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WORLD WATER SCARCITY FROM POLITICAL AND ENGINEERING PERSPECTIVES

KRYTYCZNA FAZA ŚWIATOWEGO PROBLEMU WODY - PODEJŚCIE INŻYNIERYJNE I POLITYCZNE

Water scarcity is not a new world problem. Water has been a source of conflicts and a tool of a political pressure over millennia. A dynamic development of emerging countries, industrialization and population growth have aggravated scarcity of water. Society that evolves from rural and agrarian to urban and industrial requires preserving equity and the primacy of the right to quench thirst. Water, food and energy is in a short supply, therefore, an identification of sustainable solutions that meet local demands based on culture and perceptions of users is an important approach for policy makers. Unfortunately, there is shortage of policies encouraging the population to produce and use reclaimed water although engineering solutions exist. Along with demand management measures to optimize the available water in urban areas, inter-sectorial water markets have been suggested as a means to transfer freshwater from rural areas to urban areas. Recycling the water has to be an additional and unavoidable option. This must be accompanied by expanded wastewater treatment and reuse in agriculture, particularly in peri-urban agriculture. The regulations related to withdrawals, consumption, changes in water quality, etc. require legal and monitoring systems that do not yet exist in most underdeveloped and emerging countries. In some cases, laws exist but the government ability to monitor or overcome corruption or resist to influential lobbies is inadequate. New engineering solutions, which are capable to treat water on-site, might change centralized water management approach, for example, the implementation of in-situ treatment wastewater (e.g. SMEBR) and harvested rainwater would be used for a large range of human activities. Finally, more closer and much often interactions between water professionals and policy makers, land user and city planners should be promoted to face world water scarcity.

1. Water scarcity - Human development competes with nature

The trade and economic growth have improved the quality of life for millions of people around the world, but it has come at a high cost to the environment. Subsequently, climate change is likely to contribute to the water scarcity problem by altering unfavorably the seasonal distribution of precipitation. Simultaneously every day, people somewhere in the world are creating a new use for cleaned water. Unfortunately, such use is done without well-defined limits. Deforestation is one of the largest global environmental threats. Current trends of bio-fuel production indirectly threaten forests. In river basins with limited water availability (arid and semi-arid regions) where biomass production relies on irrigation, energy from biomass can become a thread for the river basins (e.g. Aral, Caspian Sea, Ebro, Yellow River, Jordan, Euphrates). After all, an assessment of total fresh water circuit is around ~60,000 m^3/P, where available on land around ~20,000 m^3/P, while food production needs ~1,500 m^3/P, hygiene ~30 m^3/P, and water for drinking ~1m^3/P (Rubin, 2001).

Furthermore, the society evolves from rural and agrarian to urban and industrial, then, urban population growth will be the future major problem. Water scarcity is imminent for people living in mega cities of more than 20 million (Delhi, Manila), more than 10 million (Mexico City, Beijing, Mumbai, Calcutta, Lagos, Bangalore), more than 5 million (Chennai, Hyderabad, Johannesburg, Lahore, Tehran, Shenyang, Riyadh), more than 3 million (Abidjan, Caracas, Tel-Aviv), and more than 1 million (Abu Dhabi, Dubai, Cotonou, Haifa, Jerusalem). These problematic cities have been defined by various criteria as they are facing the challenge of water shortages including water scarcities, lack sustainable sources of surface or groundwater within a 100-km radius (McDonald et al., 2011). Dynamic growth of mega cities shows many problems since one source of water is not any more sufficient to respond to huge water demand. Unfortunately, even the water supply from combined resources (groundwater, surface water, rain water) might also be insufficient in near future; then, water recycling or its production *in-situ* is a necessity.

According to a NCDC report (July 2012), the 33% of USA was classified as experiencing a moderate to extreme drought and 55% felt in the category of exceptional drought. July 2012 was the hottest month on record for the USA, with the average temperature at 77.6 ^{o}F (25^{o}C), i.e. 3.3^{o}F above the 20th century average. Simultaneously, water demand has increased due to the extensive cultivation. For example in Missouri over 20 years ago, there were approximately 300,000 acres with irrigation, now there is over one million. This trend will not change. (NCDC, 2012).

