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The global urbanization – a process of the biosphere?!

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Urbanization is a phenomenon recently occurring for the first time in the long history of planet earth. About 11,000 years ago, human beings started to establish the first town-like settlements such as Jericho. Today more than half of the world's population is living in urban areas and for the mid of the 21st century it is expected that 7 out of 10 people will be urban inhabitants (UN-Habitat, 2013). This expansion of urban systems requires enormous input of resources to satisfy the needs for energy, materials and food. Thus, the Neolithic and industrial revolution with their impacts on global element fluxes were preconditions for the todays urban regions covering up to 2,7% of the total land area (Angel et al., 2005; Salvatore et al., 2005).

In consequence, geogenic and anthropogenic material fluxes today already occur in comparable scales even if considering the annual uplift of mountains (Heinloth 2003). For example, the worldwide extraction of black coal grew between 1870 and 2005 from 203.5×10^6 to 4.55×10^9 t by three orders of magnitude (Fischer Weltalmanach 2005). The global anthropogenic Cd flow exceeds twice the rate of the non-man-made flows (Baccini and Brunner 2012). Steel production increased from 1950 to 2012 from about 190 Mio t to more as 1,500 Mio t (Wirtschaftsvereinigung Stahl 2006; World Steel Association 2013). In 2012, 3.6 Billion tons of cement were produced (IMF 2013), and about 100,000 chemical substances are registered in the EU market (Commission of the European Communities 2001). Half of the annual global N fixation is actually caused by anthropogenic activities (Fowler et al. 2013). Combustion activities in urban systems are one main driver of the recent release of the climate-active gas CO_2. At present 80% of material consumption and up to 75% of carbon emissions are caused by urban systems (UNEP 2012).

Flows of chemical elements within the system Earth are substantial subjects of geochemistry as e.g. Mason (1952) stated: "Geochemistry deals with the distribution and migration of the chemical elements within the Earth in space and time". Vernadsky (1926, 1997), one of the most influential inventors of Geochemistry, already highlighted early in the 20th century the importance of organisms for the distribution of chemical elements and named the zone of biological influence on chemical element distribution the biosphere. The biosphere was not existent on earth from the very beginning of the formation of the globe but started to develop with the origin of the first living organisms about 3.7 billion years ago (Othomo et al. 2013). Three Billion years ago photosynthesizing cyanobacteria started to produce free oxygen that dramatically changed the following evolution of life and the characteristics of material flows and biogeochemical processes at the earth's surface (between lithosphere and atmosphere). Four million years ago, first hominids evolved and developed to the modern human that appeared first in Africa 200 ka ago. This short outline of human evolution finally resulted via surviving glacial periods and facing Neolithic and industrial revolutions in the today's global urbanization with all implications for global material and chemical element flows, which are managed for considerable parts by human beings. This poses the question whether urbanization is a mechanistic result of evolution under the conditions of the past. However, since urbanization is a process driven by organisms, urbanization is a process of the biosphere resulting in chemical element enrichments, chemical element combinations and chemical element ratios the earth never has faced before during its 4.6 billion lasting history as exemplarily highlighted in figure 1.

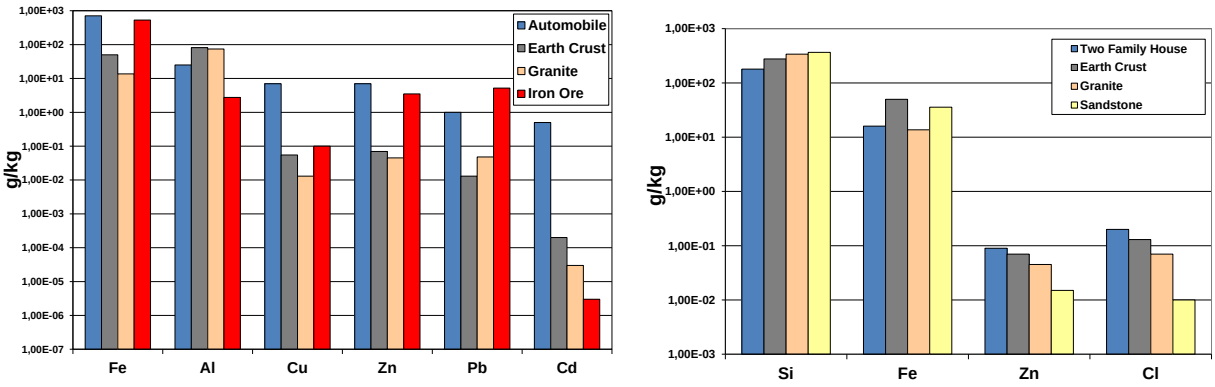

Fig. 1: Left - chemical composition of an average automobile of 1.5 t compared with respective concentrations in selected lithological formations (data from Burg and Benzinger 1984; Franke 1987; Wutz, 1982; compiled in Baccini and Brunner 1991, and from Krauskopf and Bird 1995). Right - chemical composition of a two family house compared with respective concentrations in selected lithological formations (data from Rößler and Lange 1972, Baccini and Brunner 1991, Krauskopf and Bird 1995).

