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ATMOSPHERIC CHEMISTRY AND CLIMATE IN THE ANTHROPOCENE[3]

CHEMIA ATMOSFERYCZNA I KLIMAT W ANTROPOCENIE

Abstract: Humankind actions are exerting increasing effect on the environment on all scales, in a lot of ways overcoming natural processes. During the last 100 years human population went up from little more than one to six billion and economic activity increased nearly ten times between 1950 and the present time. In the last few decades of the twentieth century, anthropogenic chlorofluorocarbon release have led to a dramatic decrease in levels of stratospheric ozone, creating ozone hole over the Antarctic, as a result UV-B radiation from the sun increased, leading for example to enhanced risk of skin cancer. Releasing more of a greenhouse gases by mankind, such as CO_2, CH_4, NO_x to the atmosphere increases the greenhouse effect. Even if emission increase has held back, atmospheric greenhouse gas concentrations would continue to raise and remain high for hundreds of years, thus warming Earth's climate. Warming temperatures contribute to sea level growth by melting mountain glaciers and ice caps, because of these portions of the Greenland and Antarctic ice sheets melt or flow into the ocean. Ice loss from the Greenland and Antarctic ice sheets could contribute an additional 19-58 centimeters of sea level rise, hinge on how the ice sheets react. Taking into account these and many other major and still growing footprints of human activities on earth and atmosphere without any doubt we can conclude that we are living in new geological epoch named by P. Crutzen and E. Stoermer in 2000 - "Anthropocene". For the benefit of our children and their future, we must do more to struggle climate changes that have had occurred gradually over the last century.

Keywords: greenhouse gases, greenhouse effect, climate changes, ozone hole, Anthropocene

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ORIGINS

Photo shows Prof. Paul Crutzen more than 70 years ago on the lap of his grandmother.

HUMAN FOOTPRINT

- **During the past 3 centuries human population has increased tenfold to 6000 million and fourfold in the 20th century [1, 2].**
- **Cattle population increased to 1400 million (one cow/family); by a factor of 4 during the past century [3].**
- **There are currently some 20 billion (20,000 million) of farm animals worldwide [4].**
- **Urbanisation grew more than tenfold in the past century; almost half of the people live in cities and megacities [5, 6].**
- **Industrial output increased 40 times during the past century; energy use 16 times [7].**
- **Almost 50% of the land surface has been transformed by human action [8].**

