (e.g. nematicides, fungicides, insecticides and herbicides) to enhance the conservation of soil biodiversity, human health and well-being. [SBSTTA 2020]

Nanotechnology-based pesticides (NBP) formulations must be taken into account in risk assessment. NBP package crop protection agents in particles sized to improve solubility or dispersion, and may be coated or suspended in inert ingredients, including surfactants, solvents, anti-microbials and other materials which give them properties absent from the raw active ingredient. Whether NBP size or properties affect exposure or toxicity to bees remains to be further investigated, but given the fact that honeybees have evolved structural adaptations to collect pollen, they also inadvertently collect other environmental particles, such as NBPs. [Hooven et al., 2019]

- ***Certain classes of pesticides require careful monitoring, further research, and action (in addition to POPs pesticides and NBP discussed supra):*** Because neonicotinoids are widely used, the broader impacts on ecosystem services of neonicotinoids requires further study. [Chagnon et al., 2015] These compounds are ubiquitous and have complex exchanges among environmental compartments, persist in water and soil environments, and bees, other wildlife and humans may be exposed to them through many different routes. As a result, international action is required to reduce exposure and look beyond chemical substitutions towards alternative techniques that minimize chemical uses, such as agroecological techniques and integrated pest management. [UNEP Assessment Report on Issues of Concern 2020]

Glyphosates are the largest-volume herbicides in use today. [Benbrook et al., 2018; GCO II 2019] Increased use of pesticides and herbicides in some areas--such as where GM crops are used—with higher use of glyphosate, glyphosate-resistant weeds, and higher doses of glyphosate [Benbrook, 2012; Mortensen et al., 2012], and possible consequences for certain soil organisms and pollinators need further exploration. [Van Bruggen et al., 2018; Gaupp-Berghausen et al., 2015; FAO BFA 2019; IPBES 2016] The fate of glyphosate in the environment and its impact on ecosystems and human health is still not fully understood. [Huhn 2018] Wide use of glyphosate promotes the adoption of genetically modified glyphosate-tolerant crops, which may significantly influence biodiversity. [UNEP Assessment Report on Issues of Concern 2020] Recent litigation settlements on the human health implications of glyphosate should also be considered.[72]

D. Hazardous Wastes and Other Wastes and Biodiversity

(i) Wastes and hazardous wastes in general

Chemicals and waste and wastewater[73] are a major global problem. [GEO-6 2019] Today, humans extract more from the Earth and produce more waste than ever before. Currently waste, through its impacts on air and water quality, has negative impacts on wellbeing, especially in poor and vulnerable communities. [IPBES 2019]

The best estimate of the global amount of municipal solid waste is around 2.1 billion tonnes per year with at least 33 per cent of that amount not managed in an environmentally safe manner. [GCO II 2019] Large volumes of

[72] https://www.nytimes.com/2020/06/24/business/roundup-settlement-lawsuits.html?searchResultPosition=4; https://www.theglobeandmail.com/business/international-business/article-bayer-settles-roundup-cancer-lawsuits-for-up-to-109-billion/.

[73] As wastewater is not regulated by the Basel Convention, it will not be addressed here. It was briefly addressed under other parts of the paper where POPs, heavy metals and pesticides were identified as being in wastewater effluents. Chemicals appearing in wastewater have been highlighted in the UNEP 2020 Assessment Report on Issues of Concern.

manufactured chemicals are deposited on soil as hazardous or solid wastes. As the proportion of discarded chemically intensive products (e.g. motor oil, batteries, paints and varnishes, cleaning agents, electronic products, solvents and pesticides) increases, municipal wastes are becoming as hazardous as hazardous wastes. [GCO II 2019] The key industrial sectors producing hazardous wastes range from large- and small-scale industries (such as chemical manufacturing and resource extraction and processing) to hospitals, offices and households.

Global data on hazardous waste generation are not exhaustive despite the progress made by many countries. [UNEP and ISWA 2015]. A 2018 report indicates that hazardous and other waste generation continues to grow at the global level, although not in every classification of country. Overall, hazardous waste generation increased by 50% between 2007 and 2015, mainly due to growth in countries with lower-middle and higher-middle income. This data for this trend is more accurate than the total amount of hazardous waste generated, that is estimated to be between 256-9 million metric tons (MT) in 2007, 332 million MT in 2011 and 390-94 million MT in 2015. [Secretariat of the Basel, Rotterdam and Stockholm Conventions, 2018]

Regional hazardous waste generation largely reflects the degree of industrialization. For example, Asian countries report that they are generating increasingly large volumes of hazardous waste. [GCO II 2019] As the economies grow in rapidly industrializing economies such as the BRICS countries (Brazil, Russia, India, China, South Africa), there is a resultant increase in the amount of hazardous waste generated. While progress has been made on systems for environmentally sound management, most developing countries still lack proper treatment and disposal facilities, while facing the challenge of increasing amounts of hazardous waste, either due to increased imports of products which become hazardous waste at the end of their useful life (e.g. TVs, electronic equipment) or through industrialization (as both production and the associated wastes and pollution are 'out-sourced' by the developed countries). [UNEP and SIWA 2015]

There are particular challenges for African countries in the context of hazardous wastes that are illegally trafficked and end up being dumped in countries without the capacity to manage them in an environmentally sound manner; the particular challenges of e-waste, including the informal recycling sector; the lack of legislation controlling imports or domestic waste management, and/or poor enforcement of existing laws; impacts of artisanal and small-scale gold mining with resultant mercury wastes; improper treatment and disposal of medical wastes; open burning and dumpsites; lack of infrastructure, such as engineered landfills; lack of data; financial instability; lower recycling rates; and human health and environmental concerns from toxic chemicals entering the environment and ecosystems from hazardous waste mismanagement in general. Wealth creation must be at the centre of the African hazardous waste management industry to maximize economic benefits. [Akpan & Olukanni, 2020]

On the generation of "other wastes", in 2015[74], the amount of household waste generated globally was estimated to be around 1.6 billion MT. That amount increased around 12% in the period 2007-2015. While the amounts are increasing in all groups of countries, with the exception of the high-income countries, the increase was most rapid in upper-middle income countries, which in 2015 generated nearly the same amount of household waste as high income countries. This data is not considered robust due in part to differences in classification between Parties to the Basel Convention on what constitutes "other wastes". [Secretariat of the Basel, Rotterdam and Stockholm Conventions, 2018]

The fact that more than half of the world's population lives in urban settings has a large impact on capacities for the environmentally sound management of hazardous and other wastes. Human activities related to population growth, urbanization, agricultural expansion, transportation, and human and industrial waste discharges are typically the main sources of water pollution. [UNEP Water 2016] They include pathogens, nutrients, heavy metals and organic chemicals from point and/or non-point sources. [GEO-6 2019]

Pollution on land is becoming an important pressure, and human-generated waste and chemicals are impacting the health of people and the functioning of many ecosystem processes. [GEO-6 2019] For example, in Asia, open dumping sites for municipal waste are a source of many chemical contaminants, with such sites linked to a degraded environment and adverse impacts on human health (i.e. dioxins in breast milk). [Tanabe & Minh, 2009]

[74] Annex II of the Basel Convention.

The COVID-19 global pandemic has led to an “abrupt collapse” of waste management chains, and countries with excess medical and domestic waste are urged to evaluate their waste management systems to incorporate disaster preparedness and resilience. To reduce socio-economic and environmental impacts, the whole waste management system must be considered from waste generation through collection, transport, recycling, and final disposal of any remains. [You et al., 2020]

The volume of marine litter and marine plastic litter is considered a major threat to biodiversity, with serious impacts reported over the last four decades. [SCBD 2012, in GEO-6 2019]

(ii) Impacts of hazardous wastes and other wastes on the environment, including biological diversity

Because hazardous wastes pose a greater risk to human health and the environment than non-hazardous wastes, greater attention needs to be paid to hazardous wastes. [UNEP and ISWA 2015]

As of August 2020, the Conference of the Parties to the Basel Convention has developed thirty technical guidelines to provide Parties with guidance on the environmentally sound management of priority waste streams, including mercury, POPs and pesticides, all covered by the Basel Convention. [75]

The impacts on the environment of these three types of pollutants have been discussed earlier in this paper, including their impacts on biodiversity and ecosystem services, and will not be re-discussed here. Each of these waste streams has their own set of guidelines, and in some cases, multiple sets of guidelines (e.g. POPs that are unintentionally emitted, pesticide POPs, etc). Each guideline describes the environmental impacts of the chemical and provides guidance on the environmentally sound management of that waste stream.

The problem with obsolete pesticides, in particular for developing countries and economies in transition as a source of soil contamination has been highlighted elsewhere in this paper. [Blankespoor et al., 2009] The Stockholm Convention effectiveness evaluation concluded that among all POPs, PCB and DDT are exported for final disposal in the largest amounts, and that given ongoing uses, this is likely to continue for several years into the future. It recommended monitoring exports under both Stockholm and Basel reporting systems to enhance the information base. It also noted that the costs of eliminating the large amounts of PCB which remain are significant, and despite the current level of financing being directed at this issue, substantial additional funding is required. [SC EE 2017] The 2019 Conference of the Parties to the Stockholm Convention[76] reiterated the need for technical, financial and other assistance to developing country Parties and Parties with economies in transition with priority accorded to the sound disposal of obsolete DDT stockpiles, in particular where stockpiles pose immediate risks to human health and the environment (as well as reporting on DDT by Parties and ensuring national capacity for long-term sustainable vector surveillance).

1. E-waste

Generation of waste electrical and electronic equipment (WEEE) is increasing throughout the world. [GCO II 2019] This is the fastest-growing waste stream due to increased consumer demand, perceived and planned obsolescence, rapid changes in technology and invention of new electronic devices, compounded by the short lifespan of some products and poor design without recycling in mind. [UNEP and SIWA, 2015] The production of EEE is one of the fastest growing global manufacturing activities, and results in increased volumes of e-waste being generated with content that is both valuable and toxic. While this poses challenges for final disposal and recycling for both developed and developing countries, the e-waste pollution problem disproportionately affects developing countries, where electronic devices are often unsafely disposed. [Needhidasan et al., 2014]

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[75] For a full list of adopted technical guidelines, see: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx.

[76] Decision SC-9/2, DDT, paragraph 5 (c).

It is estimated that in 2019, 53.6 million tonnes (Mt) of e-waste was generated, an average of 7.3 kg per capita. This has grown by 9.2 Mt since 2014 and is expected to grow to 74.7 Mt by 2030. Asia generated the highest quantity at 24.9 Mt, with China alone generating 10.1 Mt; the Americas generated 13.1 Mt; Europe 12 Mt; Africa 2.9; and Oceania .7 Mt. Europe has the highest e-waste generation per capita at 16.2 kg per capita, followed by Oceania, the Americas, Asia and Africa. [Forti, Baldé, Juehr and Bel, 2020] In 2016, China was the top generator of e-waste with 7.2 Mt/annum, USA at 6.3, Japan at 2.1, India at 2.0 and Germany at 1.9. [Arya & Kumar, 2020]

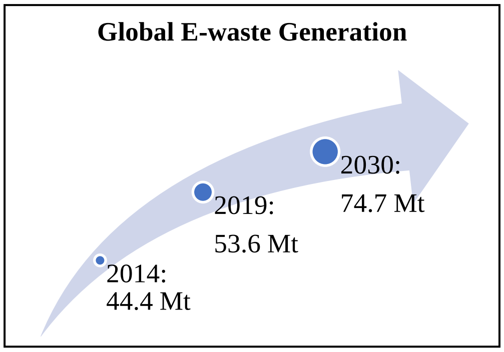

Figure 3: Global E-waste Generation

It is estimated that only about 15.5 per cent of the e-waste generated in 2014 was formally treated by national take-back schemes resulting in the highest quality of recycling and safe disposal [Baldé et al., 2015], 20% in 2016. [Ilankoon et al., 2018], and 17.4% in 2019. The e-waste rate of growth is about 2 Mt per year, while the increase in recycling grew at just .4 Mt, meaning that recycling efforts are not keeping pace with e-waste growth rates. [Forti, Baldé, Juehr and Bel, 2020]

Conversely, the fate of 82.6% of globally-generated e-waste is uncertain, with different impacts in different regions of the world. In high income countries, around 8% of e-waste is simply put in regular waste collection and subsequently landfilled or incinerated. About 7-20% of e-waste generated in high-income countries is either refurbished products that are shipped to low-or middle-income countries as second-hand products, or illegally exported under the guise of reuse when the product has no lifespan left. But the majority of such waste in high income countries is likely mixed with other waste streams, and possibly recycled but under inferior conditions. [Forti, Baldé, Juehr and Bel, 2020]

E-waste flows are hard to measure with precision, due to poor reporting under the Basel Convention and the illegal nature of many exports. Further, some of the flows may be regional and not directly North-South, and in some cases exports come from Africa to Europe (e.g. printed circuit boards for recycling). The main concern with exports to developing countries is that it adds to the existing environmental burdern and the e-waste management infrastructure is not fully developed or is non-existent, with e-waste mostly managed by the informal sector, often under inferior conditions, with severe health effects on workers and their families living nearby. [Forti, Baldé, Juehr and Bel, 2020; IPBES 2019; Ongondo et al., 2011; Akpan & Olukanni, 2020]

China, India, Ghana, Nigeria and other developing countries receive between 50% and 80% of the world's e-waste, [Lundgren, 2012] although more precise modeling is needed [Breivik et al., 2014]. Such exports contribute substantially to e-waste problems in lower income countries due to regulatory ambiguities that allow EEE export for re-use as products, regardless of actual product functionality, causing it to end up as wastes in poorer countries without the infrastructure to manage it in an environmentally sound manner. [Heacock et al., 2016] On the other hand, developing countries often export to other developing countries [Lundgren 2012; Breivik et al., 2014], and due to a Chinese import ban on waste in effect since 2018, there has been a shift of processing operations from China to other countries in Asia such as Thailand, Malaysia and Vietnam. As regulation increases in Southeast Asia, this could result in increases in imports into countries in West Africa. [Lundgren 2012; Breivik et al., 2014] Shipments to Accra, Ghana, have been rerouted through other African ports. [Daum et al., 2017] The Basel Convention is currently trying to resolve these ambiguities through the development of technical guidelines for the environmentally sound management of e-wastes as well as a review of its annexes describing regulated hazardous wastes.[77]

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[77] The guidelines can be accessed at: http://www.basel.int/Implementation/Ewaste/TechnicalGuidelines/DevelopmentofTGs/tabid/2377/Default.aspx. The review of the annexes is an ongoing process: http://www.basel.int/Implementation/LegalMatters/LegalClarity/ReviewofAnnexes/AnnexesI,III,IVandrelatedaspectsofAnnexes/tabid/6269/Default.aspx.