The natural aridity coupled with high population growth and urbanization is creating severe inequities, particularly in less-developed countries where the growth rate was assessed for 3.2% (1995–2015). The urban or peri-urban communities are rarely served by public utilities, either because they were unplanned or because of legal or political restrictions imposed on the utilities. Many of the community residents rely on informal supplies of water sold by private vendors. For low-developed countries on average, the families pay ten to twenty times (up to one hundred times in some municipalities) more per unit than residents receiving piped water service. (Bhatia and Falkenmark 1993)

Ironically, the fastest development in the earth is observed in the areas where the water scarcity is the highest, e.g. Qatar, UAE, Saudi Arabia. In Saudi Arabia, 3,600 billion m^3 (20%) of water is required for domestic use (including drinking) and 14,700 billion m^3 for agriculture (80%) purposes. However, non-renewable groundwater (shallow and deep aquifers) supplies about 94% of irrigation water (90% of total national water use). The situation is often aggravated by lack of sewage network; 40% of the population of the Saudi Arabia is served by an integrated sewage and wastewater system while in Jeddah by 22% and Medina by 21% only. Furthermore in entire Gulf region, the connection to the sewer pipes varies between 8-14%; the rest depends upon septic tanks that are occasionally drained by wastewater tankers. In Bahrain, more than 90 % of the population lives in areas with a sewage network, in Kuwait is more than 60 %; however, Oman depends mostly on a septic tank-based system (O'Sulivan, 2010). The sewage is often pumped directly to the ground affecting groundwater quality. In such cases, during rare but torrential rains, the overflow and runoff makes groundwater completely unavailable and even provokes deaths like in Jeddah in 2009.

In all above cases, governmental regulations, reduction in water use and control of corruption seem to be the key element in an adequate water supply. Consequently, improvement of groundwater management and reduction in irrigation water consumption, especially for wheat cultivation, became essential for maintaining the long-term productivity and quality of the aquifers. Then, development of regulations to improve the management of water demand and to protect and conserve water resources has been defined as a necessity. (O'Sulivan, 2010).

2. Water as a political tool

Water has been used a as a political tool over millennia. Historic events and experience have redefined values and scenario for a pathway of the modern society development.

First documented dispute regarding the access to water in Gu'edena region was described in 2500 BC. King of Lagash diverted water from to boundary canals, drying up boundary ditches to deprive Umma of water. Since that time water was used many times over centuries as a tool of political pressure, particularly as a military tool. For example, in 6th century BC, Assyrians poisoned the wells of their enemies with rye ergot; in 51 BC, Caesar attacked water supplies during siege of Uxellodunum and such shortage of water led to the surrender of the Gauls. During American Civil War (1860-1865) both sides poisoned ponds by dumping the carcasses of dead animals into them. In 1938, Chiang Kai-shek ordered the destruction of flood-control dikes of the Huayuankou section of the Yellow River to flood areas threatened by the Japanese army. The flood destroyed part of the invading army and its heavy equipment was stuck in thick mud.

During WWII (1942), Japanese chemical and biological weapon activities included tests against military and civilian targets by spiking wells and reservoirs with typhoid and other pathogens. Bombarding dams and hydropower systems was used during WWII in all fronts by Germen, Soviets, and allied forces; for example in 1944, Germen flooded the Ay River, while France in July 1944, creating a large lake slowed an advance the German groups in Normandy.

Water and food supplies were cut off during Arab siege of Jerusalem from December 1947, to July 1948. Shortages caused Israelis to begin rationing water, limiting each person to 8 L, of which 2 L were drinking water.

During war in 1998-1999, the contamination of water by Serbs disposing of bodies of Kosovar Albanians in local wells was reported. Other reports mentioned about Yugoslav federal forces poisoning wells with carcasses and hazardous materials.

Tamil Tiger rebels cut the water supply to government-held villages in northeastern Sri Lanka. Sri Lankan government's forces, then, they launched attacks on the reservoir, declaring the Tamil actions to be terrorism. Conflict around the water blockade claimed more than 425 lives in 2006.(PI, 2009).

3. Regulations

The Code of Hammurabi (1490 BC) listed already several laws pertaining to irrigation that addressed negligence of irrigation systems and water theft.

Sometimes, political decisions had personal reasons, for example between 558–528 BC, Cyrus on his way to defeat Nabonidus at Babylon, faced a powerful tributary of the Tigris (Diyalah) that drowns his royal white horse and presented an obstacle to his march. Cyrus angered and ordered his army to cut 360 canals to divert the flow of the river. (PI, 2009).

