TRENDS IN WATER USE

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Abstract

Over the twentieth century world's population rapidly grew followed by land urbanization: at the turn of the century proportion of urban population was only 13 %, in 2009 it surpassed rural population and projection shows that it's likely to rise up to 69 % by middle of 21st century. Water resources are integral part of everyday municipal, as well as economical and ecosystem needs - which are in essence mutually exclusive. As populations and economic activities grow, many countries are rapidly reaching conditions of water scarcity and misuse of fresh water that pose a serious and growing threat to sustainable development and protection of the environment. Aforementioned problems are many addressed by forcing development of ever more distant water sources. Globally, the water resources in various regions and countries are expected to face unprecedented pressures in the coming decades as a result of continuing population growth and uneven distributions of population and water. More stringent wastewater treatment and effluent discharge regulatory requirements demand adaption of new approaches in urban water supply management. New approaches now incorporate the principles of sustainability, environmental ethics and public participation in project development and revise current planning, construction and management practices. This paper presents trend in water demand and its variation in distribution across economic sectors. New approaches in water resources management are presented with critical overview of their characteristics.

Keywords

Sustainable development, water demand trend, water resources management

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1 INTRODUCTION

Freshwater resources are essential component of all ecosystems and a vital element needed to sustain almost all life on the planet. Trends in population growth, urbanization and water resources exploitation are relevant indicators of water resources management efficiency and sustainability. Pessimistic projections on the availability of freshwater resources in the upcoming decades and more stringent water quality and wastewater treatment regulatory requirements demand a new approach in water resource management. New approaches now incorporate the principles of sustainability, environmental ethics and public participation in project development and revise current planning, construction and management practices.

2 WATER DEMAND INCREASE

20th century was characterized by rapid increase in world population as well as land urbanization and this trend is projected to continue throughout 21st century. The world population has reached 7 billion in late 2011, and according to the 2010 "Revision of the official United Nations population estimates and projections" it will surpass 9 billion people by 2050 (**Fig. 1**). Virtually all of the expected growth in the world population will be concentrated in the urban areas of the less developed regions. Overall, the world population is expected to be 67 % urban in 2050 [1].

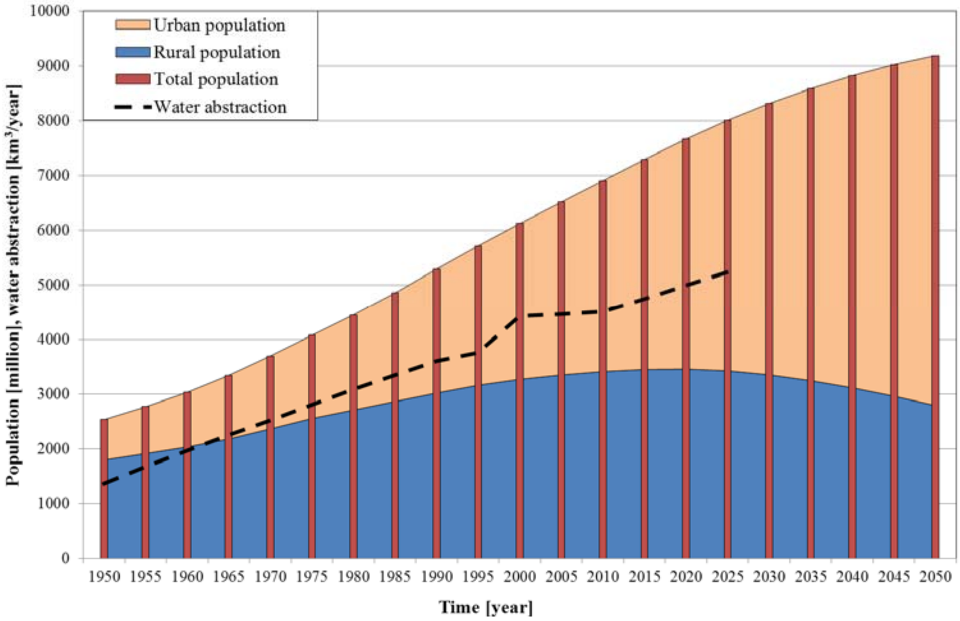

Fig. 1 Urban and rural world population [1] and the volume of total abstracted water [2].

