WATER-BASED LIFE SUPPORT SYSTEM DEVELOPMENT INFORMATION AND KNOWLEDGE

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Contents

Summary

Water, ubiquitous and present everywhere that life is found, has been curiously neglected in the twentieth century's perspectives on human economic development. At the dawn of the new millennium, it seems probable that water resources, both quality and quantity, will be a dominant preoccupation for human survival, well-being, and global community. This article offers an interpretative overview of ways that water, the alchemical element without which there is no life, can be a thread that orients diagnosis of sustainability problems, challenges, and paths ahead. Water scarcity, and the restrictions of access to good quality water by one economic agent in competition with another, or by the action of an enemy, are problems constitutive of political, civil and military conventions everywhere around the world. Water politics and economics, as a facet of "ecological distribution," is as old as human society, and is a key dimension for analysis of development and survival issues. Some of the illusions about infinite progress and control fostered during the industrial epoch in some rainy temperate climates must now be left behind. The services to life and economy furnished by nature's waters are neither indestructible nor non-scarce. Moreover, the variety of

water's uses within economic and ecosphere transformation cycles, both irreversible and reversible, is very great. An integrated approach is required for effective water resources management for sustainability. Not that the nomads of water-scarce tropical arid regions ever had any illusions on that score! But now examples can be given from predominantly green and temperate Europe, for policy challenges as diverse as the large-scale contamination of drinking supplies, the eutrophication of inland waters, and the irreversibilities of soil, port sediment, storm-water and sewage sludge contamination. Not forgetting other examples that could be given from all parts of the world, these are sufficient to evoke the primordial importance of water—as the material basis for all life, as the pathway or "raw material" for teaching and learning, as the tactile and symbolic dimensions of human knowing—in the creating and sustaining of decency in human societies.

1. Introduction

Water is the medium of all life. It is part of blood and body cells, and is the main substance in everything that is eaten and drunk. It is the vapor of the steam engine and the humidity of productive soils. It is the medium of nutrient transportation and osmotic pressure in plants, and of mobility and life support for the fishes that swim in lakes and rivers and under the ocean waves. It is that ubiquitous substance used to wash hands and clothes, to clean machines, to dilute wastes, to transport raw materials and processed goods from one place to another, to distribute heat in homes and factory buildings, to cook food, and so on. It is the permanent metaphor of movement, of the spirit, of the flows of death and life. In the words of a medieval European alchemical text (*The Book of Lambspring*):

The Sages will tell you
That two fishes are in one sea
Without any flesh or bones
Let them be cooked in their own water;
Then they also will become a vast sea,
The vastness of which no man can describe.

The topic of water is, then, impossibly large. An encyclopedia entry cannot be written for it. The "Water" entry simply cross refers to every other encyclopedia item concerning life support systems. Nonetheless, at the dawn of the present millennium, it is interesting to reflect specifically on the significance of water as the element, par excellence, at the confluence of the natural sciences, the policy sciences and the humanities. It is an economic asset, a strategic resource, a poetic resource and a security problem. It is an object of everyday knowledge to everyone. It is known in many different forms and can be found everywhere that there is life. Yet, up until very recent years it has never held a dominant place in economics and politics textbooks dealing with development. Sometimes, indeed, the water element was not even mentioned at all. Why not?

During the industrial period of Western economic history, material progress has been seen as synonymous with the augmentation of the quantity and quality of manufactured outputs. Correspondingly, value in economics has meant, foremost and sometimes exclusively, the value of produced goods and services. The services of nature such as availability of air, water, land, were obtained "free." In theoretical terms, property rights over land and water allowed the owners to claim a share of the product obtained through using "their" factors of production, yet the sunlight and air and rain was provided by nature free.

In places where water is abundant, it is often obtainable free of charge; but it is not any less, for that, a fundamental requirement of human life. Valuation is a problem linked on the one hand to costs of access, on the other hand to conflict over access under conditions of scarcity. The scarcity may, in turn, be determined in quantity and quality dimensions (such as limited river flows or aquifer renewal rates, but where the availability of water of qualities adequate for drinking or irrigation is furthermore menaced by rising salinity, bacterial contamination, heavy metals, nitrates, pesticide residues and so on).

In the history of human conflicts, environmental security in the sense of food and water access has always been a critical consideration. Yet the major calamities and irreversibilities were as often social in origin as they were ecological. Today in almost all parts of the world, there is a heightened commercial investment in water that runs alongside (not always comfortably) a heightened concern with risks of irreversible loss of water resource quality, which threatens future economic prospects for all societies, rich and poor. This is what means that, for the present millennium, the sciences and humanities must reflect in new ways on the significance of water in human well-being and economic life.