Sometimes new regulations do not find a good response of population. In 50 AC, Roman Procurator Pontius Pilate used sacred money to divert a stream to Jerusalem in order to supply it of water. However, the Jews are angered at the diversion and tens of thousands gathered to protest against the Pilate and king Herod.

Lack of adequate law and its abuse can generate uprisings. In 1748, Ferry House on Brooklyn (USA) shore of East River was burned down since New Yorkers accused Brooklynites of having set the fire as revenge for unfair East River water rights. In 1841, the reservoir in Ops Township, Upper Canada (now Ontario), was destroyed by a mob who consider it a hazard to health. The recurrent friction and eventual violent conflicts over water rights in the vicinity of Tularosa (New Mexico) involved villagers, ranchers, and farmers between1870-1881. In China, General Gao Minghen (1642) breached the dikes of the Yellow River near Kaifeng in a campaign to suppress peasant uprisings. (PI, 2009).

In 1898, military conflict nearly been arisen between Britain and France when a French expedition attempted to gain control of the headwaters of the White Nile. While the parties ultimately negotiate a settlement of the dispute, the incident has been characterized as having "dramatized Egypt's vulnerable dependence on the Nile, and fixed the attitude of Egyptian policy-makers ever since." 60 years later, Egypt sent an unsuccessful military expedition into disputed territory during pending negotiations over the Nile waters, Sudanese general elections, and an Egyptian vote on Sudan-Egypt unification. Subsequently, the Nile Water Treaty was signed when pro-Egyptian government has been elected in Sudan.

Limited water resources are a cause of conflicts not only between tribes or towns but also between the countries on all continents. Recent years brought more often regulatory solutions that frequently require third party's involvement or international negotiators. (PI, 2009).

3.1. America

Arizona called out the National Guard and militia units (1935) to the border with California to protest the construction of Parker Dam and water diversion from the Colorado River. This dispute ultimately was settled in court. However, the tension around diverting water from Colorado River valley is still present.

In South America, negotiations between Brazil and Paraguay over the development of the Paraná River were interrupted by Brazilian military forces (in 1962), which invades the area and claimed control over the Guaira Falls site. Military forces were withdrawn in 1967 following an agreement for a joint commission to examine development in the region. (PI, 2009).

3.2. Far East

The political partition, which left Indus basin divided between India and Pakistan, ensured disputes over irrigation water, but Indus Waters Agreement was reached in 1960 after 12 years of World Bank-led negotiations only.

Civil unrests over severe water shortages caused by the long-term drought have been omnipresent in 21th century. In addition, a number of ethnic conflicts have risen dramatically. For example in India, some groups accused the government of favoring the populous Punjab province over Sindh province in water distribution (2003).

Conflicts over excessive water withdrawals and subsequent water shortages from China's Zhang River have been worsening for over three decades between villages in Shenxian and Linzhou counties. In the 1970s, militants from competing villages clashed over withdrawals. The similar conflicts erupted in China many times between 1976 and 1999.

In this century in India, North Korea, Pakistan, the drought and inequality in water distribution led to many violent clashes in the region, so, media reported more than a dozen people were killed and even more injured during 5 month-period in 2009, mostly fighting over a bucket of water. (PI, 2009)

3.3. Middle East

In 1951, Jordan made public its plans to irrigate the Jordan Valley by tapping the Yarmouk River. Israel responded by commencing drainage of swamps located in the demilitarized zone between Israel and Syria, which provoked the border skirmishes between Israel and Syria. Israel, subsequently, has begun the construction of the National Water Carrier to transfer water out of the Jordan basin to the Negev Desert for irrigation. Syrian military actions along the border and international disapproval led Israel to move its intake to the Sea of Galilee.

Present Israel's sanctions against Gaza causes water shortages and a growing public health risk. Palestinians in the Jordan Valley have very little access to water, living on 10-20 liters a day. A report by Oxfam International has revealed, while the Palestinian Authority was facing a severe financial crisis, that Palestinians could generate an extra USD 1bn a year if Israel removes restrictions on the use of land and water in the Jordan Valley. (Al Jazeera, 2012).

