Human Influences

on our Environment

Sup#2.0

Air Pollution

Through the release of polluting gases, we negatively impact both the environment and us.

H_2O

water vapour

sources	evapotranspiration
impacts	condensation
potency	amplifies others
concentration	very high, varying 10~50000ppm
overall effect	very high

Plants lose water through the stomata in their leaves due to transpiration.

Surprisingly, water in its gaseous state is indeed a greenhouse gas; in fact, it contributes the most of any to the greenhouse effect – up to 70%, nearly thrice as much as carbon dioxide's peak of 25%. However, unlike other greenhouse gases, water vapour is almost entirely natural, and is dependent on the temperature itself.

But therein lies the problem. The higher temperatures rise, the more water vapour that enters the atmosphere through evapotranspiration. Warmer air can hold more moisture, and so there is a greater amount of water vapour in the atmosphere. As well as being potent at trapping heat itself, water vapour amplifies the effects of other greenhouse gases too. This in turn leads to higher temperatures, and so forms a positive feedback loop.

CO

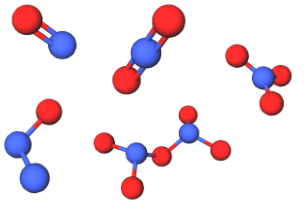
carbon monoxide

sources	incomplete combustion
impacts	poisoning
potency	may amplify others
lifespan	very short ~60d
concentration	very low ~90ppm
overall effect	dangerous

Carbon monoxide does not classify as a greenhouse gas, but is still very much a pollutant. Inhalation can be fatal. It binds *permanently* to haemoglobin in the body's erthrocytes (red blood cells), thus preventing them from being able to carry oxygen. At high enough concentrations, the body will not be able to supply enough blood, inducing comas, seizures and death.

Similarly to water vapour, carbon monoxide can exacerbate the effects of other greenhouse gases. It reacts with hydroxyl (OH) radicals in the atmosphere, which are helpful in reducing the lifetimes of certain greenhouse gases. This reduces their abundance, and so those gases will stay in the atmosphere for much longer. Carbon monoxide can also lead to increased formation of ozone.

Nitrogen oxide refers to the different binary compounds of nitrogen and oxygen, which can have any number of nitrogen and oxygen atoms. Each is produced from different sources and has varying effects on the environment and organisms. Most are highly reactive, and some are very potent greenhouse gases, with significant atmospheric lifetimes, while others damage the environment in other ways.



Nitrogen can form a multitude of different oxides.

NO_x

nitrogen oxides

sources	lightning, fertilizers
impacts	acid rain, smog
potency	very high 265
lifespan	moderate 121y
concentration	low 333ppb
overall effect	moderate

Of particular concern are nitrous oxide (N_2O) and nitric oxide (NO). N_2O is the potent greenhouse gas, also known as 'laughing gas'. It is primarily released through exhaust emissions and nitrate fertilizers. NO is not a greenhouse gas, but still has major impacts, causing acid rain and ozone depletion, and acts as a precursor to NO_2.

Sulphur dioxide is naturally ejected into the stratosphere through volcanic eruptions, where it aerosolizes into fine particulates. Especially major eruptions may cover the globe with these, which shade incoming solar radiation and cause a global cooling effect. This helps to somewhat alleviate global warming, although only slightly.

Acid rain can have devastating impacts on ecosystems.

SO_2

sulphur dioxide

sources	volcanic eruptions, coal
impacts	acid rain, particulates
lifespan	extremely short ~10d
concentration	low ~1ppm
overall effect	dangerous

$SO_2 + OH + O_2 \rightarrow SO_3 + HO_2$

$SO_3 + H_2O \rightarrow H_2SO_4$

The formation of sulphuric acid (slightly simplified).

Most of the time sulphur dioxide is a highly toxic and harmful pollutant. Inhalation results in severe health effects for both humans and animals. More importantly, sulphur dioxide reacts with water particles in the air to form sulphuric acid, otherwise known as acid rain. When this falls it acidifies the soil, inhibiting plants from absorbing essential nutrients.

Smog consists of nitrogen oxides, sulphur oxides, ozone, smoke and other particulates. Evidently, it's not great for your health.

O_3

ozone

sources	UV exposure, exhausts
impacts	UV protection, poisoning
potency	very low ~0.3
concentration	moderate 2~8ppm
overall effect	low

Ozone in the stratosphere forms a surface known as the ozone layer, which is essential to life on earth. It protects us from ultraviolet radiation, utilizing the energy from the rays to cycle between oxygen and ozone.