Population growth and technological advances have resulted in a triple increase of water withdrawal since 1950; if this trend persists, by 2025 the quantity of withdrawn water will be four times the amount abstracted in 1950. Increase in mainly urban population will result in a higher water demand which will be concentrated in major cities and surrounding slums. In order to satisfy this increased water demand current water supply providers will have to expand system capacities and resort to costly and inefficient solutions to solve this predicted problem [3].

3 WATER SCARCITY AND THE MILLENNIUM DEVELOPMENT GOALS

Although the volume of available freshwater is sufficient to meet the current and projected human needs, it is not evenly distributed across the globe and much of it is wasted, polluted and unsustainably managed. Historically, cities have relied on their closest sources of water, which in most cases were freshwater streams, lakes or springs. Soon, these resources were exhausted or degraded, and the cities were forced to invest considerable funds in the construction of dams and pipelines to bring water from more remote sources. Continually expanding cities have outgrown most water-supply systems and new sources must be developed to satisfy the needs of their population.

In the year 2000, nearly 1.1 billion people still remained without access to improved sources of water [4]. In order to deal with this problem, during the Millennium Summit in New York in 2000, 189 UN member states have adopted the Millennium Declaration. One of the set Millennium Development Goals (MDG) was to halve the proportion of people without sustainable access to safe drinking water by 2015 [5]. It has been estimated that meeting this goal would require between US$ 14 billion and US$ 30 billion a year on top of the roughly US$ 30 billion already being spent [6].

Initiative to improve access to clean drinking water since the Millennium Declaration has been strong, resulting in a significant improvement in drinking water coverage. In 2010, 89 % of the world's population was using improved drinking water sources, up from 76 % in 1990. This means that the MDG target of halving the proportion of the population without sustainable access to safe drinking water has been met, five years ahead of the 2015 target. If current trends continue, 92 % of the global population will be covered by 2015. Still, coverage with improved drinking water sources for rural population is lagging. In 2010, 96 % of the urban population used an improved drinking water source, compared with 81 % of the rural population. The gap between urban and rural areas remains wide, with the number of people in rural areas without an improved water source (653 million) five times greater than one in urban areas (130 million) [7].

4 EXPLOITATION OF WATER RESOURCES

The proportion of water resources used by a country is a complex indicator reflecting development, national water policies, and physical and economic water scarcity. At low levels of development, it is generally advantageous to increase total water withdrawal for satisfying increase in water demand. But beyond a certain "inflection point", ecosystems will be strained and competing water uses will not allow all users to receive their fair share [7]. The abovementioned inflection point cannot be easily determined because of large annual differences in precipitation. Next figure (**Fig. 2**) shows that globally water resources exploitation is exponentially increasing. Once extracted water may be used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is a final use of water, after which it can no longer be reused. Consumed water is either "lost" through evaporation, transpiration, food and industrial goods production, or it has been severely contaminated. The striped band represents the difference between the amount of water extracted and that actually consumed. When the extracted water is not returned to its aquifers, they gradually have less water available for following rounds of exploitation. The amount of water not returned to its initial aquifer is still available in a hydrological cycle, but is located in different, inaccessible forms or in a different aquifer. The most significant volume of water being globally consumed is generated by agriculture.

