1.2 The "Anthropocene"

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Abstract. Human activities are exerting increasing impacts on the environment on all scales, in many ways outcompeting natural processes. This includes the manufacturing of hazardous chemical compounds which are not produced by nature, such as for instance the chlorofluorocarbon gases which are responsible for the "ozone hole". Because human activities have also grown to become significant geological forces, for instance through land use changes, deforestation and fossil fuel burning, it is justified to assign the term "anthropocene" to the current geological epoch. This epoch may be defined to have started about two centuries ago, coinciding with James Watt's design of the steam engine in 1784.

The Holocene

Holocene ("Recent Whole") is the name given to the post-glacial geological epoch of the past ten to twelve thousand years as agreed upon by the International Geological Congress in Bologna in 1885 (Encyclopaedia Britannica 1976). During the Holocene, accelerating in the industrial period, mankind's activities grew into a significant geological and morphological force, as recognised early by a number of scientists. Thus, in 1864, G. P. Marsh published a book with the title "Man and Nature", more recently reprinted as "The Earth as Modified by Human Action" (Marsh 1965). Stoppani in 1873 rated mankind's activities as a "new telluric force which in power and universality may be compared to the greater forces of earth" [quoted from Clark]. Stoppani already spoke of the anthropocene era. Mankind has now inhabited or visited all places on Earth; he has even set foot on the moon. The great Russian geologist and biologist Vernadsky (1998) in 1926 recognized the increasing power of mankind in the environment with the following excerpt "... the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings". He, the French Jesuit priest P. Teilhard de Chardin and E. Le Roy in 1924 coined the term "noösphere", the world of thought, to mark the growing role played by mankind's brainpower and technological talents in shaping its own future and environment.

The Anthropocene

Supported by great technological and medical advancements and access to plentiful natural resources, the expansion of mankind, both in numbers and per capita exploitation of Earth's resources has been astounding (Turner et al. 1990). To give some major examples:

During the past 3 centuries human population increased tenfold to 6000 million, growing by a factor of four during the past century alone (McNeill 2000). This growth in human population was accompanied e.g. by a growth in the cattle population to 1400 million (McNeill 2000) (about one cow per average size family). Urbanisation has even increased 13 times in the past century. Similarly large were the increases in several other factors, such as the world economy and energy use (see Table 1.2.1). Industrial output even grew forty times (McNeill 2000). More than half of all accessible fresh water is used by mankind. Fisheries remove more than 25 % of the primary production of the oceans in the upwelling regions and 35 % in the temperate continental shelf regions (Pauly and Christensen 1995).

In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million years, resulting in large emissions of air pollutants. The release of SO_2, globally about 160 Tg/year to the atmosphere by coal and burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulphide from the oceans (Houghton et al. 1996). The oxidation of SO_2 to sulphuric acid has led to acidification of precipitation and lakes, causing forest damage and fish death in biologically sensitive regions, such as Scandinavia and the Northeast of North America. Due to substantial reduction in SO_2 emissions, the situation in these regions has improved in the meanwhile. However, the problem is getting worse in East Asia.

From Vitousek et al. (1997) we learn that 30-50 % of the world's land surface has been transformed by human action; the land under cropping has doubled during the last century at the expense of forests which declined by 20 % (McNeill 2000) over the same period. Coastal wetlands are also affected by humans, having resulted for instance in the loss of 50 % of the world's mangroves.

More nitrogen is now fixed synthetically and applied as fertilisers in agriculture than fixed naturally in all terrestrial ecosystems. Over-application of nitrogen fertilisers in agriculture and especially its concentration in domestic animal manure have led to eutrophication of surface waters and even groundwater in many locations around the world. They also lead to the microbiological production of N_2O, a greenhouse gas and a source of NO in the stratosphere where it is strongly involved in stratospheric ozone chemistry. The issue of more efficient use of N fertiliser in food and energy production has recently been summarised in a special publication of Ambio (2002).

The release of NO into the atmosphere from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone ("smog") formation in extensive regions of the world. Human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain

Table 1.2.1 A partial record of the growths and impacts of human activities during the 20th century

Item	Increase Factor, 1890s-1990s
World population	4
Total world urban population	13
World economy	14
Industrial output	40
Energy use	16
Coal production	7
Carbon dioxide emissions	17
Sulphur dioxide emissions	13
Lead emissions	≈ 8
Water use	9
Marine fish catch	35
Cattle population	4
Pig population	9
Irrigated area	5
Cropland	2
Forest area	20% decrease
Blue whale population (Southern Ocean)	99.75 % decrease
Fin whale population	97 % decrease
Bird and mammal species	1 % decrease

J. R. Mc Neill, Something New Under the Sun, Norton, 2000

forests (Wilson 1992). As a result of increasing fossil fuel burning, agricultural activities, deforestation, and intensive animal husbandry, especially cattle holding, several climatically important "greenhouse" gases have substantially increased in the atmosphere over the past two centuries: CO_2 by more than 30 % and CH_4 by even more than 100 % (see Table 1.2.2), contributions substantially to the observed global average temperature increase by about 0.5°C that has been observed during the past century. According to the reports by the Intergovernmental Panel of Climate Change in 1995 (Houghton et al. 2001): "The balance of evidence suggests a discernable human influence on global climate" and in 2001: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities". Depending on the scenarios of future energy use and model uncertainties, the increasing emissions and resulting growth in atmospheric concentrations of CO_2 are estimated to cause a rise in global average temperature by 1.4 – 5.8°C during the present century, accompanied by sea level rise of 9-88 cm (and 0.5-10 m until the end of the current millennium). Major anthropogenic climate changes are thus still ahead.

