GRESHAM COLLEGE

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THE INTERTWINED IMPACTS OF POLLUTION AND INEQUALITY ON HEALTH

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Every breathe we take

This weekend saw the great athlete Eliud Kipchoge and the youngest winner Brigid Kosgei win the men's and women's London marathon in astounding times. Many "personal best's" or PBs were broken; we saw the fastest in class and the fastest times for the second half. Kipchoge's time was 2 hours 2 minutes and 38 seconds. The winners came again from Kenya and Ethiopia; and it is notable that the air quality in the training camp in Iten is amongst the cleanest in Africa. In 2017, Kipchoge attempted to break the two-hour barrier; as shown in the film Breaking 2[1], he narrowly missed it. The course in Italy had been carefully selected, weather conditions, racing strategy, clothes, nutrition and hydration had all been carefully monitored. But one thing was missing – the quality of the air.

We know from research on air pollution impacts on elite athletes, that inhalation of particulate matter – the worst offender associated with incomplete combustion - is four times greater during aerobic exercise than during rest in the same conditions[2] . This had been a matter of great concern to the athletes, their coaches and national sporting bodies ahead of the 2008 Beijing Olympic Games, although mostly in terms of the impacts on performance rather than their health[3]. The evidence that poor air quality affects peak performance is the same as that of untrained individuals; decreases in maximum oxygen uptake and increases in inflammatory blood markers[4]. People who train in locations near busy roads or urban centres are likely to be exposed to pollutants through elevated breathing rates and oral breathing.

The effects are most obvious in events that require the greatest endurance such as marathon races. However, air quality is not generally an important consideration when awarding the Olympic Games or in the locations of the key international marathons. A study of seven major US marathons showed that there was a statistical, negative correlation between race-day performance and the concentrations of urban air pollutant PM_{10} (Particulate Matter smaller than 10 microns in diameter) in female runners and some evidence of a correlation in males[5].

The major sources of pollution

Pollution is the introduction of substances or energy into the environment, resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment touches all parts of the planet[6].

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[1] National Geographic and Nike (2018) Breaking2: The Documentary. https://www.nike.com/bg/en_gb/c/running/breaking2

[2] Rundell, K.(2012) Effect of air pollution on athelete health and perfomance. British Journal of Sports Medicine 46: 407-412

[3] Lippi, G. Guidi, G. and Maffulli, N. (2008) Air pollution and sports perfomrsnce in Beijing. International Journal of Sports Medicien 29 (8) 696-698. The Chinese government took drastic steps to avoid poor air quality during the Games, shutting off traffic and industry, and indeed many running records were broken.

[4] Kargarfard, M., Porsafa, P.,Rezanejad, S., and Mousavinasab, F. (2011) Effects of exercise in plluted air on the aerobic power, serum lactate level and cell blood count of active individuals. Inrernational Journal of Preventative Medicine 2(3) 145-150. Kargarfard, M. Shariat, A., Shaw, B.S., Shaw, I., Lam, E.T.C., Kheiri, A., Eatemadyboroujeni, A. and Tamrin, S.B. M. (2015) Effect of polluted air on cardiovascular and haematological parameters after progressive maximal aerobic exercise. Ling 193(2): 275-281.

[5] Marr, L. and Ely, M. (2010) Effect of air pollution on marathon running performance. Medicine and Scienec in Sports and Exercise 42(3).

[6] European Environment Information and Observation Network GEMET - General Multilingual Environmental Thesaurus. https://www.eionet.europa.eu/gemet/en/themes/.

Our industrial history has been one of spectacular chemical innovation, but this has been accompanied by increasing levels of pollution. Today, pollution resulting from human activity, has reached even the most remote areas of the planet. In the polar caps and high mountains[7], and below the ocean's abyssal zone, in trenches over 10,000 meters deep, where creatures have been found polluted with chemicals such as flame retardants, paint plasticizers and water proofers[8].

Regulatory efforts have barely kept pace with the thousands of new chemicals and materials that are produced annually, let alone reduced the use of many hazardous chemicals that have been in existence for many years. In the case of asbestos and mercury, the deadly aftermath has taken decades to address, even though the evidence of harm was widely known from an early stage in its use in industrial processes. In fact, it took 107 years and many thousands of deaths for a ban on asbestos to be implemented and for mercury it took more than 50 years to achieve agreement on the Minamata Convention [9].

Pollution is affecting our health through the food we eat, the water we drink and the air we breathe[10]. The World Health Organisation estimates that 19 million premature deaths occur annually as a result of the way we use natural resources and impact the environment to support global production and consumption[11]. Nearly a quarter of all deaths worldwide, amounting to 12.6 million people in 2012, are due to environmental causes[12], with at least 8.2 million attributable to non-communicable, environmental causes, and more than three quarters in just three regions [13]. Low-and middle-income countries bear the brunt of pollution-related illnesses, with a disproportionate impact on children.

Pollution can take many forms, ranging from organic compounds and other chemical substances to different types of energy. The severity of a pollutant for human health and ecosystems is based on its chemical nature, concentration and persistence. The specific harm caused by different pollutants depends not only upon the environment it is in (air, water or soil) but also the mix of others that are present and the actual exposure.

There are many different sources of pollution with different impacts on our health and on ecosystems. However, pollution disproportionately affects the poorest and most vulnerable in our societies (Figure 1). For example, women in low-income countries are heavily affected by exposure to household air pollution from the use of solid fuels (coal and biomass) for cooking and bear the greatest burden of air-pollution-related disease. Women generally carry the burden of caring for other household members suffering from air pollution-related ill health.

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[7] Ferrario *et al*. 2017

[8] Jamieson, A.J., Malkocs, T., Piertney, S.B., Fujii, T. and Zhang, Z. (2017). Bioaccumulation of persistent organic pollutants in the deepest ocean fauna. *Nature Ecology & Evolution* 1: 0051. http://dx.doi.org/10.1038/s41559-016-0051.

[9] European Environment Agency (2013) Late Lessons from early warnings: science, precaution, innovation. EEA Report 1/2013 ISBN 978-92-9213-356-6
http://eionet.kormany.hu/download/6/f4/90000/Late%20lessons%20from%20early%20warnings%20II.pdf

[10] Landrigan, P.J., Fulle,r R., Acosta, NJR, Olusoji, A., Arnold, R., Bibi Baldé, A., Bertollini, R., Ivey Boufford, J., Breysse, P.N., Chiles,T., Professor Dr. Her Royal Highness Princess Chulabhorn Mahidol, Cropper,M.L., Fuster, V., Greenstone, M., Hanrahan, D., Hunter, D., Khare, M., Krupnick, A., Lanphear, B., Lohani, B.N., Ma,Z., Martin, K., Mathiasen, K., McTeer, M.A., Murray, C.J.L., Ndahimananjara,J.D., Perera,F., Potočnik, J., Preker,A.S., Ramesh, J., Rockström, J., Salinas,C., Samson, L.D., Sandilya, K., Sly, P.D., Smith, K.R., Steiner, A., Stewart, R., Suk,W.A., van Schayck, O.C.P., Yadama, G.N., and Yumkella, K. (2018) The *Lancet* Commission on pollution and health. *Lancet*; **391:** 462–512

[11] Ramaswami, A., Russell, A.G., Culligan, P.J., Sharma, K.R. and Kumar, E. (2016). Meta-principles for developing smart, sustainable, and healthy cities. *Science* 352(6288) 940-943

[12]UNEP 2016 Healthy Environment, Healthy People: Thematic Report, Ministerial Policy Review Session. UNEA 2 Inf. Doc 5
https://www.unenvironment.org/about-un-environment/committee-permanent-representatives/committee-permanent-representatives/unea-0

[13] European Environment Agency (2013). *Late Lessons from Early Warnings: Science, Precaution, Innovation.* Luxembourg: Publications Office of the European Union.
http://eionet.kormany.hu/download/6/f4/90000/Late%20lessons%20from%20early%20warnings%20II.pdf.