Although constituting only about 5% of global solid waste, e-waste plays a significant employment role in the recycling sectors of some low- and middle-income countries such as China, India, Pakistan, Malaysia, Thailand, the Philippines, Vietnam, Ghana and Nigeria. For example, in Guiyu, China, possibly the largest e-waste recycling location in the world, about 100,000 people are employed as e-waste recyclers [Lundgren 2012] While the formal recycling system in China has grown in capacity and quality, due to a range of social and economic factors, the informal sector continues to play a major role. [Baldé et al., 2015] Approximately 25% of e-waste is recycled in formal recycling centres with adequate protection for workers in China. [Li & Achal, 2020]

One study suggested that over 1 million poor people in India are involved in the manual recycling operations of e-waste, most of whom have little understanding of the hazards of such waste. The hazardous materials in e-waste leach from landfills into groundwater and streams, and if the plastic components are burned, they release dioxins into the air. [Needhidasan et al., 2014] Another, however, points out the wide range of uncertainty in terms of how much e-waste is produced internal to India and how much is imported, and suggests that the total number of people working exclusively on e-waste in the informal sector is approximately 25,000. [Breivik et al., 2014] A more recent study suggests that 95% of the recycling in India is of the informal type, where 25-30% of e-waste is reused and the rest is discharged into open dumps, channels, waterways and open spaces. [Awasthi et al., 2018]Although e-waste contains valuable materials including iron, aluminum, copper, gold, silver and rare earth metals, electronic products have not been designed with their safe recycling and disposal in mind. Only an estimated 15% of global e-waste is fully recycled and only 25% of valuable metals are recovered during informal e-waste recycling. [Heacock et al., 2016] It is estimated that e-waste generated is worth approximately 20.5-25 billion dollars per annum, according to a report from the International Criminal Police Organisation (INTERPOL) [Rucevska et al., 2015] The raw material value in such wastes is approximately 57 billion USD, but at a 17.4% recycling rate, only $10 billion is extracted through current waste management practices, leaving this an "urban mine" that can be exploited with beneficial impacts for the environment. [Forti, Baldé, Juehr and Bel, 2020]

These valuable components are easy to source and relatively cheap to ship, with low risks of being caught for violating any laws that may exist, resulting in substantial illegal trade in e-waste at the global level. [Lundgren 2012] Given the valuation of the sector, increasing costs of safe disposal, increasing resource scarcity and weak regulations and enforcement, this opens up opportunities for organized illegal trafficking in such wastes, which has become a global concern, one receiving ongoing attention by the Basel Convention and INTERPOL. [GEO-6 2019; Obradović et al., 2014; Ongondo et al., 2011; Palmeira et al., 2018]

Hazardous components of e-waste can include lead, mercury, cadmium, nickel, beryllium, zinc and persistent organic pollutants like flame retardants or those found in product fluids, lubricants and coolants. These pollute ecosystems both due to their recycling, both formal and informal, but also due to conventional landfilling. [Ilankoon et al., 2018] As more of these products are dumped in landfill, this leads to the increased likelihood of environmental and human health impacts, particularly in many low- and middle-income countries where their handling and disposal is frequently unregulated. [Heacock et al., 2016] A total of 50 tonnes of mercury and 71 kt of brominated flame-retardant plastics are found in globally undocumented flows of e-waste annually, which is largely released into the environment and impacts the health of exposed workers. Improper management of e-waste also contributes to global warming. [Forti, Baldé, Juehr and Bel, 2020] It has been estimated that the import of PBDEs via e-wastes into China exceeds domestic production of brominated flame retardants by a factor of 3.5. [Breivik et al., 2014]

Toxic substances can be found within the following typical emissions or outputs: leachates from dumping activities; particulate matter (coarse and fine particles) from dismantling activities; fly and bottom ashes from burning activities; fumes from mercury amalgamate "cooking", desoldering and other burning activities; wastewater from dismantling and shredding facilities; effluents from cyanide leaching and other leaching activities [Sepúlveda et al., 2010] Most e-waste pollutants leach onto land and into water, and release toxic substances. POPs and heavy metals have been found in Guiyu, a heavy e-waste recycling city in China, in the ground and river sediments exceeding human health thresholds. Such areas are no longer suitable for growing food and water is unsafe for drinking. Long-range transport of pollutants from e-waste can impact those living near informal e-waste sectors. Pollution from such recycling is found in the air, soil, water and plants in the area, posing severe risks to the environment and human health. [Li & Achal, 2020]

Electronic waste accumulates in landfills. [IPBES 2019] For example, the Agbogbloshie dump in Accra, Ghana, is one of the 50 biggest dumpsites in the world, and perhaps the world's largest e-waste dump. It receives around 192,000 to 215,000 tonnes of e-waste annually, much of it imported, as Ghana does not regulate secondhand EEE. This pollutes soil, air and water and causes serious health impairment in the lives of 6000-10,000 informal sector workers gaining their livelihood from sorting and recycling. [UNEP and SIWA, 2015; Heacock et al., 2016; Daum et al., 2017] Because this region has considerable overlap among industrial, commercial, and residential zones, Pure Earth (formerly Blacksmith Institute) has ranked Agbogbloshie as one of the world's 10 worst toxic threats and estimates that anywhere between its 40,000 residents and up to 250,000 others could be affected by pollution from this dump. [Heacock et al., 2016] [Blacksmith Institute 2013] Waste left in fields and nearby bodies of water is ingested by animals and marine life and high residential density and e-waste processing close to food markets heightens the degree of exposure for human-environmental systems. Soil samples in open burning areas contained dioxin and furans from the burning of plastics and metals. A river close to the Agbogbloshie e-waste operations has high concentrations of copper, cadmium, lead, iron, chromium and nickel from burning and dumping, and ends up in the coastal waters of the Gulf of Guinea, along with untreated e-waste. Impacts include sparser, sicker and smaller fish stocks; adverse effects on aquatic plant and animal species in all forms; and indirect effects on humans via consumption of fish and seafood that are dietary staples for coastal residents. Significant levels of PCBs have been measured from beach samples, providing further indications that e-wastes are polluting the coast, resulting in alterations in the development of numerous species. [Daum et al., 2017]

The improper disposal of e-wastes is of increasing concern due to their volume and unknown risks to surface and groundwater quality. [GEO-6 2019] The hazardous materials they contain leach from landfills into groundwater and streams, and if the plastic components are burned, they release dioxins into the air. [Needhidasan et al., 2014] The burning of PVC cladding is done to recover copper cables, resulting in environmental pollution while at the same time poisoning the recycling operators and their neighbours. [UNEP and SIWA 2015] Human health is endangered through this environmental pollution of the soil, waters, groundwaters and air with toxic materials, as well as disturbing the ecosystem. [Obradović et al., 2014; Forti, Baldé, Juehr and Bel, 2020] Studies conducted in China and India indicate that hazardous substances from e-waste can extend beyond processing sites and into ecosystems, including from long-range transport. [Sepúlveda et al., 2010; Zhang et al. 2011]

People are exposed to hazardous substances in e-waste through multiple routes, including occupational exposure, as well as water, air, soil, dust, and food. There are three general routes of exposure: the informal recycling sector, where primitive techniques are used and exposure is high; the formal sector, where recycling techniques are designed to remove salvageable materials and protect workers; and finally, residents living within a specific distance of e-waste recycling areas due to high levels of environmental, food, and water contamination, although these exposures are less than occupational exposures. [Grant et al. 2013; GCO II 2019]

Concentrations of heavy metals were measured in foodstuffs, house dust, underground/drinking water and soil from an e-waste area in South China, with elevated levels found in all except the drinking water. However, local residents who used groundwater as a water supply source were at high non-carcinogenic risk. Rice and dust samples collected from homes close to e-waste sites had concentrations of lead, cadmium, and copper that were nearly twice the maximum permissible concentrations, and exposure from rice, combined with inhaling lead through house dust, put children at high risk for neurotoxicity and adverse developmental effects. [Zheng et al., 2013] Another study in an e-waste area in China noted that people living in e-waste recycling towns or working in e-waste recycling had evidence of greater DNA damage than did those living in control towns. Substantial quantities of pollution were found not only very close to e-waste recycling locations, but, because of contamination of the surrounding environment (specifically soil and water) and the resulting food chain, high levels of pollution due to e-waste are also found throughout southern China. [Grant et al., 2013]

A study of Chinese and Indian WEEE recycling sites found a causal relationship between the release of lead, PBDEs and dioxins and furans and concentrations found in environmental compartments (e.g. soil and air) as well as biota and humans. It highlighted the increased human risk of exposure through impacted natural resources such as soils, crops (rice), drinking water, livestock, fish and shellfish, with soil contamination important in areas that are cultivating rice. PBDEs in the soils of rice fields and bioaccumulation of dioxins and furans in red meat, milk, eggs, fish and shellfish are a matter of high concern. PBDE concentrations in fish in nearby rivers were 10-15,000 times higher than levels reported for other regions, and about 200-600 times higher than PBDE levels in bottom sediments in the same rivers. [Sepúlveda et al., 2010]

Weak e-waste regulations and limited use of safety measures for e-waste workers in Accra, Ghana foster an exploitative environment that leads to risks to human health to those working in and living near the e-waste processing sites. [Daum et al., 2017]

2. Large waste dumps and open burning of hazardous and other wastes

Waste dumps and informal recycling are major sources of pollution in many countries. Roughly 33 per cent of the world's solid waste ends up in open dumpsites. Releases from waste dumps are a key source of air pollutants. [GCO II 2019] Forty-eight of the world's 50 biggest active dumpsites are in developing countries and pose a serious threat to human health and the environment, affecting the daily lives of 64 million people. For example, the Jam Chakro site in Pakistan is one of the largest in the world, extending over 202 hectares, with an informal sector of 5,000, but affects the life and health of an additional 5 million people living within 10 kilometres of the site. [UNEP and SIWA, 2015] Such dumps do not provide for the environmentally sound management called for by the Basel Convention and its technical guidelines.

Open dumping is the most common method of hazardous waste disposal in developing countries. Uncontrolled disposal of municipal solid waste leads to severe and various environmental and social impacts: heavy metals pollution in water, soil, and plants; open burning causing polluting emissions; waste picking within open dump sites posing serious health risks to people; and release of municipal solid waste in water bodies augments global marine litter. Informal recycling occurs in both low income (Zimbabwe) and high-income developing countries (China), with pickers collecting waste from uncontrolled open dump sites that are not recognized or organized by local municipalities and can include hazardous wastes, including e-waste. This activity can help enhance materials recovery and thus reduce environmental impacts but needs to represent a key strategy for improving sustainability. [Ferronato & Torretta, 2019]

About 15 million people in low- and middle-income countries are involved in informal waste recycling of plastics, glass, metals and paper where these activities are a risk both to the people performing the tasks and to the environment, particularly the air, water and soil. Contamination by POPs and heavy metals can reach exceedingly high levels near informal recycling sites. [Yang et al., 2018]. Individuals performing resource recovery, especially e-waste pickers in developing countries, risk considerable occupational and environmental health threats with little to no state support, and yet are an integral part of the circular economy in the Global South. [Vélis, 2017] Women comprise more of those working in the informal sector [Yang et al., 2018] and with children are among the vulnerable groups working in this sector who face exposure to hazardous chemicals and heavy metals. [Heacock et al., 2016]

Open burning of waste is a large source of air pollutants, but such emissions are not included in many emissions inventories used for chemistry and climate modeling applications and are significantly underestimated. [Wiedinmyer et al. 2014; GCO II 2019] In rural areas most wastes are burned in open dumps or directly released to unmanaged landfills, leading to contaminated soils, surface waters and groundwater. [GCO II 2019] There are particular challenges in small island developing states (SIDS) where the most prevalent waste disposal approaches are landfilling, illegal dumping and backyard burning, with roughly 80% of litter ending up in the ocean or on coastlines. Nevertheless, sustainable practices are emerging despite being hindered by governance behavioural and infrastructure challenges. [SIDS Waste Management Outlook 2019]

Open burning is common in many low-income countries. [GCO II 2019; Kumari et al., 2019; Wang et al., 2017] Burning of this waste, typically at low temperatures and in an uncontrolled manner, releases large amounts of hazardous substances to the environment, making dumps a major global source of some substances of high concern such as dioxins and furans [Zhang et al., 2011] and mercury. A total of 50 t of mercury can be found in the unaccounted flows of e-waste generated in 2019 worldwide. [Forti, Baldé, Juehr and Bel, 2020] A study in India illustrated that the top two chemicals released from open burning were dioxins and furans (regulated under the Stockholm Convention), and urban dwellers were more affected by emissions from open burning. [Kumari et al., 2019] Open dumping is particularly worsened in slum areas with additional problems of high-density population, traffic, air and water pollution, and result in air contamination, odors and greenhouse gases, vectors of disease, soil contamination, visual impacts and surface water and groundwater pollution. For example, PCBs, dioxins and furans were detected in soils around dump sites in the Philippines, India, Cambodia and Vietnam. [Ferronato & Torretta, 2019]

Another source of open burning in Southeast Asia is from crop residue open burning (CROB),[78] which occurs due to large residues generated annually from a large amount of agricultural crop production. Rice straw, maize and sugarcane were the top three contributing crops. Indonesia was the top contributor to total SEA crop residue open burning emissions, followed by Vietnam, Myanmar, Thailand and the Philippines. In the Philippines and Vietnam, CROB emissions dominated over the other main open burning source, forest fires. Adverse local environmental and human health effects should not be overlooked as these emissions occur in populated areas, and mainly in the dry season when air pollution levels are highest in SEA. Substantial amounts of dioxins, PAHs and OCPs, along with large quantities of toxic fine particles are of concern and should be used to educate farmers to discourage this type of open burning.[79] [Oanh et al., 2018]

Legacy soil pollution threatens local communities and food supplies, biodiversity and fragile ecosystems. [GCO II 2019] On land, open waste dumps have local impacts on plants and animals, and soil pollution can affect the microbial population and reduce important ecosystem functioning. [Wall, Nielsen & Six, 2015; Minh, 2006] For example, foraging on dump sites increases exposure to POPs (PBDEs, PCBs, furans, and dioxins) in Mediterranean gulls. [Roscales et al., 2016]

3. Plastics and biological diversity

Microplastics are a ubiquitous pollutant; they have a high bioavailability because they are found in aquatic, atmospheric, and terrestrial ecosystems. [Horton et al., 2017] Recent modelling predicts that even with immediate and concerted action, resulting in a reduction of plastic pollution by 40% by 2040, 710 million metric tons of plastic waste will still have entered the aquatic and terrestrial ecosystems by 2040. The full implementation of all commitments to date would reduce plastic waste entering the environment by only around 7%. [Lau et al., 2020]

Plastics in marine debris come in a range of sizes, from microplastics <5 mm in diameter, through meso (<2.5 cm), macro (<1 m) to mega (>1 m). Primary plastics are those manufactured for particular applications, while secondary sources are those created by fragmentation and degradation. Thus, they encapsulate the range from nanoparticles and microbeads through to plastic bags and abandoned fishing nets. [GESAMP 2016]

Global plastic production was 359 million tonnes in 2018[80] and expected to double by 2050. [Lebreton & Andrady, 2019] There have been investments of about USD 180 billion over the last decade in plastics production facilities, and COVID-19 has caused a resurgence in single use plastics that were previously banned. [UNEP Speech of the Executive Director 2020] Macro and microplastics come from a wide variety of land- and sea-based sources, such as pellets, packaging, building and construction, electronics, textiles, microbeads, containers, plastic bags, straws and road traffic. [GESAMP 2016; Jambeck et al., 2015; Evangeliou et al., 2020]

It enters the oceans through rivers, the coastline, marine sources (e.g. dumping from ships), and the atmosphere. Some sources can be regionally important, such as ship-breaking directly on the shoreline in India and Bangladesh. [GESAMP 2016]

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[78] This does not fall under the Basel Convention, and could have been placed under the topic of POPs, since it is a source of POPs air pollution. However, this has been retained in the discussion of open burning for context.