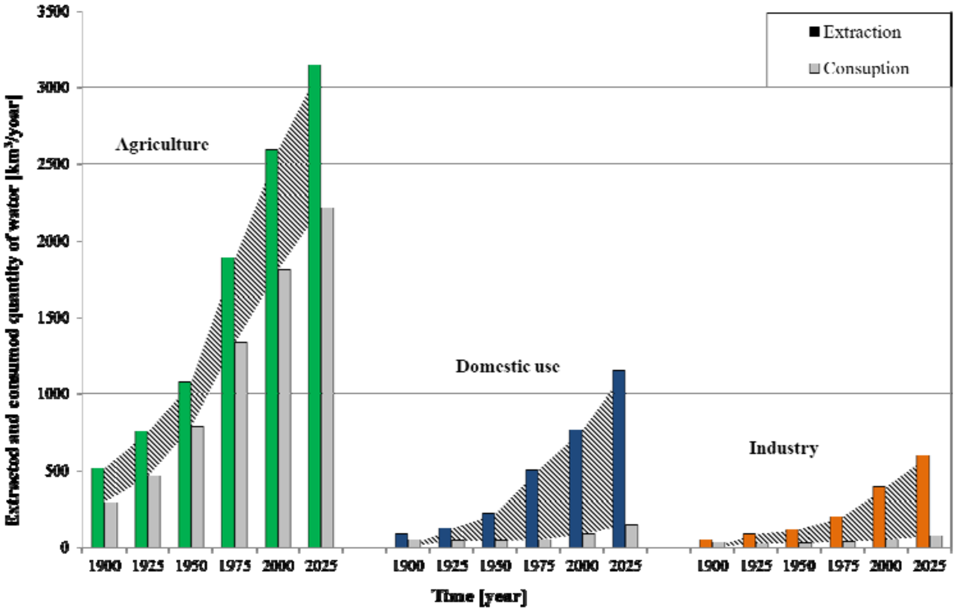

Fig. 2 Global water extraction and consumption by sector [8].

At global level, the withdrawal ratios are 70 % agricultural, 11 % municipal and 19 % industrial. These numbers, however, are biased strongly by the few countries which have very high water withdrawals. Averaging the ratios of each individual country, we find that "for any given country" these ratios are 59 %, 23 % and 18 % respectively. The ratios also vary much between regions, going from 91 %, 7 % and 2 % for agricultural, municipal and industrial water withdrawal in South Asia to 8 %, 16 % and 77 % respectively in Western Europe [9]. These relations are presented in figure (**Fig. 3**) along with the Croatian ratios which are significantly different from the worlds or European average [10].

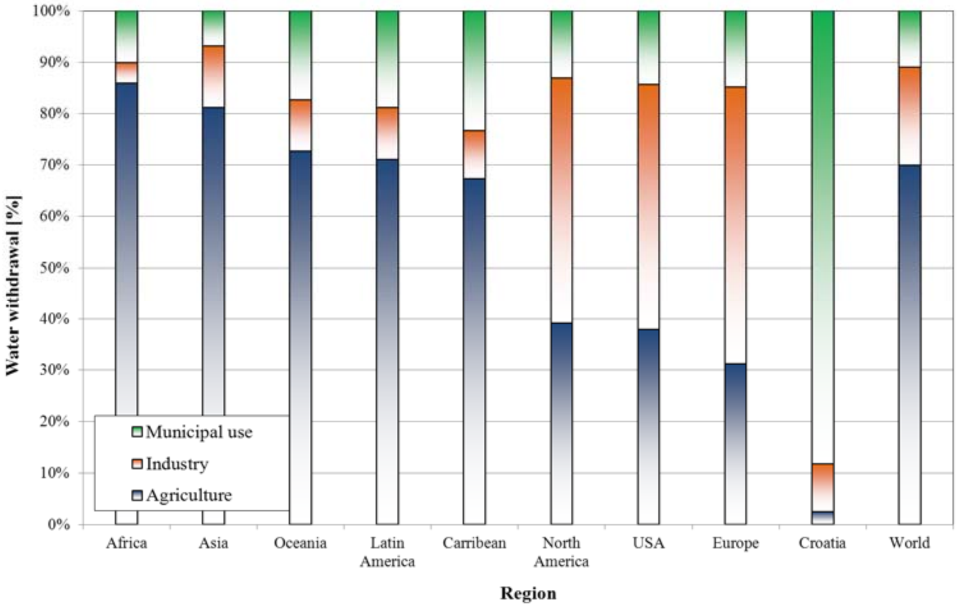

Fig. 3 Ratio of water withdrawal by sector [8].

