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VIRTUAL WORLD: E*M*ERGY, WATER, AND ENGINEERING ECOLOGY

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Abstract. The authors discuss various options for using "virtual" representations in environmental research: expanding the concept of energy expended through the concept of "e*m*ergy" by H. Odum (through the ideas and concepts of physicist S.A. Podolinsky (1850–1891), ecologist V.V. Stanchinsky (1882–1942)], economist, Nobel laureate V.V. Leontiev (1905–1999); Odum proposed the concept of materialized energy). The authors discuss the rational use of water resources through J. Allan's "virtual water" food; with the increasing water scarcity in a number of countries due to global warming, a number of strategies have emerged to overcome it, which include saving water consumption, desalting brackish or salty seawater; another alternative is to minimize water consumption by importing water-intensive products – both agricultural and industrial; virtual water in a product of economic activity is the volume of fresh water measured at the place of production of the product; there are three types of virtual water – "green" (rain), "blue" (surface or ground water) and "gray" virtual water (polluted water), the design of ecosystems with specified properties within the framework of environmental engineering (environmental engineering methods allow translating the solution this kind of virtual tasks into a practical plane – the creation of highly productive grass mixtures, the creation of football fields resistant to trampling, the creation of mariculture farms, etc.). The authors conclude that the virtual world is becoming more and more real.

Dedicated to the memory of the British geographer,
professor John Anthony Allan (1937–2021).

When the well is dry, we know the worth of water.
Benjamin Franklin (1706–1790) – American politician, diplomat, scientist, philosopher (Benjamin Franklin…, 1998, p. 53).

1. Introduction

Virtuality[1] (lat. *virtualis* – possible) is an imaginary object or state that does not really exist, but can arise under certain conditions.

At the end of 1973, an article was published in the then relatively new journal of the Royal Swedish Academy of Sciences "AMBIO: A Journal of the Human Environment" (Odum, 1973); in 1974, the article was reprinted in Mother Earth News with the following editorial foreword: "*In early November of 1973 – during a visit to MOTHER's new home in the mountains of western North Carolina – New Alchemist John Todd gave the magazine's editors about the 14^th^-generation Xerox copy of what can conservatively be described as a dynamite paper. We had only to glance at this extraordinary document to realize that the paper (originally written at the request of the Royal Swedish Academy of Sciences) is one of the most concise – yet most sweeping – examinations yet made of the real problems of the world. Read it and see for yourself...*" (Mother Earth… [electronic resource]). In this article, Howard Odum was, in fact, the first to "touch" the virtual world of ecology.

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In the first half of the twentieth century, there were ideas about an "embodied energy" [let us mention some Russian scientists who contributed to the implementation of these concepts – physicist S.A. Podolinsky (1850–1891), ecologist V.V. Stanchinsky (1882–1942), economist, Nobel laureate V.V. Leontiev (1905–1999)]. Embodied energy is the sum of all types of energies necessary for the production of any goods or services (quite a virtual value).

In the late 1960s and early 70s, Howard Odum proposed to abandon the concept of "embodied energy" and replace it with the concept of materialized energy – e*m*ergy or e*M*ergy. "E*m*ergy is a universal measure of the necessary natural resources, a measure expended to obtain a particular product of solar energy ("measure of real wealth"); the unit of eMergy is emjoule. For a complete calculation of the eMergy of the system, a system diagram is built (the main condition for constructing diagrams is that they must include all sources that contribute to the computation of eMergy), the flows of which are used to construct the eMergy table.