[79] The Stockholm Convention *Toolkit for Identification and Quantification of Releases of Dioxins, Furans and other Unintentional POPs,* January 2013, references biomass and waste burning as part of "open burning" processes, and provides methodology for developing an inventory, along with a sample inventory: http://chm.pops.int/Implementation/UnintentionalPOPs/ToolkitforUPOPs/ToolkitMethodology/tabid/196/Default.aspx.

[80] See: https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf.

Volume and growth of plastic wastes: Plastic pollution is escalating, and it is accumulating in the oceans at alarming rates. [IPBES 2019] [Jambeck et al., 2015] A frequently-quoted model estimated that 4.8-12.7 million tonnes of plastic waste entered the ocean in 2010 from coastal populations worldwide out of a total of 275 million tonnes of plastic waste generated that year, and expected to increase substantially by 2025. [Jambeck et al., 2015] However, precise data quantifying the scale of the issue is lacking, [GESAMP 2016] although as recently as July 2020 the Executive Director of UNEP stated that the global community produces 300 million tonnes of plastic waste each year, about 8 million tonnes of which end up in the oceans. [UNEP Speech of the Executive Director 2020]

Global Plastics Data

- Global plastics pollution has grown tenfold since 1980
- 300 Million tonnes of plastic waste produced globally per year
- 8 Million tonnes ends up in the oceans

Box 14: Global Plastics Data

It is estimated that between 1.15 and 2.41 million tonnes of plastic waste enters oceans every year from rivers. Most plastic waste enters between May and October, with the top 20 polluting rivers (found mostly in Asia) accounting for approximately 67% of the total global plastic waste. [Lebreton et al., 2017] Lack of certainty about amounts of plastic entering the oceans may be explained in part by the significant time interval from several years to decades between terrestrial emissions of plastics and their accumulation in offshore waters, with much of the secondary microplastics in the global ocean a result of the degradation of objects produced in the 1990s and earlier. Thus, comparing estimates of plastic emitted to the marine environment with the amounts collected offshore may be misleading. Mitigating amounts requires a cessation of emissions but also the systematic removal of plastic waste to avoid further degeneration of secondary microplastics for decades to come. [Lebreton, Egger & Slat, 2019]

River export is the most important source of microplastics input into the marine environment. Globally about 20% of microplastics originates from car tyre wear and laundry fibres discharged in the sewage system, while the share of personal care products is negligible, although in Africa it is only 1% while it is 60% for OECD countries, so more region-specific analyses are required. [van Wijnen et al., 2019] Airborne microplastics from traffic pollution (tyre wear and brake wear particles) may be entering the world's oceans at a similar rate to that from rivers (64,000 tonnes per year), with one third of all road microplastic, roughly 50,000 tonnes, ending up in the world's oceans each year via the atmosphere. The Arctic may be a particularly sensitive receptor region, where light-absorbing properties of these particles may also cause accelerated warming and melting of the cryosphere. [Evangeliou et al., 2020]

Microplastics are found in the ocean surface, the water column, the seafloor, the shoreline and in biota. Understanding fluxes of microplastics and hot-spots requires understanding the movement between these compartments, which is complex and driven by many factors including winds, currents and particle size and shape. [GESAMP 2016]

Based on modelling, it has been estimated that 5.25 trillion plastic particles weighing approximately 268 940 tons are in the oceans, although this is only 0.1% of world annual plastic production. Much of it is within the five sub-tropical ocean gyres[81], where ocean currents cycle and gather marine debris. [Eriksen et al., 2014] Another model estimated there to be from 15 to 51 trillion particles, weighing between 93 and 236 thousand metric tons, which is approximately 1% of global plastic waste estimated to enter the ocean in the year 2010, while acknowledging knowledge gaps in sources, transformation and fate of plastics in the ocean. [van Sebille et al., 2015]

The highest concentrations of net-collected plastics are in the subtropical gyres, with the largest mass reservoir in the North Pacific Ocean, possibly due to inputs from coastal Asia and the United States. [van Sebille et al., 2015] Certain East Asian seas near Japan showed concentrations of microplastics 16 times greater than in the North Pacific and 27 times greater than in the world oceans on average, transported on ocean currents from the Yellow Sea and East China Sea. Higher levels may be from higher plastic waste input by the Asian continent, but the source of plastic pollution is nearly impossible to determine. [Isobe et al., 2015] Twenty-two years of ship-survey data collected in the western North Atlantic Ocean and Caribbean Sea revealed that more than 60% of 6136 surface plankton net tows collected buoyant plastic pieces, typically millimeters in size, with the highest concentration in

[81] There are five major ocean gyres, which are large systems of rotating ocean currents: the North and South Pacific Subtropical Gyres, the North and South Atlantic Subtropical Gyres, and the Indian Ocean Subtropical Gyre: https://oceanservice.noaa.gov/facts/gyre.html.

subtropical latitudes and associated with observed large-scale convergence in surface currents. [Law et al., 2010]

Microplastics have also been observed in some of the most remote marine environments, including the Arctic. A first assessment of microplastics and other anthropogenic particles in Hudson Bay and the surrounding eastern Canadian Arctic waters of Nunavut revealed that 90% of surface water and zooplankton samples and 85% of benthic sediment samples contained microplastics or other anthropogenic particles, and were from distant sources, although additional investigation is needed on the transport mechanisms responsible. [Huntington et al., 2020] It has also been found in Arctic sea ice [Kanhai et al., 2020] with concentrations higher than in oceanic gyres, with the potential for substantial quantities of legacy microplastic contamination to be released into the ocean as ice melts, [Obbard et al., 2014] and in the Southern Ocean, where microplastics have been found but in general at lower concentrations than other oceans. [Isobe et al., 2017] It has also been found on the deep-seabed floor. [Ramirez-Llodra, 2011]

Impacts on biota: in general

The long-term ecological consequences of microplastics in the marine environment are: losses in ecosystem productivity by interference with nutrient production and cycling; physiological stress in organisms (e.g., behavioral alterations, immune responses, abnormal metabolism, and changes to energy budgets); and threats to ecosystem composition and stability. Some ecosystems are particularly vulnerable to microplastic disturbances, such as wetlands, estuaries, mangroves, the deep ocean seafloor and the Arctic. The toxicities range from the erosion of individual species to the defective development of biological communities to the collapse of ecosystem functioning. [Ma et al., 2020]

Impacts on biota: entanglement and ingestion:

Marine debris is a major threat to marine and coastal biodiversity. Three-quarters of all marine debris is plastic, a persistent and potentially hazardous pollutant, which fragments into microplastics that can be taken up by a wide range of marine organisms. [Secretariat of the CBD 2016]

There is a widespread impact of plastic pollution due to (1) the diverse array of species exposed to plastics in environment (including unfragmented and degraded/microplastics); (2) the high incidence of exposure with biological populations (with several populations close to an 80% ingestion rate); and (3) it is easily transferred through the food web. Scientific have classified the ecological effects of plastic debris in marine ecosystems on major classes of biota: phytoplankton, zooplankton; cnidaria; echinoderms; annelids; porifera; mollusca; crustacea; fish; sea turtles; marine mammals; and seabirds. Microplastics can impact an organism at many levels of biological organization, including at the levels of populations and assemblages. Still, the majority of the evidence is at levels that are sub-organismal (e.g. changes in gene expression, inflammation, tumour promotion) or affect individual organisms (i.e. death). [GESAMP 2016]

Overall, there are more than 800 marine and coastal species affected by marine debris through ingestion, entanglement, ghost fishing and dispersal by rafting as well as habitat effects. There are an estimated 519 marine and coastal species affected by ingestion of or entanglement in marine debris, which includes the effects of ghost fishing. The number of seabird and marine mammal species affected by marine debris ingestion or entanglement is steadily rising. [Secretariat of the CBD 2016; Ryan et al., 2009] Entanglements result in impaired movement, feeding, reduced reproductive capacity, lacerations, and death. [Derraik 2002; Kuhn in Bergmann et al., 2015]

Ingestion of indigestible debris affects individual fitness, is linked to reduced reproductive success, and causes direct mortality. Ingestion can be intentional as predators mistake plastic for prey (common in seabirds) or unintentional where plastics are ingested along with target prey (generally in filter feeders). Visual predators often mistake microplastics for prey due to similar size and shape, as in the case of Amberstripe scads feeding on blue polyethylene fragments resembling their usual prey of plankton, also allowing an entry of such plastics into the foodweb. [Ory et al., 2017]

Secondary ingestion involves animals feeding on prey that has previously ingested plastic (trophic transfer). Ingestion has been linked to (1) blockage of gastrointestinal tract leading to death; (2) partial blockage of digestive tract which contributes to poor nutrition and dehydration; (3) reduced stomach capacity, resulting in lower nutrient uptake; (4) toxicity from associated chemicals. [Kuhn in Bergmann et al 2015; Gregory, 2009; Lusher in Bergmann et al., 2015]

There are 557 species affected by either entanglement or ingestion of plastic marine debris. 100% of marine turtle species are affected, up to 66% of marine mammal species, and 50% of seabird species are affected by entanglement or ingestion of plastics from the ocean. The suffering and death of individuals, in combination with the likelihood of higher-level population effects, indicates the need for plastic inputs into the marine environment to be rapidly reduced. [Kuhn in Bergmann et al., 2015]

Major threats to **sea turtles** have been direct exploitation, degradation of nesting habitat, and bycatch, with the effects of plastic debris an emerging concern that puts additional pressure on sea turtles, which interact with plastics in the environment through ingestion and entanglement. Ingestion of plastic debris has been documented in all sea turtle species, in all ocean basins and is linked to obstruction, damage, and/or inflammation of digestive tract, leading to reduced digestive capacity; reduced swimming ability (making them more vulnerable to bycatch) and death. It is likely that every **loggerhead turtle** foraging in the epipelagic zone of the Mediterranean has ingested some plastic debris several times during its life. There are difficulties in conducting comparisons between various studies undertaken to date and the typical use of stranded turtles creates a bias in results. The negative consequences of debris ingestion are far from understood and the negative effects at the population level need further study. [Casale et al., 2016] **Sea turtles** dying of known causes unrelated to plastic ingestion had less plastic in their gut than those that died of either indeterminate causes or directly due to plastic ingestion (e.g. gut perforation). There was a 50% probability of mortality found once an animal had 14 pieces of plastic in its gut, providing a critical link between recent estimates of plastic ingestion and the population effects of this environmental threat. [Wilcox et al., 2018]

A literature review (from 1962 to 2012) reported (a) 59%, 80 of 135, species of **seabirds** had ingested plastic; (b) the average ingestion rate per species was 29%. Predictive modelling suggests that, due to the increases in global plastic production, the number of affected species, and average ingestion rate, will continue to increase in the future unless interventions successfully reduce the amount of plastic pollution. [Wilcox et al., 2015]

A study of South African **freshwater birds** confirmed that African freshwater ecosystems and the biodiversity they support are under threat from microplastic contamination. Ducks in two freshwater systems were found to have ingested microplastics, with foraging method (which differs among species) affecting the amount of microplastic found in duck faeces. Ducks also carry microfibres on their feathers, and plastic loads are greater at a site receiving effluent from a sewage treatment plant. [Reynolds & Ryan, 2018]

The implications of plastic ingestion for apex predators need further study. Microplastic ingestion was found in 35% of **planktivorous fish** in the North Pacific Central Gyre, with blue, white and clear—colours most resembling its prey—primarily ingested. Further implications of this for lower trophic level species and whether they are passing non-digested plastic up the food chain to apex predators needs further consideration. [Boerger et al., 2010] A subsequent study of **apex predators** found plastic fragments ranging in size (micro, meso, and macro) in 18% of top apex predator fish stomachs: 12.5% of **swordfish**; 12.9% of **albacore;** 32.4 % of **tuna**. The study confirms trophic transfer of plastic debris to apex predators (secondary ingestion) and mindful that apex predators are consumed by humans, recommended further research about human health implications of apex predator ingestion of microplastics and toxins commonly associated with plastic debris (e.g. POPs). [Romeo et al., 2015] Plastic debris was found in the stomachs of 18.8% of blackmouth **catshark**, an apex predator feeding near the bottom of the water column. [Alomar & Deudero, 2017]

In the Thames River, areas with large wet wipe clusters were linked to low **clam** level density, and clams adjacent to the wet wipe reefs were found to contain synthetic polymers, some of which may have originated from the reefs. [McCoy et al., 2020] Microplastic ingestion from toothpaste was linked to structural damage of gills and digestive glands of Mediterranean **mussels**, leading to necrosis of other tissues. [Bråte et al., 2018]

Based on the evidence of widespread presence of plastics in the environment, it is highly likely that organisms in terrestrial and freshwater will also encounter microplastic particles, although this area has been much less explored than impacts on the marine environment. It is mainly marine species that have been studied for the effects of plastics, but the limited studies conducted to date with soil and freshwater species confirm the potential for microplastics to have detrimental effects on the physiology of species across many ecological niches. [Horton et al., 2017]

Ingestion of 'junk', including plastic debris, by a critically endangered species in a terrestrial biome, the **California condor**, resulted in reduced nestling survival, and was considered to be the primary cause of nest failure in the reintroduced condor population and threatened the re-establishment of a viable breeding population in southern California. [Mee et al., 2007]

Earthworms exposed to polyethylene particles transported those particles into their burrows, thus possibly affecting groundwater and other organisms and this high concentration of microplastics is also a possible explanation of the stress response demonstrated by the earthworms. [Huerta Lwanga et al., 2017]

The impacts of microplastics on soil has been little studied. Use of sewage sludge and plastic mulching in agriculture are huge sources of microplastics in soils. Microplastics in the soil have a detrimental ecological impact on soil macro- and microbiota and are a major route for transferring toxic chemical pollutants, heavy metals and pesticides into the human food chain, and further research is needed. [Sarker et al 2020; Chae & An, 2018; Wang et al., 2019]

Impacts of Plastics on Marine Biota

- Entanglement (and possible death)
- Ingestion: e.g. reduced feeding, growth, movement, & possible death
- Contamination by chemicals: affects development, reproduction
- Rafting: spread of invasive alien species/pathogens/POPs

- **Freshwater species impacts**: more research required, contaminants an issue

- **Terrestrial and soil impacts:** an emerging global change threat?