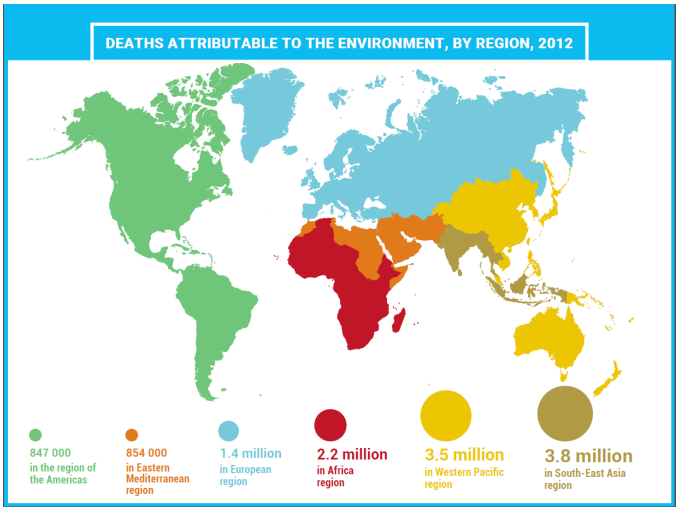

Figure 1: Number of deaths attributable to environmental factors in 2012 by region[14]

Vulnerability to pollution varies amongst individuals and across societies. Factors that increase individual vulnerability include age, gender, location and residence, fuels used for cooking and heating, access to water and occupation. Biological factors that increase individual vulnerability include genetic susceptibility and underlying diseases, such as asthma, heart disease or diabetes.

Diseases related to pollution cause productivity losses that can reduce performance, cause work and school absenteeism, and perpetuate existing societal inequalities. The resulting health care costs in rapidly industrializing countries is consuming as much as 7% of national health budgets., and the global economic burden of disease caused by ambient air pollution alone across 41 countries was estimated to amount to USD 5.1 trillion in 2015. The impacts across the diseases are significant (see table 1).

Disease	**DALY's per year**	**Risk factor**
Diarrhoea diseases	57 million	Inadequate water, sanitation
Asthma	11 million	Air pollution, second-hand tobacco smoke, indoor mould and damp, asthmagens
Lower respiratory infections	51 million	Household and ambient air pollution
Chronic obstructive pulmonary disease	32 million	Use of polluting fuels for cooking and exposure to dust
Cardiovascular diseases	119 million	Air ollution, lead and tobacco soke exposure
Cancer	49 million	Exposure to air pollution, radiation, chemicals
Neonatal conditions	26 million	Exposure of mothers to air pollution, tobaccco smoke, pesticides and chemicals, unsafe water and inadequate sanitation

Table 1 Diseases with some of the largest total annual health burden from environmental factors in terms of death, illness and disability in 2012 (Disability Adjusted Life Years – DALYs) WHO

Air pollution

"Every hour, 800 people are dying, many after years of suffering, from cancer, respiratory illnesses or heart disease directly caused by breathing polluted air." David Boyd, UN Human Rights Special Rapporteur, Geneva March 2019

[14] Prüss-Ustün, A., Wolf, J., Corvalán, C., Bos, R. and Neira, M. (2016). *Preventing Disease through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks.* World Health Organization. http://apps.who.int/iris/bitstream/10665/204585/1/9789241565196_eng.pdf?ua=1

The air pollutants of greatest concern for human health are aerosols and the products of incomplete combustion of fossil fuels and biomass, such as black carbon coming from four main sources:

a) **Stationary** including power plants, manufacturing facilities and mining with limited emission controls. Facilities that burn coal or other poor-quality fuels or that rely on diesel-powered generators due to a lack of grid reliability are generally the worst offenders.
b) **Households** especially in low-income countries that rely on biomass fuels for heating and cooking and where people are heavily exposed.
c) **Controlled and uncontrolled biomass burning** sources related to agricultural waste burning and land and forest clearance, wildfires and residential and other waste combustion are important sources of air pollution and can deliver a toxic cocktail of chemicals which get bound up in particulate matter.
d) **Mobile** including petroleum-powered cars, trucks, and buses in both the private and public sectors. They are the main source of air pollution in cities. Old and poorly maintained vehicles that burn low-grade fuels are especially hazardous. Emissions from ships and aircraft are the major mobile sources of air pollution near ports and airports.

Dust storms are also a source of pollution. They can create the conditions for aerosolised, particulate matter to be transported thousands of kilometres into heavily populated areas, where people can die from asphyxiation or exposed to fine mineral particulates, or harmful combinations of pollutants, dust, spores, bacteria, fungi, and potential allergens carried along with mineral dusts[15,16], through complex interactions as yet not fully understood [17,18]. Airborne dust also causes poor visibility, leading to increases in road accidents and aviation hazards, disruption of communications, transportation and supply chain infrastructures, directly damage crops, and kills livestock.

Other air pollutants which affect human health include nitrogen and sulphur oxides, benzene, heavy metals and ozone.

AIR	HUMAN IMPACT	ECOLOGICAL EFFECT	ECOSYSTEM SERVICES IMPACTED
Fine particulate matter ($PM_{2.5, 10}$) containing sulphates, nitrates, ammonia, sodium chloride, polycyclic aromatic hydrocarbons, organic carbon, mineral dust, and water	Breathing disorders Cardiovascular disease Cancer	Loss of visibility Impaired photosynthesis	Changes in productivity
Black carbon - a specific type of fine particulate produced from energy production and incomplete combustion	Breathing disorders Cardiovascular disease[16] Cancer	Albedo reduction and thus further contribution to climate change Impaired photosynthesis	Cooling Changes in productivity
Nitrogen oxides emissions from transport, energy production	Lung irritation	Acidification Eutrophication	Altered nutrient cycling; increased system losses
Ammonium emissions from agriculture	Lung irritation	Eutrophication	Reduced food provisioning; increased net primary productivity

[15] Kellogg, C.A., Griffin, D.W., Garrison, V.H., Peak, K.K., Royall, N., Smith, R.R. and Shinn, E.A. (2004). Characterization of aerosolized bacteria and fungi from desert dust events in Mali, West Africa. Aerobiologia 20, 99–110
[16] Smith, D.J., Griffin, D.W., McPeters, R.D., Ward, P.D. and Schuerger, A.C. (2011). Microbial survival in the stratosphere and implications for global dispersal. Aerobiologia 27, 319–332
[17] UNEP, WMO, UNCCD (2016). Global Assessment of Sand and Dust Storms. United Nations Environment Programme, Nairobi.
[18] Knippertz, P. (2014). Meteorological aspects of dust storms. In Mineral Dust: A key Player in the Earth System (ed. Knippertz, P. and Stuut, J.B.W.). pp.121–147. Springer

Sulphur dioxide	Premature deaths Damage to buildings	Acidification	Loss of biodiversity
Ground level ozone	Impaired immune system; breathing disorders, cardiovascular effects, some reproductive and development effects[16]	Reduced plant growth; increased plant susceptibility to stress	Reduced plant biomass and net primary productivity; altered climate regulation through carbon sequestration
Heavy metals, including lead and mercury, from transport, energy production, industrial sources, contaminated sites, extractives industry, unregulated burning of waste	Neurological development, harmful effects on the nervous, digestive and immune systems, lungs and kidneys[17]	Toxicity build-up in food chains	Reduction of available food due to contamination
Benzene - used in petroleum products including motor fuels and in other chemical solvents	Range of acute and long term adverse health effects and diseases, including cancer and aplastic anaemia[18]	High acute toxic effect on terrestrial plants and some aquatic life. plants[19,20]	Potential reduction of plant biomass, long term reduction of marine populations in polluted areas

Water

Today, 2.4 billion people are still using unimproved sanitation facilities, including 946 million people who, according to WHO, still practice open defecation[19]. In Africa, 42 per cent of health facilities do not have access to an improved water source within 500 metres[20]. Unsafe water, inadequate sanitation or insufficient hygiene result in 3.5 million deaths worldwide, representing 25 per cent of the premature deaths of children younger than 14[21]. Indeed, developing countries represent more than 97 per cent of the total deaths related to poor water, sanitation and hygiene.

