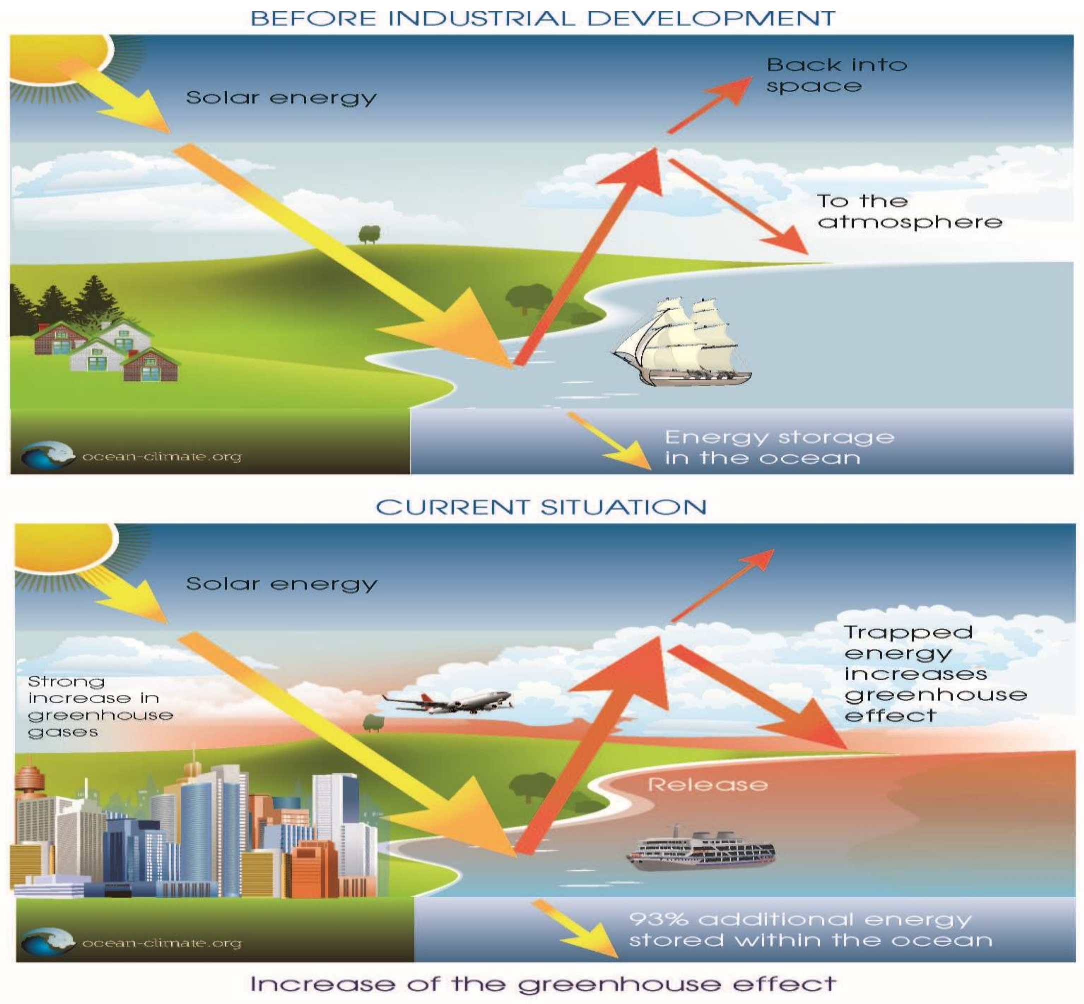
One Ocean – Stopping Oceanic Pollution is the biggest challenge of Climate Change Dr Carolyn V. Currie

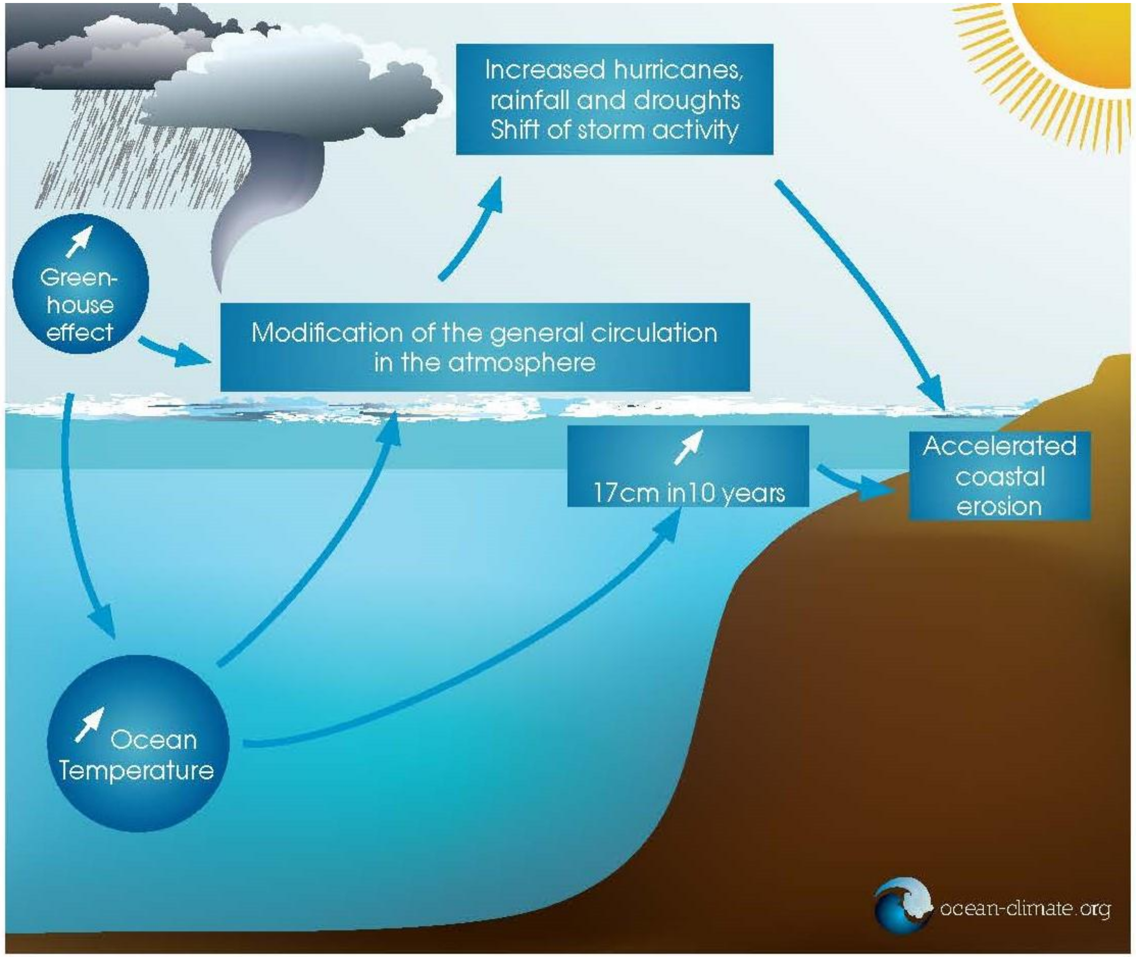
An outline of Discussion Paper I in the One Ocean series.

- There has been a concentration of climate change solutions on air pollution which ignores one vital factor. That the ocean covers 70 percent of Earth's surface, containing about 1.35 billion cubic kilometres of water, constituting about 97 percent of all water on Earth. The ocean's size means that it plays a major role in determining weather patterns and hence both local and world climatic events. The critical role of the ocean is in balancing global temperatures as water absorbs heat in the summer and releases it in the winter
- Rising amounts of greenhouse gases are preventing heat radiated from Earth's surface from escaping into space as freely as it used to. Most of the excess atmospheric heat is passed back to the ocean. As a result, upper ocean heat content has increased significantly over the past few decades. Upper layers are accumulating heat faster than deeper layers, but averaged over the full depth of the ocean, the 1993–2022 heat-gain rates are approximately 0.64 to 0.83 Watts per square meter averaged over the surface of the Earth.
- As there is more water than land covering the Earth's surface, it is no surprise that the warming of the oceans has accounted for around 93 % of the warming of the planet since the 1950s
- From 1901-2020 the sea surface temperature rose at a rate of 0.14°F per decade. The ocean warming effect is not evenly distributed, having the greatest impact in the Southern Hemisphere. A viscous cycle is generated by increasing temperatures melting polar ice caps so that as the total area of the global ice and snow cover shrink, it reflects less solar energy back into space, further warming the planet. This in turn results in more freshwater entering the oceans, changing the currents further.