Industrial chemicals, mainly chloroflurocarbons, deplete the ozone layer by reacting with the ozone molecules. As a result, we are exposed to more ultraviolet radiation. At the same time, the increased exposure also leads to more low-level ozone being formed. Volatile organic compounds and nitrogen oxides, driven by the energy of the rays, react to produce ozone, which leads to smog.

respiration transport fossil fuels

The major sources of carbon dioxide.

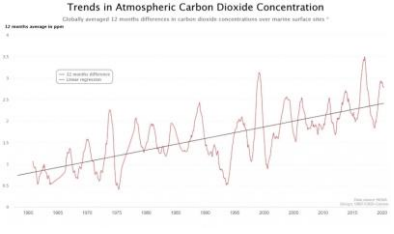
Carbon dioxide is by far the gas humanity emits the most. It is a consequence of almost every aspect of our daily lives, from electricity generation through burning fossil fuels, to transportation such as cars and planes.

CO_2

carbon dioxide

sources	respiration, combustion
impacts	enhanced greenhouse effect
potency	low 1
lifespan	average, varying ~100y
concentration	high 420ppm
overall effect	very high

The most abundant and immediately concerning greenhouse gas. While its potency is low compared to other gases, its much higher concentration more than makes up for it. Aside from being the main contributor to the enhanced greenhouse effect, carbon dioxide dissolves in water to form carbonic acid (H_2CO_3) and carbonate ions (CO_3), which leads to acid rain and acidification of the oceans.



Global carbon dioxide levels rise relentlessly.

$H_2O + CO_2 \rightarrow H_2CO_3$

Formation of acid rain from carbon dioxide.

$C_2H_3O_2 \rightarrow CH_4 + CO_2$

$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

Methane production through methanogenesis.

Archaea, a domain (level above kingdom) of prokaryotes respire anaerobically to produce methane, consuming acetate ions or hydrogen and carbon dioxide in the process.

$NO + HO_2 \rightarrow NO_2 + OH$

$NO_2 + OH \rightarrow HNO_3$

The formation of nitric acid.

CH_4

methane

sources	livestock, methanogenesis
impacts	ignition, explosions
potency	moderate 25
lifespan	short 12y
concentration	average 1900ppb
overall effect	high

Along with carbon dioxide, methane is one of the most problematic greenhouse gases. While there is less of it in the atmosphere, it has a significantly higher global warming potential of 84 over a 20-year period.

Methane is the primary component of natural gas, which is used in homes for heating, refrigeration and cooking. This releases carbon dioxide, though – instead, most methane is released from the belching of livestock. Since the global meat industry is incredibly large, this accumulates to a significant amount of emissions.

CFCs

chloroflurocarbons

sources	industry
impacts	greatly enhanced greenhouse effect
potency	extremely high >10000
lifespan	worryingly high 100~3200y
concentration	low
overall effect	average

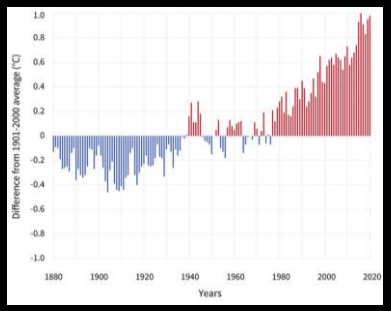
A class of industrial compounds (often haloalkanes), including chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), along with sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). They are commonly sourced from refrigerants, propellants, and solvents. Of all the greenhouse gases, they are by far the most potent, reaching up to 10,000 times the potency of carbon dioxide. Even worse, they remain in the atmosphere for a substantial length of time. As such, many industries have found alternatives to reduce emissions, and they are gradually being phased out.

Greenhouse Effect

Without the greenhouse effect, Earth would be uninhabitable. The same applies if it is amplified too far.

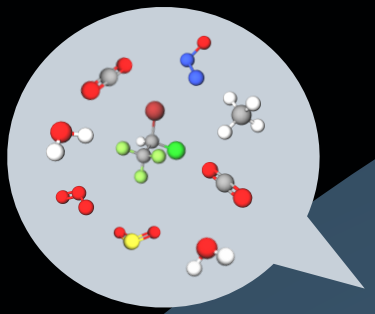
The greenhouse effect is a perfectly natural phenomenon, and highly important. The Earth's atmosphere is unique in that it traps heat energy from the Sun's rays, warming the entire planet by about 30°C. So without it, our planet would be a freezing sphere of ice, extremely unfriendly to life; life on Earth as we know it wouldn't have developed.