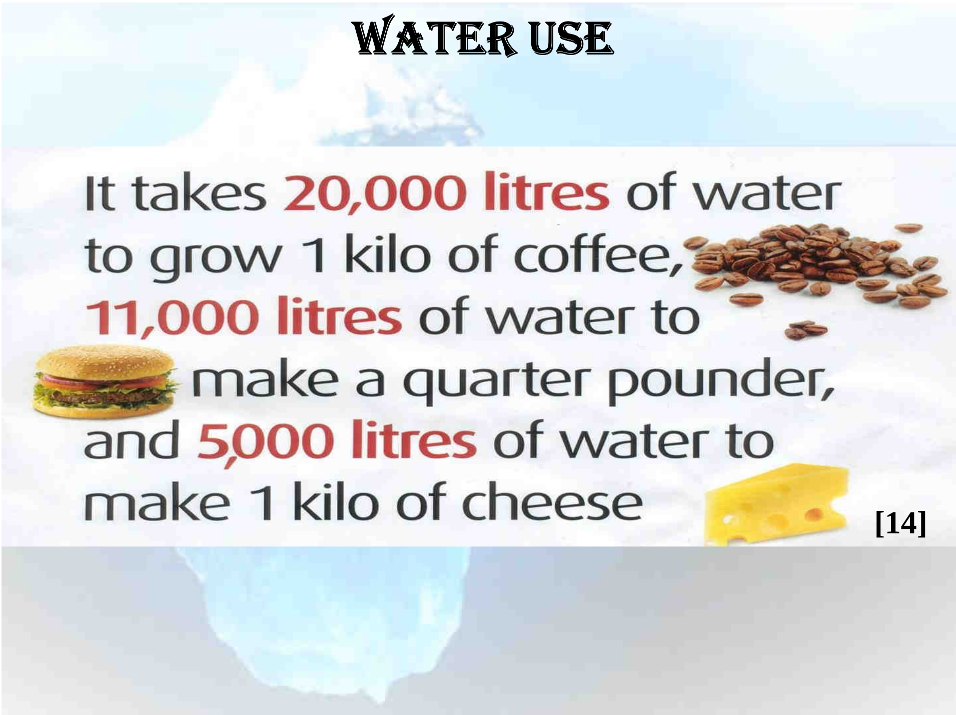
HUMAN FOOTPRINT

- **Fish catch increased 40 times**
- **The release of SO_2 (110 Tg/year) by coal and oil burning is at least twice the sum of all natural emissions; over land the increase has been 7 fold, causing acid rain, health effects, poor visibility, and climate changes due to sulfate aerosols [9].**
- **Releases of NO to the atmosphere from fossil fuel and biomass burning is larger than its natural inputs, causing regional high surface ozone levels [10].**
- **Several climatically important ”greenhouse gases” have substantially increased in the atmosphere, *eg* CO_2 by 40%, CH_4 by more than 100% [10, 11].**

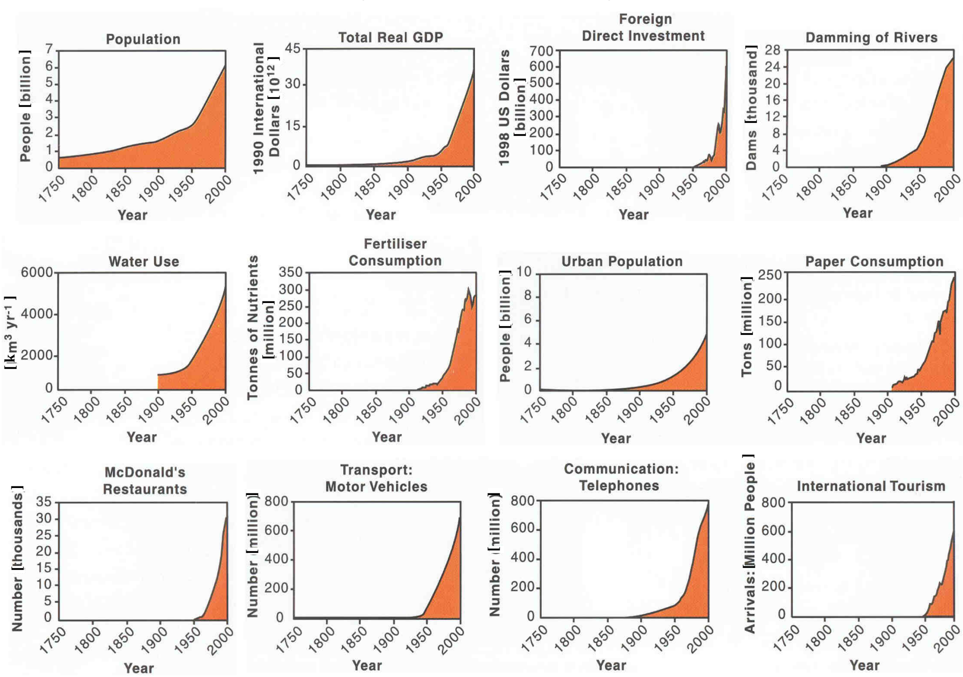
WATER USE

Water use increased 9 fold during the past century to 800 m^3 per capita/year; 65% for irrigation, 25% industry, ~10% households [12].

1 kilo of meat → 16,000 litres of water
1 kilo of grain → 1,000 litres of water [13]



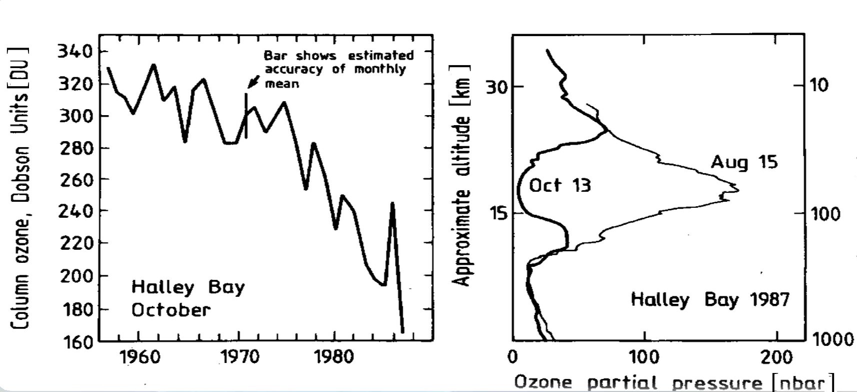
THE GREAT ACCELERATION [15]