Poor water quality and sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio, as well as persistent stunting as a result of subclinical bacterial infections[22]. Lack of access to clean water and sanitation causes 58 per cent of cases of diarrhoeal diseases in low and middle-income countries[23]. Almost 1,000 children per day die from diarrhoeal diseases because of poor sanitation, poor hygiene or unsafe drinking water: diarrhoeal diseases are the third leading cause of the death of children under 5[24]. Even in the European region's low and middle-income countries, about 10 people per day die from diarrhoea caused by inadequate clean water, sanitation and hand hygiene.

Sanitation is part of a growing global issue linked to wastewater pollution management: Only 20 per cent of globally produced wastewater – domestic, industrial and from agriculture – receives proper treatment[25], leading to two principal water quality problems: chemical (and specifically nutrient) contamination and microbial pollution[26]

[19] World Health Organization, United Nations Children's Fund (2015) Progress on Sanitation and Drinking Water – 2015 update and MDG assessment.

[20] World Health Organization, United Nations' Children's Fund (2015) Water, sanitation and hygiene in health care facilities.

[21] Prüss-Üstün Annette et al. (2008), Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health. WHO, Geneva.

[22] World Health Organization (2014) WHA Global Nutrition Targets 2025: Stunting Policy Brief. http:// www.who.int/nutrition/topics/globaltargets_stunting_policybrief.pdf.

[23] World Health Organization (2014) Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low- and middle-income countries.

[24] World Health Organization, United Nations Children's Fund (2015) Joint Monitoring Programme for Water Supply and Sanitation – 2015 Fact sheet.

[25] United Nations Environment Programme (2010) Sick Water - The Central Role of Wastewater Management in Sustainable Development. http://www.grida.no/publications/ rr/sickwater/.

[26] UN-Water (2014) A Post-2015 Global Goal for Water: Synthesis of key findings and recommendations from UN-Water.

Excessive nutrients in fresh and coastal receiving waters leads to eutrophication, negatively affecting ecosystems, and freshwater and marine resource productivity, thereby impacting livelihoods. High concentrations of nitrates and nitrites also affect health negatively[27].

FRESHWATER	HUMAN HEALTH	ECOSYSTEM	ECOSYSTEM SERVICES
Nutrients (nitrates and phosphates)	Impairment of neurological functions due to harmful algal blooms, and development e.g. blue baby syndrome,	Eutrophication, harmful algal blooms such as blue-green algae (cyanobacteria), changing habitats	Provisioning services: Productivity of coral reefs and fish stocks Habitat or supporting services: changes to species distributions and functions
Heavy metals	Impairment of neurological development, heart, kidney disease	Toxicity	Provisioning services: Productivity of food and fish stocks
Pesticides	Cancer; sterility and other reproductive disorders	Reduction in population size of species such as frogs	Control of pests, vectors
Endocrine disrupting chemicals	Hormonal disruption	Feminization of fish	Habitat or supporting services: Widespread population impacts, affecting habitats and maintenance of genetic diversity
Pharmaceuticals	Increased antimicrobial resistance	Reproductive disorders of fish	Provisioning services: Productivity of fish and stock
Waste, building debris and plastics	Consumption related	Reduced alimentary functioning; mortality related to entanglement and ingestion of fish	Provisioning services: Productivity of fluvial stocks and species Habitat or supporting services

Land and soil

Inevitably many pollutants accumulate in the land and soils. Land and soil pollution is largely the product of poor agricultural practices, inefficient irrigation, improper solid waste management including unsafe storage of obsolete stockpiles of hazardous chemicals and nuclear waste, and a range of industrial, military and extractive activities. Leachates from mismanaged landfills and uncontrolled dumping of waste from households, industrial plants and mine tailings can contain heavy metals, such as mercury and arsenic, trace metals, organic compounds, pharmaceuticals including anti-biotics and microorganisms[28]. Pollutants easily degrade land, soils and the underlying aquifers and are hard to remove. Thus, humans and wildlife living near former industrial sites and some reclaimed lands are at potential risk of continued exposure to pollution if sites are not decontaminated properly. Land and soil pollution is an increasing concern with the growth in demand for land for food production, housing or nature conservation, against a limited supply.

Although many high-income countries have robust programmes to identify, assess and remediate soil contamination, the problem still persists with significant economic implications. Many low- and middle-income countries lack basic information about the location, severity and potential risks of "pollution hotspots". Without such information, it is difficult to effectively prioritize challenges, allocate resources and implement (often very costly) solutions to protect drinking water supplies and farmland.

[27]European Environment Agency (2013). (ibid)

[28] Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H. *et al.* (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet* 380(9859), 2224-2260. https://doi.org/10.1016/S0140-6736(12)61766-8.

The primary pollutants of concern in land and soil include heavy metals such as lead, mercury, arsenic, cadmium and chromium, persistent organic pollutants and other pesticides, and pharmaceuticals, such as antibiotics used for livestock management. These degrade soil biodiversity and functioning, and can reduce agricultural productivity, thus negatively impacting livelihoods, disease control and food security, and cause a variety of non-communicable diseases, and even death in humans and wildlife[29].

LAND AND SOILS	HUMAN IMPACT	ECOLOGICAL EFFECT	ECOSYSTEM SERVICES IMPACTED
Heavy metals from sedimentary and aerosolization processes, transport, energy production, industrial sources, contaminated sites, extractives industry	Neurological development, harmful effects on the nervous, digestive and immune systems, lungs and kidneys	Toxicity build-up in food chains	Reduction of available food due to contamination
Pesticides	Cancer; sterility and other reproductive disorders	Disappearance of bees, other insects and butterflies, reptiles, birds and mammals	Control of pests, vectors
Plastic debris and litter	Various leachates causing potential harmful effects	Congested alimentary systems, leading to starvation. Toxicity build-up in fodder and prey	Reduction in productivity and cycling of nutrients Distorted predator prey dynamics
Pharmaceuticals from use of antibiotics in livestock	Increased antimicrobial resistance	Soil microbial populations developing new resistant forms	Provisioning services Productivity of soil and livestock

Marine

Oceans and coastal waters receive a large percentage of their waste and pollutants, including debris and plastics, nutrients, oil, heavy metals and radioactive waste from a multiplicity of land-based sources[30,31,32,33] with the rest coming from the shipping industry, fisheries and other sea-based sources. Nutrients from agricultural run-off is causing eutrophication in seas with least 500 recorded dead zones in coastal areas around the world[34]. This is

[29] Tóth, G., Hermann, T., Da Silva, M. and Montanarella, L. (2016). Heavy metals in agricultural soils of the European Union with implications for food safety. *Environment international* 88, 299-309. https://doi.org/10.1016/j.envint.2015.12.017.

[30] Food and Agriculture Organization of the United Nations (2016b). *The State of World Fisheries and Aquaculture 2016: Contributing to Food Security and Nutrition for All.* Rome. http://www.fao.org/3/a-i5555e.pdf.

[31] Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-I. *et al.* (2015). Feeding 9 billion by 2050–Putting fish back on the menu. *Food Security* 7(2), 261-274. http://doi.org/10.1007/s12571-015-0427-z.

[32] Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A. *et al.* (2015). Plastic waste inputs from land into the ocean. *Science* 347(6223), 768-771. http://doi.org/10.1126/science.1260352.