Box 15: Impacts of Plastics on Biota

Impacts on biota from contaminants in plastics:

Under the section on POPs, the relationship with plastics was flagged as a challenge/emerging issue, where it was noted that plastic debris: both contains and accumulates contaminants, including POPs; coupled with ocean currents, contributes to long range transport of POPs; marine plastic debris, unlike sediments, remains bioavailable to the marine food chain; plastics plus the POPs they contain result in greater adverse effects on marine species. More details are provided below.

Microplastics can be a source and sink of hazardous chemicals to organisms, but its relative importance as a source of chemicals to wildlife relative to others (e.g. water, sediment, diet) remains under investigation. [GESAMP 2016] Contaminants in plastics could be significant to freshwater and soil ecosystems where such chemicals are expected to be found in higher quantities than in the marine environment due to their proximity to industrial sources. The location where microplastics may accumulate in soil and surface freshwaters are therefore likely subject to the release of these chemicals, resulting in a complex set of leach mixtures. Landfills are likely to be full of such leachate. [Horton et al., 2017]

In isolation, microplastics might not be the single most toxic environmental contaminant, but the ubiquitous nature of plastic contamination of the natural environment at the global scale, and the wide range of interactions of microplastics with a range of biotic and abiotic aspects of terrestrial ecosystem functions, suggests that they might well represent an important driver of global change across major terrestrial and continental ecosystems of the planet. There is a growing body of evidence that microplastics interact with terrestrial organisms that mediate essential ecosystem services and functions, such as soil dwelling invertebrates, terrestrial fungi and plant-pollinators, thus suggesting that microplastic pollution might represent an emerging global change threat to terrestrial ecosystems. [De Souza Marchado et al., 2018]

Indirectly microplastics act as reservoirs for other chemical pollutants. Chemical pollutants adsorb/attach to the surface of plastics, effectively increasing their concentration (increasing the potential to bioaccumulate and biomagnify). [Ma et al., 2020] Hydrophobic organic pollutants adsorb to microplastics in marine environments; the result is concentrations of these pollutants at greater concentrations than in the surrounding water and is linked to adverse environmental effects. [Ziccardi et al., 2016]

Three types of chemical pollution are associated with plastic debris: (1) ingredients (monomers, additives) in plastic itself, including PBDEs, metals, phthalates and bisphenol-A; (2) byproducts of manufacturing (i.e. chemicals released during combustion of raw material petroleum, (3) chemical contaminants already present in ocean or atmosphere (including POPs, DDT, PAHs, HCH, HCB, PBDE, HBCD, BPA, NP, OP, and PCBs and metals, i.e. Hg) that accumulate on plastics. [GESAMP 2016] Changes to environmental conditions will influence the dynamics between chemicals and plastics, impacting on chemical accumulation and bioavailability. [Horton et al., 2017]

[Rochman in Bergmann et al., 2015] At least 78% of priority pollutants and 61% of priority substances listed as toxic by the US Envionmental Protection Agency and the European Union are associated with plastic debris as either (1) ingredients of the plastic, or (2) substances that have adsorbed onto plastics in the environment. [Rochman et al., 2013a]

Once ingested, microplastics have been linked to both development and reproductive disturbances in a wide range of wildlife species as constituent contaminants (phthalates and bisphenol-A) leach into the organism. [Oehlmann et al., 2009] In marine lugworms, exposure to polystyrene microplastics was linked to (1) reduced weight; (2) reduced feeding activity; (3) increased bioaccumulation of PCBs. [Besseling et al., 2013] Pollutants, additives (including PBDE) and microplastic (through ingestion rather than sorption through the body wall) were transferred to lugworm tissues at concentrations sufficient to disrupt ecophysiological functions linked to health and biodiversity. [Browne et al., 2013]

Chronic exposure to microplastics affected behaviour, resulting in reduced growth and reproduction in *C. dubia* (water flea). Microplastic fibres pose a greater risk to water fleas than microplastic beads, with reduced reproductive output observed at concentrations within an order of magnitude of reported environmental levels. [Ziajahromi et al., 2017]

A positive correlation between plastic debris and bioaccumulation of PCBs in marine organisms has been found. [Teuten et al., 2009; Yamashita et al., 2011] Plastics act as a vector for organic pollutants, leaching chemicals into the water column and interstitial water. The chemicals released from these pellets reduce the viability of sea urchin larvae (exposure reduced embryonic development by 58-66%). [Nobre et al., 2015]

Plastics as a vector or habitat:

Microplastics can transport invasive alien species, including harmful algal blooms and pathogens. [GESAMP 2016] Beyond macro- and micro-plastics, plus persistent organic pollutants, non-indigenous species and algae linked with red tides are transported with plastics. [Barnes et al., 2002 [IPBES 2019] Floating plastic debris can persist for long periods of time, subsequently facilitating the transport of invasive alien species. [Gregory, 2009]

An estimated 295 species have been known to **disperse by rafting on debris**. This includes bryozoans, sponges, molluscs, crustaceans, polychaete worms, barnacles, macroalgae, annelid worms, and echinoderms. Invasive alien species including Mediterranean mussel, brown seaweed, and Asian shore crab have been transported to North America via floating plastic debris/rafts. [Secretariat of CBD 2016]

Floating litter provides **habitat for diverse array of species** (387 taxa, including invertebrates, bryozoans, crustaceans, molluscs, and cnidaria) have been reported "rafting" on plastic waste. The diversity of species is dependent on (1) size of accumulated "raft" of litter, and (2) type of waste (e.g. bacteria affinity for Styrofoam)."Rafts" facilitate the dispersal of organisms, increasing the likelihood that the organisms on the raft will invade new ecosystems [Kiessling from Bergmann et al., 2015] The light weight and durability of plastic make it a vector for the transport of non-indigenous species, supporting a diverse and widespread rafting assemblage inhabiting North Pacific plastic debris, some expected (barnacles) and others not (boring organisms). The number of rafting taxa were positively correlated with the size of the raft. [Goldstein et al., 2014]

Plastic waste is known to **host pathogens**, increasing the likelihood of disease outbreaks as pathogens disperse via "microbial rafting," which is highest in tropical regions close to the equator and lower in polar regions. As the highest biodiversity is found in equatorial regions (ocean and terrestrial ecosystems), the impact of plastic-hosted pathogens increases if microbial rafting is highest where biodiversity is highest. [Barnes, 2002] Plastic debris can provide habitat for pathogens, microbial communities, bacteria, and viruses, making them a potential vector for disease to both humans and aquatic organisms. [Zettler et al., 2013; De Tender et al., 2015] A potentially pathogenic bacteria (Vibrio) was found on a number of marine microplastic particles in the North/Baltic Sea. [Kirstein et al., 2016]

The generation of microplastic wastes may be fueling the spread of **antibiotic resistance**, as plastic pollution facilitates increased gene exchange among bacteria, as compared with free-living aquatic bacteria, which can affect aquatic microbial communities on a global scale and the evolution of aquatic bacteria and is a neglected hazard for human health. [Arias-Andres et al., 2019] Heavy metals such as mercury, lead, zinc, copper and cadmium are accumulating in the environment at critical concentrations and triggering co-selection of antibiotic resistance in bacteria. When such bacteria are present on rafting plastic, they can transfer genetic elements horizontally to distantly related bacterial human pathogens more easily than in free living microbes, making microplastics an emerging hotspot for metal driven co-selection of multidrug-resistant human pathogens. Therefore, the marine environment is co-polluted with metal, antibiotics, human pathogens and microplastics, thus posing an emerging health threat globally. [Imran, Das and Naik 2019].

Contact with plastic debris increased the likelihood of **disease in reef building corals** from 4% (no contact) to 89%. Reefs perform valuable ecosystem services (coastline erosion mitigation) and contribute to the economy (tourism) - lost/reduced capacity to perform services when corals diseased. Pathogens associated with plastic marine life "raft" to new environments, spreading disease in corals [Lamb et al., 2018].

(iii) Nature's contributions to people

Many of the implications for ecosystem services related to mercury and POPs mentioned in those sections of this report are relevant for hazardous wastes and are not repeated here, but a number of points are worth highlighting.

For Asia-Pacific Economic Cooperation countries, the estimated **damage from plastics** to fisheries and aquaculture, marine transport, shipbuilding and marine tourism from marine debris was USD 11.2 billion in 2015. [UNEP Speech 2020]

Food provision and freshwater/groundwater regulation are affected as a result of hazardous waste management practices: Intensive e-waste recycling cities like Guiyu, China are no longer suitable for growing food and water is unsafe for drinking. [Li & Achal, 2020] Microplastics hinder sustainable crop production and food safety and act as vectors for major chemical pollutants into transport pathways, indirectly impacting food safety. [Sarker et al., 2020] 25% of fish sold for human consumption in a Californian market were found to have microplastics debris [Rochman in Bergmann et al., 2015]. Microplastics that co-pollute the marine environment with metal, antibiotics, and human pathogens pose an emerging health threat globally, threatening humans who ingest marine derived foods. [Imran, Das & Naik, 2019] Waste left in fields and nearby bodies of water is ingested by animals and marine life and high residential density and e-waste processing close to food markets heightens the degree of exposure for human-environmental systems. [Daum et al., 2017].

Provision of food, including supporting identity*:* A river close to the Agbogbloshie e-waste operations has high concentrations of copper, cadmium, lead, iron, chromium and nickel from burning and dumping, which end up in the coastal waters of the Gulf of Guinea, along with untreated e-waste. Impacts include sparser, sicker and smaller fish stocks and indirectly affect humans via consumption of fish and seafood that are dietary staples for coastal residents. [Daum et al., 2017].

Physical and psychological experiences*:* millions are affected due to long-range transport of pollutants from e-waste that can impact those living near informal e-waste sectors. [Li & Achal, 2020] Dumpsites damage the environment and health of hundreds of millions living on or around them. [ISWA 2019] When pathogens associated with plastic marine life "raft" to new environments, such as corals, and spread disease, this results in a loss to the economy (tourism), when corals are diseased. [Lamb et al., 2018] Microplastics that co-pollute the marine environment with metal, antibiotics, and human pathogens also pose an emerging health threat to recreational activities in the marine environment. [Imran, Das & Naik, 2019].

Regulation of air and water quality are affected due to open burning and large open dumpsites where hazardous wastes are improperly managed. [Li & Achal, 2020].

Formation, protection and decontamination of soils are affected due to soil pollution. Soil samples in open burning areas contain dioxin and furans from the burning of plastics and metals. [Daum et al., 2017] Soil pollution can affect the microbial population and reduce important ecosystem functioning. Soil biodiversity can play a crucial part in providing a more stable supply of food and a higher nutritional value of the food produced and contributes to both water and air quality. [Wall, Nielsen & Six, 2015] There is a growing body of evidence that microplastics interact with terrestrial organisms that mediate essential ecosystem services and functions, such as soil dwelling invertebrates, terrestrial fungi and plant-pollinators, thus suggesting that microplastic pollution might represent an emerging global change threat to terrestrial ecosystems. [De Souza Machado et al., 2018]

Microplastics affect **regulation of coastal water quality**, such as when pathogens associated with plastic marine life "raft" to new environments, spreading disease in corals, [Lamb et al., 2018] thus interfering with valuable coastline erosion mitigation services.