In 1975, as upstream dams were filled during a low-flow year on the Euphrates, Iraqis claimed that flow reaching its territory is "intolerable" and asked the Arab League to intervene. Syrians claimed they were receiving less than half the river's normal flow and pulled out of an Arab League technical committee which was formed to mediate the conflict. Subsequently, Syria closed its airspace to Iraqi flights, and both countries transfer troops to their mutual border. Saudi Arabia successfully mediated the conflict.

In 1990s, the realization of Grand Anatolia Project by Turkey engendered interruption the Euphrates flow and threatening downstream located countries. In fact, Turgut Ozal threatened to restrict water flow to Syria to force it to withdraw support for Kurdish rebels operating in Turkey.

During the period 1991-2001, United States deliberately pursued policy of destroying Iraq's water systems through sanctions and withholding contracts. In 1993-2003, Iraqi government reportedly poisoned and drained the water supplies of southern Shiite

Muslims. The European Parliament and UN Human Rights Commission deplored use of water as a weapon in the region.

In 2000, Kyrgyzstan cut off water to Kazakhstan until coal was delivered. Then, Uzbekistan cut off water to Kazakhstan for non-payment of debts. (PI, 2009)

3.4. Africa

South Africa supported the coup in Lesotho over support for ANC and anti-apartheid and water negotiations (1986). Then, new government in Lesotho quickly signed Lesotho-Highlands water agreement.

In fact, humans compete for water sources with animals. It was reported in 2000s, that clashes between villagers and thirsty monkeys left apes dead and many villagers wounded. The fight started after water tankers brought water to a drought-stricken area and monkeys desperate for water attacked the villagers.

The civil war (2003-2007) in Sudan has included violence against water resources by bombing and poising wells (Tina, Khasan Basao). Darfur's wells were intentionally contaminated as part of a strategy of harassment against displaced populations. (PI, 2009).

3.5. Europe

In 1992, Hungary repealed a 1977-treaty with Czechoslovakia concerning construction of the Gabcikovo/Nagymaros project based on environmental concerns. Slovakia continued construction unilaterally, completed the dam, and diverted the Danube into a canal inside the Slovakian Republic. Massive public protest and movement of military to the border resulted and this issue was taken to the International Court of Justice.

In 1994, a threat by Moldavian General Nikolay Matveyev to contaminate the water supply of the Russian 14^{th} Army in Tiraspol (Moldova) with mercury was reported.

In 2014, Ukraine has been cutting water supply through a canal stretching from the Dnepr River to Crimea after its referendum and joining Russian Federation. Crimean farmers were estimated to lose up to USD 140 million. (UT, 2014)

3.6. Australia

The Australian continent has never been free of conflicts over water rights. A number of incidents have been reported following 10 years of drought and water restrictions, leading scholars to suggest a link between persistent urban water restrictions and civil unrest. It was even led to a murder in Sydney in 2007. (PI, 2009)

3.7. Regulated water market

Development of regulations to improve the water management with respect to its demand, protection and conservation are necessary. However, regulations should include a long time planning, since a short at-hock approach does not solve the problem - opposite, it might aggravate the situation. For example, during warm summer of 1998, the city of Amman (Jordan) suffered a water shortage. The public was forced to buy water from vendors, and the black-market price of water reached USD 14/m^3. At another occasion in Jordan, the government paid farmers USD 120/ha for not planting vegetables and annual crops (Shatanawi and Al-Jayyousi 1995; Bino and Al-Beiruti 1998 in Faruqui et al., 2001).

Since the population grows and settlement patterns change, i.e. the society evolves from rural and agrarian to urban and industrial, it is necessary to preserve equity and the primacy of the right for the thirsty. Then, it means that more water have to be allocated for domestic purposes.

However, considering the fact that the distribution of water in arid regions includes mostly 80% for agriculture, 10% for domestic and 10% for industrial use, reducing of freshwater for agriculture can affect national food availability and have socioeconomic impact on farm workers. "Since the first priority must be water for drinking and domestic purposes, not agriculture, the concept of food self-sufficiency must give a way to national food security or regional food self-sufficiency, and imports of 'virtual water' through the purchase of foods and products produced where it is most efficient. The water scarcity benchmark level of 1000 m^3/P/y includes the amount necessary for food self-sufficiency"(Faruqui, et al., 2001).

Therefore, there is a tendency to trade the water. For example in Israel, given the current rate of urbanization and an unchanging combined industrial-domestic water consumption rate of 342 L/P/y, 80% of freshwater will be used in cities and industry and 20% in agriculture by 2030 (Lundqvist and Gleick 1997 in Faruqui et al., 2001).