However, the enhanced greenhouse effect is a phenomenon caused purely by human activity. Through our lifestyle we emit tonnes of greenhouse gases, which contribute to and exacerbate the greenhouse effect. If allowed to continue, it will lead to serious global warming, resulting in (potentially) catastrophic climate change.



No matter how you put it, there is a clear trend.

The greater the concentration of greenhouse gases in the atmosphere, the more infrared radiation that is absorbed overall, and so the more heat energy that remains trapped within the Earth's atmosphere. Prior to the industrial age, carbon dioxide concentrations remained fairly balanced in the atmosphere, while other highly potent greenhouse gases like nitrous oxide and CFCs weren't present at all. In recent decades, human activity and industry have greatly impacted the concentration of greenhouse gases, especially methane through massive livestock farms, and nitrous oxide through exhaust emissions and increased fertilizer use.



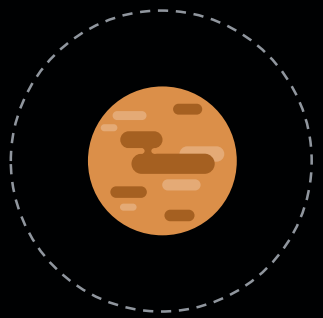
Clouds, which are found in the troposphere layer of the atmosphere, both reflect light and absorb heat. Mid and low-level clouds block sunlight from reaching the ground and reflect it, resulting in a cooling effect. Other light-coloured surfaces do this too, such as snow plains.

High-level clouds, which are becoming more prevalent as temperatures increase and water vapour rises, do quite the opposite, absorbing solar radiation and trapping the heat. As of right now, it is quite uncertain how clouds will impact global warming and climate change in the future.

And then there's also the polar caps melting. With global temperatures rising, land ice and glaciers that have formed over millions of years are steadily melting. The sheet ice that reforms in the Arctic each winter is drastically depleting. This releases huge amounts of water into the oceans, resulting in rising sea levels. In especially low-level settlements, this has meant they've had to migrate – as such, they are known as climate change refugees.

As temperatures rise, it will bring about climate change. The effects are numerous and devastating. Extreme weather events and temperature fluctuations will become more common – droughts, heatwaves, hurricanes and tornadoes – causing widespread disruption and destruction to habitats, ecosystems and also humanity. Organisms will die, and crops will fail, unable to cope with the heat.

Most other planets do not have an atmosphere, which is why they are inhospitable for life.



Sunlight from the Sun reaches the Earth as short-wave solar radiation.

reflected sunlight

The atmosphere is transparent to allow solar radiation to penetrate through. Around 30% is reflected back into space by high albedo surfaces, which help to cool the Earth. The remaining 70% that reaches the Earth's surface is absorbed as heat energy, of which 24% is then re-released as infrared radiation. A large portion of this escapes back into space.

escaped infrared

Heat energy is re-released as long-wave infrared radiation.

released infrared

trapped infrared

Greenhouse gases, such as carbon dioxide and methane, trap heat energy by absorbing the infrared radiation and re-releasing it out in all directions. This means half is released back into space, while the other half radiates back towards the Earth. As a result, more heat energy remains trapped in the Earth's atmosphere, causing global warming.

Calling it the 'greenhouse effect' is actually a flawed analogy, as unlike a greenhouse where the heat is physically trapped, in the case of our atmosphere it is simply re-emitted and dispersed in all directions, which then results in a net warming on the inside. Regardless, it conveys the idea pretty effectively.

Ground & Water Pollution

We damage our Earth much closer to home, through our misuse and exploitation of what it provides us.

eutrophication

Loads of minerals and nutrients sounds great, right? Well, everything in moderation. An excess of them in aquatic ecosystems, known as nutrient pollution, can be disastrous. In particular, nitrogen and phosphorus provide the perfect conditions for algae, phytoplankton and other micro-organisms to explode in numbers.

Often, factories and manufacturing plants will directly dump waste into nearby rivers. This is exceedingly polluting, making conditions uninhabitable for many organisms, and deposits heaps of nutrients into the river stream. As these flow downstream, the impacts become apparent.

Sewage is released into the river.

The nutrients allow algae and phytoplankton to explode in numbers.

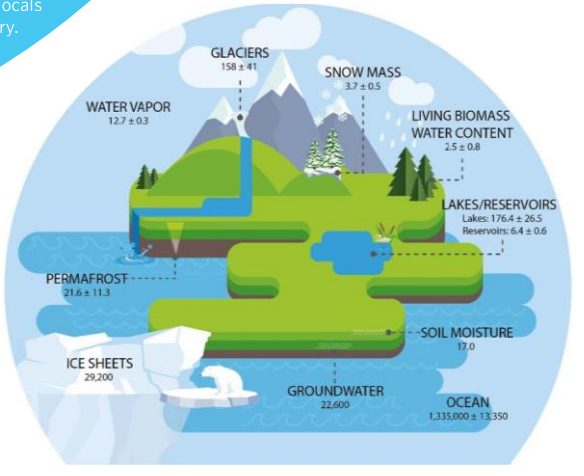
Waste is also harmful due to encouraging bacterial growth.