(iv) Challenges and emerging issues

- ***Need to capitalize on the value of e-waste and adopt a more circular model of production for electronic products****:* numerous authors have pointed out the value of e-waste [such as Forti, Baldé, Juehr and Bel, 2020] and the concept of **urban mining** as a way of achieving several of the 2030 Sustainable Development Goals (SDGs) and/or a circular economy. [Arya & Kumar 2020; Xavier et al., 2019; Gunarathne et al., 2019] Coupled with this is the need to turn the **informal waste sector** globally into something safe and sustainable. [Arya & Kumar 2020; Vélis, 2017; Ferronato & Torretta, 2019]. Improved recycling of e-waste would also help reduce the problem of open burning of hazardous wastes in open dump sites. Despite the potential value in recycling e-waste, the products are neither designed nor assembled with recycling principles in mind. [Forti, Baldé, Juehr and Bel, 2020] The future of e-waste is uncertain, but with a growing middle class and increasing numbers of electric cars and artificial intelligence functions in products, among other things, an increase in e-waste in future can be expected. A recent report highlights three possible future scenarios for managing e-waste, which are largely dependent on the degree to which businesses act in accordance with a new model of circular production. [[StEP, UNU ViE-SCYCLE & UNEP IETC 2019]
- ***Expand plastics research and policy focus:***
    - Little research has been done on the terrestrial aspects of plastics, even though some estimates are that contamination on land might be 4- to 23-fold larger than in the oceans. [Horton et al., 2017] The widespread presence, environmental persistence, and various interactions with continental biota suggest that microplastic pollution, including nanoplastics, might represent an emerging global change **threat to terrestrial ecosystems**. [De Souza Marchado et al., 2018] Taking note a of a recent report prepared for it on wastes containing nanomaterials, the Conference of the Parties to the Basel Convention has requested further information from Parties and others, including on best practices for the environmentally sound management of wastes containing nanomaterials.[82]

    - The emerging threat of micro-plastic contamination and ingestion to **freshwater biodiversity** needs to be recognised and mitigated. [Reynolds & Ryan, 2018]

    - Microplastics act as an emerging hotspot for metal driven co-selection of multidrug resistant human pathogens and pose serious threat to humans that undertake recreational activities in the marine environment or ingest marine derived foods. Therefore, the **marine environment, co-polluted with metal, antibiotics, human pathogens and microplastics, poses an emerging health threat globally**. Strategies should be developed to control metal and microplastic pollution in terrestrial and aquatic environments worldwide. [Imran, Das & Naik, 2019]

    - To avoid a massive build-up of plastic in the environment, **coordinated actions are needed at the global level**, including reducing plastic consumption; increasing rates of reuse, waste collection and recycling and expanding safe disposal systems; accelerating innovation in the plastic value chain. [Lau et al., 2020] The Conference of the Parties to the Basel Convention recently noted that the prevention, minimization and environmentally sound management of plastic waste as well as the effective control of its transboundary movement will reduce the amount of plastic waste entering the environment.[83] Discussions currently underway under the purview of the UN Environment Assembly are considering a global legally binding convention as an option.[84]

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[82] Decision BC-14/14. SAICM has nanotechnology and manufactured nanomaterials as one of its emerging policy issues, with the Organisation for Economic Cooperation and Development (OECD) and the United Nations Institute for Training and Research (UNITAR) leading actions.
[83] Decision BC-14/13, paragraph 2.
[84] Several options, including a global convention, will be considered by the UN Environment Assembly in February 2021: https://environmentassembly.unenvironment.org/expert-group-on-marine-litter.

- ***Address the COVID-19 pandemic and waste issues in an environmentally sound manner:***
    - Uncontrolled dumping and burning pose environmental and human health risks: increased disposal of medical masks, gloves, gowns and other personal protective equipment; open waste dumps as sources of health risk and risks to the informal waste picking sector. [UNEP & IGES 2020]
    - Increased use of single use plastics due to COVID-19 is not necessary. [UNEP Speech 2020] The implications of increased impacts of disinfectant and cleaning solutions are being studied. [UNEP & IGES 2020] Increased use of wet wipes and improper disposal have implications for aquatic wildlife/systems. [McCoy 2020]
    - All countries facing excess medical and domestic waste as a result of the COVID-19 pandemic should be evaluating their entire waste management system from generation through collection, transport and recycling and final disposal in order to incorporate disaster preparedness and resilience. [You et al., 2020]

V. Conclusions from the exploratory study on interlinkages between chemicals and wastes and biodiversity

1. Pollution is one of the key drivers of biodiversity loss. Chemicals and wastes are ubiquitous in the environment and found in all parts of the globe, and global production and distribution of chemicals-based products continues to increase. The Basel, Rotterdam, Stockholm and Minamata conventions address some of the most significant chemicals and waste pollution that has been identified over the last several decades and are thus contributing to the conservation and sustainable use of biological diversity.

2. Mercury is persistent in the environment, and while some emissions are naturally-occurring (e.g. rock weathering), anthropogenic emissions are increasing, polluting the air, freshwater and oceans, with severe consequences for human health and the environment, particularly biodiversity (e.g. mercury bioaccumulation in biota). Artisanal and small-scale gold mining (ASGM) is the biggest polluter to air, lands and waters, often fed by the illegal trade in mercury. Significant re-volatilization is expected to occur due to melting permafrost, snow and ice as a result of climate change.

3. POPs are human-made chemicals that are persistent in the environment and are found around the globe in air, water and soil. While the concentrations of legacy POPs continue to decline or remain at low levels, emissions from PCBs continue and along with DDT continue to be found in biota, the former associated with population declines in killer whales. For POPs listed after 2004, concentrations in air are beginning to show decreases, although in some instances increasing and/or stable levels are observed, but information is lacking for human tissues and other media. Re-volatilization continues to occur, including for legacy POPs such as PCBs, and more is expected due to climate change. Large remaining stockpiles of obsolete pesticides and PCBs remain an issue.

4. There needs to be a reduction in nature's exposure to pesticides. Global food security is under threat due to the threats to bees, other pollinators, and the deterioration in soil ecosystems, partly due to pesticides. Agricultural runoff, including pesticides, is a major source of water pollution and contaminant of groundwater aquifers. The impacts of certain high-use pesticides on nature need monitoring and action (e.g. glyphosate, neonicotinoids). The illegal trade in pesticides continues to add to human and environmental exposure.

5. Mismanagement of hazardous wastes in large waste dumps around the world--including e-waste, mercury waste, POPs waste and pesticide waste--is resulting in serious impacts on biological diversity and ecosystem services as well as the health of millions of people, particularly those involved in the informal

recycling sector and their communities, and those living near those dumps due to open burning and other releases. The transboundary movement of e-wastes to poorer countries lacking recycling infrastructure continues to add to the environmental impacts of such wastes, although all countries are having difficulties properly managing the volume and complexity of e-waste. The volume of e-waste is expected to continue to grow and needs proactive measures globally to manage it.

6. Plastics, the production of which is expected to double by 2050, have demonstrated impacts on marine species through entanglement, ingestion, contamination, and transport/rafting (including the spread of antibiotic resistance, pathogens and POPs), but may also pose a serious threat to terrestrial ecosystems, including soils. Concerted proactive actions are needed at the international level to address this rapidly growing menace.

7. Mercury, POPs, pesticides and hazardous and other wastes (e.g. plastics) are negatively impacting soil biodiversity around the world. Soils are one of the main global reservoirs of biodiversity with more than 40 per cent of living organisms in terrestrial ecosystems associated directly with soils during their life cycle.

8. Transformation of key polluting sectors in developing countries, such as ASGM and informal e-waste recycling, can provide major benefits for biodiversity and ecosystem services, as well as the human health of workers and their communities, while promoting significant economic sectors and contributing to a circular economy.

9. Nature’s contributions to people and ecosystems world-wide are impacted by mercury, POPs, pesticides and hazardous and other wastes as they impede nature’s ability to regulate air and freshwater quality, soils and organisms, create and maintain habitat, and they reduce pollination and seed dispersal services. These pollutants also affect services such as the provision of food and feed, materials and assistance, and genetic diversity. They affect non-material contributions of particular importance to indigenous peoples around the world, including those regarding the consumption of traditional foods that also support spiritual and religious identity, as well as experiences with nature that contribute to social cohesion, recreation, learning and inspiration.

10. High levels of contamination are found in countries or regions that are megadiverse (e.g. ASGM using mercury), from mercury, POPs, pesticides and hazardous and other wastes, as well as in vulnerable ecosystems like the Arctic, and in locations close to intense industrial activity, often in urban centres. These pose particular challenges for biological diversity and ecosystem services, as well as for human health.

11. Of particular concern is the impact of mercury, POPs, pesticides and hazardous and other wastes in combination with other chemicals, and other natural and anthropogenic stressors--such as climate change, hunting pressure, invasive alien species, emerging pathogens, and changes in food web dynamics--which are having an impact on biodiversity, ecosystem services and human health. Further emphasis in research is needed to enhance understanding on mixtures and cumulative effects, including from long-term low-dose exposures, and how to address them. Risk assessment for pesticides needs improvement, for example, by focusing on high use, ubiquitous pesticides, and on the formulated products rather than just the active ingredient, and by placing a greater emphasis on post-approval monitoring.

12. Climate change is a key factor amplifying the effects of chemicals but is also expected to contribute to the continued re-volatilization of both mercury and POPs, which are persistent in the environment and can cycle between environmental compartments for extended periods of time. Melting permafrost and ice are expected to release significant quantities of both mercury and POPs into the environment.

13. Environmental monitoring for POPs and mercury needs to be improved and consistent in all regions of the world so that the risks to human health and the environment can be fully understood in all regions. Although discussion of the possibility of a broader science platform for chemicals and hazardous wastes is

under consideration as part of the ongoing beyond-2020 discussions--the equivalent of the IPCC for climate and IPBES for biodiversity—the current convention processes for environmental monitoring and examining effectiveness are extremely valuable.

14. Illegal trade in mercury, POPs, pesticides and hazardous and other wastes (particularly e-waste) continue to exacerbate both environmental and human health risks, often in poorer countries with limited infrastructure to combat it.

15. Many species are evolving rapidly as they adapt to human drivers of change, including some changes – such as resistance to antibiotics and pesticides – that pose serious risks for society. Close monitoring of such developments is required. Similarly, new technologies that could reduce pesticide use, such as gene drives, require careful assessment due to their potentially irreversible impacts if released into the environment. Reduction of pesticide use, rather than the search for alternatives to current pesticides, can be achieved through alternative techniques, such as integrated pest management practices and agroecological farming.

VI. Building on the Interlinkages Study: How the Minamata, Stockholm, Rotterdam and Basel conventions can contribute to the post-2020 global biodiversity framework (GBF) and to the Conference of the Parties to the CBD

Earlier parts of this study have identified the international context, the importance of 2020 and 2030 as target years for international action on pollution and biodiversity, and the range of issues under the above four MEAs that target the nexus of pollution and biodiversity. Despite substantial efforts to date and many successes, the data show that the 2020 WSSD target for chemicals and hazardous wastes has not been met, Aichi Target 8 has not been met by 2020, and substantially more needs to be done to achieve the Sustainable Development Goals by 2030.

This part of the study will first illustrate the interlinkages between these two areas of importance to the environment and the SDGs. It will then describe in more detail the background to the development of the post-2020 global biodiversity framework and outlines recommendations to date on how Aichi Target 8 can be built upon. It then explores how the four MEAs and the CBD can build on this study in the context of the post-2020 global biodiversity framework and going forward.

A. The 2030 SDGs: where biodiversity and chemicals and waste converge

The sound management of chemicals and waste is an enabler to many of the SDGs, starting with SDG 12 on sustainable consumption and production. Of 196 targets and 30 indicators under the SDGs, around 69 targets and 91 related indicators have been cited to be relevant to chemicals and waste.[85] The Implementation Plan of the UN Environment Assembly's Towards a Pollution-Free Planet aims to accelerate and scale up action to reduce pollution and to support countries in implementing the 2030 Agenda and achieving the SDGs through existing MEAs and other international initiatives.[86]

In its 2019 report, IPBES noted that SDG Target 12.4 on waste management is an area likely to have many positive implications for nature and nature's contributions to people as well as a greater quality of life for all people. The

[85] SAICM/IP.4/INF/15. http://www.saicm.org/Portals/12/documents/meetings/IP4/INF/SAICM_IP4_INF_15_TWG_FINAL.pdf.
[86] UNEP/EA.4/3: https://environmentassembly.unenvironment.org/pre-session-working-douments-unea-4

report considered that waste, through its impacts on air and water quality, has negative impacts on wellbeing, especially in poor and vulnerable communities. This target relates closely to SDGs 6, 14, and 15, as well as aspects of SDGs 3 and 11, in terms of trends in pollution and its impacts on health and the environment. [IPBES 2019] This has been illustrated in Figure 4, below, the first two columns from IPBES with a third column introduced to illustrate the contributions of the Minamata, Stockholm, Rotterdam and Basel conventions to this broader range of targets involving pollution.[87]

SDG	Relevant Target	BRS and M convention contributions
12: Ensure sustainable consumption and production patterns 	**Target 12.4:** By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.	While currently, the BRS Secretariat provides data for UNEP for indicator 12.4.1, all 4 conventions are implicated in this target. While GCO II concluded that the 2020 target would not be met, providing updated targets for purposes of the CBD post-2020 could help recalibrate the 12.4 target of 2020 in a meaningful way for the chemicals and waste cluster. In addition, the contribution of the SAICM pre- and post-2020 efforts on matters outside the scope of the 4 conventions could be factored in here.
	Target 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.	BC has ongoing initiatives focusing on waste minimization and prevention. Waste Without Frontiers II and the review of progress under the strategic framework 2011-2020 will help measure progress towards reaching this target. Data on waste generation has been difficult to obtain.
6: Ensure access to water and sanitation for all	**Target 6.3** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and	All 4 conventions contribute to Target 6.3. Mercury, POPs, pesticides, and hazardous and other wastes, all shown in this paper to pollute groundwater and freshwater.

[87] It should be noted that the Minamata Convention website has its own listing of SDGs and mercury at: http://www.mercuryconvention.org/Implementation/SDG/tabid/8150/language/en-US/Default.aspx. Similarly the BRS website has its own listing on contributions of the BRS conventions to the SDGs at: http://www.brsmeas.org/Implementation/SustainableDevelopmentGoals/Overview/tabid/8490/language/en-US/Default.aspx

	substantially increasing recycling and safe reuse globally **Target 6.6** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	BC also contributes to the recycling and reuse component. Actions taken under all 4 conventions can contribute to this target.
14: Conserve and sustainably use the oceans, seas and marine resources	**Target 14.1** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	All 4 conventions can contribute, within their respective scopes, to the reduction of both marine pollution and marine plastic debris. For example, ASGM activities, POPs and pesticide run-off and plastic debris from rivers contribute pollution to the marine environment.
15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss	**Target 15.1** By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements **Target 15.3** By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	All 4 conventions can contribute, within their respective scopes, to the conservation and sustainable use of such ecosystems, through reductions of emissions and releases of harmful chemicals and wastes. Where emerging chemical or waste issues arise that are not within their scopes, SAICM or UNEA are possibly implicated. Issues were raised in this paper about soil degradation arising from the chemicals or waste addressed under each of the four conventions.
3: Ensure healthy lives and promote well-being for all at all ages	**Target 3.9** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.	By focusing on protection of the environment and human health, all 4 conventions contribute to this goal. Specific activities, such as focusing on the informal ASGM and waste-picking sectors, as well as reducing pollution near such sites, can help those workers as well as their families and communities.
11: Make cities inclusive, safe, resilient and sustainable.	**Target 11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and	Local mercury and POPs air pollution (as well as long-range) can be reduced through improved implementation of the Stockholm and Minamata conventions. The

11 SUSTAINABLE CITIES AND COMMUNITIES	municipal and other waste management **Target 11.A** Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	Basel Convention can contribute to improved municipal and other waste management, particularly through technical guidance on the environmentally sound management of hazardous waste streams ending up in municipal landfill.