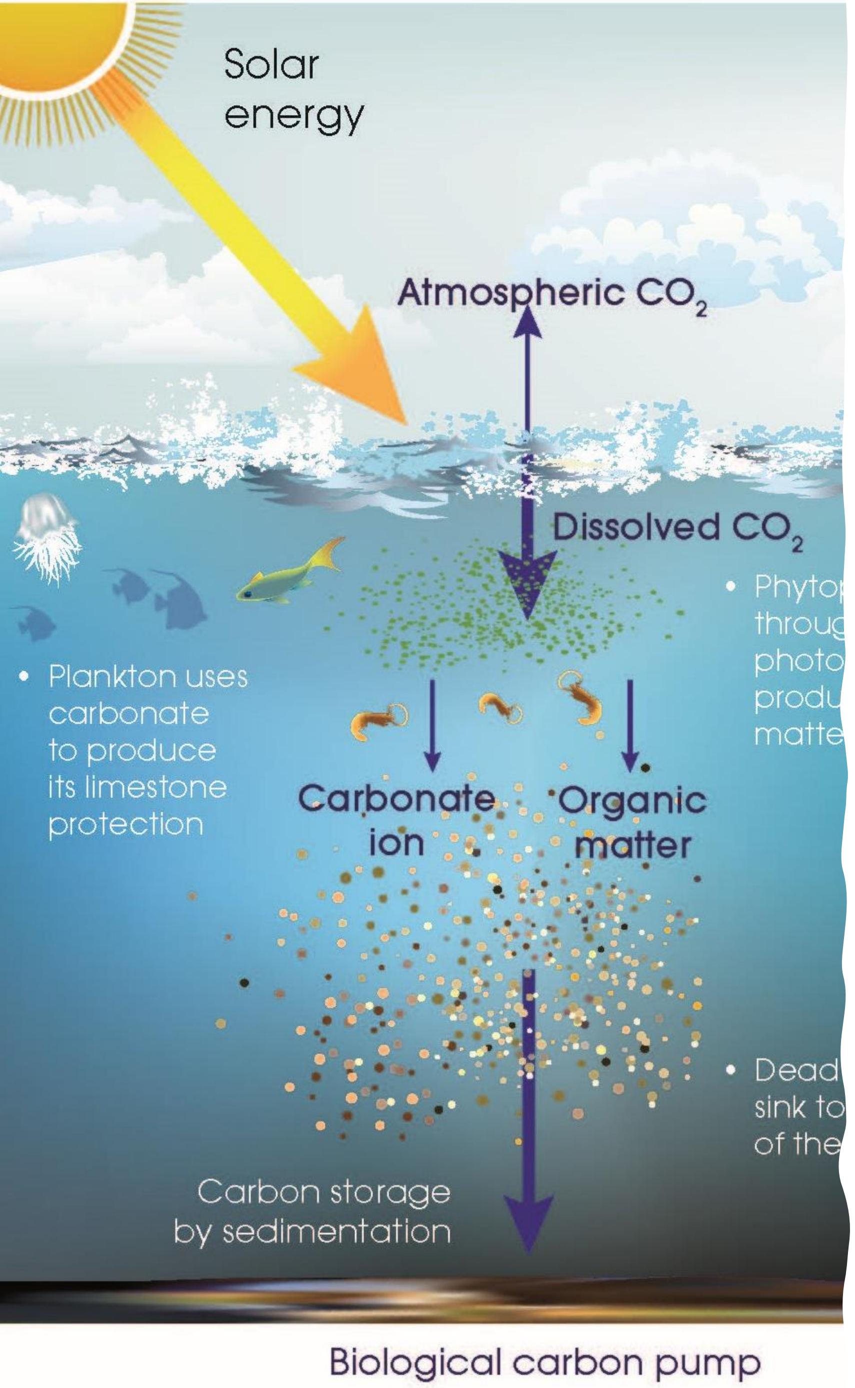


The link between the oceans, seas, waterways and the climate, oxygen production and carbon capture

- The effect of increasing oceanic temperatures is deoxygenation and rising sea levels es causing the loss of breeding grounds and mass migrations with consequences for food scarcity and economic challenges. Rising temperatures intensify hurricanes and droughts and floods.
- However, it has been argued that the impact of greenhouse gases in raising ocean temperatures may be far less that the effect of marine pollution from the spreading of harmful substances such as oil, plastic, industrial, sewage, agricultural waste, and chemical particles into the ocean. Apart from causing the ocean to heat, pollution lowers oxygen content and destroys the ocean's ability to capture carbon and help regulate global temperatures. Besides normal environmental solutions to littering, stopping the use of artificial fertilisers and fossil fuels, there has been a distinct lack of attention focussing on improving and preventing using the ocean as a vast sewerage dump.
- The world's sewage must go somewhere, and unfortunately 80% of the sewerage produced by the global population makes its way into the world's oceans untreated. An analysis of roughly 135,000 watersheds reveals that large amounts of key pollutants come from human wastewater, not just agricultural runoff. Individual sites have long been known to be major sources of coastal pollution.

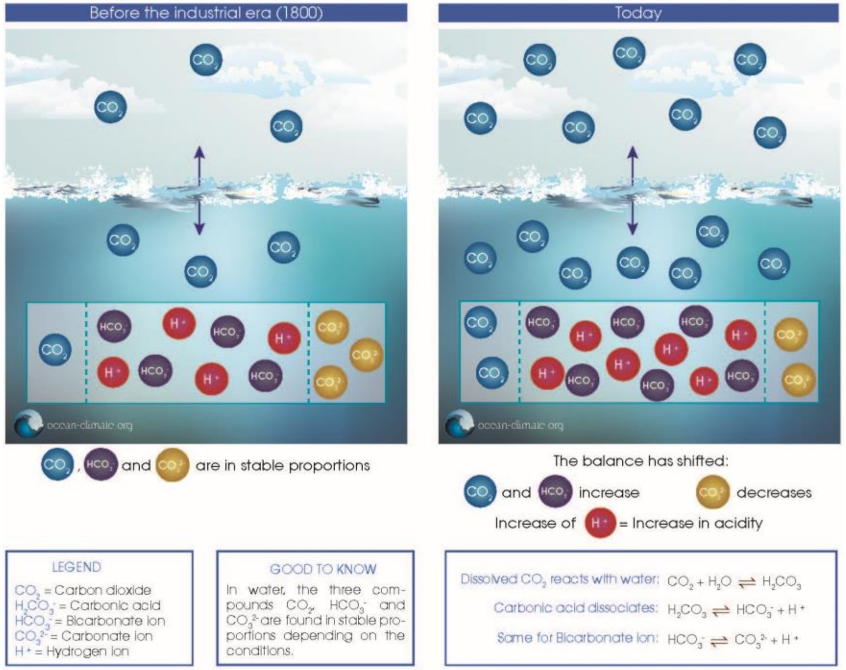


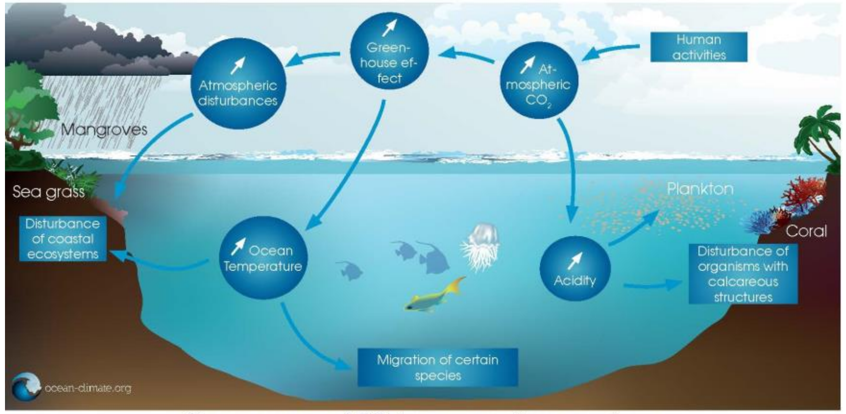
Physical consequences of the increase of atmospheric CO_2



Untreated Sewage and Wastewater as the source of Oceanic pollution and destruction

- Individual sites have long been known to be major sources of coastal pollution. "We've never had a global understanding of how big the problem is," says Cascade Tuholske, a geographer at Columbia University's Earth Institute. He and his colleagues took a broad look at the issue by calculating the amounts of faecal pathogens and nitrogen—which can fuel harmful algal blooms and create oxygen-deprived dead zones—flushed into the ocean inhuman wastewater at nearly 135,000 sites around the world.
- Surprisedly, they found that they could attribute about half of the nitrogen pollution to just 25 locations and the source of around half of the pathogens to 25 sources, in some cases the same ones. Sewage pollution of our oceans and other water bodies poses several challenges and has myriad impacts, as discussed in the article. Sewage is the single biggest factor causing coastal pollution. A worldwide estimate shows that 104 of 112 coral reefs are impacted by sewage directly or indirectly. Over 60% of bays in the US Atlantic suffer from seagrass decline, while saltmarshes, mangroves, and fisheries are also heavily impacted.
- However apart from the effect on marine life and causing an increase in evaporation with severe weather effects, the toxic pollution reduces the oceans ability to act as a carbon sink (up to 60% of carbon dioxide can be captured) and as producer of the oxygen we breath.