Along with demand management optimizing the available water in urban areas, inter-sectorial water markets have been suggested as a means to transfer freshwater from farmers in rural areas to urban areas. This must be accompanied by expanded wastewater treatment and reuse in agriculture, particularly in peri-urban agriculture. Regulated water markets have been very successful in developed countries, and inter-sectorial transfers through water markets are inevitable in the arid zone countries. (Faruqui et al., 2001).

Regulated water markets have been successful in Chile and the United States. In 1991, during a drought period, the California Water Bank purchased water from farmers for about USD 0.10/m^3, representing 25% more profit than they could get by planting crops. The water was then sold at an average price of USD 0.14/m^3 to critical urban and agricultural users (Bhatia and Falkenmark 1993).

Chile's Water Law also allows transfers. The city of La Serena met its growing water demand by buying water from farmers at a much lower cost than the alternative of contributing to the construction of the Puclaro dam, which has been postponed for years (Postel, 1995).

Raising prices for water in urban areas can help simultaneously to reduce the demand of served customers and to provide an economic incentive for inter-sectorial water markets. There is a room to raise prices for the served middle and upper classes since water rates in low developed countries are typically less than one-sixth the full cost of water provision (Bronsro 1998). The actual full cost of providing water services varies from country to country, but in Israel, the only country in the Middle East, where water is charged at full cost (USD 1/m^3) including a surcharge for wastewater treatment in urban areas.

In many counties, water law is related to the tradition. Islamic water law in terms of water utilization priority is traditionally prioritized as follows: first, for domestic purposes (drinking water and domestic activities); second, for domestic animal watering; and third, for agriculture (Allan and Mallat, 1995).

In Iran, where the law is based upon *sharia*, irrigation water must be sold at average cost (comprising both operation and maintenance costs and capital depreciation). This requirement is enshrined in the 1982 Just Distribution of Water Law. (Sadr in Faruqui et al., 2001).

Poverty has been increased in underdeveloped countries and the question about rights to accessing to water raises. The basic human-need standard of 50 L/P/d suggested by Lundqvist and Gleick (1997) shows that in all mega cities with growing shantytown, a realistic water price should be better defined. It was suggested (Sadr in Faruqui et al., 2001) that price must allow for reinvestment into the system to serve the unserved poor, and would be less than they currently pay, but higher than that for the serviced urban residents. Tariffs should be structured to supply everyone with a lifeline water volume, as is done in Iran, where about the first 30 L/P/d is provided to all households (5,000 L/household/month), based on an assumed average of six persons per household (Sadr in Faruqui et al., 2001). Nevertheless, some economists suggest that governments should subsidize income, not water, and this argument finds sympathy among many scholars.

In some studies, the formation of water associations was suggested. For example, the strengthening water users' associations (Highlands and Southern Ghors, Jordan) help small farmers by exerting effective pressure on the government and bringing about favorable changes both in water policy and services provided (Shatanawi and Al-Jayyousi, 1995).

On the other hand, the corporations and lobbies are liable to have excessive influence on government policies. Large farmers, in particular, as well as the upper class in urban areas, tend to have very strong lobbies for their interests. (Faruqui et al., 2001)

The regulation of facilities related to withdrawals, consumption, changes in water quality, etc. require sophisticated legal and monitoring systems that do not yet exist in many countries. In some cases, laws exist but the government ability to monitor or overcome corruption is weak. Even in EU, the implementation of the Water Framework Directive has not been completed yet.

Problems with water supply in Poland may be similar to other countries; it is mostly related to an adequate balance between consumers and users. Then, water resources may be unevenly distributed in the future. “Potential water deficit in Poland results not from the lack of water in general, but from the lack of water in the right place and of adequate quality. Reservoirs in Poland with a total capacity of about 4 billion m^3 equal approximately to 6.5% of average annual runoff volume do not provide the full protection against floods and drought, and do not guarantee adequate water supply” (Ostojski et al., 2012). Incorrect estimation of the amount of water in Poland might lead to an improper water management.

4. Engineering sustainable solutions

Peaceful solutions with respect to water scarcity are often provided by engineers not politicians. For example, Leonardo da Vinci (1503) prepared plans and invented a machine for ditch excavation to divert the Arno River in order to finalize the conflict between Pisa and Florence regarding their access to water.