Quantities of abstracted water differ greatly from region to region: East Asia, Latin America, Africa and a few smaller regions withdraw 3 times less water than an average OECD country and 5 times less then USA [11]. There are considerable differences in the per capita amounts of freshwater abstracted within each of the European countries as well: from a 24 m^{3}inhabitant^{-1}year^{-1} (Cyprus) to 269 m^{3}inhabitant^{-1}year^{-1} (Iceland). Croatia withdraws 129 m^{3}inhabitant^{-1}year^{-1}, which is higher than the European Union average of 93 m^{3}inhabitant^{-1}year^{-1} [12]. USA abstracts an amount of 1602 m^{3}inhabitant^{-1}year^{-1} [13]. When examining water abstracted for municipal use, there are even higher discrepancies between countries, from 71 L^{1}inhabitant^{-1}day^{-1} (Romania) up to 1861 L^{1}inhabitant^{-1}day^{-1} (Lithuania). In the year 2011, Croatian municipal use of water averaged at 183 L^{1}inhabitant^{-1}day^{-1} [10] while an average USA citizen used 370 L^{1}inhabitant^{-1}day^{-1} of water [13].

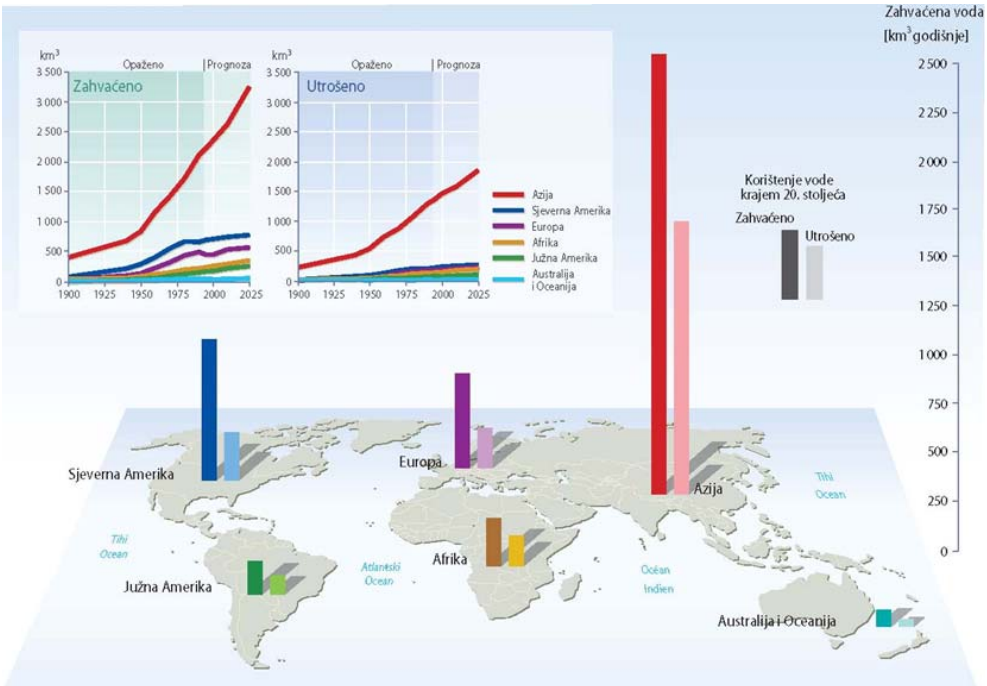

Fig. 4 Total withdrawn and consumed water by continent [2].