OZONE HOLE

- **Humanity is also responsible for the presence of many toxic substances in the environment and even some which are not toxic at all, but which have, nevertheless, led to the ozone hole [16].**
- **Among the „greenhouse gases“ are also the almost inert CFCs (chlorofluorocarbons) gases. However, their photochemical breakdown in the stratosphere gives rise to highly reactive chlorine and bromine gases (radicals), which destroy ozone by catalytic reactions. As a consequence UV-B radiation from the Sun increases, leading for instance to enhanced risk of skin cancer [17].**

OZONE HOLE



[18]

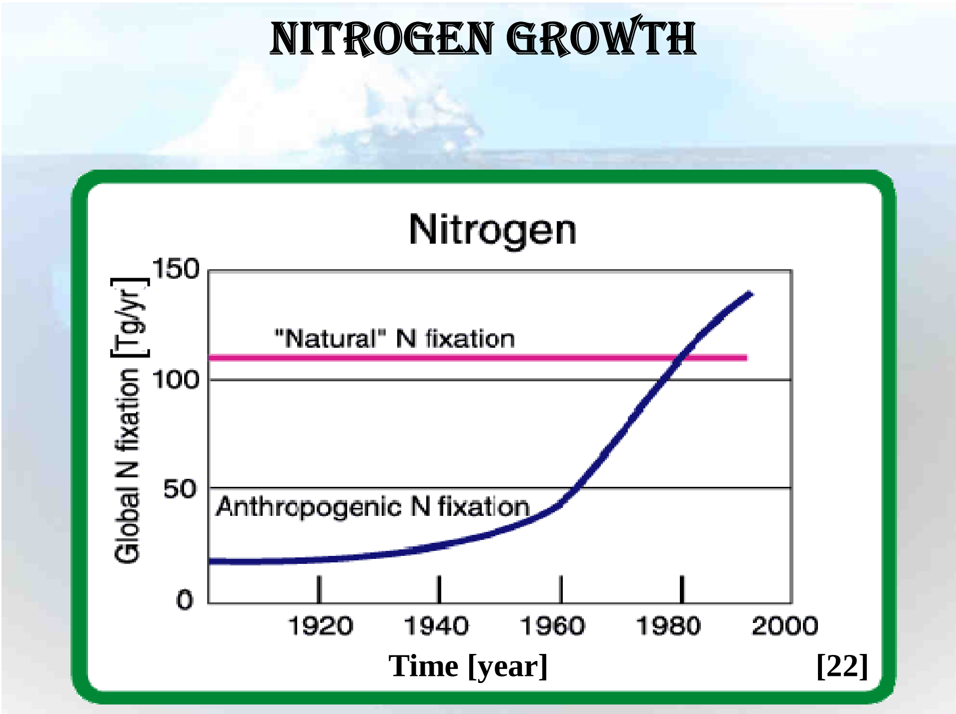
Fortunately, the CFC gases are no longer produced, but it will take 50 years or more to heal the ozone hole [19].