It cannot be said that in Russia the issues of ecological economy or economic ecology (Rozenberg, 1994, 2017) did not attract the attention of researchers. However, the closest thing to the ecological, energy and economic vision of problems in the system "Man – Nature" is the research of T.A. Akimova (Moiseenkova), for example: (Moiseenkova, 1989; Akimova, Khaskin, 1998; Akimova, 2012). It is necessary to mention the ever-growing number of publications on valuation of ecosystem services and natural capital, led R. Costanza (Costanza et al., 1997) – professor at the Crawford School of Public Policy at the Australian National University, as well as universities in Portland (Portland [OR]), Vermont (Burlington [VT]), Maryland (College Park, MD), and Louisiana (Baton Rouge [LA]). In our country, this direction is associated with the names of prof. Moscow State University, economist S.N. Bobylev (Bobylev, 2004; Bobylev, Zakharov, 2009, 2014), corr. RAS, geographer A.A. Tishkov (2004, 2010) and a number of other researchers (Kudinova, Rozenberg, 2014; Rozenberg, 2015; Rozenberg et al., 2017).

2. Results and Discussion

It was "virtual" energy (e*m*ergy). Now let's talk about "virtual" water.

Almost all ecologists recognize the inevitably impending devastation of the planet's water resources as the most dangerous risk that can put the world on the brink of disaster. Lack of water will lead to food problems. If such a negative scenario develops, the current economic (energy) crisis will seem to be just an insignificant nuisance.

The total volume of water on Earth is about 1,35–1,4 billion cubic km., that is, for every person there is about 200 million cubic m. It would seem a huge amount. However, 96,5% of the total is the salty waters of the World Ocean, unsuitable for consumption, and another 1% is salty groundwater and mountain lakes. Fresh water reserves account for only 2,5% of the total volume of water on Earth. Almost all of the water consumed by humans comes from lakes, rivers and shallow underground sources, while its main reserves are found in glaciers (Antarctica, Arctic, Greenland) and deep aquifers. So, there are 5 million cubic meters per person. of fresh water. About 70% of the water consumed in the world from surface sources and groundwater is used for irrigation of agricultural lands, 20% is used in industry and 10% – for domestic purposes (Konchev, 2012).

With the increasing water deficit in a number of countries due to global warming, a number of strategies to overcome it have emerged, which include saving water consumption, desalting brackish or salty seawater. Another alternative is to minimize water consumption by importing water-intensive products, both agricultural and industrial, including energy. This is how the concept of "virtual water" was born. Its creator (in 1993) was the British geographer J. Allan, professor at King's College and the School of Eastern and African Countries at London University (Allan, 1993, 1998). In 2008, for his work in this area, he was awarded the Stockholm Water Prize by the Stockholm International Water Institute.

The concept of virtual water helps us understand how much water was required to produce various goods and services. Virtual water in a product of economic activity (raw material, product or service) is the volume of fresh water measured at the place of production of the product. This refers to the amount of water used at various stages of the production chain. There are three types of virtual water – "green" (rain), "blue" (surface or groundwater) and "gray" virtual water (polluted) (Aldaya et al., 2010; Suduk, Shcherbakova, 2019).

When we talk about the export of virtual water, we are talking about its volume associated with the export of goods or services from any country or region, or the total volume of water required to produce products for export. The flow of virtual water between two countries or regions is the volume of water moved from one place to another as a result of trade in goods or services. Without giving tables of virtual water content in various types of products (they can be easily found on the Internet), as an example, we will only point out that for the production of 1 kg of beef 15 thousand liters of water are required, and for 1 kg of wheat - thousand liters. Approximately 61% of the global trade in virtual water is in cereals, 17% in trade in livestock products, and only 22% in industrial products. Overall, 16% of the world's water used for agricultural and industrial products is exported as virtual water. The table 1 shows the ratio of import and export of virtual water (average over 5 years; [Chapagain, Hoekstra, 2004, p. 44]). The results are clear enough and do not require comments.

Table 1

Countries by the ratio of imports and exports of virtual water for 1997–2001
Страны по соотношению импорта и экспорта виртуальной воды за 1997–2001 гг.