According to fundamental principles of geochemistry, which were invented by Goldschmidt (Goldschmidt 1923), that describe the association of chemical elements within different envelopes or spheres of the system earth, the anthropogenic impact on distribution of chemical elements results in the formation of the anthroposphere (Rößler and Lange 1972, Baccini and Brunner 1991). The anthroposphere can be separated into two zones of anthropogenic influence on element fluxes, which are the agrosphere (Krishna 2003) and the astysphere (Norra 2009, 2012), and for some extend both spheres superimpose each other (fig. 2). In Greek language asty is the opposite of agros. Agros is describing society's farming sector and asty the physical properties of urban systems.

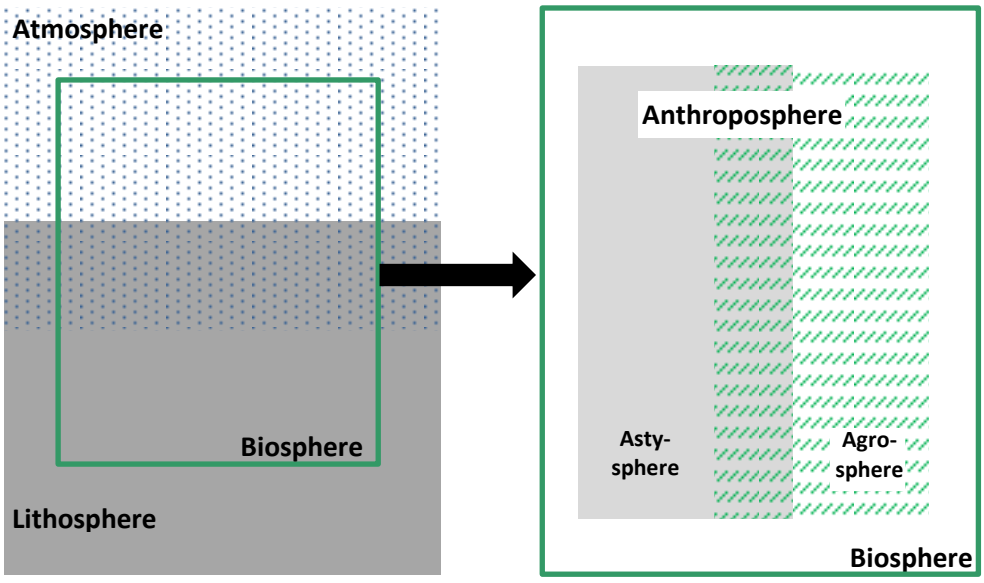

Fig. 2: non-scalar sketch of spheres. Left – the biosphere between atmosphere and lithosphere. Right – the composition of the anthroposphere as part of the biosphere.

Like other organisms before, human beings are changing the global element flows creating ecosystems (also urban systems are ecosystems) appropriate to guarantee the survival of more than 7 billion individuals. However, the resource consumption to sustain the current processes in the anthroposphere negatively effects the natural ecosystems with respect to climate stability, air, water

and soil quality or biodiversity. For Vernadsky (1965, 1997), an evolution intrinsic solution to overcome this challenge is the evolvement of the noosphere, when human knowledge based development and control of the biosphere replaces uncontrolled and non-sustainable exploitation of the earth's resources (Norra 2014a). Although some knowledge is available on energy consumption and bulk material flows to reach this state; from a geochemical point of view, we are just at the beginning to understand the impact of urban systems on chemical element flows within the Astysphere and the system earth. A fundamental compilation like the "Data of Geochemistry" on elemental composition of rocks published by F.W. Clarke (1908) is urgently needed for urban materials. A more comprehensive knowledge about chemical element flows in urban systems would substantially contribute to a sustainable management of resources comprising the development of concepts for optimization of resource use, urban mining and recycling and the minimization of environmental pollution and destruction (Norra 2014b)

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