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Towards engineering
harmony between water,
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Groundwater bodies in ecology and ecosystems

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Abstract

The symbiosis of two worlds, abiotic and biotic, requires a diffusible and active bridge between them, which is water. Furthermore, water takes part in photosynthesis in plants allowing biological organisms to transform inorganic materials into organic ones. The hydraulic connections between surface and ground waters ensure water availability and quality. These interactions have an important ecological significance. The transition zone between the two systems, known as an ecotone, ensures the smooth mutual contribution of the surface, hyporheic and ground water ecosystems. Finally the groundwater systems have their own "groundwater ecology". As every alteration to the natural environment, climatic change affects the ecosystems, modifying the water supply (precipitation) and ecosystems parameters; e.g., directly in the case of temperature and humidity, or indirectly in the case of pH, electric conductivity, redox potential, and carbon dioxide (CO_2) entrainment.

Key words: symbiosis, hydraulic connections, hyporheic zone, ecotone, climatic change.

1. Introduction

The co-existence and thus the association and mutual interaction between the geological world (abiotic phase) and the biological world (biotic phase) is primarily possible through the role of the water, especially subsurface water within and between these phases. This is a very old scientific field. As the nature of ecosystems must also be defined by their aqueous systems these became the focus of intensive investigations. The outcome of such studies has replaced the view that the geological phase provides the material "on which" or "in which" the living world survives and evolves with much broader considerations which accept a multitude of interactions between the geological and organic world. Yet, the principal bridge between the two is water and here mainly subsurface water; i.e., groundwater.

Initially the science of ecology as well as the concepts of ecosystems formed a scientific field within the discipline of Biology. Although biologists did not forget the role of the geological environment, their main target was the living world. However, scientific developments transformed our knowledge of both worlds, and ecosystem analyses now include the geological point of view and establish interactive links to the organic world. Thus, the geological environment, with its lithosphere, hydrosphere and atmosphere, and the biological world, with its multitudes of life forms, are, in the present holistic view, united and form the ecosystems. (Gohau 1987; Lovelock 2007; Pavlides 2007).

2. Ecology and water

Thales, by naming water as *origin of everything*, frees himself from the mythological thinking, which was the heritage of Homer and the Theogony by Hesiodus. The experience of water in many forms becomes the basis for the Thales philosophic approach concerning the unity and entity of the natural world. Thales with Anaximander and Anaximenes founded the philosophy related to a simple and unified natural world. Heraclitus added one more step among the pre-Socrates philosophers by describing a framework very close to a symbiotic planet. He underlined that *one is everything*, which means that the beings in their entity are in a continuous argument with antithetical tendencies. Analysing these terms within the present philosophical and scientific context, concepts such as coexistence, symbiosis, living space, food chain, parasitism, life cycle, photosynthesis, mutual action and reaction between living beings and the abiotic and biotic environment can be detected. Thus, already, the pre-Socrates philosophers had a holistic view of the natural world and approached the concept of coexistence and without giving it a special name.

In the Middle Ages, the ancient doctrines of science dominated provided they agreed with the religious dogmas of the period. Among the ancient philosophers, Aristotle was oft quoted since his sayings could easily be adapted by the church. This was a period of guided systematization and criticism. The taxis of the creation elements could not be called in question. During the last decades of the 16th century and the initial decades of the 17th century, a peculiar cosmic theory stated that... *nature is absolutely unalterable and invariable...* This doctrine concerned the geologic and biologic parts of nature and the overlapping climate. However, some scientists resisted as in the field of Biology scientific expeditions, paleontology, the anatomy with comparative anatomy, the physiology, the microscopic discovery of the cell and so on pointed at evolution, irrespective of the nature of its mechanism, as essential for the development of biological diversification.

The concept of Ecology was established in 1886 by Ernst Haeckel, one of the scientists who carried on the work of Darwin. Haeckel presented a first definition of Ecology (Stournaras 2006) in his three volumes of *Generelle Morphologie der Organismen* with a clear separation of the inorganic and organic world.

As indicated above, during the past decades, a fundamental change of view has taken place and ecology today is based on truly holistic concepts (this is also valid for the aquatic sciences starting from hydrology, hydrogeology, hydrometeorology and all other water related sciences). Thus, the main principles of ecology, the mutual active symbiosis of the two worlds are recognized in the *law of Liebig* (law of minimum) which states that for each living being there is a minimum limit of necessary substratum, mainly of water and minerals. *The law of Shelford* (law of tolerance) declares that the tolerance of an organism is not unlimited with respect to modification of environmental parameters. Although species with a wide ecological range do exist, most organisms fit into rather narrow ecological niches.

The contemporary consideration about the mutual coexistence of the two worlds was initiated by the Russian geoscientist Vladimir Vernadsky (Vernadsky 1926, rep. 1997). It is true that Vernadsky preceded his era and scientists were not ready to understand his view: "... When Lynn Margulis and I introduced the Gaia Hypothesis in 1972 neither of us was aware of Vernadsky's work and none of our much learned colleagues drew our attention to the lapse. We retraced his steps and it was not until the 1980s that we discovered him to be our most illustrious predecessor... (declaration by J. Lovelock)" (Vernadsky 1926, republished in 1997, revised and annotated by M. Mc Menamin).

Two points of his works are here especially important, because he noted that *life is a main geological factor* on the earth. Furthermore, he described the living matter as *vitalized water*, which is a perfect definition of the life. Within this framework, life on our planet is characterized by the direct or indirect, visible or presumed, permanent or temporary symbiosis, which permitted to the biologist Lynn Margulis to call our planet, a *symbiotic planet* (Margulis 1999).

It is the history of an ecosystem which determines its ecological conditions and the role of water compartments as substratum for survival and evolution... This is why the biotic societies cannot be reformed *de novo*, that evolution is not reversible and that ecosystems cannot be divided into segments. In addition the status of an ecosystem will be determined by the hydraulic regimes which dominate the water cycle within its borders and, here, groundwater often plays a more important role than is immediately visible.

3. Groundwater in ecosystems

3.1. The hydraulic connections

As noted above, water is a fundamental environmental element and, at the same time, the principal bridge between the organic and inorganic worlds. Therefore, the "internal" water bodies (surface and ground water) and their hydraulic relationships are of special interest in ecosystem analyses. For the