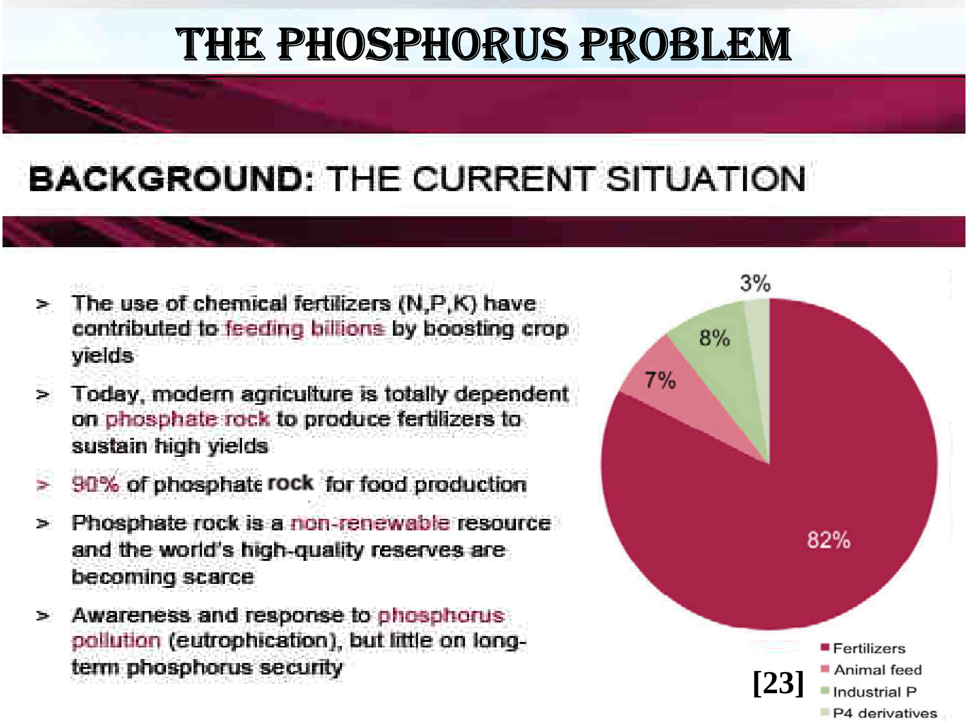
HUMAN FOOTPRINT

- **E.O. Wilson: „Before humans existed, the species extinction rate was (very roughly) one species per million species per year. Estimates for current species extinction rates range form 100 to 10,000 times that, but most hover close to 1,000 times prehuman levels (≈ 10% per century)”.**
- **S.R. Palumbi [20]: „Mankind also effects evolutionary change in other species, especially in, commercially important, pest and disease organisms, through antibiotica and pesticides. This accelerated evolution costs at least $33 billion to $50 billion a year in the United States”.**

MAN THE ERODER

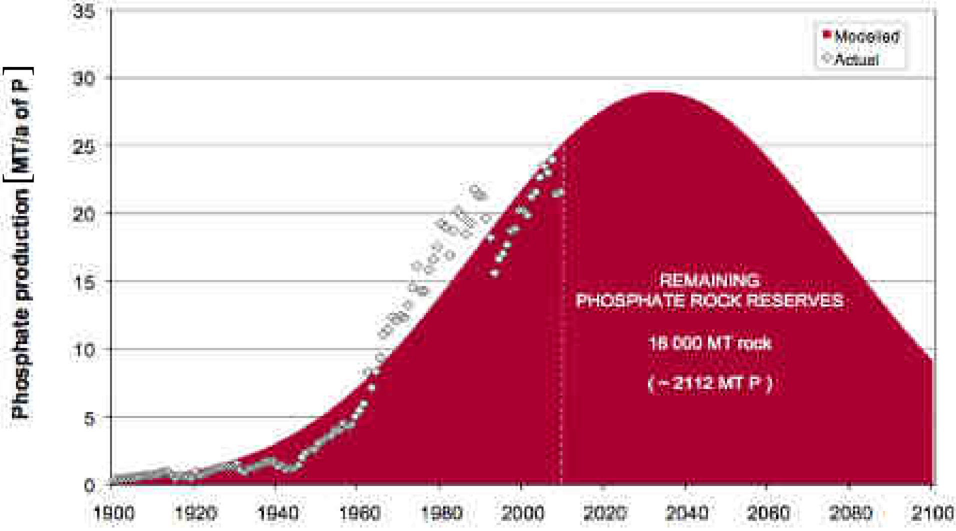
- **Man-caused erosion (crop tillage, land conversion for grazing and construction): 15 times natural erosion [21].**
- **At current rate anthropogenic soil erosion would fill the Grand Canyon in 50 years [21].**


NITROGEN GROWTH
Nitrogen
150
100
50
0
Global N fixation [Tg/yr]
"Natural" N fixation
Anthropogenic N fixation
1920
1940
1960
1980
2000
Time [year]
[22]


THE PHOSPHORUS PROBLEM
BACKGROUND: THE CURRENT SITUATION
> The use of chemical fertilizers (N,P,K) have contributed to feeding billions by boosting crop yields
> Today, modern agriculture is totally dependent on phosphate rock to produce fertilizers to sustain high yields
> 90% of phosphate rock for food production
> Phosphate rock is a non-renewable resource and the world's high-quality reserves are becoming scarce
> Awareness and response to phosphorus pollution (eutrophication), but little on long-term phosphorus security
3%
8%
7%
82%
Fertilizers
Animal feed
Industrial P
P4 derivatives
[23]