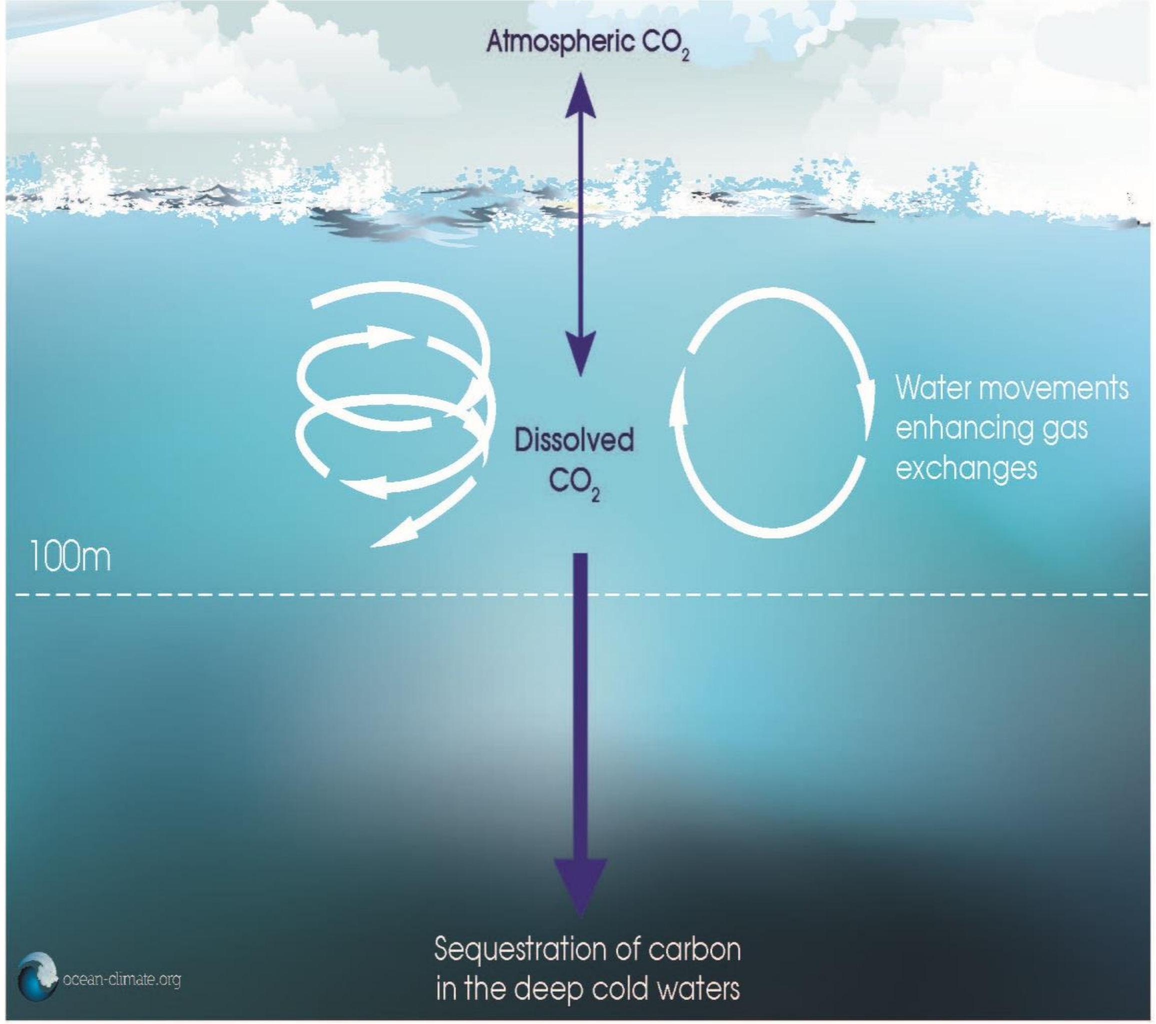


Consequences of CO_2 increase on the ecosystems

Is Pollution of Oceans still a problem?

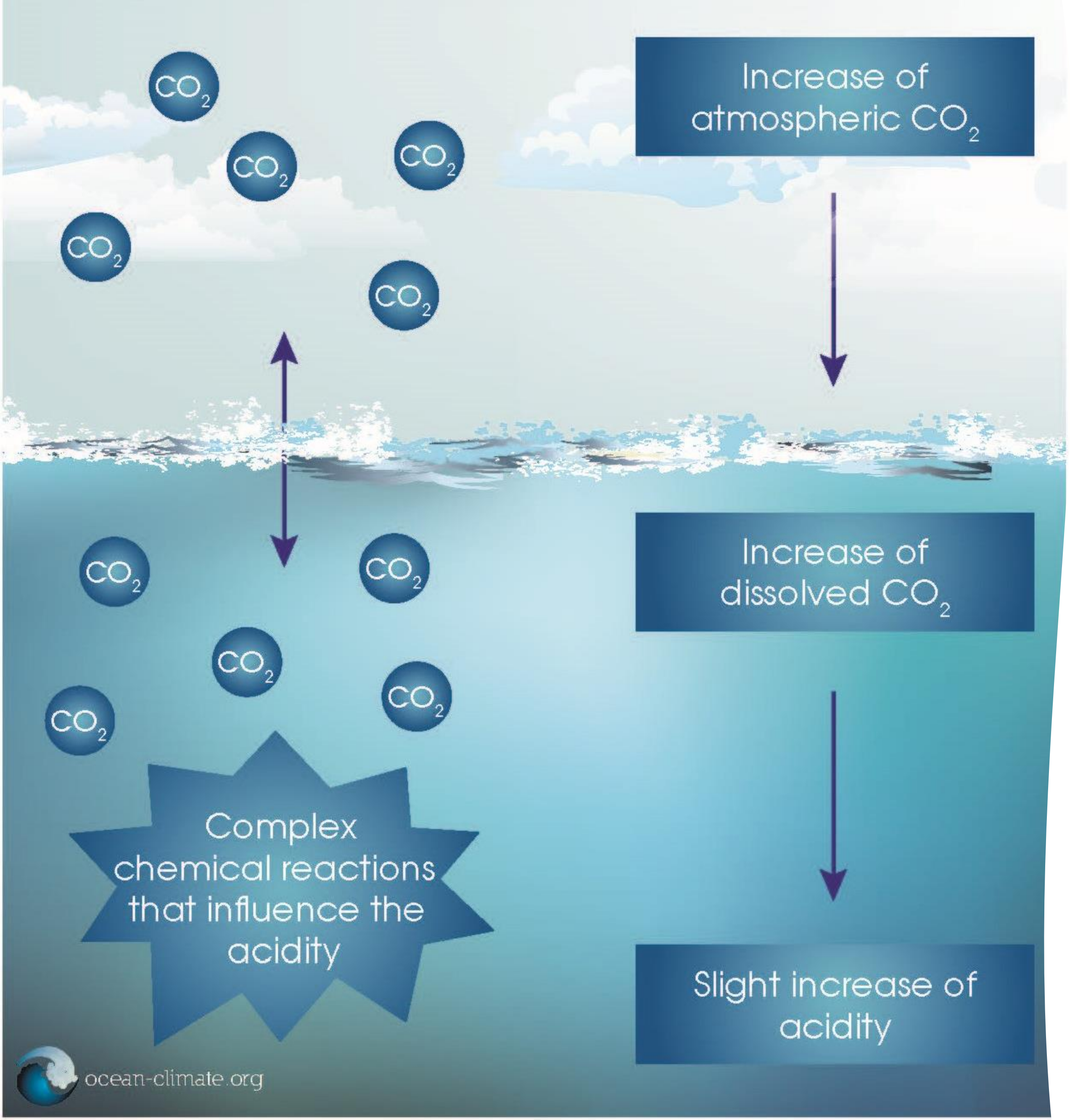
- The world's oceans play a crucial role in sustaining life on our planet. Not only do they provide a habitat for countless species, but they also contribute significantly to the amount of **oxygen** in the atmosphere, producing over half.
- However the amount of oxygen produced by the oceans varies depending on several factors. One of the most significant factors is the temperature of the water. Colder water holds more dissolved oxygen, which means that areas with colder water tend to have higher oxygen concentrations. Conversely, warmer water holds less dissolved oxygen, which can lead to areas of low oxygen known as hypoxic zones. As the world's oceans warm due to climate change, this will adversely affect the ability of the planet's largest source of water to hold oxygen.
- Another factor that can affect oxygen production in the oceans is nutrient availability.
- Oceans also influence the Earth's **climate** through a constant transfer of heat from the Equator towards the poles. [9] Evaporation from the ocean's surface brings rain to much of the Earth's land surfaces. In fact, almost all rain that falls on land starts off in the ocean.
- Outside of Earth's equatorial areas, weather patterns are driven largely by **ocean currents.**
- However, the most important factor presently which is being distorted is the ability of the oceans to act as a natural and huge **carbon sink**. "It is difficult to determine the quantity of carbon stored by these mechanisms, but it is estimated that the ocean concentrates 50 times more carbon than the atmosphere