A *leit motiv* of the new perspectives on water management is to provide for sustainability. Viewed in economic and technical terms, this entails real costs such as investments in new forms of quality assurance and supply (e.g., water purification stations, desalination plants), and new infrastructures (e.g., canals, new pipes, leak control). It means research and monitoring, hydrosystem modeling, waste management, building and services design. This brings new information and communications challenges, and combinations of management prudence and audacity—for example the new utilization and stewardship challenges of foregoing groundwater exploitation beyond thresholds of safety for quality and quantity sustainability.

Box 1 below gives a description of the new journal *IJW (International Journal of Water)*, as an example of a new communication forum on all aspects of water in relation to the environment and society.

At the societal level, the sustainability provision entails collective commitments in the sense of the Brundtland report, *Our Common Future* (World Commission on Economic Development 1987)—providing for present needs whilst not compromising the interests of future generations. Human technological imagination has transformed almost everywhere the surface of the planet, its waters, its weather patterns (and even, some say, the ocean currents). People share, in a way that never was before, the same oceans, the same atmosphere, the same genetic heritage and the same waste disposal domains. Rain waters and rivers are now so tightly harnessed that many no longer flow to the sea. Yet, despite this prowess, humankind does not control the complex ecosystems and biosphere processes upon which all depend. Sustainability in societies depends on coming to terms in new ways with these challenges of physical as well as moral and economic interdependencies. The renewed study of water, not only in the sciences but also in arts and humanities, in its everyday manifestations and the geopolitical and large-scale economic manipulations, is one way of enabling this to be done.

*IJW***,** the *International Journal of Water* established in the year 2000 (see http://www.interjournals.com) creates a forum for insights and communication between policymakers, government agencies, citizens, consumer bodies, industry, public authorities and members of academic and research institutions on all aspects of water, environment and society. Its subject coverage includes:
• Marine and freshwater ecosystems • Aquatic and coastal biodiversity • Fisheries science and governance • Water in the economy • Consumptive and non-consumptive uses • Recycling and re-use • Cultural perceptions of water, waste and pollution • Political economy of water • Sustainable development • Technical and ecological economics analyses of water use, pollution and treatment • Comparative legal aspects of water resource management • Agricultural pollution and degradation • Protection and rehabilitation of ground and surface water • The water supply sector • Water and tourism • Climate change and hydrology • Public sector strategies for pollution management and waste disposal • Toxic wastes • Clean technologies • Health hazards of water pollution • Water basin analyses • Hydrosystem engineering • Symbolic dimensions of water • Heavy water • Water geopolitics • Environmental education, public information and technical training

Box 1. A new journal

2. Sustainability and Water's Transformation Cycles

Water as a chemical substance is written as H_2O. Two atoms of hydrogen (the lightest element, composed of one proton with its companion electron), are bonded to one atom of oxygen (which, from a nuclear chemical point of view, is the result of the combination and transformation of three α-particles, each α-particle being composed of two protons with two neutrons, the nucleus of a helium atom). Water has a molecular weight of about 18, which is the sum of 2×1 for hydrogen (one proton each) plus 16 for oxygen (8 protons and 8 neutrons)—although, to be exact, not all waters are equal; there is also (for example) "heavy water" where one or both of the hydrogens is a deuterium (with a neutron as well as a proton), and this is a useful water form because it can be used as a component in nuclear fission and fusion processes, including some classes of nuclear reactors.

2.1 From Atoms to Ecosystems: Water's Emergent Complexity

It is not possible to deduce the properties of water, in its myriad manifestations around the Earth spanning the three physical phases—solid, liquid and gas—from the behavior of its component elements hydrogen and oxygen. Water is a liquid which, at typical earthly atmospheric pressures, freezes into ice at 0°C, and boils to vapor at 100°C (which shows already one societal role of water—in the calibration of the temperature scale). By comparison, hydrogen under typical earthly conditions is a gas, in molecules of H_2, which with a molecular weight of about 2, is lighter than air and also highly combustible (whence, the famous explosion of the Hindenberg hydrogen-filled airship in the 1930s). Oxygen under typical earthly conditions, is also a gas, O_2, with a molecular weight of about 32, nearly twice as heavy (per molecule) as water. The earth's air is made up of about 20% O_2 and nearly 80% nitrogen (formula N_2 with a molecular weight of 28), plus traces of water vapor and other gases.