[33] Joint Group of Experts on the Scientific Aspects of Marine Environment Protection (2016). *Sources, Fate and Effects of Microplastics in the Marine Environment: Part 2 of a Global Assessment.* GESAMP Reports and Studies No. 93. Kershaw, P.J. and Rochman, C.M. (eds.).

[34] Shepherd, J.G., Brewer, P.G., Oschlies, A. and Watson, A.J. (2017). Ocean ventilation and deoxygenation in a warming world: introduction and overview. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 375(2102). http://doi.org/10.1098/rsta.2017.0240.

having an impact on fishing communities[35] and, on the productivity of fish stocks. Aquaculture can also be a significant source of pollution, because of outflows of nutrient rich waters, and in some cases the use of antibiotics. The number of large oil spills (greater than 700 tonnes) from tankers annually, has been decreasing, with the average number of tanker incidents involving large oil spills now at an average of 1.7 per year since 2010 ((International Tanker Owners Pollution Federation Limited 2017). However, oil from spills nearshore can have locally devastating impacts on the environment, with the clean-up introducing further chemicals in the ocean. Radioactive waste leaked into the ocean is also an important source of pollution and currently there are currently no legal instruments to control leaking of radioactive materials in the oceans as evidence by the UN Scientific Committee on the Effects of Atomic Radiation in light the events in Fukoshima.

Although the concentration of some chemicals that have been banned for over 20 years is declining, the same trend is not seen in the most recently regulated chemicals such as mercury. This is a concern, as it means that there are still high levels of mercury in the environment exposing humans and wildlife who rely on fish resources for their source of protein[36]. Some studies show that mercury levels in the global environment could double by the year 2050, if current pollution and deposition rates continue, with a new study demonstrating a clear correlation with build-up of mercury in seafood[37] .

Booster biocides, introduced as a substitute for tributyltin, are broad spectrum anti-foulants which together with persistent organic pollutants can cause disruption to local marine habitats such as coral reefs and seagrass beds, and organisms at the base of the food chain. Just as with other pesticides, they are persistent and pervasive[38] .

Records of persistent organic pollutants found in beached plastic pellets in relation to modelling of the distribution of plastic debris in the ocean indicate that this form of pollution reaches all large marine ecosystems, raising concerns about the health of ecosystem and of the over 3.5 billion humans who depend on the ocean as their main food source. Persistent organic pollutants have for long been known to accumulate in the tissues of marine mammals, birds and other species causing problems for the human populations that depend on them as their main food source. This is especially true for indigenous peoples, such as those found in the circumpolar region of the Arctic where marine organisms are the traditional source of food.

Marine litter and debris can cause physical harm to marine life (entanglement, ghost fishing, ingestion) and act as a carrier for persistent bio-accumulative and toxic substances; provide habitats for microbial communities; act as a potential vector for disease; and provide a means to transport invasive alien species across the ocean[39] . Plastic debris, that fragments into small pieces less than 5mm, but does not biodegrade in the marine environment, can now be found in all the world's oceans and seas, even in remote areas such as deep trenches and uninhabited islands in the Pacific Ocean, far from human contact. Research on the physical and toxicological effects of microplastics provides evidence of trophic transfer in planktonic food chains as well as the direct uptake of microplastics by marine invertebrates[40]. Ingestion of microplastics by fish has been shown to cause physiological stress, liver cancer, and endocrine dysfunction, affecting female fertility and the growth of reproductive tissue in male fish. These effects are thought to be caused by the plastic itself (physical components and chemical ingredients) as well as from chemical pollutants that sorb onto the plastic from the surrounding seawater. Under

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[35] Rochman, C.M., Hoh, E., Kurobe, T. and Teh, S.J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports* 3(3263), 3263. http://dx.doi.org/10.1038/srep03263

[36] Island Sustainability Alliance CIS Inc, Citizens Against Chemical Pollution, Arnika Association and IPEN Heavy Metals Working Group (2013). *Mercury in Hair of Fish Eaters: Case Studies from Tokyo, Japan and Rarotonga, Cook Islands.* http://ipen.org/hgmonitoring/pdfs/cook_islands-japan_mercury_report-hair.pdf.

[37] Sunderland, E.M. and Mason, R.P. (2007). Human impacts on open ocean mercury concentrations. *Global Biogeochemical Cycles* 21(4). http://doi.org/10.1029/2006GB002876.

[38] Price, A.R.G.P. and Readman, J.W. (2013). Booster biocide antifoulants: is history repeating itself? In *Late Lessons from Early Warnings: Science, Precaution, Innovation II.* Copenhagen: European Environment Agency. chapter 12. 265-278. https://www.eea.europa.eu/publications/late-lessons-2/late-lessons-chapters/late-lessons-ii-chapter-12

[39] Zarfl, C. and Matthies, M. (2010). Are marine plastic particles transport vectors for organic pollutants to the Arctic? *Marine Pollution Bulletin* 60(10), 1810-1814.
https://doi.org/10.1016/j.marpolbul.2010.05.026.

[40] Wright, S.L., Rowe, D., Thompson, R.C. and Galloway, T.S. (2013). Microplastic ingestion decreases energy reserves in marine worms. *Current Biology* 23(23), R1031-R1033. https://doi.org/10.1016/j.cub.2013.10.068.

laboratory conditions, Nano-size microplastics have been shown to cross cell membranes, resulting in tissue damage (Secretariat of the Convention on Biological Diversity 2016).
At the fourth UN Environment Assembly in March 2019, several Resolutions were adopted relating to marine plastics and litter. It was estimated that three quarters of marine litter is now comprised of plastic and that 4.8 to 12.7 million tonnes of plastic waste enters the ocean every year from inadequate waste management[41], with between 1.15 and 2.41 million tonnes of plastic waste entering the ocean every year from rivers, three quarters occurring between May and October. The top 20 polluting rivers, mostly located in Asia, account for 67 per cent of the global total [42].