The Deep Sea and its water column may be the largest carbon sink on Earth



Physical carbon pump

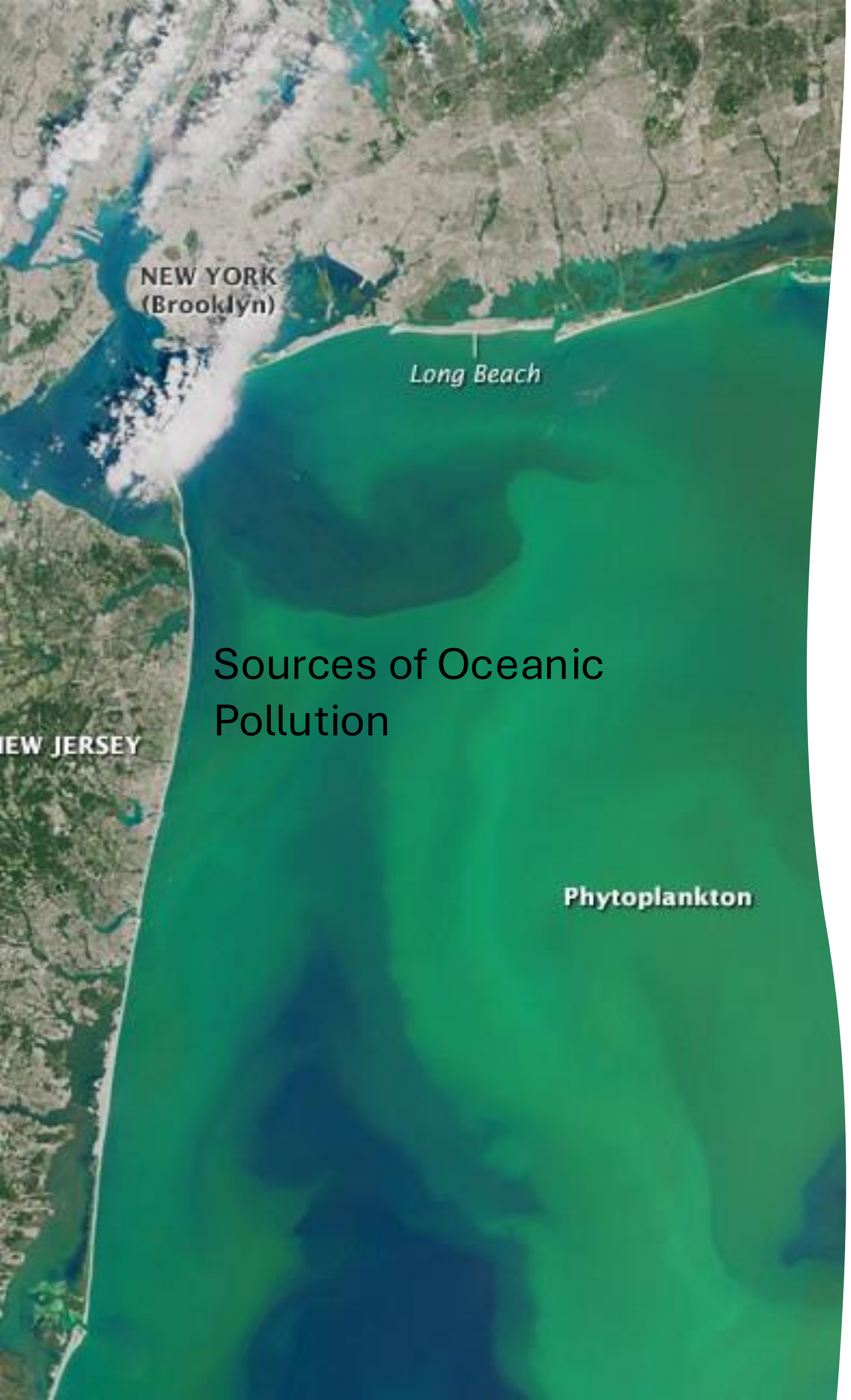
- A carbon sink is a natural or artificial reservoir that absorbs and stores the atmosphere's carbon with physical and biological mechanisms. Coal, oil, natural gases, methane hydrate and limestone are all examples of carbon sinks. Nowadays, other carbon sinks come into play: humus storing soils (such as peatlands), some vegetizing environments (such as forming forests) and of course some biological and physical processes which take place in a marine environment.
- These processes form the well-known « ocean carbon pump ». It is composed of two compartments: a biological pump* which transfers surface carbon towards the seabed via the food web (it is stored there in the long term), and the physical pump* which results from ocean circulation. In the Polar Regions, more dense water flows towards the Deep Sea dragging down dissolved carbon. In high latitudes water stores CO2, more easily because low temperatures facilitate atmospheric CO2 dissolution (hence the importance of Polar Regions in the carbon cycle).
- For some scientists, the Deep Sea and its water column may be the largest carbon sink on Earth but its large-scale future is still unknown. Also, with ocean acidification, this process could become less efficient because of a lack of available carbonates.
- The depth of the ocean is on average 4000 metres. In this area also known as "deep sea" there is no light, extremely high pressure, and temperatures that are much more stable than at the surface. The Deep Sea plays a major role in climate change mitigation. By storing a large part of the CO2 produced by human activities and by absorbing the heat accumulated by greenhouse effect, the Deep Sea slows down the warming of surface waters and land. Thanks to this immense mass of water, climate change is still "bearable" for most species on Earth.



Simplified mechanism of ocean acidification

Acidification and temperature effects

- The increase in water temperature, even by a 10th of a degree every 10 years in certain Polar Regions, enables some predator crabs to expand their territory and decimate species until then protected by extremely cold waters (-1,5°C).
- In other regions, there are concerns regarding **the acidification effect of waters,** which have absorbed great quantities of CO2, and can cause the deterioration of deep coral reefs, while many fish and shellfish species depend on them. Lab studies show that a combination of this phenomenon with deoxygenation of waters, like in the Gulf of Mexico, where the warming of deep waters is particularly critical.
- As deep biodiversity reacts rather rapidly to change, it is crucial to consider these risks to avoid jeopardizing the mitigation capacity of oceans toward climate disruption and other services provided by the Deep Sea's biodiversity.
- Scientific research shows that climate change impacts on the ocean have already affected fisheries. While abundance of several cold-water species is reducing, some tropical species are appearing on our coasts. In future decades ocean warming and acidification can affect growth and reproduction processes of many marine organisms, which may reduce stocks available for many significant commercial species. For instance, shellfish (such as oysters, and mussels) are especially sensitive to acidification. Also, while they are crucial for the economy of small islands and human nutrition, almost all coral ecosystems in tropical areas are expected to disappear by 2050. Climate change is also going to impact bacterial and phytoplankton communities, which are key to the marine food web. Consequently, if we keep on producing greenhouse gases at the current pace, while simultaneously reducing the ocean's role as a carbon sink, changes expected before the end of the century in terms of biodiversity could be like those that occurred during the prior 20 or 30 million years.