Why is water, whose molecules are so light, not a gas at atmospheric temperature and pressure, like O_2, or for another example, methane (with formula CH_4 and molecular weight of about 16)? The reason is the peculiar propensity of water molecules for "hydrogen bonding" which means, nontechnically speaking, that water molecules tend to cling onto each other. The shape of water molecules and their hydrogen-bonding tendencies is also what explains why water expands significantly when it freezes, and this is rather important for life on earth, because were it not the case, frozen water would immediately sink into rivers, lakes and the oceans, so that new freezing would take place on the surface. The result would be rapid seasonal cooling of entire water bodies and/or permanent ice on the bottoms of oceans and lakes.

Water is an accommodating medium. It readily accepts as "host" a wide variety of other substances, either dissolved in forms such as molecules (e.g., carbon dioxide (CO_2) or oxygen (O_2) itself) or chemical ions (such as Na^+ and Cl^-, the ions of common salt), or suspended as fine particles, some of which are classed as mud. It also accepts combinations in chemical reactions with many other molecules, both organic and inorganic, in ways that are quite helpful to life. One of the most famous of these is photosynthesis, which in plant cells in the presence of the family of pigmented molecules called chlorophylls and activated by solar radiation, is approximately the following reaction: $6\ H_2O + 6\ CO_2 \rightarrow C_6H_{12}O_6 + 6\ O_2$, or in everyday terms, water held in the cells of plants plus carbon dioxide drawn from the air yields sugars (and from there, more complex carbohydrates) plus oxygen. Whence, not only do plants provide the basic energy food source for animals (who mostly live, one way or another, off plant carbohydrates), they also renew the air by reconverting CO_2 (a by-product of animal metabolism, expelled through breathing) back into the O_2 that is needed by these same animals as an input for the combustion of their carbohydrate "fuels."

2.2 Water Thermodynamics: Perspectives of Quality and Degradation

Water wanted to live
It went to the sun it came weeping back
Water wanted to live
It went to the trees they burned it came weeping back
They rotted it came weeping back
Water wanted to live
It went to the flowers they crumpled it came weeping back
It wanted to live
It went to the womb it met blood
It came weeping back
It went to the womb it met knife
It came weeping back
It went to the womb it met maggot and rottenness

It came weeping back it wanted to die

It went to time it went through the stone door
    It came weeping back
It went searching through all space for nothingness
    It came weeping back it wanted to die

Till it had no weeping left
    It lay at the bottom of all things
        Utterly worn out utterly clear.
(from *How Water Began to Play (Eskimo Songs II)* by Ted Hughes)

There are many aspects of physical and chemical cycling, that take in the whole planetary hydrological cycle, such as evaporation of water from the oceans' surface, re-condensation as snow and rain, transport through the atmosphere and precipitation onto land (as well as sea) where it may soak into soils, run down into rivers, be taken up by plants or for industrial uses, and so on. Many other chemical substances are involved, such as the nitrogen compounds that are obtained by "fixing" of atmospheric N_2 by bacteria in the soil, then taken up by plants, converted into proteins and other things, transformed into animals' flesh, and subsequently once again "broken down" in the phases of death and decomposition of the living forms. As Ted Hughes' *Eskimo Song* suggests, the pathways of life (and death) are the pathways of water's transformation in every respect.

In the 1970s, much emphasis was placed on a thermodynamically lucid analysis of economic systems, and sustainability. Energy units of measure took on a prominent place in national statistics and national research budgets, and new energy journals blossomed. Yet, the alchemical elements are four; and fire and air must be complemented by earth and water. At the dawn of the new millennium, it seems probable that water resources, both quality and quantity, will be a dominant preoccupation for human survival, well-being, and global community.

This does not mean to put aside the energy concerns. On the contrary it is to enrich them. Thermodynamics is the preeminent science of quantity and quality issues—energy conservation on the one hand, entropic irreversibility on the other hand—the First and Second Laws of Thermodynamics. The steam engine, which was the first technological model for the science of thermodynamics was analyzed in the nineteenth century from the point of view of temperature gradients and energy degradation. The main focus was the heat flows and work, although (with different cultural imperatives) the focus might equally have been on the pathways of transformation of the water to steam to atmospheric vapor and back, as rain or snow, to earth again.

The complexity of the water transformation cycles is easily visualized through the rustic example of the waterwheel. Consider the falling water caught by a large wheel, which turns on its axle, drives a shaft, and thereby runs a mill; the energy coming from the waterfall is eventually dissipated as heat, noise, water turbulence, and wear-and-tear on materials. Although the energy is conserved, and necessarily still exists, it can no longer be applied to useful work. This much all engineers know; but, where does the "used up" water go?