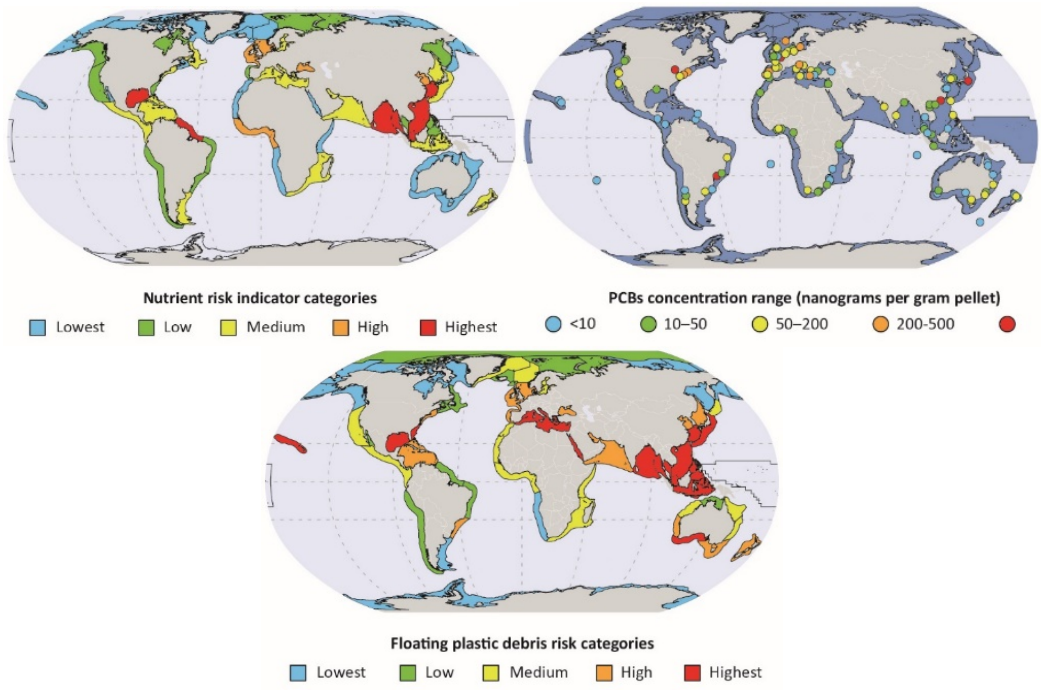


Figure 2: Marine and coastal pollution risks in large marine ecosystems: **a) Nutrient risk:** The nutrient risk indicator takes into account both the amount of nutrients discharged from lands, by rivers to each large marine ecosystem and the extent to which these added nutrients will lead to harmful algal growth. **b) Persistent organic pollutants risk:** global distribution and hotspots show that polychlorinated biphenyls (PCBs) have spread around the global ocean, including to remote areas; **c) Floating plastic debris risk** based on the amount of plastic debris per unit area of each large marine ecosystem estimated from models. This map is for plastic pieces of about 5 mm diameter and bigger. Estimated distribution of smaller plastic particles is similar[43] .
Another potential source of pollution is deep sea mining. It is still in the exploration phase, with an area of around 1.5 million km^2 under contract with the International Seabed Authority, with operations expected that actual mining in about two years. Recent research warns in particular about the plumes mining in the deep sea would create, made of sediment re-suspensions containing among others heavy metal particles and which could travel for hundreds of kilometres smothering marine ecosystems. Scientific knowledge is still limited on the impacts of deep-sea mining on deep-sea ecosystems, but scientists are increasingly calling for a precautionary approach [44].

[41] Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A. *et al.* (2015). Plastic waste inputs from land into the ocean. *Science* 347(6223), 768-771. http://doi.org/10.1126/science.1260352
[42] Lebreton, L.C., Van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A. and Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications* 8(15611). http://doi.org/10.1038/ncomms15611.
[43] Van Cauwenberghe, L. and Janssen, C.R. (2014). Microplastics in bivalves cultured for human consumption. *Environmental Pollution* 193, 65-70. https://doi.org/10.1016/j.envpol.2014.06.010
[44] Boetius, A., Haeckel, M., Hamman, K., Janssen, F. and JPIO Project Team (2017). Potential Impacts of Exploitation Activities on the Marine Environment. *Environmental Management Strategy Workshop*. Berlin, 20 March 2017. https://www.isa.org.jm/files/documents/EN/Workshops/2017/Berlin/PPT/ABoetius.pdf

There is a growing number of campaigns highlighting different aspects of marine and soil pollution. In particular, the growth and pervasiveness of marine litter and plastics has led to combined efforts of campaigning (e.g. #CleanSeas), individual, business and government voluntary commitment processes in the UN and widespread uptake in social media and through films[45].

MARINE	HUMAN HEALTH	ECOSYSTEM	ECOSYSTEM SERVICES
Nutrients (nitrates and phosphates)	Impairment of neurological development, cancers due to harmful algal blooms	Eutrophication, harmful algal blooms	Provisioning services: Productivity of coral reefs and fish stocks
Oil	Noxious fumes; skin disorders	Disruption to local food chains	Provisioning services accumulation of various chemicals , productivity of benthic fauna, shellfish and fish stocks Habitat: Impairment of physical structures and
Heavy metals e.g. from mining and seabed extractive industries;[46]	Impairment of neurological development, heart, kidney disease	Toxicity; impact on seabird populations	Provisioning services: Productivity of food and fish stocks Habitat or Supporting Services: widespread population impacts
Booster biocides	Cancer; sterility and other reproductive disorders	Disappearance of algae, corals, invertebrates and fish species	Control of pests, vectors
Pesticides	Cancer; sterility and other reproductive disorders	Impacts on seabird populations and other species	Changed predator prey dynamics
Endocrine disrupting chemicals	Hormonal disruption	Feminization of fish, thyroid disorders in whales and other mammals	Habitat or supporting services: Widespread population impacts, affecting habitats and maintenance of genetic diversity
Pharmaceuticals	Increased antimicrobial resistance	Reproductive disorders of fish	Provisioning services: Productivity of fish and stock
Waste, debris and plastics	Consumption related	Reduced alimentary functioning; mortality related to entanglement and ingestion	Provisioning services: Productivity of aquatic stocks and species Habitat or supporting services: Widespread population impacts
Light, heat and noise		Disruption to migratory patterns, spawning and echolocation systems	Provisioning services: productivity of aquatic organisms Habitat or supporting services: changes in trophic dynamics

Chemical and heavy metal pollution

Chemicals are important for development and are responsible for advances in health, but certain types of chemicals, such as persistent organic pollutants (POPs), can build up to dangerous levels in humans and wildlife causing adverse reproductive, developmental, immunological, hormonal, and carcinogenic effects. Exposure to endocrine disrupting chemicals (EDCs) such as dioxins, furans, polychlorinated biphenyls (PCB), DDT and

[45] https://www.youtube.com/watch?v=-DEc16dEMns

[46] Royal Society (2017) Future ocean resources: metal rich minerals and genetics. London ISBN: 978-1-78252-260-7

potential EDCs (phthalates, bisphenol A) can occur through food, water, dust, air and skin contact with various materials. EDCs can be found among chemical additives in electronics and electrical equipment, household cleaning products, textiles and furniture.

Although information is only available for a small number of chemical exposures, the World Health Organisation estimates that some 107,000 people die annually from exposure to asbestos and 674,000 died from exposure to lead in 2010[47]. Lung cancers cause 1.6 million deaths per year, out of which approximately 36 per cent – 568,000 deaths – are estimated to be linked to occupational exposure to chemicals and air pollution[48]. Globally, in 2013, 3.3 million cases of human poisonings were reported (it is likely that many cases were not reported) – almost the same as those injured from assaults with firearms (3.6 million)[49]. On a yearly basis, it is estimated that excessive exposure to and inappropriate use of pesticides contribute to poisoning a minimum of 3 million people, especially impoverished rural workers[50]The impacts on health from activities such as mining particularly affect vulnerable communities in Africa, Latin America and Asia.

Meanwhile, heavy metals such as lead, chromium, and cadmium contaminate agricultural soil, entering farm operations through application of sewage sludge as fertilizer, and the use of metal-based pesticides. The agricultural sector is also the world's largest user of antibiotics, using 70 per cent of all that is manufactured[51]. Overuse of pharmaceutical products (antibiotics and antimicrobial agents) – both in human medicine and veterinary practice – are contributing to the generation of resistant strains of microbes in humans, posing serious threats to health. Children are particularly susceptible to the negative health impacts of chemicals. Impacts on mental health are particularly significant. For example, mercury and lead exposure in utero and early in life can result in mental retardation, seizures, vision and hearing loss, and delayed development[52]. The consumption of fish contaminated with methyl mercury is by far the most significant source of mercury exposure in humans. About 50 per cent of global anthropogenic mercury emissions are from Asia and the Pacific, mostly from coal-burning power plants, industrial boilers and artisanal small-scale mining.

Toxic heavy metals pollution is a public health risk – especially for children and pregnant women Sources of heavy metal pollution include a variety of industrial, household and agricultural activities, such as mining and smelting operations, preparation of nuclear fuels and electroplating (Cr, Ca), coal and other fuel burning, pigment and dye production, chemical production, leather tanning, informal recycling of lead-acid batteries and electronic waste, poor incineration of hospital waste, and mismanagement of household and industrial waste. Heavy metals can become highly concentrated through ion exchange or precipitation into soils and lie dormant. As they do not decay, they pose a different kind of challenge for remediation. Some plants and microorganisms can be used to remove some heavy metals such as mercury such as in the treatment of mining tailings; the vegetation is then incinerated to recover the heavy metals.