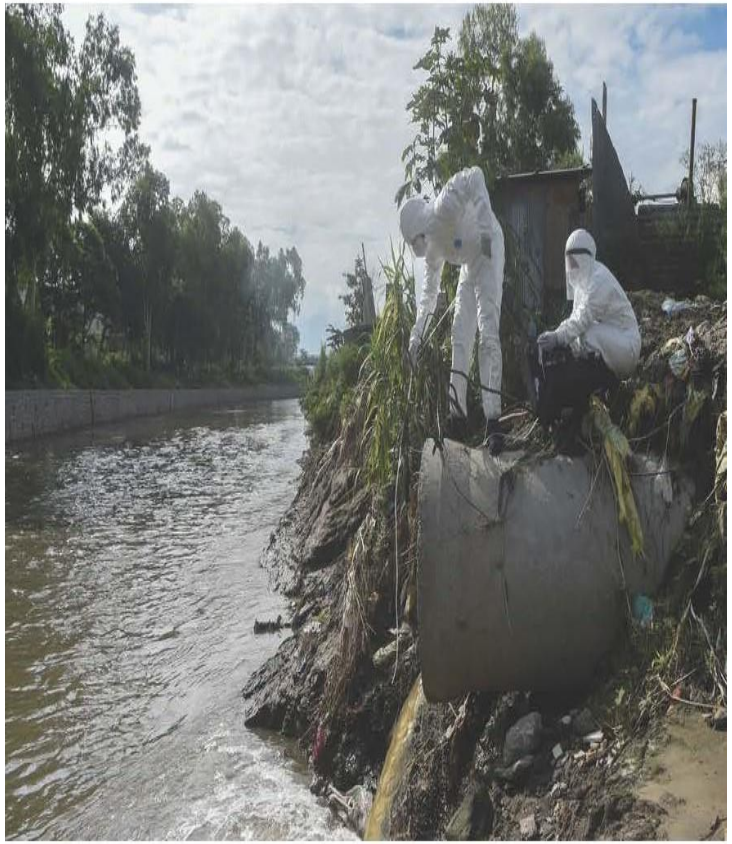


Sources of Oceanic Pollution

Half of the World's Coastal Sewage Pollution Flows from Few Dozen Places

An analysis of roughly 135,000 watersheds reveals that large amounts of key pollutants come from human wastewater, not just agricultural runoff

BY NIKK OGASA



In this picture taken on August 7, 2020, researchers wearing personal protective equipment (PPE) collect samples from a pipe dumping raw sewage into the Manohar River in the Balakumari area of Lalitpur, Nepal, near Kathmandu. Credit: Prakash Mathema/AFP/Getty Images

- There are three types of wastewater, or sewage: domestic sewage, industrial sewage, and storm sewage. Domestic sewage carries used water from houses and apartments; it is also called sanitary sewage. Industrial sewage is used water from manufacturing or chemical processes. Storm sewage, or storm water, is runoff from precipitation that is collected in a system of pipes or open channels.

- Domestic sewage is slightly more than 99.9 percent water by weight. The rest, less than 0.1 percent, contains a wide variety of dissolved and suspended impurities. Although amounting to a very small fraction of the sewage by weight, the nature of these impurities and the large volumes of sewage in which they are carried make disposal of domestic wastewater a significant technical problem. The principal impurities are putrescible organic materials and plant nutrients, but domestic sewage is also very likely to contain disease-causing microbes. Industrial wastewater usually contains specific and readily identifiable chemical compounds, depending on the nature of the industrial process. Storm sewage carries organic materials, suspended and dissolved solids, and other substances picked up as it travels over the ground. The amount of putrescible organic material in sewage is indicated by the biochemical oxygen demand, or BOD; the more organic material there is in the sewage, the higher the BOD, which is the amount of oxygen required by microorganisms to decompose the organic substances in sewage. It is among the most important parameters for the design and operation of sewage treatment plants. Industrial sewage may have BOD levels many times that of domestic sewage. The BOD of storm sewage is of particular concern when it is mixed with domestic sewage in combined sewerage systems.
- Problems with **wastewater** is that it is made up of sewage as well as grey water which runs away from our houses; this could include water used for showering, washing dishes, or watering the garden. Industrial water is also included, which could contain chemicals, acids, and heavy metals, as well as surface run off which is water running off the ground, collecting substances such as animal faeces, agricultural fertilisers, and car oil along the way. All this water is collected in sewage systems and when the system gets overwhelmed, many authorities release this untreated chemical concoction into rivers and oceans to stop the dirty water flowing back up our drains. This has devasting impacts on our natural environment,

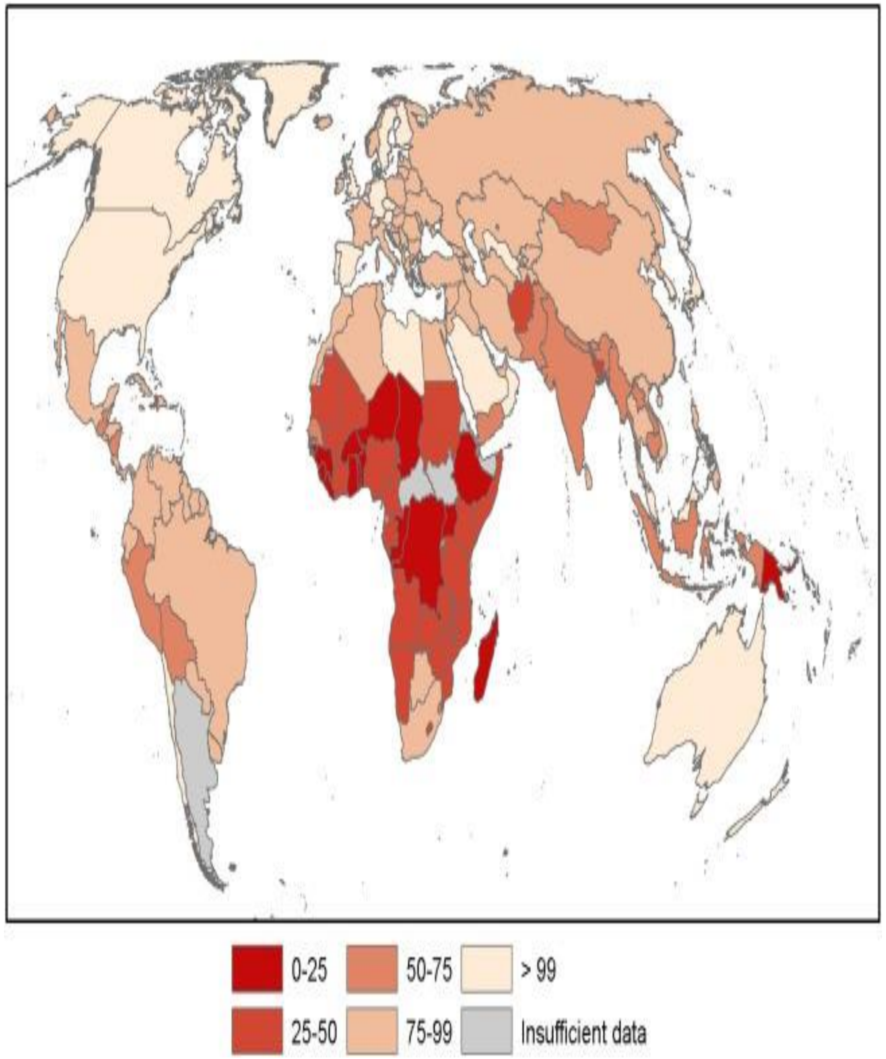
- Waste is often perceived as mostly a developing world problem, but the developed world is as responsible — largely due to antiquated municipal sewage systems that combine rainwater and wastewater in the same pipes. As a result, intense precipitation events regularly flush raw sewage into waterways in the U.S., U.K., and EU.

  The food we eat, fluids we drink, and medicines we take, once expelled from our bodies, must end up somewhere. Thanks to the recently published scientific Tuholske model and highlighted by Ogasa, the destination of a global flood of human waste into coastal areas has at last been tracked for all to see. And it doesn't make for a pretty picture.

  Sewage attracts bacteria which then break down the waste and, in the process, use up large amounts of oxygen which can leave that local path of ocean lacking oxygen

- **Agricultural fertilisers** are another major component of wastewater and can have detrimental effects in the ocean. Fertilisers are composed of nitrogen and phosphorous which do an excellent job of making plants grow faster, exactly what we want on land but unfortunately, they also have the same effect in the water. The high level of nutrients in fertilisers causes algae to blossom and bloom and as a result, the new clouds of algae block sunlight from marine plants which leaves them struggling to grow. When the algae die, it takes with it a lot of the oxygen in the water, leaving marine animals struggling too and this can also lead to dead zones, such as the 7728 square mile area of the Gulf of Mexico which is now largely devoid of life.

  Wastewater also contains **industrial chemicals and heavy metals** which can cause coral bleaching whilst also causing diseases and reduced reproductive success in both corals and other marine creatures



Studies on sewage and wastewater

- According to the Tuholske new model, wastewater adds around 6.2 million tons of nitrogen to coastal waters worldwide annually; equivalent to around 40% of the amount emitted by agricultural runoff. Nitrogen is one of the worst pollutants of our planet's oceans, causing toxic algal blooms, eutrophication and dead zones. The study mapped 135,000 watersheds planetwide and found that just 25 of them account for almost half the nitrogen "inputs from wastewater into the ocean."