Scientists from Jordan, Israel, and Palestine work together on the project on a canal joining Red Sea with Dead Sea, which will permit to: a) complete the lost water volume in Dead Sea, b) build a system of water treatment plants which will supply water to all countries, and c) produce energy due to difference of elevation between both seas. (EUROMED 08)

4.1. Middle East

Presently, countries having access to sea water commonly use the desalination process as a solution for the water scarcity. However, water generated from desalination is costly and its production is not environmental friendly since disposal of brine, generated by desalination units, increases the salt concentration in the Gulf water and affects marine environment. The processes for desalinizing seawater and distributing it in Saudi Arabia, an adjoining country is costly and much higher than the maximum theoretical cost of USD 1.80/m^3 (Abderrahman in Faruqui et al., 2001).

An approach to water consumption, generation and discharge will evidently change in the coming years. New sources of water have to be considered, so, wastewater will be seen as a source of water. There is already tendency to see adequately treated wastewater as irrigation water, grey water, and water to recharge groundwater table. Such facilities have been built in Gulf area, Asia and America (e.g. advanced wastewater treatment and recycling plant at the Al Ghail Industrial Park, UAE). (Emirates News Agency, WAM 2008).

Some recycling measures have been already implemented at a smaller scale; for example, ablution water is recycled for toilet flushing at the two Holy Mosques at Makkah and Al-Medina as well as highly saline water from Wadi Malakan is also used for the same purpose in Makkah (Abderrahman in Faruqui et al., 2001).

Urine is officially recognized as important reclaimed water for irrigation since contains 95% of water while 5% is comprised of both the macro-nutrients (N,P,K) as well as traces of some micro-nutrients. It is generally a well-balanced nitrogen rich fertilizer and the average person produces enough urine per year to cover 300-400 m^2 of land to a level of 50-100 kg/ha of nitrogen (Feineigle, 2011). At the same time, the price of fertilizer is out of the reach for more than half the world population; however, diluted urine used as fertilizer can alleviate hunger in many under-development countries.The World Health Organization (WHO) has developed a multi-barrier system (9 barriers) to prevent the spread of any disease from separation at the sources to harvesting. (WHO, 2006).

An extensive reuse of wastewater is restrained by believes. However, the Council of Leading Islamic Scholars (CLIS) of Saudi Arabia postulated the *fatwa* (CLIS 1978) that postulated “Impure waste water can be considered as pure water and similar to the original pure water, if its treatment using advanced technical...Then it can be used to remove body impurities and for purifying, even for drinking.”

Soil in arid zones does not have adequately components: organic matter, and nutrients. In most cases, it has too high Sodium Adsorption Ratio (SAR) or salinity index and it is difficult to be cultivated. Use of wastewater without a pre-treatment often increases SAR and creates unsuitable conditions for sensitive crops (e.g. wheat).

Reducing the amount of freshwater available for agriculture raises concerns about national food availability and the socioeconomic impact on poor farmers and farm workers. The IDRC (Canada) has been responsible for development of pilot-testing grey-water treatment using on-site, small-scale, trickling filters for home gardens in the low-density settlements surrounding Jerusalem, aquatic wetlands using water lettuce or duckweed in the Jordan Valley and Morocco, and low-mechanical content-activated sludge in Egypt. (Faruqui et al., 2001)

It is suggested that most of crops in arid countries have to be grown increasingly and eventually exclusively, with treated wastewater. It is recommended to implement various advanced techniques, e.g. membrane submerged electro-bioreactor system to produce high quality water for agriculture as well as for domestic activities (see Canada below).

4.2. America

On a broad scale, the 1980s and 1990s were characterized by unusual wetness with short periods of extensive droughts, the 1930s and 1950s were characterized by prolonged periods of extensive droughts with little wetness, and the first decade of the 2000s saw extensive drought and extensive wetness. According to the weekly U.S. Drought Monitor (USDM), about 38.4% of the US territory was classified as experiencing moderate to exceptional drought at the end of March 2014. March 2014 was ranking as the 13th driest and 44th coolest March region-wide. The drought is expected to continue and possibly intensify into the end of November for a large part of the country, which is expected to have both short-term and long-term impacts across nearly the entire affected area. Some authors (Masters, 2013) predict that the drought has cost more than USD 35 billion in the Midwest, and it is predicted to reduce the US Gross Domestic Product by 0.5-1%, equating to a loss of USD 75 to USD150 billion.