Table 1.2.2 Composition of Dry Air at Ground Level in Remote Continental Areas

	FORMULA	CONCENTRATIONS 1998 /pre-industrial	GROWTH (% YEAR) average (1990-1999)
Nitrogen	N_2	78.1 %	
Oxygen	O_2	20.9 %	
Argon	Ar	0.93 %	
Carbon dioxide	CO_2	365/280 ppmv	+ 0.4
Methane	CH_4	1.745/0.7 ppmv	+ 0.3 –0.5
Ozone	O_3	10-100/20 (?) nmol/mol	variable
Nitrous oxide	N_2O	314/270 nmol/mol	+ 0.25
CFC-1	$CFCI_3$	0.27/0 nmol/mol	< 0 (decline)
CFC-12	CF_2CI_2	0.53/0 nmol/mol	< 0 (decline)
OH (HYDROXYL)	OH	$\approx 4 \times 10^{-14}$	?

Furthermore, mankind also releases many toxic substances in the environment and even some, the chlorofluorocarbon gases ($CFCl_3$ and CF_2Cl_2), which are not toxic at all, but which nevertheless have led to the Antarctic springtime “ozone hole” and which would have destroyed much more of the ozone layer if no international regulatory measures to end their production by 1996 had been taken. Nevertheless, due to the long residence times of the CFCs, it will take at least another 4-5 decades before the ozone layer has recovered.

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it thus is more than appropriate to emphasise the central role of mankind in geology and ecology by using the term “Anthropocene” for the current geological epoch. The impact of current human activities is projected to last over very long periods. According to Loutre and Berger (Loutre and Berger 2000), because of past and future anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour even over the next 50,000 years.

To assign a more specific date to the onset of the “Anthropocene” is somewhat arbitrary, but we suggest the latter part of the 18th century, although we are aware that alternative proposals can be made. However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly noticeable. This is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several “greenhouse gases”, in particular CO_2, CH_4 and N_2O. Such a starting date coincides with James Watt’s invention of the steam engine in 1782.

Without major catastrophes like an enormous volcanic eruption, an unexpected epidemic, a large-scale nuclear war, an asteroid impact, a new ice age, or continued plundering of Earth's resources by partially still primitive technology (the last four dangers can, however, be prevented in a real functioning noösphere) mankind will remain a major geological force for many millennia, maybe millions of years, to come. To develop a world-wide accepted strategy leading to sustainability of ecosystems against human induced stresses will be one of the greatest tasks of mankind, requiring intensive research efforts and wise application of the knowledge thus required in the noösphere, now better known as knowledge or information society.

Hopefully, in the future, the "anthropocene" will not only be characterised by continued human plundering of Earth's resources and dumping of excessive amounts of waste products in the environment, but also by vastly improved technology and management, wise use of Earth's resources, control of human and domestic animal population, and overall careful manipulation and restoration of the natural environment. There are enormous technological opportunities. Worldwide energy use is only 0.03 % of the solar radiation reaching the continents. Only 0.6 % of the incoming visible solar radiation is converted to chemical energy by photosynthesis on land and 0.13 % in the oceans. Of the former about 10 % go into agricultural net primary production. Thus, despite the fact that humans appropriate 10-55 % of terrestrial photosynthesis products (Rojstaczer, Sterling and Moore 2001), there are plenty of opportunities for energy savings, solar voltaic and maybe fusion energy production, materials' recycling, soil conservation, more efficient agricultural production, et cetera. The latter even makes it possible to return extended areas now used for agricultural to their natural state.

There is little doubt in my mind that, as one of the characteristic features of the "anthropocene", distant future generations of "homo sapiens" will do all they can to prevent a new ice-age from developing by adding powerful artificial greenhouse gases to the atmosphere. Similarly, any drop in CO_2 levels to excessively low concentrations, leading to reductions in photosynthesis and agricultural productivity would be combated by artificial releases of CO_2. With plate tectonics and volcanism declining, this is not a scenario devoid of any realism, but of course not urgent in any way. And likewise, far to the future, "homo sapiens" will deflect meteorites and asteroids before they could hit the Earth (Lewis 1996). Humankind is bound to remain a noticeable geological force, as long as it is not removed by diseases, wars, or continued serious destruction of Earth's life support system, which is so generously provided by nature cost-free.

Conclusions

To conclude: existing, but also difficult and daunting tasks lie ahead of the global research and engineering community to guide mankind towards global, sustainable, environmental management into the anthropocene (Schellnhuber 1999).

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