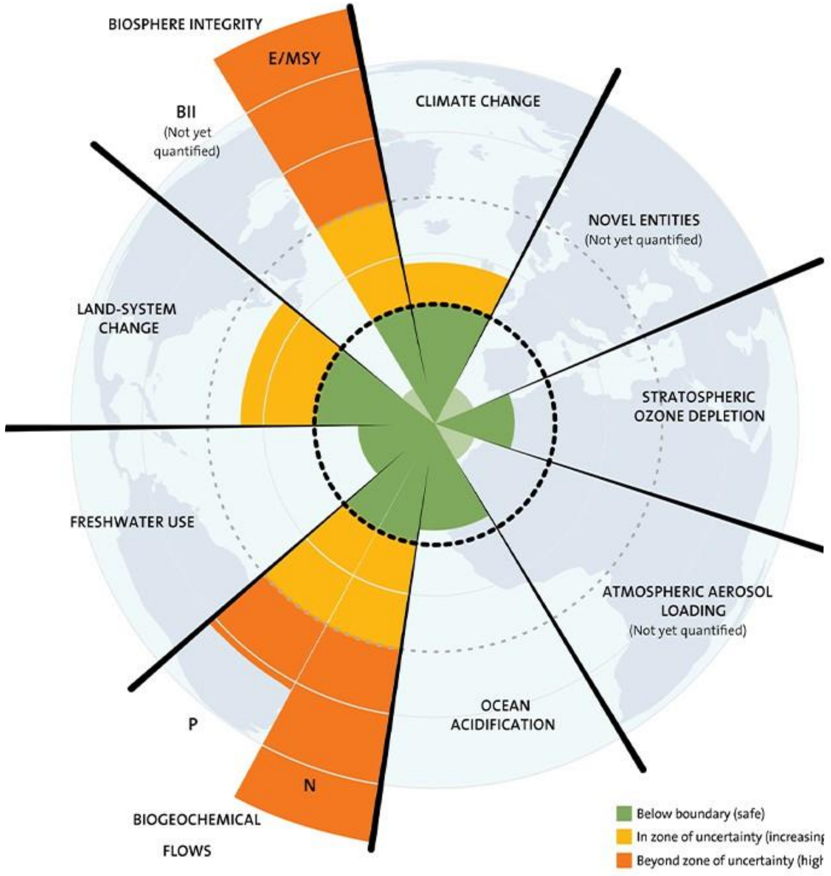
- "The sheer scale of wastewater impacts on coastal ecosystems, especially in terms of nitrogen inputs, was pretty surprising," said Cascade Tuholske, a postdoctoral researcher at the Columbia Climate School, who was part of the interdisciplinary team that created the model.

- In assessing direct and septic coastal wastewater releases, the study found that the worst nitrogen-polluting watersheds are "concentrated in India, [South] Korea and China, but are also found in other continents, and a single watershed — the Chang Jiang (Yangtze) River in northern China — account[s] for (11%) of global wastewater [nitrogen]." In another finding, South America and Africa account for much higher nitrogen levels than previously thought, while a U.S. watershed, the Mississippi, figures among the major offenders.

- Nitrogen release is just one problem caused by human wastewater. Tuholske and his team also tracked faecal indicator organisms. They found that the 25 most polluted watersheds —" located on almost every continent" — emit 51% of these organisms, "in particular in densely-populated deltas and estuaries in Southern and Eastern Asia, as well as in Africa."

- The global study doesn't claim to be comprehensive: "Our paper doesn't look at heavy metals, phosphorus, plastics. I mean there's pharmaceutical products [too]," Tuholske said. "The list goes on and on for what we put into our watersheds that are hitting coastal areas."

Globally, human inputs of nitrogen and phosphorus due to agricultural synthetic fertilizer runoff and human waste have already pushed us beyond the safe planetary boundary set by scientists



- *1. Effect of Toxic Wastes on Marine Animals*
- The oil spilled in the ocean could get on to the gills and feathers of marine animals, which makes it difficult for them to move or fly properly or feed their children. The long-term effect on marine life can include cancer, failure in the reproductive system, behavioural changes, and even death.

- *2. Disruption to the Cycle of Coral Reefs*
- Oil spill floats on the surface of the water and prevents sunlight from reaching to marine plants and affects the process of photosynthesis. Skin irritation, eye irritation, lung and liver problems can impact marine life over a long period of time.

- *3. Depletes Oxygen Content in Water*
- Most of the debris in the ocean does not decompose and remain in the ocean for years. It uses oxygen as it degrades. As a result of this, oxygen levels go down. When oxygen levels go down, the chances of survival of marine animals like whales, turtles, sharks, dolphins, penguins for a long time also goes down.

- *Failure in the Reproductive System of Sea Animals*
- Industrial and agricultural wastes include various poisonous chemicals that are considered hazardous for marine life. Chemicals from pesticides can accumulate in the fatty tissue of animals, leading to failure in their reproductive system.

- *Effect on Food Chain*
- Chemicals used in industries and agriculture get washed into the rivers and from there are carried into the oceans. These chemicals do not get dissolved and sink at the bottom of the ocean. Small animals ingest these chemicals and are later eaten by large animals, which then affects the whole food chain.

- *Affects Human Health*
- Animals from impacted food chain are then eaten by humans, which affects their health as toxins from these contaminated animals get deposited in the tissues of people and can lead to cancer, birth defects or long-term health problems.

- Tuholske and his team overlaid their wastewater pollution map atop coral and seagrass areas around the world. They found that 56% of the planet's coral reefs and 88% of its seagrass meadows are exposed to nitrogen in wastewater, predominantly due to direct and septic wastewater inputs.[18]

How to dispose of Wastewater and Sewerage

A sewerage system, or wastewater collection system, is a network of pipes, pumping stations, and appurtenances that convey sewage from its points of origin to a point of treatment and disposal. There are combined systems and separate ones. Systems that carry a mixture of both domestic sewage and storm sewage are called combined sewers. Combined sewers typically consist of large-diameter pipes or tunnels, because of the large volumes of storm water that must be carried during wet-weather periods. They are very common in older cities but are no longer designed and built as part of new sewerage facilities. Because wastewater treatment plants cannot handle large volumes of storm water, sewage must bypass the treatment plants during wet weather and be discharged directly into the receiving water. These combined sewer overflows, containing untreated domestic sewage, cause recurring water pollution problems and are very troublesome sources of pollution.

New wastewater collection facilities are designed as separate systems, carrying either domestic sewage or storm sewage but not both. Storm sewers usually carry surface runoff to a point of disposal in a stream or river. Storm sewers are usually built with sections of reinforced concrete pipe. Corrugated metal pipes may be used in some cases. Storm water inlets or catch basins are located at suitable intervals in a street right-of-way or in easements across private property.

The pipelines are usually located to allow downhill gravity flow to a nearby stream or to a detention basin. Storm water pumping stations are avoided, if possible, because of the very large pump capacities that would be needed to handle the intermittent flows.

Pumping stations are built when sewage must be raised from a low point to a point of higher elevation or where the topography prevents downhill gravity flow. Special non clogging pumps are available to handle raw sewage. They are installed in structures called lift stations. There are two basic types of lift stations: dry well and wet well. The size and capacity of wastewater treatment systems are determined by the estimated volume of sewage generated from residences, businesses, and industries connected to sewer systems as well as the anticipated inflows and infiltration (I&I). The predominant method of wastewater disposal in large cities and towns is discharge into a body of surface water. Suburban and rural areas rely more on subsurface disposal. There are three levels of wastewater treatment: primary, secondary, and tertiary (or advanced).

For all levels of wastewater treatment, the last step prior to discharge of the sewage effluent into a body of surface water is disinfection, which destroys any remaining pathogens in the effluent and protects public health. . Ultraviolet radiation, which can disinfect without leaving any residual in the effluent, is becoming more competitive with chlorine as a wastewater disinfectant.

Offsetting Revenues from Alternative Uses of Wastewaters

- Obviously Less Developed Countries have allocated low priorities to the effects of sewerage on the ocean – however there are ways in which costs of the above-described expensive systems can be offset**.** Wastewater can be used for **nutrient farming and making fertilisers**. Australia has proven it can use convert human waste into fertilisers.

- Given that wastewater is rich in nutrients and other chemicals, sewage treatment facilities have gained recognition as resource recovery facilities, overcoming their former reputation as mere pollution mitigation entities.