Countries	Gross export (Gm^3/yr)	Gross import (Gm^3/yr)	(Im – Ex)
Canada	95.3	35.4	–59.9
USA	229.3	175.8	–53.5
Italy	38.2	89.0	–50.8
China	73.0	63.1	–9.9
France	78.5	72.2	–6.3
Russia	**47.7**	**46.1**	**–1.6**
Belgium-Luxembourg	42.2	47.1	+4.9
Netherlands	57.6	68.8	+11.2
Germany	70.5	105.6	+35.1

3. Conclusions

At the World Economic Forum in Davos (2009), it was stated that a lack of water resources will lead to the fact that over the next 20 years water will become the main area of activity for investors, since for many countries the need for water has become more important than the need for oil. "Probably, the “market” of water, similar to the oil market, will not arise, but three sectors will actively develop: 1) the market of water protection technologies; 2) water saving technologies; 3) the market for water-intensive products. The latter has the ability to become a leader. It will be possible to take advantage of these opportunities only with serious preparation for the development of export water-intensive industries" (Perelet, 2010, p. 169). Water-intensive technologies can become the backbone of our economy in the post-oil period. Hydro resources of Russia exceed 97 thousand cubic km. If one translates these resources into a monetary value, one can talk about $ 800 billion a year. Russia has an excellent chance to move from the "oil" period to the "water" one not only without losses, but also significantly strengthening its economic positions.

Finally, a few words about the "virtuality" of environmental engineering (Rozenberg, 1986, 2005). Among the main tasks of environmental engineering (Rozenberg, 2005, Rozenberg et al., 2016) there is "designing ecosystems with specified properties" (an example is the lawn of a football field – it is necessary to create an ecosystem that is resistant to trampling with the lowest possible productivity). The methods of environmental engineering make it possible to translate the solution of this kind of virtual problems (see the definition of "virtuality" at the beginning of the article) into a practical sphere (see, for example, [Mirkin et al., 1987]). By the way, online conferences, the defense of dissertations (as well as training and lecture courses) in a pandemic are also elements of the "virtual world".

Concluding the article, we quote the words of a neurolinguist, Professor T.V. Chernigovskaya (2017), with whom it is difficult to disagree: "The virtual world is becoming more and more real. But what to do about it? The person is happy there. Because there you can kill everyone, then turn off, turn on, and again everyone’s alive - wonderful!".

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ВИРТУАЛЬНЫЙ МИР: ЭМЕРГИЯ, ВОДА И ИНЖЕНЕРНАЯ ЭКОЛОГИЯ

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Аннотация. Авторы обсуждают различные варианты использования «виртуальных» представлений в исследованиях окружающей среды: расширение понятия затраченной энергии через понятие «эмерджентность» Г. Одума, который предложил концепцию материализованной энергии (через идеи и концепции физика С.А. Подолинского (1850–1891), эколога В.В. Станчинского (1882–1942), экономиста, лауреата Нобелевской премии В.В. Леонтьева (1905–1999). Обсуждаются вопросы рационального использования водных ресурсов через питание «виртуальной водой» Дж. Аллана; с ростом дефицита воды в ряде стран из-за глобального потепления появился ряд стратегий его преодоления, которые включают экономию водопотребления, опреснение солоноватой или соленой морской воды; другая альтернатива – минимизировать водопотребление за счет импорта водоемкой сельскохозяйственной и промышленной продукции; виртуальная вода в продукте хозяйственной деятельности – объем пресной воды, измеренный в месте производства продукта; различают три вида виртуальной воды – «зеленая» (дождь), «голубая» (поверхностная или подземная вода) и «серая» виртуальная вода (загрязненная вода), проектирование экосистем с заданными свойствами в рамках инженерной защиты окружающей среды (инженерно-экологические методы позволяют перевести решение подобного рода виртуальных задач в практическую плоскость – создание высокопродуктивных травосмесей, создание устойчивых к вытаптыванию футбольных полей, создание ферм марикультуры и др.). Авторы приходят к выводу, что виртуальный мир становится все более реальным.