Figure 4: IPBES linkages of pollution issues to various SDGs

Through a horizon-scanning exercise of the European environmental science community regarding chemicals in the environment, a recent study examined what types of improved understanding of the impacts of chemicals on environmental health is needed to help deliver the SDGs, for which chemicals play a key role (see Annex VII). It concluded that current research on and regulation of chemicals in the environment tend to take a simplistic view and do not account for the complexity of the real world. Among the top questions were how to define, distinguish and quantify the effects of multiple stressors on ecosystems (#3); how do we improve risk assessment of environmental stressors to be more predictive across increasing environmental complexity and spatiotemporal scales (#2); how can interactions among different stress factors operating at different levels of biological organization be accounted for in environmental risk assessment? [Van den Brink et al., 2018] Many of these questions echo those that have arisen in Part IV of this study.

B. The post-2020 global biodiversity framework: background

The year 2020 marked the end-date of the strategic framework for biodiversity 2011-2020 and its 20 global biodiversity targets (Aichi Targets) of the Convention on Biological Diversity (CBD). The Fifteenth Conference of the Parties to the Convention on Biological Diversity is expected to adopt a post-2020 global biodiversity framework with a view to enabling the achievement of the Convention's 2050 vision of "Living in harmony with nature."[88] The post-2020 global biodiversity framework is also a vehicle to help deliver the SDGs as established by CBD COP decision 14/34. The September 30, 2020 global summit on biodiversity provided a venue for many countries to renew their pledge for the realization of the 2050 vision through a wide reiteration of commitment to preserve land and marine ecosystems, reduce pollution, increase climate mitigation and adaptation, fight land degradation and halt biodiversity loss.

An Open-ended Working Group (OEWG) was established to negotiate the post-2020 global biodiversity framework and has conducted two meetings to date, with OEWG-2 in February 2020 considering a zero draft. OEWG-2 requested the Co-Chairs and the Executive Secretary under the oversight of the Bureau to update the zero draft, taking into account the outcomes of OEWG-2 and written submissions. The revised zero draft was posted in August 2020[89] and will be updated to taken into account the outcomes of the next meetings of the CBD's Subsidiary Body on Implementation (SBI) and the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), taking place between May 3 and June 13, 2021. A first draft of the post-2020 framework will be prepared by the co-chairs based on this input and thematic consultations and made available for the third meeting of the OEWG, expected to occur thereafter in 2021.[90]

For the 2nd OEWG in February 2020, UNEP contributed two papers on the chemicals and waste cluster and their possible contributions to the process, including a thought-starter and an assessment of interlinkages between chemicals and waste and other clusters, including biodiversity, that had been submitted for the 4th meeting of the

[88] Timing will be affected by the global pandemic, with the latest developments are posted at: https://www.cbd.int/conferences/post2020. The current projected date is October 2021.
[89] https://www.cbd.int/doc/c/3064/749a/0f65ac7f9def86707f4eaefa/post2020-prep-02-01-en.pdf.

[90] Ibid. Timing will be affected by the global pandemic, with the latest developments are posted at: https://www.cbd.int/conferences/post2020. The co-chairs' May 2021 update can be found at: https://www.cbd.int/conferences/post2020/co-chairs-updates

SAICM International Process for the Strategic Approach and sound management of chemicals and waste beyond 2020 (SAICM IP-4).[91]

In preparatory activities for the post-2020 period (the Bern-I workshop), a group consisting of representatives of the chemicals and waste conventions and the biodiversity-related conventions identified three areas for collaboration in the post-2020 framework: targets and indicators, communications and messaging, and linked scientific activities. Joint activities could be organized on the emerging risks for biodiversity associated with pesticides, persistent organic pollutants, mercury, pharmaceuticals and plastic waste.[92] The UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) also provided a background paper for the Bern-II consultation which was postponed, to stimulate anticipated discussions.[93]

C. The pollution target in the post-2020 global biodiversity framework

Earlier parts of this study illustrated the interlinkages between chemicals and wastes and biodiversity, as well as outlining the scope of the four chemicals and waste MEAs and their ongoing work in preventing and addressing certain forms of pollution that contribute to impacts on biodiversity. These can provide the basis for guidance for the post-2020 period pollution target and/or its implementation, through decisions of their respective conferences of the parties.

Aichi Target 8 reads as follows:

Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

In the technical paper supporting this target, excess nutrients were highlighted as included in the term “pollution”.[94] Most of the reporting on this target in the CBD Parties’ Fourth National Reports addressed nutrients, rather than other pollutants.

UNEP’s Assessment paper on linkages outlined linkages with other clusters, including biodiversity.[95] Among some of the areas suggested for the chemicals and waste cluster to contribute to the biodiversity post-2020 framework related to targets and indicators, as well as process options. The Assessment outlined an option for expanding Aichi Target 8 to identify, for example, priority pollutants/chemicals, such as bisphenol A, cadmium, triclosan,[96] mercury and other heavy metals, POPs, microplastics and endocrine disruptors.[97] It suggested that the target could also be

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[91] UNEP (2020). A thought starter: Strengthening the links between the biodiversity post-2020 framework with chemicals & waste. https://s3.amazonaws.com/cbddocumentspublic-imagebucket-15w2zyxk3prl8/a426992b24d9968973e92a2878b5ad5f
UNEP (2020). Assessment paper on linkages with other clusters related to chemicals and waste management and options to coordinate and cooperate on areas of common interest. Submission to Fourth meeting of the intersessional process considering the Strategic Approach and the sound management of chemicals and waste beyond 2020.
http://www.saicm.org/Portals/12/documents/meetings/IP4/INF/SAICM_IP4_INF_3.pdf

[92] Bern 1, CBD/POST2020/WS/2019/6/2.

[93] https://wedocs.unep.org/bitstream/handle/20.500.11822/32961/Bern2.pdf?sequence=1&isAllowed=y. The paper raises questions for participants at the workshop to consider.

[94] UNEP/CBD/COP/10/INF/12/Rev.1 (2010).

[95] SAICM/IP.4/INF/3, Submission from UNEP: Assessment on linkages with other clusters related to chemicals and waste management and options to coordinate and cooperate on areas of common interest: http://www.saicm.org/Portals/12/documents/meetings/IP4/INF/SAICM_IP4_INF_3.pdf. Also available from the UNEP website at: https://wedocs.unep.org/bitstream/handle/20.500.11822/33816/CCW.pdf?sequence=1&isAllowed=y

[96] An antimicrobial used in soaps. Noted in GCO II, Part II, Chapter 5 as one of “Other issues where emerging evidence indicates a risk”: “The agreed criteria resulted in the identification of issues for: arsenic, bisphenol A (BPA), glyphosate, cadmium, lead, microbeads, neonicotinoids, organotins, polycyclic aromatic hydrocarbons (PAHs), phthalates and triclosan.” (p. 320)

[97] Pursuant to Resolution 4/8 of UNEA, the secretariat was asked to prepare a report on matters in which emerging evidence indicates a risk to human health and the environment, identified by SAICM and the GCO, including an analysis of existing regulatory and policy frameworks and their ability to address those matters in the achievement of the 2020 goal, in particular for lead and cadmium. The report, dated September 2020, is available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y.

strengthened by defining parameters or units, such as the amount of chemical used, toxicity, etc. in order to assess the impact on biodiversity and habitats and to target the most harmful substances, and by identifying available data sources and where there are gaps.

On the process side, suggestions for collaboration included: working on plastics wastes with partners (including the Basel Convention); addressing the sustainable transformation of the ASGM sector under the Minamata Convention on Mercury; focusing on pesticide use and pollinators; sharing lessons learned in addressing illegal trade; sharing global data sources; capitalizing on and sharing existing, networks, indicators and data; taking action on waterbirds and lead poisoning, and on excess nutrients (the latter two outside the scope of the four conventions).

It also included suggestions from the Institut du développement durable et des relations internationales (IDDRI) that highlighted four potential ways to mobilise the chemicals conventions for biodiversity: (i) Expanding the list of pesticides included in the Stockholm and Rotterdam convention annexes (ii) Reinforcing institutional collaborations between biodiversity and other clusters, for example by developing joint programmes, such as the strategic initiative on pollinators developed by the CBD and FAO which recommends measures on pesticides (iii) Enhancing non-state and multistakeholder cooperation between biodiversity and chemicals actors through platforms like SAICM or partnerships under the MEAs (iv) Building collaboration at the level of national instruments and actors.[98] [Kinniburgh & Rankovic, 2019]

Other inputs into the SAICM process are of relevance to the post-2020 global biodiversity framework. For SAICM IP-4, a Technical Working Group (TWG) prepared a document on proposed (non-agreed) targets for the beyond-2020 Framework over the course of three meetings.[99] Target A-3 provides: "*By [xx], measures identified to prevent or, minimize harm from chemicals throughout their life cycle [and waste], are implemented and enforced by [countries] [governments]*." The IOMC[100] members of the TWG proposed developing the following indicators in a supplementary paper[101]: waste-related indicators, depending on the scope agreed for wastes, could be based on existing SDG waste-related indicators; an agriculture sector indicator: *Countries which have implemented pesticide legislation based on the FAO/WHO International Code of Conduct*; *Implementation of the GHS*; another legislative indicator: *Number of countries that have legislation in place to manage industrial and consumer chemicals.*

The supplementary paper also suggested that the following could be of relevance using Aichi Target 8 as a starting point and reflecting indicators that had been welcomed by the Thirteenth Conference of the Parties of the CBD[102]:

[TARGET:] By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity:

[INDICATORS:]

• *Trends in emissions, NOX*

• *Trends in emissions, SOX*

• *Trends in emissions, POPs*

• *Trends in mercury emissions*

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98 https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/D%C3%A9cryptage/201906-IB0719EN-chemicals%20CBD.pdf
99 SAICM/IP.4/3. http://www.saicm.org/Portals/12/documents/meetings/IP4/Docs/SAICM_IP4_3_Proposed-targets-TWG-SAICM-smcw-beyond-2020.pdf.
100 The IOMC is the Inter-Organization Programme for the Sound Management of Chemicals, established in 1995 as an international coordinating group to promote the sound management of chemicals worldwide, and consists of UNEP, FAO, ILO, UNIDO, WHO, OECD, UNITAR, World Bank and UNDP.
101 SAICM/IP.4/INF/15. http://www.saicm.org/Portals/12/documents/meetings/IP4/INF/SAICM_IP4_INF_15_TWG_FINAL.pdf.
102 Decision XIII/28. The indicators can be found at page 8 of: https://www.cbd.int/doc/strategic-plan/strategic-plan-indicators-en.pdf.

• *Trends in pesticide use and related hazards*

• *Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density (indicator for SDG target 14.1)*

• *Mortality rate attributed to unintentional poisoning (indicator for SDG target 3.9)*

It should be noted that these are not all the indicators developed under Target 8. However, the supplementary paper also noted that the Basel, Rotterdam and Stockholm Conventions contain an indispensable wealth of knowledge that should be built upon, such as trends in POPs emissions, and the number of Parties with national hazardous waste management strategies or plans under the Basel Convention. It also notes the potential indicators under the Minamata Convention which are being developed to support its first effectiveness evaluation, noting that trends in mercury emissions, or trade in mercury, could be useful measures. Lastly the paper touches on the Montreal Protocol and noted that further analysis was needed on its possible contributions.

UNEP also submitted a draft outline of the Assessment Report on Issues of International Concern to SAICM IP-4 as a follow-up to Resolution 4/8 of the UN Environment Assembly in 2019.[103] The full Assessment Report on Issues of Concern, made available in September 2020,[104] will also be part of the documentation for IP-4. It consists of an assessment of eight emerging policy issues and other issues of concern under SAICM and 11 issues with emerging evidence of risks identified by GCO-II in 2019.

Under SAICM issues, the report assesses chemicals in products (CiP), endocrine disrupting chemicals (EDCs), environmentally persistent pharmaceutical pollutants (EPPPs), hazardous substances in the life cycle of electrical and electronic products (HSLEEP), highly hazardous pesticides (HHPs), lead in paint, nanotechnology and manufactured nanomaterials, and per- and polyfluoroalkyl substances (PFASs). It reviews how current regulatory and policy frameworks address them by specific instruments and actions, building on GCO-II findings and highlighting challenges and opportunities.

The 11 issues where emerging evidence indicates risks identified by GCO-II are: arsenic, bisphenol A, glyphosate, cadmium, lead, microbeads, neonicotinoids, organotins, polycyclic aromatic hydrocarbons (PAHs), phthalates and triclosan, assessing current exposure as well as instruments and actions under current regulatory and policy frameworks, highlighting challenges and opportunities.

Annex 6 of this study compares the scope of the four conventions against the list of SAICM issues and those in the UNEP Assessment Report on Issues of Concern for UNEA-5.

Some inputs to the post-2020 biodiversity framework process have made relevant suggestions about how to structure goals, targets and indicators.

[Mace et al., 2018] argue that the CBD's ambitious 2050 vision and the steep decline in biodiversity call for an ambitious approach to targets. They note that siloed approaches do not work, and propose clearly specified goals for biodiversity recovery, measurable and relevant indicators of progress and a suite of actions that can collectively achieve the goal in the required timeframe. They propose using the 2050 vision as the goal: "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people". Measurement would be done by existing indices, such as the Red List Index, and new metrics would need to be developed. Finally, actions would have to address major drivers of biodiversity loss and ecosystem change, rather than using traditional methods of protected areas or species conservation planning. Integrative polices for sustainable consumption and production can benefit biodiversity that can help contribute to achievement of multiple SDGs simultaneously. [Mace et al., 2018]

The World Wildlife Federation (WWF) recommended that the post-2020 global biodiversity framework[105]:

[103] SAICM/IP.4/INF/13. http://saicm.org/Portals/12/documents/meetings/IP4/Background/Assessment_Report_on_Issues_of_International_Concern.pdf

[104] https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y

[105] https://s3.amazonaws.com/cbddocumentspublic-imagebucket-5w2zyxk3prl8/789d12946fd8e11ee5849fd7f1818e8f

1. **Systematically cross-maps its goals and targets** with the goals and targets present in other biodiversity-related multilateral agreements, processes and other instruments (and their strategies, plans, objectives) and helps ensure the consistent use of indicators; and
2. **Reinforces synergies in the implementation and enabling conditions** of biodiversity-related multilateral agreements, processes and other instruments.