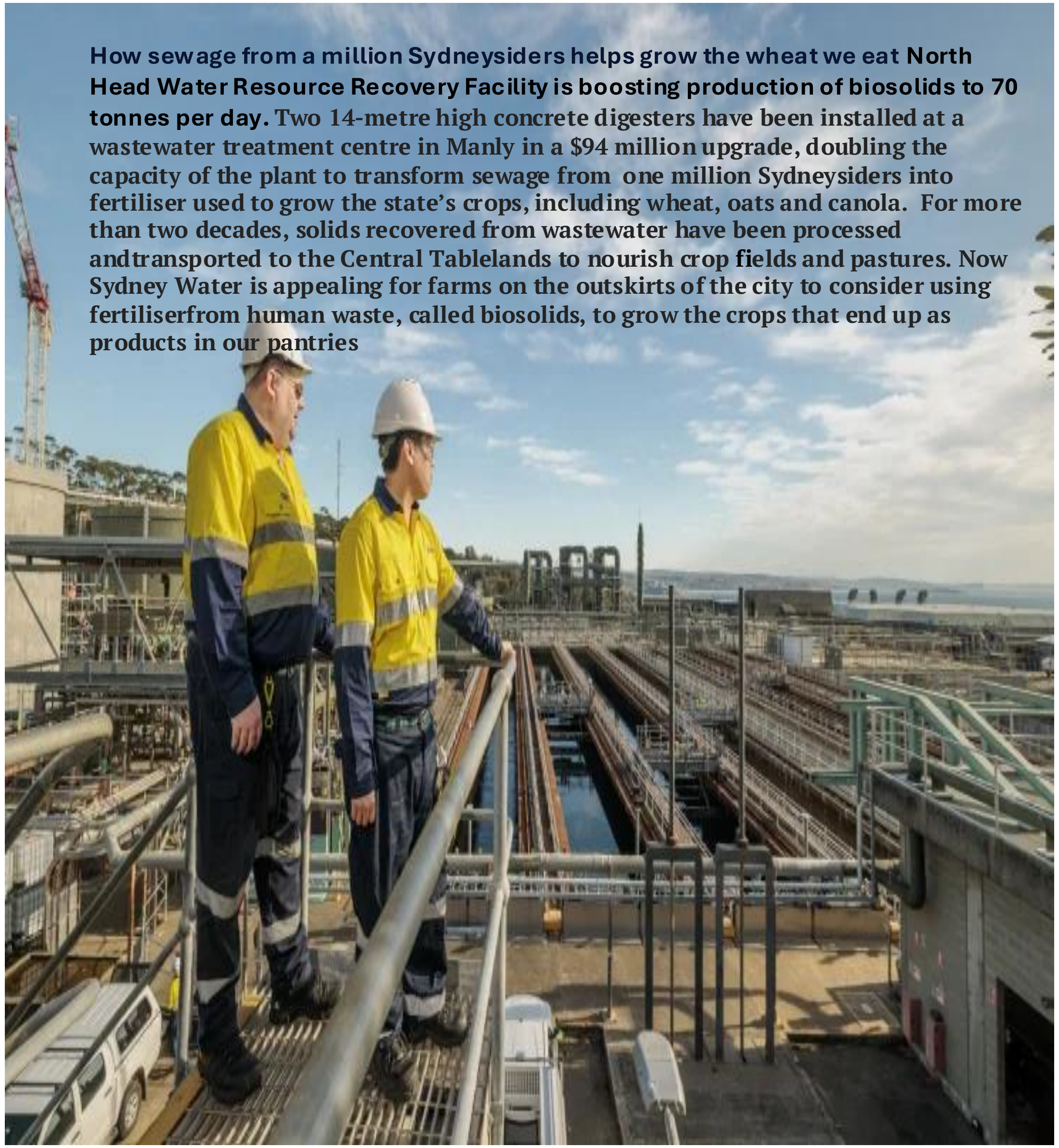
- Wastewater can be a valuable resource in cities or towns where population is growing, and water supplies are limited. In addition to easing the strain on limited freshwater supplies, the reuse of wastewater can improve the quality of streams and lakes by reducing the effluent discharges that they receive. Wastewater may be reclaimed and reused for crop and landscape irrigation, groundwater recharge, or recreational purposes. Reclamation for drinking is technically possible, but this reuse faces significant public resistance.

- There are two types of wastewater reuse: direct and indirect. In direct reuse, treated wastewater is piped into some type of water system without first being diluted in a natural stream or lake or in groundwater.

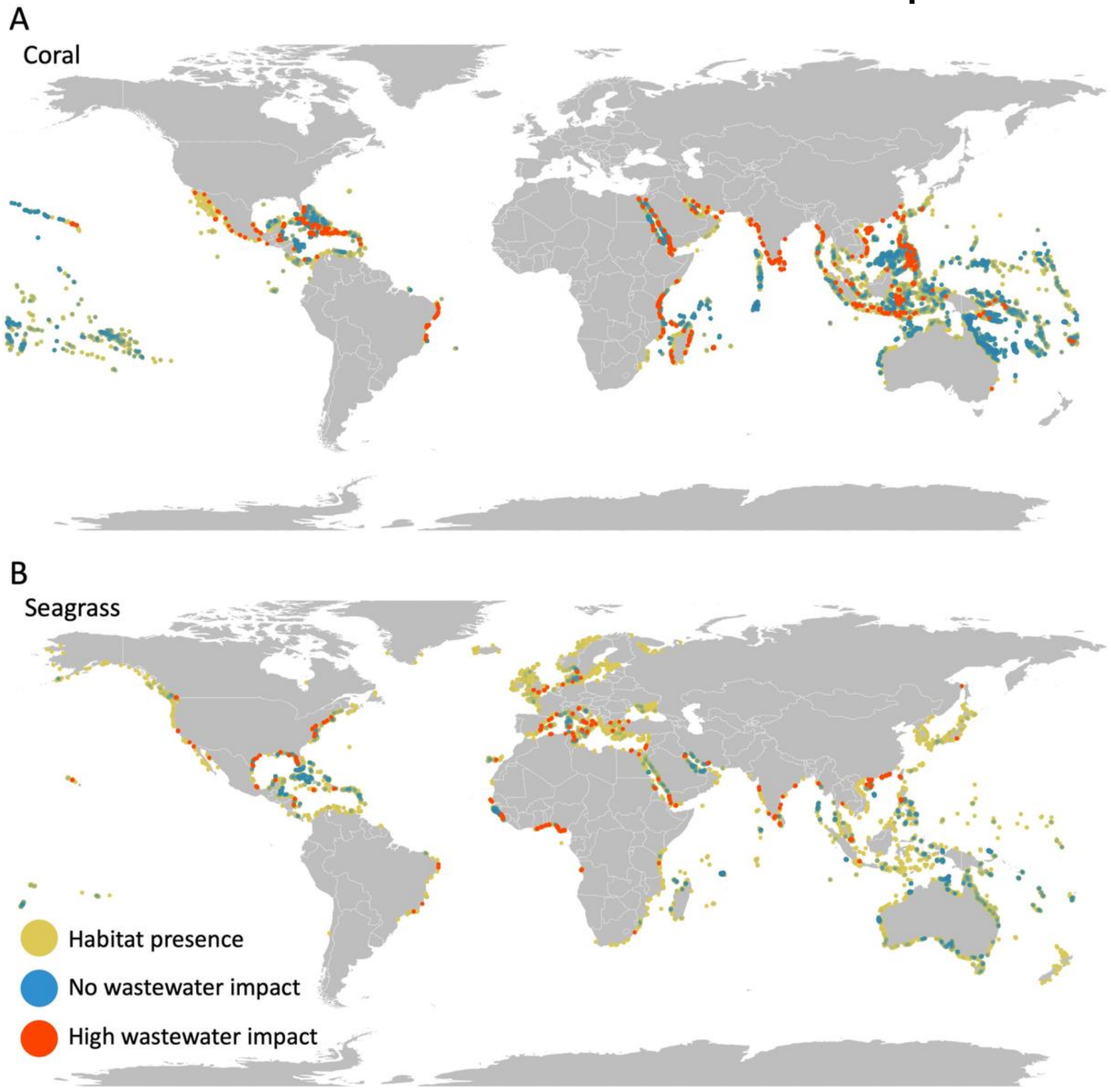
- Indirect reuse is also accomplished by discharging reclaimed wastewater into a groundwater aquifer and later withdrawing the water for use. Discharge into an aquifer (called artificial recharge) is done by either deep-well injection or shallow surface spreading.