Some heavy metals are necessary for humans in minute amounts (Cobalt, Copper, Chromium, Nickel), while others are carcinogenic or toxic, affecting the central nervous system (Mercury, Lead, Arsenic), the kidneys and liver (Mercury, Lead, Cadmium, Copper), skin, bones and teeth (Nickel, Cadmium, Copper, Chromium). Although the specific impacts vary by pollutant and exposure pathway, these often cause developmental impairment and non-communicable diseases. Once released into the environment, these metals do not biodegrade and can jeopardize ecological and human health for generations.

Lead is one of the most harmful chemicals, especially to young children, because it can build up in the body over time and cause severe, long-term effects. Exposures once thought acceptable are now known to be harmful; no safe exposure level has been identified. Blood lead concentrations as low as below 5 μg/dL may be associated,

[47] Lim, S. S., et al., (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the (Global Burden of Disease Study 2010 Lancet 380(9859): 2224–2260; World Health Organization (2014)Global Status Report on Non Communicable Diseases 2014.

[48] World Health Organization (2016)Global Status Report on Non Communicable Diseases 2016.

[49] Global Burden of Disease Study 2013 (2015). The Lancet, Vol. 386, No. 9995, p743–800. http://www.thelancet.com/globalburden-of-disease

[50] Jeyaratnam, J. (1990) Acute pesticide poisoning: a major global health problem" World health statistics quarterly.Volume:43 Issue: 3 Pages: 139–44. More recent data for somecountries can be found at the World Health Organization, Acute pesticide poisoning: a proposed classification tool (2008), Bulletin of the World Health Organization, vol 86:3.

[51] Mellon and Fondriest (2001)Hogging it: estimates of animal abuse in livestock, Nucleus, 23:1-3

[52] European Environment Agency (2013) ibid.

especially in children, with reduced intelligence quotient (IQ), reduced cognitive abilities, dyslexia, behavioural disorders and hearing problems, and may also cause delayed puberty. Absorbed lead is stored in bone but can be mobilized back into blood during pregnancy, becoming a renewed source of exposure for the mother and the foetus. In lead-exposed women there is secretion of small amounts of lead into breast milk, further exposing infants. The Institute for Health Metrics and Evaluation (IHME) has estimated that in 2013 lead exposure accounted for 853 000 deaths due to long-term effects on health, with the highest burden in low- and middle-income countries. IHME also estimated that lead exposure accounted for 9.3% of the global burden of idiopathic intellectual disability, 4% of the global burden of ischaemic heart disease and 6.6% of the global burden of stroke[53]
The world's most well-known heavy metal poisoning incident occurred with mercury in Minamata, Japan, during the 1950s and 60s. Exposure to mercury is linked to liver and brain damage at high doses and is a particular threat to the brain development of foetuses and young children[54]. Mercury occurs in water, air and soil, but childhood exposure is generally the result of industrial releases, such as in artisanal and small-scale gold mining. In 2016,16.7 million people, (65% in Africa) are exposed in ASGM with an average of 2.96 disability adjusted life years[55]. Mercury bioaccumulates and magnifies in fish and shellfish and is thus a source of dietary exposure to humans. Other heavy metals of note in terms of human exposure include beryllium, and arsenic. Beryllium is used in the nuclear weapons industry, chronic beryllium disease has been diagnosed in scores of workers, despite exposure levels being below recommended guidelines. The major issue with beryllium is that secondary users and recyclers do not generally have the expertise, resources or knowledge to prevent the disease in neighbouring communities and workers. Arsenic in drinking water can come from geological processes and mining. The best documented cases of wide scale geogenic arsenic poisoning comes from Bangladesh, where bore holes for drinking water were not tested. In Bangladesh today, 25% of households drink water contaminated with arsenic at levels above the WHO guideline value of 10 parts per billion[56].
Globally, at least 3 million people are poisoned every year by excessive exposure and inappropriate use of pesticides with health effects on all[57]. The main driver for the use of synthetic chemical pesticides is the impact of insects, diseases and weeds on crop yields, estimated in the 1990s to account for 40 per cent of the world's losses. 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 USA. However, their use has also created an almost universal human and environmental exposure to agricultural chemicals and side effects with well-reported effects amongst those experiencing acute exposure[58]). Lifestyles, unsustainable consumption patterns, agricultural subsidies, and the expansion of monocultures are helping to drive the use of agricultural chemicals and pesticides. 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 a group of insecticides, known as neonicotinoids, which have been linked to losses of bee colonies in various countries and which led to a decision in 2013 to restrict the use of three forms by the European Union[59] . Pending further treatment, residual agrochemicals on food products can also directly expose people through their diet.
Chronic pesticide exposures to women, men and children vary considerably. Prolonged low-level exposure to pesticides may induce chronic effects in children, including birth defects, asthma, cancer and neurological

[53] Institute for Health Metrics and Evaluation (2016). *Global Burden of Disease Compare Data Visualization.* University of Washington. http://vizhub.healthdata.org/gbd-compare (Accessed: 14 August 2017).
[54] Grandjean, P. (2013). *Only One Chance: How Environmental Pollution Impairs Brain Development--and How to Protect the Brains of the Next Generation.* Oxford University Press. http://www.fluorideresearch.org/462/files/FJ2013_v46_n2_p052-058_sfs.pdf

[55] Lancet 2017 ibid
[56] Pathey, P. (2015). *Bangladesh: Multiple Indicator Cluster Survey 2012-2013 - Final Report.* Dhaka: Bangladesh Bureau of Statistics (BBS) and United Nations Children's Fund. https://www.unicef.org/bangladesh/MICS_Final_21062015_Low.pdf.
[57]European Environment Agency (2013) ibid
[58] Task Force on Systemic Pesticides (2014). *Worldwide Integrated Assessment of the Impact of Systemic Pesticides on Biodiversity and Ecosystems.* Springer. http://www.tfsp.info/assets/WIA_2015.pdf
[59] European Commission (2017). *EU Efforts for Bee Health*. [https://ec.europa.eu/food/animals/live_animals/bees/health_en.

alterations[60] [61]. The number of women working as pesticide applicators varies but, in some countries, *"women make up 85% or more of the pesticide applicators on commercial farms and plantations, often working whilst pregnant or breastfeeding.*"[62] . Women are also uniquely exposed to pesticides even when they do not directly apply them. In Pakistan, where cotton is picked by women, a survey found that 100 per cent of the women picking cotton 3-15 days after pesticides had been sprayed suffered acute pesticide poisoning symptoms[63]. In Chile, in 1997, of the 120 reported pesticide poisonings, 110 were women, nearly all employed in the flower industry[64]. Other routes of exposure not generally taken into account in exposure assessments include weeding and thinning sprayed crops, picking tea-leaves, washing out the pesticide containers or washing pesticide-contaminated clothing.

Some scientists have identified a connection between pesticides and breast cancer rates[65]. While the importance of pesticides and breast cancer is not widely accepted among public health experts, a number of studies suggest that some classes of pesticides (such as organochlorines) may be more carcinogenic to breast tissue than others. It is also known that women's higher levels of hormonally-sensitive tissues make them more vulnerable to the effects of the endocrine disrupting substances, with pregnant and breast-feeding women at particular risk, as well as children exposed at a time when they are developmentally vulnerable that can cause lifelong harm and increase the risks of such harmful effects as preterm births, birth defects, childhood, reduced sperm function and a range of adult diseases. Adverse effects can also be carried in utero. Overall, women generally have higher percentages of body fat, which means that they carry more lipophilic pesticides and for longer periods, resulting in greater internal exposure and more bioaccumulation[66]. This is especially true for indigenous populations in the Arctic.