A footnote includes the BRS conventions (although not Minamata) in the phrase "biodiversity-related multilateral agreements processes and other instruments". WWF also notes that these are two-way processes: the other biodiversity-related multilateral agreements, processes and other instruments would need to do the same for the above recommendations to be fully effective.

As to timing, WWF suggests that such a mapping exercise be conducted once goals and targets have been defined for the post-2020 global biodiversity framework.

D. Building on the Interlinkages Study

1. In mapping the interlinkages between chemicals and wastes and biological diversity, this exploratory study reflects that environmental challenges and their solutions are inter-related, complex and shared. This exploratory study provides a baseline for future work and collaboration between conventions in different spheres and within them. To achieve the 2050 vision of the Convention on Biological Diversity (CBD) through its post-2020 global biodiversity framework and its 2030 pollution target, the significant ongoing contributions of the Basel, Rotterdam, Stockholm and Minamata conventions need to be fully harnessed. Conversely, knowledge and insights garnered through collaboration with the CBD and related protocols and conventions can benefit the work of the four global chemical and waste conventions.

2. As the international community finalizes and implements the post-2020 global biodiversity framework, collaboration between the four chemicals and waste conventions and the biodiversity-related conventions can provide ongoing refinements to the targets and indicators on pollution as they relate to mercury, POPs, pesticides and hazardous and other wastes. This is particularly important as the 2020 GBO-5 concluded that CBD Aichi pollution Target 8 was not achieved.

3. Target 8 did not reference the significant chemicals and waste biodiversity-related issues addressed under the four conventions, and information in this study and the ongoing work of the four conventions can contribute to achieving the CBD's 2030 pollution target. Their ongoing work includes national reporting, environmental monitoring, and treaty effectiveness and strategic framework evaluations where biodiversity considerations could be increasingly integrated, along with efforts to contribute to the 2030 SDGs, which this study highlights as a point at which chemicals/waste and biodiversity issues also converge.

4. More specifically, whether or not the 2030 biodiversity pollution target is drafted to reflect priority pollutants/chemicals such as mercury and other heavy metals, POPs, pesticides, wastes (including plastics) this study provides baseline information about key interlinkages that can serve the four conventions' governing bodies to consider the detailed contributions they could make to the refinement and implementation of the CBD's 2030 pollution target and indicators going forward. Examples could include specific targets related to mercury air emission reductions, reduction of concentrations of POPs in environmental media, enhanced focus of the Rotterdam Convention on neonicotinoids and glyphosate pesticides, the enhancement of legislative implementation of the Basel Convention's plastic waste amendments, or decisions on international cooperation and coordination that build these inter-convention connections (e.g. forwarding this study to the CBD Conference of the Parties, or working on common areas of concern such as ASGM).

5. This study also highlights that current research on and regulation of chemicals in the environment tends to take a simplistic view and does not account for the complexity of the real world, including how to

differentiate and quantify the effects of multiple stressors on ecosystems and how to improve risk assessment of such stressors (including at different levels of biological organization) to enhance predictability. Enhanced and focused collaboration between the chemicals and waste conventions and those related to biodiversity provides an opportunity for each to share their pressure points and complexities and mobilize limited resources towards prioritized solutions that benefit both. Collaboration on ASGM, plastics, e-waste, pesticides and pollinators, illegal trade, the sharing of monitoring data and scientific research, along with shared communications and messaging, could produce significant benefits to both the biodiversity and chemicals and wastes worlds.

6. Each of these worlds can also alert the other to emerging issues of concern and key developments. This study has identified UNEP's Assessment Report on Issues of Concern for UNEA-5, which consists of an assessment of eight emerging policy issues and other issues of concern under SAICM (e.g. nanomaterials, e-waste) and 11 issues with emerging evidence of risks identified by GCO-II, and identified possible contributions of the four MEAs to addressing those issues (see Annex 6). It also identified the ongoing SAICM intersessional process as it shapes the beyond-2020 framework on chemicals and wastes and how this relates to the four chemicals and waste conventions.

7. Ultimately, this exploratory study identifies a significant number of areas of convergence between chemicals/wastes and biodiversity and suggests the need to resolve challenges in these areas of convergence in a manner that better reflects the interconnectedness within our natural environment.

Annex 1: Mapping of the Minamata Convention and impacts on and benefits to biological diversity

Convention Control Measure	Article of the Minamata Convention	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
Supply and Trade	3 No new primary mercury mines; closure of active mines within 15 years of entry into force for a Party, restrictions on trade in elemental mercury	Mining and related production can result in releases to land/waters/air; illegal trade can result in emissions and releases Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, soils, fresh or marine waters	Habitat creation and maintenance; regulation of freshwater quality; regulation of soils; regulation of organisms
Mercury-added Products	4 Parties not allowed to manufacture, import or export mercury-added products in Part I of Annex A after 2020 unless registered for an exemption or subject to Art. 4.2; special rules for dental amalgam	Emissions to air and releases to land/waters from the production, use and improper disposal of products Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, soils, fresh or marine waters	Habitat creation and maintenance; regulation of freshwater quality; regulation of soils; regulation of organisms
Industrial Processes using mercury	5 Rules governing when mercury is/is not allowed to be used in manufacturing processes	Emissions to air and releases to land/waters through processes Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, soils, fresh or marine waters	Habitat creation and maintenance; regulation of freshwater quality; regulation of soils; regulation of organisms
ASGM: Largest source of air pollution and	7	Emissions to air	Impacts on both aquatic (fish, marine mammals) and terrestrial species	Habitat creation and maintenance; regulation of air quality; regulation

releases to land and waters	Parties with ASGM activities that are more than insignificant must develop and implement a national action plan and submit this to the Secretariat within three years of entry into force of the Convention for it	Releases to land and waters Persistence and re-volatilization maintain mercury in environment for decades or centuries	(e.g. raptors), particularly in biodiversity hotspots/megadiverse countries (e.g. Amazon and other rainforests, activities near rivers) affecting fish, dolphin, reptile, amphibian species Due to methylation, aquatic species greatly affected, especially apex predators in Arctic, such as polar bears, whales, dolphins Long-range transport to vulnerable ecosystems like the Arctic; melting permafrost releases	of freshwater quality; regulation of soils; regulation of organisms; food and feed; physical and psychological experiences; supporting identities; learning and inspiration; medicinal, biochemical & genetic resources
Emissions Mercury air pollution: Annex D sources: Coal-fired power plants Coal-fired industrial boilers Smelting/roasting in non-ferrous metals production Waste incineration facilities Cement clinker production facilities	8 Requirements for new and existing Annex D sources, with new sources requiring the use of BAT and BEP within five years of entry into force of the Convention for the Party (or emission limit values that are consistent with BAT)	Emissions to air have both local and long-range impacts Deposition in water can result in formation of methylmercury Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species (e.g. raptors), soils, fresh or marine waters; due to methylation, aquatic species greatly affected, especially apex predators Long-range transport to vulnerable ecosystems like the Arctic; melting permafrost releases	Habitat creation and maintenance; regulation of freshwater and coastal water quality; regulation of soils; regulation of organisms; food and feed; physical and psychological experiences; supporting identities; learning and inspiration; medicinal, biochemical & genetic resources
Releases to land and waters: other sources	9 Parties to identify relevant point source categories and take measures to control releases from them	Releases to land and waters from identified relevant point source categories Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, soils, fresh or marine waters; due to methylation, aquatic species greatly affected; soil communities impacted	Habitat creation and maintenance; regulation of freshwater and coastal water quality; regulation of soils; regulation of organisms

Wastes	11 Management of domestic mercury wastes; transboundary movements of mercury waste subject to the Basel Convention	Releases to land from improper waste disposal; subsequent releases to water Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, including soils and soil communities, fresh water and coastal water quality and species; soil communities impacted	Habitat creation and maintenance; regulation of freshwater and coastal water quality; regulation of soils; regulation of organisms
Contaminated Sites	12 Development of strategies for identifying contaminated sites; guidance on management of contaminated sites	Releases to land from improper contaminated site management Persistence and re-volatilization maintain mercury in environment for decades or centuries	Impacts on both aquatic and terrestrial species, including soils and soil communities, fresh water (including ground water) quality and species; soil communities impacted	Habitat creation and maintenance; regulation of freshwater and coastal water quality; regulation of soils; regulation of organisms

Annex 2: Mapping ASGM countries with Megadiverse characterization

Top ASGM countries (per air emissions) (as per GMA 2018 OR reporting ASGM activity as more than insignificant under Article 7 of the Minamata Convention as of Aug 11/20) (in alphabetical order)	**The Like-Minded Megadiverse Countries[106]** (alphabetical order)	**Diversity Status** (alphabetical order; info from CBD country profiles[107] except where unavailable, and as noted)
Bolivia	✓	One of top 15 megadiverse countries in world
Brazil	✓	Most biologically diverse country in the world. At least 103,870 animal species and 43,020 plant species are currently known, comprising 70% of the world's catalogued animal and plant species. It is estimated that Brazil hosts between 15-20% of the world's biological diversity, with the greatest number of endemic species on a global scale. Brazil's biodiversity is ever-expanding, with an average of 700 new animal species discovered each year.

[106] The group of like-minded megadiverse countries (LMMCs) comprises Bolivia (Plurinational State of), Brazil, China, Colombia, Costa Rica, Democratic Republic of Congo, Ecuador, Ethiopia, Guatemala, India, Indonesia, Iran (Islamic Republic of), Kenya, Madagascar, Malaysia, Mexico, Peru, Philippines, South Africa, and Venezuela (Bolivarian Republic of)
[107] CBD country profiles: https://www.cbd.int/countries/

Burkina Faso		Burkina Faso hosts a large biodiversity, including 128 species of mammals, 516 species of birds, 60 species of reptile and amphibians, 121 fish species, 1,515 species of insects and 1,951 species of flora.
China	✓	China: third most biodiverse with 10% of all plant species and 14% of all animal species (UNDP) first in bird species and containing 20% of world's fish species (CBD country profile)
Colombia	✓	Colombia has 10% of global species, ranked first in bird and orchid species diversity and second in plants, butterflies, freshwater fishes and amphibians
Costa Rica	✓	Costa Rica has 5% of global species: goseecostarica.com. Includes 900 bird species and more than 250 mammal species. Asuaire.com
Democratic Republic of Congo	✓	One of world's 10 mega-biodiverse countries, but taxonomic inventories have not been maintained.
Ecuador	✓	One of the 17 megadiverse countries of the world, particularly with flora.
Gabon		8000 plant species, 600 birds 150 mammals and 100 amphibians
Ghana		3600 species of flora, 221 species of amphibians and reptiles, 728 species of birds, 225 mammalian species. (CBD profile) Also part of the Guinean Forests of West Africa, a global biodiversity hotspot. https://www.microsfere.org/en/ghana/guinean-forests-of-west-africa-biodiversity-hotspot.html
Guinea		The Guinean forests of West Africa are considered one of the world's 25 biodiversity hotspots, located in part in Guinea.
Guyana		Over 8000 species of flora and 1800 species of fish, amphibians, birds, reptiles and mammals.
Indonesia	✓	Considered one of the 17 megadiverse countries by Conservation International, has to of the world's 25 biodiversity "hotspots", 10% of the world's flowering species (25,000), 12% of the world's mammals (515 species), 16% of reptiles, 17% of birds (1600 species).
Mali		640 known bird species, with many migratory species; a number of endangered mammals, such as the pygmy hippopotamus and manatee. (CBD profile) It has 1700 plant species and 1000 animal species. (Wikipedia, based on an inaccessible UNEP document.)
Myanmar		11,800 species of vascular plants; 251 mammals; 1056 bird species; 279 reptiles; 82 amphibians; 841 medicinal plants, 96 bamboos; 350 freshwater species, 800 marine

		fish, 9 species of seagrass, 51 coral species, 5 marine turtles.
Nigeria		Variable climatic conditions and physical features have endowed Nigeria with some of the richest flora and fauna on the continent. (CBD profile) The Guinean forests of West Africa are considered one of the world's 25 biodiversity hotspots, located in part in Nigeria. https://www.microsfere.org/en/ghana/guinean-forests-of-west-africa-biodiversity-hotspot.html
Peru	✓	Peru: 25,000 species of plants and 695 of known breeding birds; 460 known mammal species; about 2000 fish species http://www.discover-peru.org/facts-about-peru%e2%80%99s-biodiversity-and-environment/
Philippines	✓	One of 18 mega-biodiverse countries, containing 70-80% of the world's plant and animal species. 5th globally in # of plant species; has 5% of world's flora. Is a biodiversity hotspot with 700 threatened species.
Sudan		1431 known species of amphibians, birds, mammals and reptiles. (rainforests.mongabay.com); high levels of insect diversity (UNDP/GEF ABS-sustainable development.net). More than 4000 plant species (worldatlas.com)
Suriname		Approximately 5000 plant species;715 birds; 360 marine fish; 175 reptiles; 192 mammals, 102 amphibians, 318 freshwater species
Togo		3500 species of terrestrial flora; 501 aquatic species; 4000 animal species; 170 species of mushrooms. (CBD profile) The Guinean forests of West Africa are considered one of the world's 25 biodiversity hotspots, located partly in Togo. https://www.microsfere.org/en/ghana/guinean-forests-of-west-africa-biodiversity-hotspot.html
United Republic of Tanzania		Harbours 6 of 25 globally known biodiversity hotspots, including mountain and coastal forests, Great Lakes, marine coral reefs, the Right Valley lakes, and grassland savannas (e.g. Serengeti National Park). Hosts a number of important populations of globally endangered species.
Venezuela	✓	1400 bird species; 3900 fungi species; 23,000 orchid species. Rankred.com

Annex 3: Mapping of the Stockholm Convention and impacts on and benefits to biological diversity