Water, energized by the sun, falling as rain and flowing with gravity's ups and downs, is the fundamental resource of organic life. Ecological economic activity, as all life, unfolds as so many small eddies, flows and recyclings in the planet's water cycles, an open history within the bounds of planetary exergy potentials. In the nineteenth century, to speak of energy was to evoke the immense powers of nature potentially at work for progress in industrial production. Man lived, and progressed, by tapping into—and indeed hastening, augmenting, hurrying on—the one-way flow of entropic degradation. But water, also, was being degraded (perhaps not quite irreversibly?), and this was more and more noticed as the twentieth century wore on.

There is a peculiar aspect to the problem of water quality. Water can become "dirty" or contaminated along its way. Water that has become "used" for economic purposes such as a leather tanning or dairy factory, or that has passed through a fertilized field or a rubbish disposal site, may flow onwards into other "natural" systems—but now in a polluted condition. This can menace the viability of nonhuman life forms, can impose opportunity costs for other potential economic uses, and can pose direct problems for human health. The water is "degraded" in its qualities.

The thermodynamician Clausius, in the late nineteenth century, generalized from the properties of idealized heat engines to the entire universe. He told a story of a "heat death" occurring some time in the unimaginably distant future, when the entropy will have risen to its maximum possible. Perhaps the story will be told, in an all-too-imaginable not-very-distant future, where all the rivers, lakes and seas of the world have risen to an unlivable level of chemical degradation?

3. Water's Value—a Problem of (Unequal) Distribution

3.1 Scarcity and Unequal Ecological Distribution

David Ricardo, at the beginning of the nineteenth century in the rainy and temperate climes of England, was aware of the degradation of the fertility of soils, yet had still been able to write in the *Principles of Political Economy and Taxation* of the indestructible powers of the land, and could proclaim confidently that "the brewer, the distiller, the dyer, make incessant use of their air and water for the production of their commodities; but as the supply is boundless, they bear no price." Today, even in places where there is regular temperate rain (such as, for example, in most of western Europe, or in New Zealand) it is now clear that this simplification is far from true.

Of course, for the societies of the Indian subcontinent, of arid regions in southern Africa, and of the Middle East, Mediterranean Basin and other water-scarce regions, there were never many illusions on this score. Water scarcity, and the restrictions of access to good quality water by one economic agent in competition with another, or by action of an enemy, has been a variable constituent of political, civil and military conventions of society, for hundreds of years everywhere.

Most environmental resources and services, and dis-services, are not in the market and never will be. Although water supply through pipes or canals can be marketed, the ecological conditions of water quality and quantity production, and degradation, cannot be wholly commodified. The term "ecological distribution" refers to the non-commodity environment as a source of human well-being, and seeks to highlight this nonmarket character. It highlights the social, spatial, and temporal asymmetries or inequalities in the nonmarketed use by humans of environmental resources and services, and in the burdens suffered, such as pollution. In these terms the following sorts of questions can be asked:

- What is the distribution of the benefits of the present patterns of natural resource and environmental exploitation?
- What mechanisms of capital flow, institutional power, technological change, etc., determine these patterns over time?
- Which classes, regions or social groups carry the principal burdens of the unwanted side-effects of resource exploitation and waste disposal?
- Which social groups benefit most, and which suffer most from the impairment of life-support functions and from the loss of environmental amenities resulting from environmental degradation?
- How are these benefits and burdens distributed across societies, across space and time? How are these temporal and spatial asymmetries valued (or devalued)?

Hydrological cycles and societal water management systems are complex, so ecological distribution issues are also complex.

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Biographical Sketch

Prof. Martin Paul O'Connor is from Christchurch, New Zealand, and studied physics and humanities in his native country and in Paris. After completing his Ph.D. in economics (*Time and Environment*) at the University of Auckland in New Zealand, he was for several years a Lecturer in Economics at the University of Auckland before taking up a professorial position at the University of Versailles St-Quentin-en-Yvelines (UVSQ) in Paris, in 1995. He has research degrees in physics, sociology and economics, and specializes in interdisciplinary work in ecological economics theory, development theory, environmental policy and social sciences epistemology. In New Zealand during the 1980s he was active in a range of critical and consulting studies including public policy, environmental and social impact assessments, energy and banking sector studies, in parallel to academic teaching and writing. Since 1995, as Project Manager at the C3ED (Centre d´Economie et d´Ethique pour l´Environnement et le Développement) research institute, he has participated in numerous French and European studies in the environmental valuation, green accounting, scenario studies, integrated assessment, risk and water governance fields. He is a member of the editorial advisory boards for the journals *Capitalism Nature Socialism (CNS)* and *Environmental Values*, and currently edits the interdisciplinary *International Journal of Water (IJW)*, published by Inderscience. With colleagues he is active in the development of international teaching networks, notably through the 3^E-SDP (European Ecological Economics and Sustainable Development Policy) program including North-South cooperation.