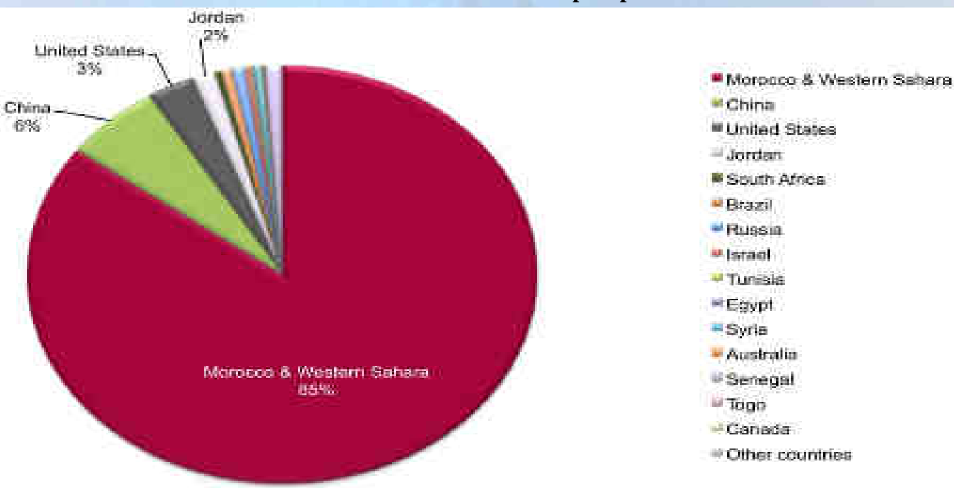
THE PHOSPHORUS PROBLEM [24]

The story of phosphorus: Global food security and food for thought



THE PHOSPHORUS PROBLEM [24]

Share of global reserves of phosphate rock. **Four countries control around 80 % of the world‘s phosphate rock reserves.**



HUMAN FOOTPRINT

- **Dead zones in coastal oceans have spread exponentially since the 1960s due to eutrophication fueled by runoff of fertilizers and burning of fossil fuels [25].**

ANTHROPOCENE

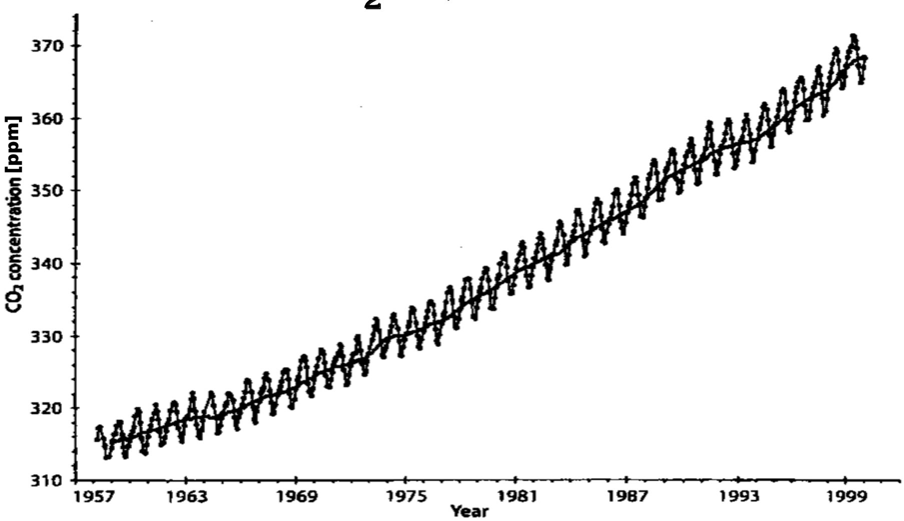
Since the beginning of the 19th Century, by is own growing activities, Mankind opened a new geological epoch: the Anthropocene.

We are clearly affecting climate and can deliberately do so.

ANTHROPOCENE

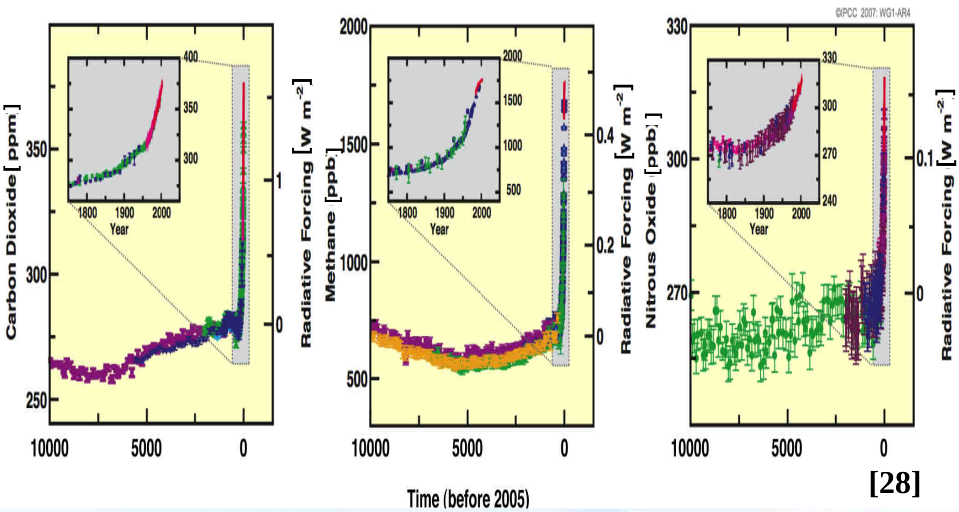
The impact of humans on global economy and environment has undergone major stepwise expansions, especially during the second half of the past century. Expansion of mankind, both in numbers and per capita exploitation of Earth's resources has been astounding.
Considering many still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, Paul J. Crutzen and Eugene F. Stoermer [26] in their publication from 2000 proposed the term „anthropocene" for the current geological epoch to emphasize the central role of mankind in geology and ecology. The impacts of current human activities will continue over long periods.