OECD member countries have reduced their average water use per capita by 11 %, and a reduction in water use has been achieved in 50 % of member countries. However, despite this trend, population growth caused an increase in the overall volume of water withdrawn in most of the countries. Only 9 OECD countries (all located in Europe) have managed to decrease their overall water abstraction in a period from 1980 to 1997 [11].

5 RENEWABLE WATER RESOURCES

Internal renewable water resources (IRWR) are that part of the water resources (surface water and groundwater) generated from endogenous precipitation. External water resources are the part of a country's renewable water resources that enter from upstream countries through rivers (external surface water) or aquifers (external groundwater resources). The total external resources are the inflow from neighbouring countries (trans boundary flow) and a part of the resources of shared lakes or border rivers. Total actual renewable water resources (TARWR) present the sum of internal renewable water resources and incoming flow originating outside the country and is valued as a maximal theoretical quantity of available water [14]. Globally, total water withdrawals still represent only a small share – about 9 % of internal renewable water resources (IRWR), but this average masks large geographical discrepancies (**Fig. 5**). The rate of withdrawal varies greatly by country or region. Europe withdraws only 6 % of its internal resources and just 29 % of this goes to agriculture [9]. Croatia withdraws only 1.51 of its IRWR [14]. The intensive agricultural economies of Eastern Asia withdraw 20 % of their internal renewable resources, of which more than 80 % goes to irrigation. In many of the low rainfall regions of the Middle East, Northern Africa and Central Asia, most of the exploitable water is already withdrawn, with 80 % - 90 % of that going to agriculture, and thus rivers and aquifers are depleted beyond sustainable levels [9].

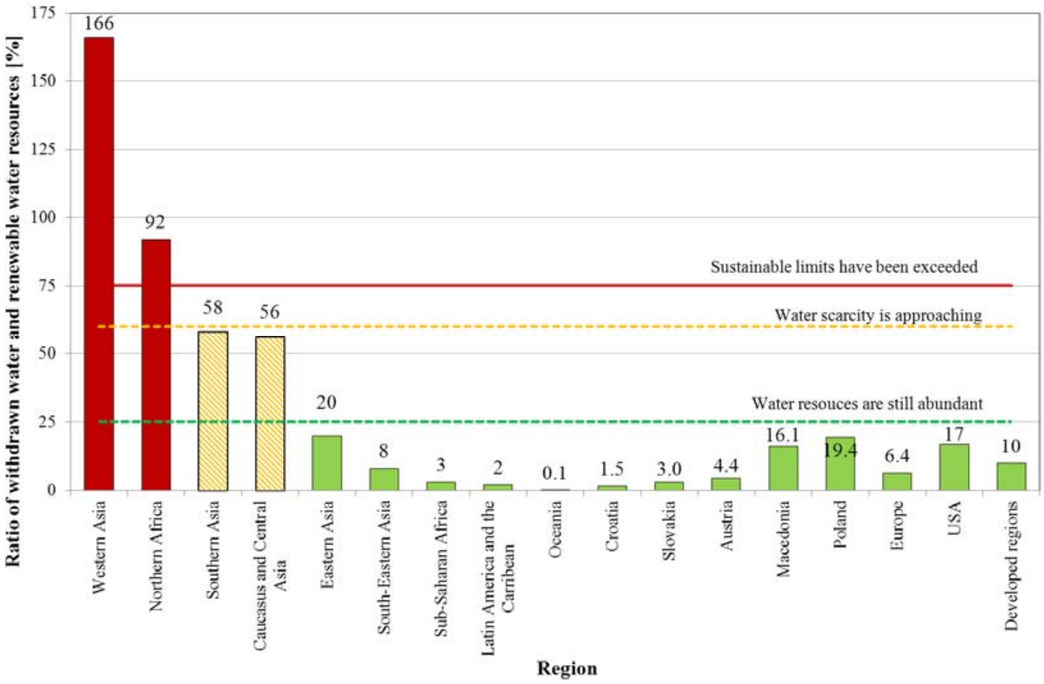

Fig. 5 Ratio of withdrawn water and internal renewable water resources [11, 14].