Almost 91% of California territory is affected by drought over the years. Inhabitants often, designing their own systems to response to drought catastrophic situation. For example Jerrard designed a filter system for domestic wastewater, which removes soap, cosmetics, and various slats inadequate for irrigation. However, this recycled water does not have a quality of drinking water and cannot be used to irrigate plants having underground edible parts; it is rather used for grass, bushes and trees. (ENEX, 2014)

Brightwater Water Reclamation Plant in Woodinville, WA of 36 MGD flow (pick hours130 MGD) uses MBR to produce Class A quality water. Washington State identified standards for four classes of reclaimed water, with Class A being the highest. Class A reclaimed water can be safely used for many purposes that do not require drinking water, such as industrial processes, irrigation of edible crops, gardens and landscaping, and irrigation of public areas such as parks and recreational fields. Brightwater is initially designed to distribute about 7 million gallons (MGD) of Class A reclaimed water each day for off-site uses, and eventually could distribute up to 21 MGD as demand requires. (KC, 20014).

In Florida, Orange County operates the South, Eastern, and Northwest Water Reclamation Facilities, which has treatment capacities of 43 MGD, 19 MGD and 10.5 MGD, respectively. They produce approximately 51 MGD of reclaimed water and 37 dry tons of biosolids every day. Reclaimed water is used for citrus irrigation, industrial reuse, wetlands enhancement and residential and golf course irrigation. (NBP, 2014)

Implementations of engineering solutions depend on an adequate local (or national) policy. In USA, Senate Bill 09-080, allows limited collection of rainwater and use precipitations for landowners only. Colorado water law declares that the state of Colorado claims the right to all moisture in the atmosphere that falls within its borders and that "said moisture is declared to be the property of the people of this state, dedicated to their use pursuant". Gray water for less than 2000 gallons (Waskom and Kallenberger 2012) systems requires permits from local health department. In fact 13 states have already regulations with regards to gray water and rain harvesting (e.g. Texas, Oklahoma, Arizona where rain belong to the state, Utah 9,5 m^3 /month). (NCSL, 2013)

A main source of drinking water in California is 400-km-length canal brining water from Colorado River with at the level of 45 m^3/s. Nevertheless, Irvine Ranch Water District (IRWD) maintains one of the largest recycled water systems in the nation with more than 400 miles serving more than 4,500 metered connections. The IRWD and Orange County Water District in Southern California are established leaders in recycled water. American engineering firms install various systems to reclaim water similar to those located in Orange County, and in other locations throughout the world such as Singapore. Such water is given more advanced treatments and is used indirectly for drinking. (NEWater, 2014).

4.3. Canada

The "Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing" provides detailed design of rain water collection system. These guidelines are used for getting LEED certificate.

However, the highest consumer of water, beside agriculture in Canada, is mining industry. The Alberta Economic Development Authority (AEDA, 2013) reported that in Lower Athabasca in 2005, producers of oil and gas used 25% of allocated water flow of 0.551 billion m^3 while estimated return was 14%. Natural available water flow in this area is estimated for 20 billion m^3, and it is predicted that by 2020, this industry will increase water usage by 86% of allocated licence. Technologies considering a better water conservation for industry already exist, however, some of them still require to improve their recycling capabilities, especially for tailings pond water use. Recently, policy has driven water conservation and reuse in the energy sector. Energy Resources Conservation Board (ERCB) drafted directive strongly discouraging the use of fresh water and encouraging to increase the recycling rate. It is suggested that degree of water recycling should be assessed by cumulative effects of water reuse as the option with the least environmental impact. (AEDA, 2013)

Government supports the implementation of municipal wastewater and industrial water reuse. There is no easy answer as to what kind of re-use system is needed. It depends on the desired performance targets, daily demand, size roof area, tank size, etc. Rain water harvesting is still the most popular in urban areas, e.g. City of Calgary. Whether the provision of rainwater tanks can lead to downsizing of storm water management facilities depends on tank size and filling ratio, then, a continuous simulation is preferred for evaluation (City of Calgary, 2005).