CO_2 GROWTH



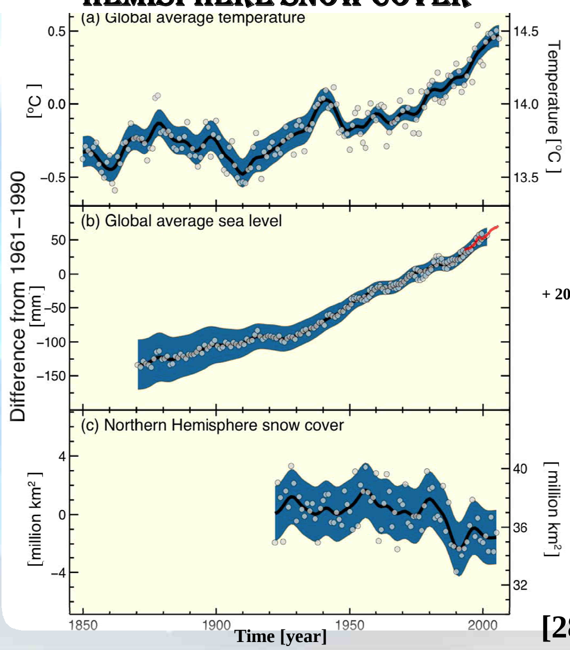
The „Keeling curve", showing the steady increase in atmospheric CO_2 concentration recorded monthly at Mauna Loa in Hawaii, 1958-1999 (adapted from [27])

CHANGES IN GREENHOUSE GASES FROM ICE-CORE AND MODERN DATA



[28]

CHANGES IN TEMPERATURE, SEA LEVEL AND NORTHERN HEMISPHERE SNOW COVER



+ 0.76°C (2001-2005) – (1850-1899)

+ 20cm

[28]

GREENHOUSE EFFECT

IPCC (2007) [28]:
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
Average global surface temperature rise 2.0-4.5°C (1.1-6.4°C) by 2100.
Sea level rise 19-58 cm by 2100; S. Rahmstorf [29]: 0.5-1.4 m by 2100.

REDISTRIBUTION OF PRECIPITATION

Enhanced risk for extreme weather (flooding, desertification)?

Increase in heat waves in Europe, as in the summer of 2003?

Too rapid climate changes, so that ecosystems cannot adapt.

Melting permafrost: Additional release of CO_2 and CH_4 [30]?

W. Broecker: super-interglacial?

ACIDITY

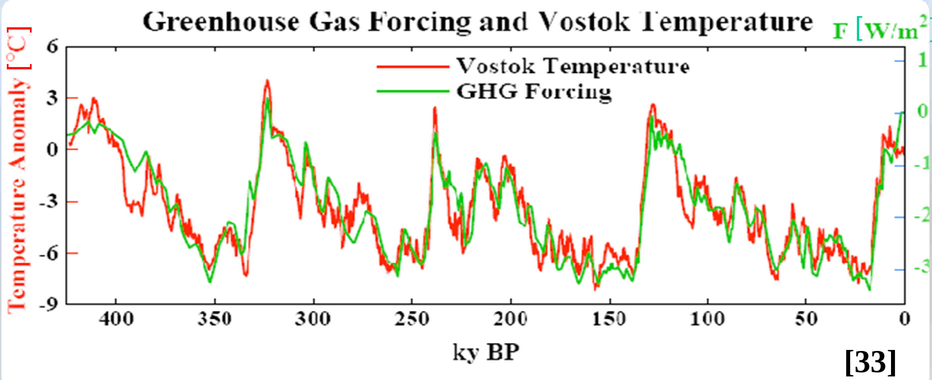
- **Acidity of ocean water increased by 0.1 pH units, hindering carbonate-secreting organisms building their skeletons [31].**