In terms of physical water scarcity it is estimated that on average withdrawal rate above 25 % of renewable water resources represents substantial pressure on water resources – and more than 60 % is 'critical'; at 75 % sustainable limit has been exceeded. Two regions which have exceeded sustainable limits are Western Asia and Northern Africa, while Southern Asia and Caucasus and Central Asia are approaching water scarcity levels [14].

6 SUSTAINABLE MANAGEMENT OF WATER RESOURCES

Water resources face competing demands from uses to support human health, economic development, and environmental services. In this sense, water is the perfect example of a sustainable development challenge – encompassing environmental, economic, and social dimensions. Reconciling these three aspects through appropriate water management is a significant policy challenge for governments [11].

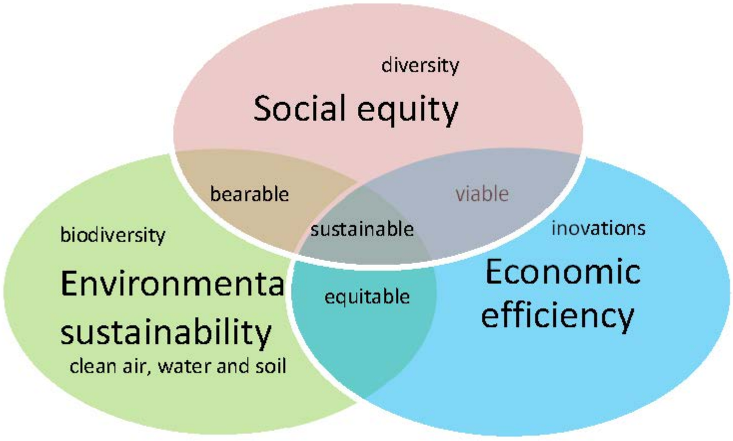

Fig. 6 Three dimensions of sustainability [15].

Poor water management is considered to be a limiting factor of sustainable development in the upcoming decades. Social, economic and ecological impacts generated by current water management techniques and an increasing water scarcity call for a new approach which involves sustainability principles, environmental ethics, public participation and re-evaluates the current methods of designing, building and management of water supply systems [16].
It is important to distinguish at the outset two main dimensions of water management:

1) water as a natural resource that is an integral part of the natural ecosystem; and
2) water as the key element of water services, which are generally infrastructure-intensive.

The first dimension involves the abstraction of water and its allocation among competing uses (e.g. industry, agriculture, municipal water supply, and ecological, aesthetic and recreational purposes). It also involves protection of surface-water bodies and groundwater reservoirs from degradation. The second dimension involves investment, operation and management of the infrastructure systems, and delivery of water services to final customers (i.e. treatment and distribution of piped water, wastewater collection and treatment, and irrigation networks) [11]. About 40 % of the world's population lives in trans boundary river basins, and more than 90 % live in countries with basins that cross international borders [17]. In order to successfully sustainably manage water resources an "ecosystem" principle should be implemented; water resources should be managed on a basin level so an equitable and reliable division of water resources is achieved for current and future generations. Sustainability can be achieved only by implementing technologically and economically viable solutions, especially in existing water supply systems which need to be expanded or improved to meet the increasing water demand. Clear understanding of availability and allocation of water in a hydrologic cycle as well as a clear concept of human impact on environment are prerequisites for achieving sustainable water management [16].
Water scarcity and overexploitation of freshwater resources present constantly growing threat to sustainable development. If management of water and land resources doesn't become more effective, food production and technological growth as well as ecosystem upon which they rely are endangered. Despite this negative trend, some progress is being made. For example, OECD countries have significantly reduced industrial and urban discharges to waterways, with the total share of the population connected to public wastewater treatment plants in OECD countries reaching an average of 65 %, and many of the rest using private sewage treatment. OECD countries have also cleaned up a number of the worst polluted freshwater

bodies. They have increased their water use efficiency, with several realising overall reductions in water use over the last two decades. Many have started to apply more integrated approaches to water management, following a “whole-basin” or “ecosystem” approach. Four essential conditions set for support of sustainable water management are:

1) Making markets work;
2) Improving the coherence of decision making;
3) Harnessing science and technology;
4) Working in partnership with developing countries.