Following industrial disasters such as Minamata and Itai-Itai public concern over pollution has resulted in numerous pollutants being identified as of serious concerns to public health. While chemicals have benefits for human society, they also have significant harmful impacts. The impacts of chemicals on people and other living organisms vary from cell-mutagenesis to neurological damage, damage to reproduction and development, metabolic effects, immunotoxicity, pulmonary inflammation and the emergence of antibiotic resistant bacteria[67]

Over 100,000 die annually from exposure to asbestos and lead in paint is known to affect children's IQ. . Children poisoned by mercury and lead also develop problems in their nervous and digestive systems and kidney damage. Many impacts of chemicals such as endocrine disruptors and developmental neurotoxicants and long-term exposure to pesticides on human health and well-being and biodiversity and ecosystems are still to be fully assessed. With so many new chemicals and materials continuously being designed and released on the market, it is important that adequate chemicals management over their entire life cycle takes place - from the extraction, production, formulation and use phases, through to final disposal - as very little is known about their behaviour

[60] Eskenazi, B., Kogut, K., Huen, K., Harley, K.G., Bouchard, M., Bradman, A. *et al.* (2014). Organophosphate pesticide exposure, PON1, and neurodevelopment in school-age children from the CHAMACOS study. *Environmental research* 134(October), 149-157. https://doi.org/10.1016/j.envres.2014.07.001.

[61] Raanan, R., Harley, K.G., Balmes, J.R., Bradman, A., Lipsett, M. and Eskenazi, B. (2015). Early-life exposure to organophosphate pesticides and pediatric respiratory symptoms in the CHAMACOS cohort. *Environmental health perspectives* 123(2), 179. https://doi/org/10.1289/ehp.1408235.

[62] United Nations Environment Programme (2016i). *Global Gender and Environment Outlook: The Critical Issues.* Nairobi. http://wedocs.unep.org/bitstream/handle/20.500.11822/7628/-Global_gender_and_environment_outlook_The_critical_issues-2016ggeo_summary_report.pdf.pdf?sequence=3&isAllowed=y.

[63] Tahir, S. and Anwar, T. (2012). Assessment of pesticide exposure in female population living in cotton growing areas of Punjab, Pakistan. *Bulletin of environmental contamination and toxicology* 89(6), 1138-1141. http://doi.org/10.1007/s00128-012-0857-7.

[64] Wesseling, C., Parra, M. and Elgstrand, K. (1998). *Fruit Production, Pesticides and the Health of Women Workers.* International Development Cooperation Internal Report 4. Stockholm: National Institute for Working Life.

[65] Schinasi, L. and Leon, M.E. (2014). Non-Hodgkin lymphoma and occupational exposure to agricultural pesticide chemical groups and active ingredients: a systematic review and meta-analysis. *International journal of environmental research and public health* 11(4), 4449-4527. http://doi.org/10.3390/ijerph110404449.

[66] Liew, Z., Wang, A., Bronstein, J. and Ritz, B. (2014). Job exposure matrix (JEM)-derived estimates of lifetime occupational pesticide exposure and the risk of Parkinson's disease. *Archives of environmental & occupational health* 69(4), 241-251. http://doi.org/10.1080/19338244.2013.778808.

[67] Diamond, M.L., de Wit, C.A., Molander, S., Scheringer, M., Backhaus, T., Lohmann, R. *et al.* (2015). Exploring the planetary boundary for chemical pollution. *Environment international* 78, 8-15. https://doi.org/10.1016/j.envint.2015.02.001.

in the environment (for example, transboundary transport via water, air or bio-accumulation) and the effects of these materials on biodiversity and whole ecosystems[68].

One of the challenges in dealing with chemicals is the gaps in publicly accessible data and consumer information on chemical performance and safety throughout different supply chains and on the chemical composition of products, articles waste streams and residues. This is especially true for some developing and transition economies, where the lack of national legislation, lack of access to information on handling toxic chemicals and their environmental and health effects, lack of funding, and poor technological and human resources means that they these are potentially more vulnerable, and disproportionally affected by toxic hazards. Multilateral environmental agreements and key global and regional processes such as the Strategic Approach to International Chemicals Management (SAICM) can play a vital role in improving this situation.

Of the tens of thousands of chemicals on the market, relatively few have been thoroughly evaluated to determine whether they can cause adverse effects on human health and the environment (Figure). Moreover, the assessment of the health risk of chemical substances focuses primarily on the effects of individual substances for determining the doses of toxicological concern and have a limited ability to evaluate the combined impact of chemical mixtures. The European Union Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation requires companies to identify and manage the risks linked to the substances they manufacture. However, this legislation only focuses on individual substances, disregarding the effects of combined exposure to mixtures of chemical and physical agents. To date, under the pre-registration requirement of the European Union's chemicals regulation, REACH, over 145,000 chemical substances have been pre-registered. A reset of the United States chemical inventory is expected to give an estimate of the number of chemicals in commerce as being between 14,000 and 15,000. In June 2017 the International Council of Chemistry Associations Global Product Strategy Chemicals Portal provided access to data for over 4,500 chemicals.

Major routes of human and environmental exposure to pollutants are through food and water intake (for example pesticide residues) and through exposure to toxic chemicals in the workplace, and from specific consumer products found amongst detergents, textiles, cosmetics, construction materials and furniture (World Health Organization and United Nations Environment Programme 2013). Food safety is intimately linked to the quality of the environment, where food is produced, and then further down the chain in food processing, washing, and preparation. The joint Food and Agriculture Organization/World Health Organization committee on food additives carries out food safety risk assessments on food additives, contaminants and residues of veterinary drugs residues.

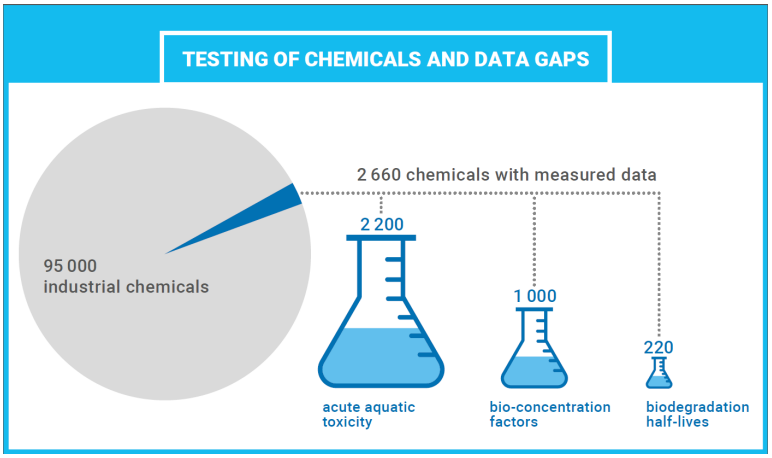


Figure Testing of chemicals and data gaps.

Out of a set of 95 000 industrial chemicals, 2200 had data on acute aquatic toxicity, 1000 on the extent to which they build up in the environment (bio-concentration factors), and 220 on how long it takes them to break down (biodegradation half-lives)[69].

[68] European Environment Agency (2013) ibid

[69] European Chemicals Agency (2017). *Pre-registered Substances*. [https://echa.europa.eu/information-on-chemicals/pre-registered-substances

Releases of ionizing radiation and exposure of workers from coal extraction for power generation including nuclear, and the materials needed for solar energy remain a concern (United Nations Scientific Committee on the Effects of Atomic Radiation). Most of the exposure risks for occupational cancer are preventable. About 125 million people in the world are exposed to asbestos at the workplace, with the more than 107 000 deaths each year due to asbestos-related lung cancer, mesothelioma and asbestosis resulting from occupational exposures. One in three deaths from occupational cancer is caused by asbestos.

Poorly managed waste

Global municipal solid waste generation levels are expected to double by 2025, although at different rates according to regions and countries: the higher the income level and rate of urbanization, the greater the amount of solid waste produced[70]. Some United Nations Human Settlements Programme (UN-Habitat) health data indicate twice as high rates of diarrhoea and six times more acute respiratory infections for children living in households where solid waste is dumped or burned in the yard compared to households in the same cities which benefit from a regular collection service. Uncollected waste may also result in blocked drains which aggravate floods and spread infectious disease.