HUMAN-MADE EMISSIONS

Stabilisation of Atmospheric Concentrations. Reductions in the human-made emission required to stabilise concentrations at current levels

Greenhouse Gas	**Reduction Required**
Carbon Dioxide	**> 60%** [32]
Methane	**(achieved, but long term stabilisation is uncertain for instance by thawing of permafrost)**
Nitrous Oxide	**70-80%** [32]
CFC-11	**achieved**
CFC-12	**achieved**

TEMPERATURE ANORMALY



[33]

ARCTIC CLIMATE

- **„New studies indicate that the Arctic oceans ice cover is about 40% thinner than 20-40 years ago“ [34].**
- **There is dramatic climate change happening in the Arctic, about 2-3 times the pace for the whole globe: Robert Corell, Chairman of the Arctic Climate Impact Assessment, November 2004 [35].**
- **Melting of permafrost, causing releases of CO_2 and CH_4 [30].**
- **2008: For first time commercial ships through northwest and northeast passages.**

HUMAN FOOTPRINT

•Wastes: Only 20-30% of N fertilizer is taken up by plants [36].
Only about 50% of food produced is consumed.

Future agriculture: Loss of agricultural soil through erosions is a serious problem. Even worse is the loss of phosphorous. Some studies indicate dangerous depletion in agricultural regions (tropics).

From generation to generation the effect of human activities is accumulating and even accelerating. No other specie has developed in this matter.

Mankind only species that produces weapons of mass destruction (nuclear, chemical, biological).
Mankind will remain a major environmental force for many millennia. A daunting task lies ahead for scientists and engineers to guide society towards environmentally sustainable management during the era of the Anthropocene. This will require appropriate human behaviour at all scales.

CAN WE CHANGE?

Living up to the Anthropocene means building a culture that grows with Earth's biological wealth instead of depleting it. In this new era, nature is us [38].

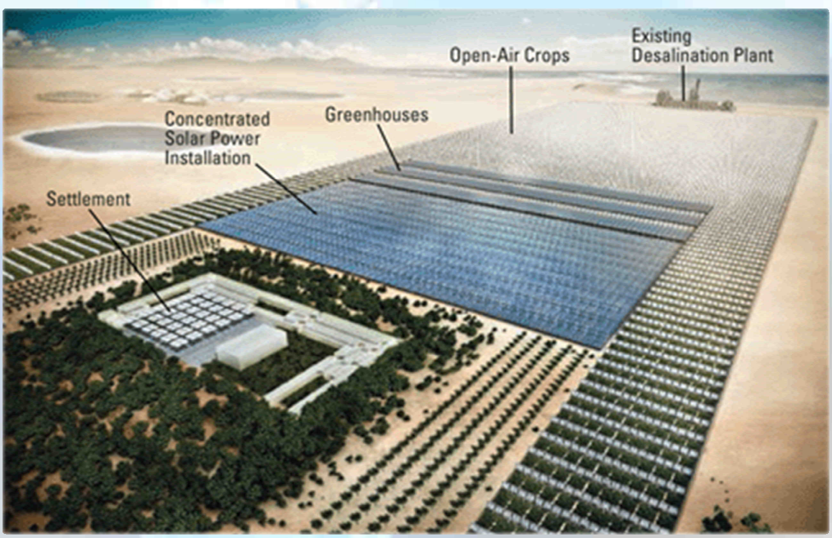
PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	To be determined		
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof	To be determined		

[38]

Boundaries for processes in red have been crossed. Data sources: ref. 10 and supplementary information

WE CAN CHANGE



Just add water. SFP's combination of technologies coaxes crops, electricity, and fresh water from unproductive desert [39].

FOR THE BENEFIT OF CHILDREN AND THEIR FUTURE

Photo shows Prof. Paul Crutzen in 1999 together with his then two-year old grandson Jan Oliver.