The goal of sustainable water resources development and management is to meet water needs reliably and equitably for current and future generations by designing integrated and adaptable systems, optimizing water-use efficiency, and making continuous efforts toward preservation and restoration of natural ecosystems [16].

7 CONCLUSION

Current water exploitation practices and projected trends presented in this paper are created from datasets published by national statistical agencies. Methods used for data acquisition in certain world areas may not have followed “best practices” as many of the world’s countries do not have adequate personnel, technology or guidelines for collecting the desired information. Any conclusions that may be drawn from this paper should take in account the accuracy of gathered information. Nevertheless, water scarcity induced through increased global water demand is an on-going issue which affects numerous world regions and the demand for water resources will definitely increase in the upcoming decades. The limits of sustainability may be loosely defined but the apparent degradation of an ecosystem in some regions caused by overexploitation of water resources is an evident indicator of an unsustainable and wasteful water management practices. Global water resources are plentiful, but often unevenly distributed, polluted and mismanaged. Implementation of new technical solutions, improved water management techniques and more coherent decision making is a crucial step in achieving sustainability and satisfying world’s current and future needs for water.

References

[1] United Nations, *World Urbanization Prospects The 2011 Revision*, Department of Economic and Social Affairs, New York, 2012.

[2] UNEP, *Vital Water Graphics - An Overview of the State of the World's Fresh and Marine Waters*, United Nations Environmental Programme, Nairobi, Kenya, 2008.

[3] United Nations, *Water: A shared responsibility - The United Nations World Water Development Report*, UNESCO, Paris, France, 2006.

[4] WHO/UNICEF, *Global Water Supply and Sanitation Assessment 2000 Report*, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2000.

[5] United Nations, *United Nations Millennium Declaration*, United Nations Millenium Summit, New York, 2000.

[6] WEHAB Working Group, *A Framework for Action on Water and Santation*, World Summit on Sustainable Development, Johannesburg, 2002.

[7] United Nations, *The Millennium Development Goals Report 2011*, United Nations Department of Economic and Social Affairs, New York, 2011.

[8] OECD, *OECD Environmental Outlook to 2030*, OECD Publishing, 2008.

[9] FAO, *AQUASTAT - FAO's Information System on Water and Agriculture*, Food and Agriculture Organization of the United Nations, Land and Water Division, 2012.

[10] CBS, *Statistical Yearbook of the Republic of Croatia 2011*, Croatian Bureau of Statistics, Zagreb, Croatia, 2011.

[11] OECD, *Improving Water Management: Recent OECD Experience*, Organisation for Economic Co-operation and Development, Paris, 2003.

[12] EUROSTAT, *Europe in figures - Eurostat yearbook 2011*, Publications Office of the European Union, Kirchberg, Luxembourg, 2011.

[13] J. F. Kenny, N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace, and M. A. Maupin, *Estimated use of water in the United States in 2005*, U.S. Geological Survey, Reston, Virginia, 2009.

[14] FAO, *Review of World Water Resources by Country*, Food and Agriculture Organization, Rome, 2003.

[15] P. H. Raven, L. R. Berg, and D. M. Hassenzahl, *Environment*, John Wiley & Sons, Inc., Jefferson City, 2010.

[16] T. Asano, F. L. Burton, H. L. Leverenz, R. Tsuchihashi, and G. Tchobanoglous, *Water reuse: issues, technologies and applications*, Metcalf & Eddy, New York, 2007.

[17] C. W. Sadoff and D. Grey, "Cooperation on International Rivers - A Continuum for Securing and Sharing Benefits," *Water International*, vol. 30, 2005.