Uncontrolled dumpsites, and in particular the mixing of hazardous and other wastes, can cause diseases in neighbouring settlements and among waste workers, where life expectancy is significantly shorter than the rest of the population. The 50 biggest active dumpsites affect the daily lives of 64 million people. Electronic waste (e-waste) is the fastest growing type of waste. Close to 42 million metric tonnes of e-waste were generated in 2014 and this figure continues to rise[71]. While recycling is positive, the unsound dismantling, material recovery and final disposal of e-waste, containing various hazardous contents such as heavy metals and Endocrine Disrupting Chemicals, can result in major environmental and human health impacts through the release of hazardous substances into soil, water and air[72]. Further reducing the amount of transboundary movements of hazardous and other wastes is also crucial, as they represent important challenges endangering developing countries with wastes, they do not have the capacity to manage safely.

Human Right to a Clean Environment

A clean environment is essential for life and health.

The right to a healthy environment comes with the implicit corollary that pollution needs to be controlled. However, the ethical dimensions of pollution and its prevention are multi-level, extending from the individual to societal to global. The determination that pollution increases the risk for a particular disease or has an adverse health effect brings with its strong societal implications and entails an ethical imperative for action.

For example, on a daily basis adults inhale 10,000 liters of air, exposing themselves to myriad contaminants, some injurious to health. While children inhale a lesser absolute volume of air, their inhalation volume in relation to body size exceeds that for adults. Thus, even for pollutants at seemingly low concentrations, the total dose of inhaled toxic pollutants may be enough to cause injury and disease, and also to exacerbate many chronic diseases, such as childhood asthma.

The risks of air pollution vary across societies, with vulnerability varying among individuals. Factors that increase individual vulnerability include age, gender, location and residence, and occupation. Biological factors that increase individual vulnerability include genetic susceptibility and underlying disease, such as asthma, heart disease or diabetes. However, despite the growing evidence of harm to human health, only 109 Member States had adopted air quality standards by 2015, 73 had a specific air quality policy, Act or Rules, and 104 had vehicle emission standards (see Figure).

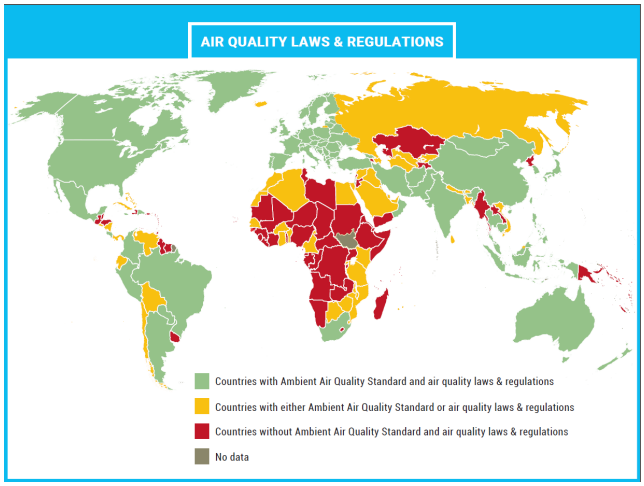
Implementing measures to control pollution, raises a series of complex issues with ethical dimensions. For example, what principles of risk management will guide implementation? Should approaches that are ethical reflect the full range of susceptibility and address the inequities that are inevitable within populations? Should there be consideration of having a "margin of safety"? Or, if risk-free levels cannot be identified based on the

[70]Hoornweg Daniel, Bhada-Tata Perinaz, (2012) What a Waste – A Global Review of Solid Waste Management, The World Bank, Urban Development Series Knowledge Paper, March 2012, No. 15

[71] Baldé CP et al. (2015), The global e-waste monitor-2014, United Nations University, IAS-SCYCLE, Bonn, Germany.

[72] Planet RE: think 2012. Available from http://planetrethink.com/.

scientific evidence, what ethical principles should be followed for risk management? What ethical principles should guide decision-making in such scenarios?



The seeming ethical dilemma of slowing economic development by introducing pollution reduction strategies and policies should not delay control of pollution in low- and middle-income countries. Indeed, abundant experience from high-income and some upper-middle-income countries indicates that imposition of pollution controls does not slow economic growth and indeed benefits national economies by preventing productivity losses and reducing health care costs. But be that as it may, the ethical imperative for immediate action against pollution is clear.
For water, this ethical dimension is already well recognised in the Sustainable Development Goals. Between 1990 and 2015, 2.1 billion people gained access to improved sanitation worldwide. However, fulfilling the human right to water and sanitation requires that all people have access to affordable, safe and acceptable water and sanitation. This higher standard is reflected in Sustainable Development Goal 6, which calls for States to "ensure availability and sustainable management of water and sanitation for all".
However, there is no similar commitment to the human right to breathe clean air in the Sustainable Development Goals. In 2017, a Special Advisor to the UN Secretary General was appointed to develop the legal and ethical basis for the human right to breathe clean air.

> The failure to respect, protect and fulfil the right to breathe clean air is inflicting a terrible toll on people all across the world. The statistics presented in the present report depict a public health catastrophe, yet the numbers fail to capture the magnitude of human suffering involved. Each premature death, every illness and every disability afflicts an individual with hopes, dreams and loved ones. Air pollution is a preventable problem. The solutions – laws, standards, policies, programmes, investments and technologies – are known. Implementing these solutions will of course entail large investments, but the benefits of fulfilling the right to breathe clean air for all of humanity are incalculable." David Boyd, UN Human Rights Special Rapporteur, March 2019, Geneva[73]

He went on to say said that failing to ensure clean air constituted a violation of their fundamental right to a healthy environment, a right that is legally recognised by 155 States and should be globally recognised.

> "People cannot avoid inhaling whatever contaminants are present in the air inside their homes or in their communities," "Air pollutants are everywhere, largely caused by burning fossil fuels for electricity, transportation, and heating, as well as from industrial activities, poor waste management and agricultural practices."

[73] https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=24248&LangID=E

The Special Rapporteur emphasised that air pollution was a preventable problem and has called on States to abide by their legal obligations to ensure clean air, which is essential for fulfilling the rights to life, health, water and sanitation, adequate housing, and a healthy environment. He has identified seven key steps that each State must take to ensure clean air and fulfil the right to a healthy environment: monitor air quality and impacts on human health; assess sources of air pollution; make information publicly available, including public health advisories; establish air quality legislation, regulations, standards and policies; develop air quality action plans at the local, national and, if necessary, regional levels; implement the air quality action plan and enforce the standards; and evaluate progress and, if necessary, strengthen the plan to ensure that the standards are met.
Boyd recommended that the General Assembly– which has adopted many resolutions on the right to clean water– adopt a resolution on the right to clean air, which he believes could help spur and guide action.

Call to Action

Today, there are many actions and voluntary commitments that the public, governments and business are being asked to support[74]. The analyses of these undertaken for the third and fourth United Nations Environment Assemblies show that if delivered they can make a significant contribution to cleaning up the environment and improving both human and ecosystem health.
With this is mind, five leading academies from USA, Germany, South Africa and Brazil are launching a Global Call for Action on June 19th, 2019 at the United Nations. The academies are home to many of the world's leading doctors and specialists who concur that air pollution alone represents an existential threat to human life. Add to this the moral imperative of breathing clean air and drinking clean water and it is clear that we need to act urgently. Tackling pollution from all its various aspects will also allow us to address climate change, food safety, clean water and sanitation and some of the root causes of under-development of the children's cognitive potential and well-being and health in older and more vulnerable people.

[74] For example, #BeatPollution #CleanSeas #BreatheAir