Eutrophication is bad and all, but of course polluted water in the river is a major problem too! The river is no place to dump rubbish, especially not toxic or concentrated industrial sewage.

Most rivers will eventually lead to the sea, spewing all the polluted water into the oceans. Freshwater rivers that may have previously been used by locals are now dirty and unsanitary.

All these thriving organisms respire, consuming large amounts of precious oxygen. This leaves the fish deprived, and their numbers soon deplete. Overall, there is a severe loss of biodiversity in the river ecosystem.

Pesticides have been used increasingly often to combat pests.



The distribution of water in Earth's various stores.

pesticides

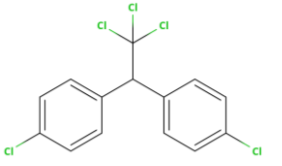
A striking example of how human intervention in nature can have undesirable consequences is the use of pesticides. In the modern age of monoculture, where expansive fields of a single crop are grown at high densities, pests can quickly become a troublesome issue.

Surprisingly, sometimes using pesticides is more harmful than not. Many powerful pesticides are indiscriminate, killing both the pests and their natural predators, which help to keep them under control.

Pests invade and feed on crops, quickly multiplying.

pesticides are used. › pests and predators alike are eliminated. › without predators to hunt them, the pests return in full force. › helpless, farmers use even more pesticides. › the vicious cycle continues.

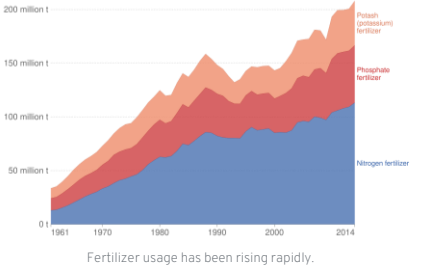
Without natural predators to control their numbers, the pests are able to multiply much faster, and may even become immune to the pesticide being used. To combat this, many farmers will simply spray even more pesticide. This leads to a vicious cycle. On the other hand, leaving the natural predators to do their thing, or introducing a new organism that feeds on the pest, can be far more effective than spamming pesticides. Although, care must be taken to ensure the organism *only* feeds on the pest, to ensure the rest of the ecosystem is not disrupted. This is known as biological control.



DDT (dichlorodiphenyltrichloroethane), an infamously deadly pesticide.

fertilizers

Similar to eutrophication and pesticides, fertilizers are another way in which human interventions impact the environment. In an effort to help their crops grow more effectively, and to counteract the lack of nutrients in the soil after being drained dry by previous crops, farmers will often use excessive amounts of fertilizers. These release nitrate ions, among others, into the soil. If these get washed into the river, they will lead to the issues of eutrophication. Some may also get released into the air through the nitrogen cycle, forming various nitrogen oxides that have numerous harmful effects.



Fertilizer usage has been rising rapidly.

Deforestation & Pesticides

Trees are often said to be the 'lungs of the planet'.

deforestation

The ultimate and most destructive way in which we damage the environment. Trees are arguably the most vital organisms on our planet, yet we ruthlessly cut them down, to clear space for settlements, agriculture and manufacturing. This has pronounced effects on both the ecosystems in which they reside, and the entirety of the globe.

Deforestation greatly disrupts the harmony of the forest ecosystem. Trees not only provide essential habitats for a variety of species, but are integral to preventing floods and landslides, and maintaining the balance of the water cycle. Most importantly of all, the leaves of trees photosynthesize, using carbon dioxide to form starch, releasing oxygen in the process. Trees are the key to capturing and reversing all the carbon dioxide that has been polluting the atmosphere over the years.

root support photosynthesis water cycle

The importance and major benefits of trees.

Trees play an important role in the water cycle. The canopy blocks rainfall as it travels down, reducing the amount that reaches the soil. This lowers the likelihood of large floods occurring due to excess rainfall. It also prevents soil erosion and leaching, where the surface soil is degraded, with soil and minerals being washed away. All plants require water, and trees absorb vast amounts of water from the soil through their roots. Again, this helps to control floods and soil erosion. The trees then lose this water through transpiration, continuing the water cycle.