CONCLUSIONS

- **Since the beginning of the 19th century, by his own growing activities, Mankind opened a new geological epoch: the Antropocene;**
- **During the last 100 years Mankind impact on the environment is enormously big;**
- **Concentration of „greenhouse gases" have substantially increased in the atmosphere causing *ia* rapid climate changes;**
- **Environmentally sustainable management during the epoch of the Anthropocene is the only way to survive for us and for future generations**

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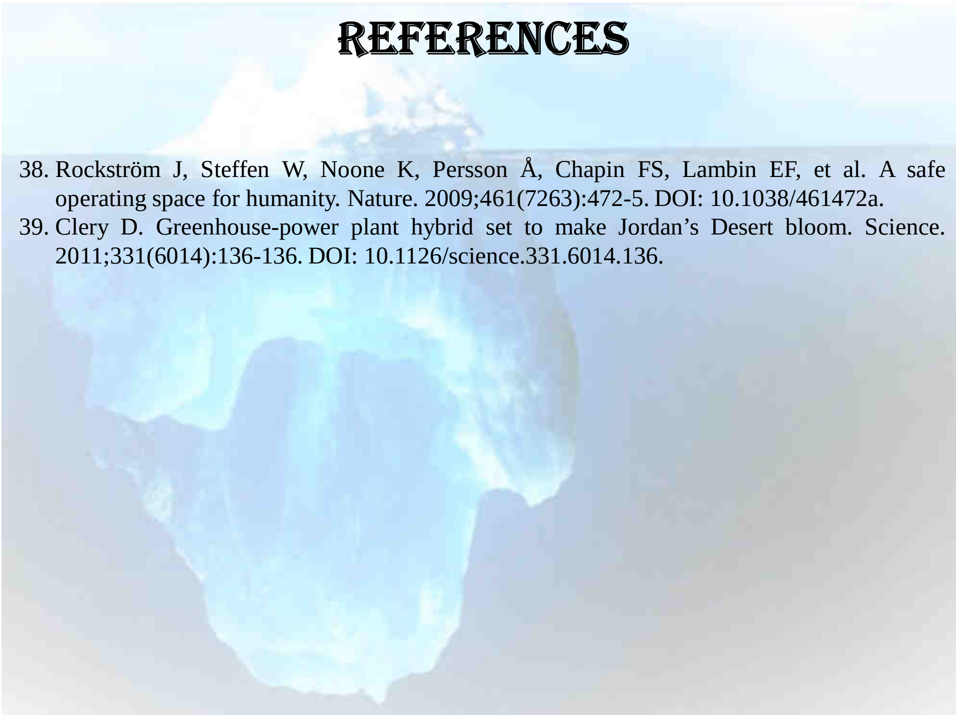

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CHEMIA ATMOSFERYCZNA I KLIMAT W ANTROPOCENIE

Abstrakt: Człowiek wywiera coraz większy wpływ na środowisko na różne sposoby, w wielu przypadkach ostro ingerując w procesy naturalne. W ciągu ostatnich 100 lat liczebność ludzkiej populacji wzrosła - z nieco ponad 1 mld do 6 mld, a od 1950 roku do chwili obecnej nastąpił dziesięciokrotny rozwój działalności gospodarczej. W ciągu kilku ostatnich dekad XX wieku antropogeniczna emisja freonów doprowadziła do drastycznego spadku poziomu ozonu stratosferycznego, tworząc dziurę ozonową nad Antarktydą. Następstwem tego zjawiska jest wzrost promieniowania UV-B, który pociąga za sobą katastrofalne skutki, m.in. zwiększa ryzyko zachorowań na raka skóry. Uwalniane do atmosfery, przez człowieka, w dużych ilościach gazy cieplarniane, takie jak CO_2, CH_4, NO_x, powodują zwiększenie efektu cieplarnianego. Nawet jeśli wzrost emisji zostanie zatrzymany, stężenia gazów cieplarnianych w atmosferze będą nadal rosnąć i pozostaną na wysokim poziomie przez setki lat, a to doprowadzi do ocieplenia klimatu na Ziemi. Wzrost temperatury przyczyni się do aprecjacji poziomu wód morskich. Będzie to spowodowane topnieniem lodowców górskich i czap lodowych. Utrata lodu Grenlandii i lądolodów Antarktydy, w zależności od tego, w jaki sposób zareagują na ocieplenie, może przyczynić się do wzrostu poziomu mórz i oceanów nawet o dodatkowych 19-58 centymetrów. Biorąc pod uwagę wyżej wymienione przykłady i wiele innych ważnych, wciąż wzrastających, śladów działalności człowieka na Ziemi bądź w atmosferze, bez żadnych wątpliwości można stwierdzić, że żyjemy w nowej epoce geologicznej nazwanej przez P. Crutzena i E. Stoermera w 2000 roku Antropocenem. Dla dobra naszych dzieci i ich przyszłości musimy intensywniej walczyć ze zmianami klimatycznymi, które miały miejsce w ciągu ostatniego stulecia.

Słowa kluczowe: gazy cieplarniane, efekt cieplarniany, zmiany klimatyczne, dziura ozonowa