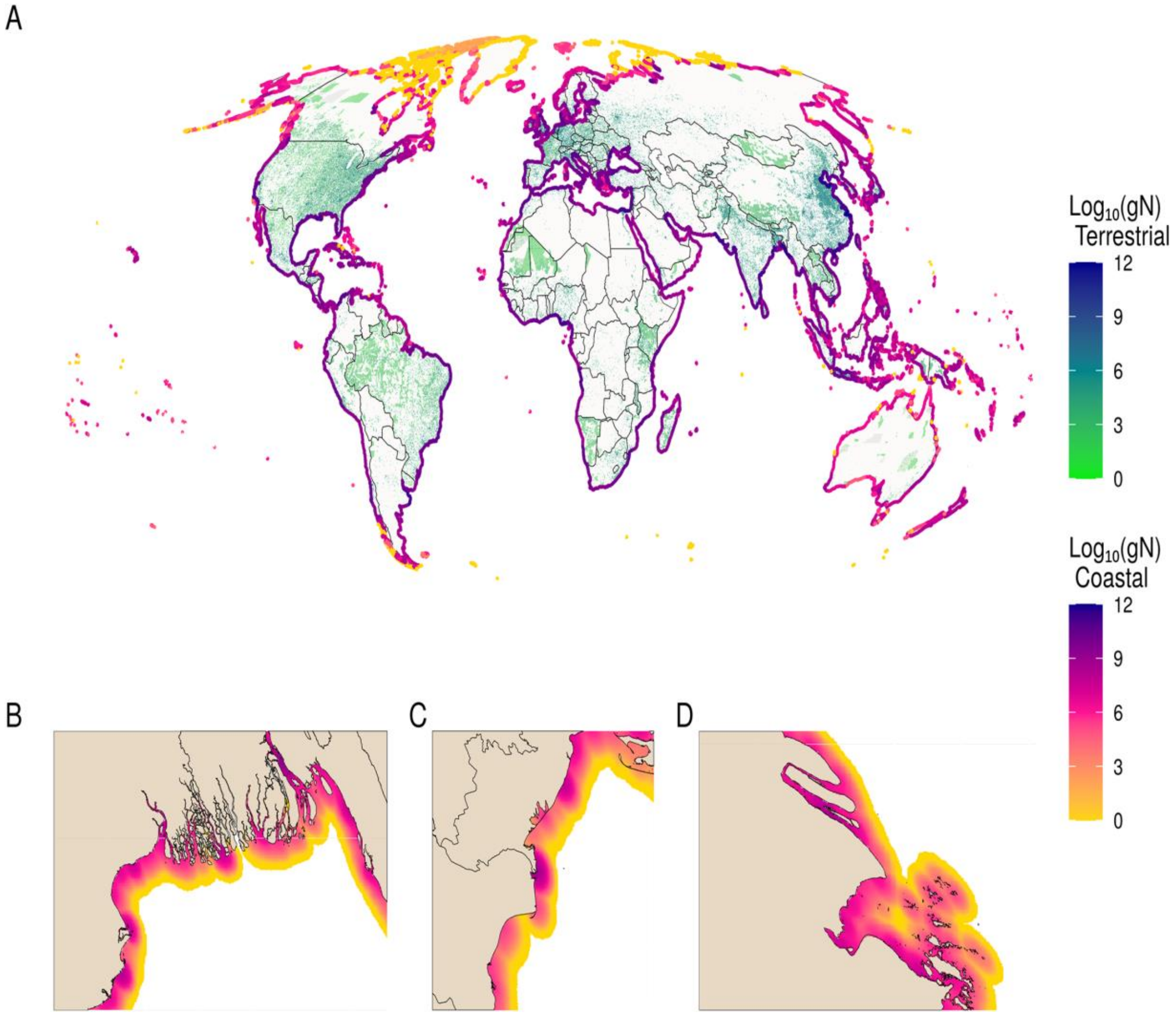
- Quality and treatment requirements for reclaimed wastewater become more stringent as the chances for direct human contact and ingestion increase. The impurities that must be removed depend on the intended use of the water. For example, removal of phosphates or nitrates is not necessary if the intended use is landscape irrigation. If direct reuse as a potable supply is intended, tertiary treatment with multiple barriers against contaminants is required. The use of grey-water recycling systems in new commercial buildings offers a method of saving water and reducing total sewage volumes.

- There are a variety of ways to use heat energy of municipal sewage, the most effective of which is to use sewage. That is, release the excess heat in the building into the city sewage through the unit in summer and extract and release it into the building in winter. (Huber Technology)



Wastewater Impact and Image of Ocean pollution





Legislation governing Pollution of the oceans.

- Around 2/3rds of the oceans are considered international waters beyond the boundaries of any country. The 'high seas' however are not lawless. Seafarers, ships, companies and countries are all subject to maritime law: a system of rules, international agreements and conventions that together govern activities on the high seas. However, countries do have the right to claim 'exclusive economic zones' (EEZs) up to 200 nautical miles from their coastlines. Within these zones, countries have special rights to explore and exploit natural resources, such as fish, oil and gas. While these laws are meant to ensure that no single nation can lay claim to our ocean, they also come with a problem: if 'no one' owns the ocean, who's responsible for caring for them? Outside of these zones, both vessels and countries are subject to maritime law.

- Maritime law is a system of laws, conventions and regulations that govern activities on the seas and oceans. It covers a wide range of issues, from navigation, shipping, seafarer welfare and piracy to fishing, marine pollution and conservation. One of the principles of maritime law is the freedom of the high seas. This principle means that all countries have the right to use the oceans for navigation, fishing, and other activities without interference from others. The ocean is free for all. But there is a counter to this. The United Nations Convention on the Law of the Sea, adopted in 1982, recognises that the ocean is the 'common heritage of humankind', and that 'No State shall claim or exercise sovereignty or sovereign rights over any part of the Area or its resources'. While the ocean is free for all, it should not be *a* free for all, open to exploitation and abuse. Major challenges around ratifying and enforcing the UN Convention on the Law of the Sea remain, and it has limited influence over what individual countries choose to do within their own exclusive economic zones and what occurs beyond.

- One potential answer to that question came in 2023 with the passing of the UN High Seas Treaty – officially known as the *International legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction.*

- This treaty allows for the creation of a network of marine protected areas, designed to 'protect, preserve, restore, and maintain biodiversity and ecosystems. This could aid the campaign to protect 30 per cent of the ocean by 2030, one of the key targets of the UN's 17 Sustainable Development Goals for 2030.The treaty also requires countries to conduct Environmental Impact Assessments (EIAs) on planned marine activities such as deep sea mining before they are authorised. This is designed to lead to better understanding of human impacts on the ocean, and challenge actions 'that may cause substantial pollution of or significant and harmful changes to the marine environment'. The High Seas Treaty has been called a 'breakthrough' for international conservation efforts and marine diversity. But there is still work to be done: countries must first legally adopt the agreement and then work together to implement the treaty's requirements.

- However, each country is responsible for its own sewage treatment and wastewater and the performance of our most advanced nations is reviewed below and shown to be flawed. Moreover, the UN Treaty offers no assistance to those Less Developed Countries with flawed methods of treating sewerage and wastewaters.

- **A Huge Gap in International Regulation of Shipping**

- It has been estimated that 20 million people are using leisure ships. There are two main problems with current international sewage regulation. First, ships are allowed to dump *untreated* sewage into the ocean if they are further than 12 nautical miles from the coast. Think about that. Raw sewage can be dumped into most of the ocean[25]

The necessity for a system of Oceanic Governance - Saving our oceans with a new Regulatory Model

- As has been pointed out before, but which is still not accepted let alone understood by the vast majority, is that even if we employed techno-fixes such as Bill Gates' *Solar Radiation Management Company*, it would not stop climate change's evil twin, ocean acidification, which is threatening to collapse the entire marine ecosystem. A recent paper by marine biologists and environmental consultants has warned that human society faces extinction if nothing is done to reverse the destruction of the oceans.

As a result of many years of negotiation the gap in regulation will hopefully be remedied from 2023 onwards by The High Seas Treaty, which was signed in New York on 20 September, during the United Nations High Level Week[27]. The treaty started in June 2023 as an agreement under the United Nations Convention on the Law of the Sea (UNCLOS) on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction. Areas beyond national jurisdiction comprise the high seas and the seabed beyond national jurisdiction.

So, although as of 2023 we have a 2023 UN Treaty on the Seas we have no regulatory model to police it. The second paper in this series reviews the challenges and limitations of this Treaty proposing an alternative governance model, which should be urgently considered in view of the necessity for all signing nations to enact it into their own national legislation in order for it to become legally binding.