Convention Control Measure	Article of the Stockholm	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
Ban on production, use, import and export OR taking the legal and administrative measures necessary to eliminate	3 **Annex A (elimination):** *Pesticides:* aldrin alpha HCH beta HCH chlordane chlordecone dieldrin dicofol endrin heptachlor lindane mirex PCP and its salts and esters Technical endosulfan and its related isomers toxaphene *Industrial chemicals*: DecaBDE HBB HBCDD HexaBDE HeptaBDE HCB HCBD PeCB PCB PCN PentaBDE PFOA, its salts and PFOA-related compounds SCCP TetraBDE **Annex B (restriction)** DDT (*pesticide*)	Emissions and releases during production and use; import and export promote continued use. Local and long-range transport, including to vulnerable ecosystems (e.g. Arctic, Antarctic, ocean trenches). Persistence and re-volatilization maintain POPs in environment for decades	POPs continue to be found in air, water and human milk/blood samples. Impacts on both aquatic (e.g. fish) and terrestrial species (e.g. birds), fresh and marine waters. Far more research on aquatic species, including marine mammals, particularly in the Arctic: whales, seals, dolphins Apex predators affected due to bioaccumulation/magnification (e.g. sled dogs, polar bears, whales, raptors) Melting permafrost and sea ice expected to release POPs from those sinks	Habitat creation and maintenance; regulation of air and freshwater quality; regulation of soils; regulation of organisms; food and feed; physical and psychological experiences; supporting identities; learning and inspiration; medicinal, biochemical & genetic resources

	PFOS, its salts and PFOSF			
Unintentionally-produced POPs: HCB HCBD PeCB PCB Dioxins (PCDD)/ Furans (PCDF) PCN	Article 5, Annex C: **sources requiring BAT are:** Waste incineration Cement Kilns firing hazardous waste Production of pulp using chlorine Thermal processes in metallurgical industry **Sources requiring promotion of BAT/BEP:** Open burning of waste in landfills	Primarily releases to air, which can have local impacts and be transported long-range, ending up in terrestrial and aquatic ecosystems Open waste burning Persistence and re-volatilization maintain POPs in environment for decades	POPs continue to be found in air, water and human milk/blood samples. Impacts on both aquatic and terrestrial species, fresh or marine waters. Marine mammals particularly affected, polar bears, as well as fish and seabird species.	Habitat creation and maintenance; regulation of air and freshwater quality; regulation of soils; regulation of organisms; food and feed; physical and psychological experiences; supporting identities; learning and inspiration; medicinal, biochemical & genetic resources
Stockpiles and wastes	Article 6: managing stockpiles, domestic waste management of POPs wastes; transboundary movement of POPs wastes (governed by Basel); contaminated sites	Releases to land or water from stockpiles and wastes, including municipal landfill Persistence and re-volatilization maintain POPs in environment for decades POPs adhering to plastics and transferring to species; being part of microplastics	Aquatic and terrestrial species Aquatic and terrestrial species Impacts on aquatic species	Habitat creation and maintenance; regulation of freshwater quality; regulation of soils; regulation of organisms; food and feed; medicinal, biochemical & genetic resources

Issues specific to POPs Pesticides (as per pesticides section of paper)			Soil impacts, soil community impacts, in addition to above impacts	regulation of soils; regulation of organisms food and feed; medicinal, biochemical & genetic resources

Annex 4: Mapping of the Rotterdam Convention and impacts on and benefits to biological diversity

Convention Control Measure	Article of the Rotterdam Convention	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
Listing in Annex III and preparation of Decision Guidance Document (DGD)	Article 9 As of the 2019 COP, 52 chemicals listed, 35 pesticides (including 3 severely hazardous pesticide formulations), 16 industrial chemicals, and 1 chemical in both the pesticide and industrial chemical categories.	The provision of information to guide import decisions is intended to promote the environmentally sound use of chemicals and pesticides	Intent to avoid through provision of information	Intent to avoid through provision of information
Import of listed chemicals from other Parties (import and response obligations) & Export of listed chemicals to other Parties (export obligations)	10 & 11	Improper use (e.g. over-application, drift, accidental poisonings) and waste management of hazardous chemicals— leads to contamination in soils, plants and waters	Improper use of pesticides can have a potential direct adverse impct on all biodiversity, including all non-target organisms, be they terrestrial, aquatic, marine, flora or fauna—and indirectly through the adverse impacts on all environmental compartments (water, soil sediment, air) and habitats.	Habitat creation and maintenance, pollination and dispersal of seeds; formation, protection and decontamination of soils; regulation of organisms detrimental to humans; food and feed; regulation of freshwater; medicinal, biochemical and genetic resources; physical and psychological experiences; learning and inspiration; supporting identities.
Export notification for non-listed chemicals where ban or restriction taken by exporting Party	12	Improper use and waste management of hazardous chemicals—found in soils, plants and waters—in this case without the benefit of a DGD as per Article 9, but requiring notification	Same as above	Same as above
Contaminated Sites	No provision	Right of Parties to say no to	Prevention of impacts on soils and	Habitat creation and maintenance, pollination and

		undesired imports will prevent stockpiles of chemicals, including obsolete chemicals	soil communities, plants, aquatic species	dispersal of seeds; formation, protection and decontamination of soils; regulation of organisms detrimental to humans; regulation of freshwater.

Annex 5: Mapping of the Basel Convention and impacts on and benefits to biological diversity

Basel Issue	Article of the Basel Convention	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
E-waste	PIC system (Articles 4, 6, 8, 9, Annexes) Interim technical guidelines adopted in 2019 Linked to review of annexes to clarify waste/non-waste issue	• Increased quantities disposed of globally • Contain toxic chemicals, including heavy metals and POPs • Often disposed in open dumps, recycled by large informal recycling sector with health implications, and/or open burning • Illegal trafficking involved • Pollutes soil, groundwater, freshwater and coastal waters	• Leachates into soil, plants and water • Particulate matter and fly ash into air pollution) • Fumes from mercury burning into air • Effluents from cyanide leaching into soil, plants, and freshwater, may lead to coastal waters • Impacts of above on soil, territorial species such as birds, and aquatic species, including fish	Habitat creation and maintenance; regulation of air quality; regulation of freshwater and coastal water quality; formation, protection and decontamination of soils; regulation of organisms detrimental to humans; production of food; physical and psychological experiences
Large waste dumps and open burning of hazardous and other wastes	PIC system (Articles 4, 6, 8, 9, Annexes, Technical Guidelines) The Basel Convention and its technical guidelines on mercury, POPs, pesticides, e-waste and other wastes call for the environmentally sound management of hazardous and other wastes	• Heavy metal pollution in water, soil and plants • Open burning causing polluting emissions not reflected in inventories • Waste picking via informal sector posing health risks • Contamination from POPs and heavy metals in soils, surface and groundwater	• Leachates into soil, plants and water • Particulate matter and fly ash into air pollution) • Fumes from mercury burning into air • Effluents from cyanide leaching into soil, plants, and freshwater, may lead to coastal waters • Impacts of above on soil, territorial species such as birds, and aquatic species, including fish	Habitat creation and maintenance; regulation of air quality; regulation of freshwater and coastal water quality; formation, protection and decontamination of soils; regulation of organisms detrimental to humans; production of food; physical and psychological experiences

Basel Issue	Article of the Basel Convention	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
Plastics and microplastics	PIC system (Articles 4, 6, 8, 9, Annexes) + plastics amendments taking effect in January 2021 + Updating of technical guidelines on plasticwastes + Plastic Waste Partnership	• Ubiquitous in aquatic, atmospheric and terrestrial ecosystems • Volumes are escalating • 8 million tonnes enter the oceans each year, mainly through river export • Over 5 trillion plastic particles in the oceans • Also important for terrestrial ecosystems • Appearing in Antarctic and Arctic, the latter extensively	• Losses in ecosystem productivity due to interference with nutrient production and cycling • Physiological stress in organisms • Threats to ecosystem composition and stability (e.g. wetlands, estuaries, mangroves, deep ocean and the Arctic) • Entanglement and ingestion affecting over 500 marine species • Some species of sea turtles have a 100% ingestion rate; 59% of seabirds have ingested plastic; 35% of planktivorous fish; 18% of apex predator fish; condors, earthworms, soil communities also ingest • Impacts on biota from contaminants in plastics: POPs in plastics, and POPs which adhere to plastics, both impact biota, including soil biota	Habitat creation and maintenance; regulation of air quality; regulation of freshwater and coastal water quality; formation, protection and decontamination of soils; regulation of organisms detrimental to humans; production of food (e.g. fisheries/aquaculture); physical and psychological experiences (e.g. swimming, tourism)

Basel Issue	Article of the Basel Convention	Pollution Issue	Biodiversity Impacts	Nature's Contributions to People impacted
			• Plastics serve as a vector or habitat for invasive alien species or pathogens and may fuel the spread of antibiotic resistance	
Mercury, POPs and pesticide wastes (and many others)	PIC system (Articles 4, 6, 8, 9, Annexes)	• Pollution as identified in sections on mercury, POPs and pesticides and elsewhere in the waste section	• Impacts on biota as identified in sections on mercury, POPs and pesticides and elsewhere in the waste section	Impacts on Nature's Contributions to People as identified in sections on mercury, POPs and pesticides and elsewhere in the waste section

Annex 6: Mapping of GCO II 2019 emerging Policy issues, SAICM issues of concern and emerging issues, and the Minamata, Stockholm Rotterdam and Basel conventions

GCO II Issues of International Concern[108]	SAICM emerging policy issues/issues of concern	Coverage under the Minamata, Stockholm Rotterdam and Basel conventions[109]
Arsenic		BC: Annex I, Categories of wastes to be controlled: Y24 wastes having arsenic or arsenic compounds as constituents if they have Annex III hazard characteristics, such as poisonous, toxic, ecotoxic or capable of yielding a leachate; Annex VIII A1010, A1030
Bisphenol A		BC: Y13, A3050
Glyphosate		BC: A4030
Cadmium		BC: Annex I, Categories of wastes to be controlled: Y26: cadmium or cadmium compounds as constituents; Annex VIII A1010; A1020
Lead	Lead in paint	BC: Annex I, Categories of wastes to be controlled: Y31: lead; lead compounds as constituents; A1010, A1020
Microbeads (microplastics in personal care products)		
Neonicotinoids		BC: A4030
Organotins		RC: TBT listed as both pesticide and industrial chemical BC: Annex I, Y4: wastes from the production, formulation and use of biocides and phytopharmaceuticals; A4030
Polycyclic aromatic hydrocarbons (PAHs)		BC: Y9 From the Assessment of Issues of Concern: “The Basel Convention addressed PAHs at the end of products’ life cycles, for example in ship breaking, and could cover the movement of used tyres, but it does not directly address consumer products that contain PAHs during their production and use.”
Phthalates		BC: A4030
Triclosan		BC: A4030
	Endocrine-disrupting chemicals	SC: a number of POPs are EDCs, (e.g. PCBs, BDEs) RC: a number of listed chemicals are EDCs BC: waste aspects of listed SC and RC chemicals addressed by Basel
	Chemicals in products	SC: issue identified in 2017 EE, chemicals such as brominated flame retardants, fluorinated water repellents stay in products and concerns exist over recycling. Other additives e.g. UV-328 to be considered under SC. MC regulates mercury in products
	Hazardous substances within	SC: regulates BDEs and other brominated flame retardants in e-products

[108] For a full discussion of these, An Assessment of Issues of Concern, finalized in September 2020 for purposes of UNEA-5: https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y
[109] Taking into account the Assessment of Issues of Concern for UNEA-5 where relevant, available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y

GCO II Issues of International Concern[108]	SAICM emerging policy issues/issues of concern	Coverage under the Minamata, Stockholm Rotterdam and Basel conventions[109]
	the life cycle of electrical and electronic products	RC: lists BDEs and other brominated flame retardants BC: interim guidelines on e-waste; historical partnerships on mobile phones and e-waste; regulates disposal of Hg wastes; BDE waste MC regulates mercury in products
	Nanotechnology and manufactured nanomaterials	BC: decision BC-14/14 on nano-wastes requests information from Parties and observers on best practices
	Environmentally persistent pharmaceutical pollutants	SC: PFOA, its salts and PFOA-related compounds (e.g. PFOI used for the production of PFOB) BC: Y2 and Y3 waste streams cover pharmaceuticals
	Perfluorinated chemicals and transition to safer alternatives	SC: PFOS listed in Annex B since 2009; PFOA listed in Annex A in 2019; PFHxS is proposed for listing in 2021 to Annex A without exemptions; 2019 tightened regulation of PFOS through amendment RC: PFOS listed since 2013; PFOA, its salts and PFOA-related compounds proposed for listing in 2021 BC: technical guidelines exist for PFOS and under development for PFOA
	Highly hazardous pesticides	SC: has regulated production, use, import and exports of POPs pesticides (e.g. DDT) RC: numerous pesticides including severely hazardous pesticide formulations subject to RC PIC procedure BC: regulates waste pesticides and has technical guidelines on them; separate TGs for DDT MC: the use of mercury in pesticides, biocides and topical antiseptics is not allowed after 2020

Annex 7: Top research questions from a horizon-scanning workshop

The top 22 research questions arising from the European horizon-scanning workshop and their ranking and scores [Van den Brink et al., 2018]
1 How can interactions among different stress factors operating at different levels of biological organization be accounted for in environmental risk assessment?
2 How do we improve risk assessment of environmental stressors to be more predictive across increasing environmental complexity and spatiotemporal scales?
3 How can we define, distinguish, and quantify the effects of multiple stressors on ecosystems? 4 How can we develop mechanistic modeling to extrapolate adverse effects across levels of biological organization?
5 How can we properly characterize the chemical use, emissions, fate, and exposure at different spatial and temporal scales?
6 Which chemicals are the main drivers of mixture toxicity in the environment?
7 What are the key ecological challenges arising from global megatrends?
8 How can we develop, assess, and select the most effective mitigation measures for chemicals in the environment?
9 How do sublethal effects alter individual fitness and propagate to the population and community levels?
10 Biodiversity and ecosystem services: What are we trying to protect, where, when, why, and how?
11 What approaches should be used to prioritize compounds for environmental risk assessment and management?
12 How can monitoring data be used to determine whether current regulatory risk-assessment schemes are effective for emerging contaminants?
13 How can we improve in silico methods for environmental fate and effects estimation?
14 How can we integrate evolutionary and ecological knowledge to better determine vulnerability of populations and communities to stressors?
15 How do we create high-throughput strategies for understanding environmentally relevant effects and processes?
16 How can we better manage, use, and share data to develop more sustainable and safer products?
17 Which interactions are not captured by currently accepted mixture toxicity models?
18 How can we assess the environmental risk of emerging and future stressors?
19 How can we integrate comparative risk assessment, life cycle analysis, and risk–benefit analysis to identify and design more sustainable alternatives?
20 How can we improve the communication of risk to different stakeholders?
21 How do we detect and characterize difficult-to-measure substances in the environment?

22 Where are the hotspots of key contaminants around the globe?

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