Since a quality of effluent is crucial for its reuse, wastewater treatment, which implies membrane processes, can generate an exceptionally quality effluent. An advanced system SMEBR (submerged membrane electro-bioreactor) was developed for such purpose (Elektorowicz et al., 2009). The SMEBR's design and configuration take into consideration the requirements of the simultaneous processes such as biodegradation, electrocoagulation and membrane filtration (Bani-Melhem and Elektorowicz, 2010). The system removes almost all undesirable pollutants and transforms wastewater to piscine water in one hybrid reactor. The reclaimed water, beside these superior characteristics, has neither color nor odor and the pH value is neutral. Furthermore, the system precipitates the metals present in wastewater. (Elektorowicz et al., 2012)

As it was mentioned above, many fast developed cities in arid zones are connected to the sewer pipes by 14% only. Fortunately, sewage transported by tankers also can be treated by means of SMEBR system. Furthermore, the SMEBR's modular system can be applied to either large wastewater treatment facilities or mobile units or facilities in remote locations. In addition, it has a minimum footprint since it substitute: primary clarifier, coagulation/flocculation unit, secondary clarifier, and all nutrient removal units. An amount of biosolids (sludge) generated within the reactor is much smaller than in common bioreactors and expresses much better filterability properties. (Hasan et al., 2012).

4.4. Asia

Singapore has a rising demand for water and it is on the lookout for alternative sources and innovative methods for water harvesting. Considering the fact that the average annual rainfall of Singapore is 2,400 mm, it maximizes the harvesting the raining water. In Singapore, a deep tunnel for sewerage system is designed to collect, treat and reclaim used water and convey it through a graded, 48 km-long deep tunnel to the centralized water reclamation plant in Changi. The plant treats up to 800,000 m^3 of used water a day to international standards. The treated water is either discharged five kilometers out to sea through two deep sea pipes, or is sent to the NEWater purification unit. Singapore uses highly purified reclaimed water. Since Singapore is space limited, Changi water reclamation plant is one-third the size of conventional water treatment plants. In this treatment system, gravity conveys wastewater through the graded deep water tunnel at a depth of 20 to 55 meters, which eliminates the need for pumping stations (i.e. decrease of energy used).

Water reclamation does not include Changi airport only but also high-rise buildings, urban residential area, as well as capturing urban runoff. They utilize the roofs of high-rise buildings, run-off from airports, as well as integrated systems combining run-off from industrial complexes, aquaculture farms and educational institutions. (NEWater, 2014).

4.5. Europe

EU focuses on water protection and management. Specific guidelines are laid down for improving drought risk management. The EU Commission recommended in particular that the Member States develop drought risk management plans and fully apply the Water Framework Directive based on the exchange of good practices between countries and on methodologies developed by EU. Furthermore, it recommends optimizing the use of the EU Solidarity Fund and European Mechanism for Civil Protection for Member States that are hit by drought.

The establishment of river basin districts and the designation of the competent national authorities in Member Countries have been in progress, although international cooperation in some instances needs to be improved. The EU documents make a number of recommendations to the Member States with a view to integration of sustainable management of water into other national policies and making the most of public participation. EU also admits that the treatment of urban water is to be varied according to the sensitivity of the receiving waters. In 2003, seventeen European cities with populations of over 150,000 did not have treatment systems. (EU, 2014).

In Germany that has an annual rainfall between 563 mm and 855 mm, there is a growing interest in the promotion of household rainwater collection. Due to serious industrial air pollution and strict regulations regarding drinking water standards, household rainwater supplies are limited to non-potable uses such as toilet flushing, clothes washing and garden watering. The main advantage of designing rainwater collection systems in this way (or in conjunction with seepage wells) is that many German cities charge householders an annual rainwater drainage fee, which is waived off if rainwater runoff is retained or returned to ground allowing significant savings. In many German towns and cities, grants and subsidies are available to encourage householders to construct rainwater tanks and seepage wells.

Rainwater harvesting at Frankfurt airport is the biggest in Germany and helps to save approximately 1,000,000 m^3 of water per year. The cost of the system was USD 63,000 in the year 1993. A system was installed with an expectation of handling 13 million people every year, and it collects water from roofs surface area of 26,800 m^2. The rain water is stored in the basement of the airport in six tanks with a storage capacity of 100 m^3. The reclaimed water is mainly used for toilet flushing, watering plants and cleaning the air conditioning system with refined river water.

No many recovery water systems were implemented in Europe. REWAGEN, EU-funded project on “Electrochemical water treatment system in the dairy industry with hydrogen recovery and electricity production, is an exception. Fraunhofer IGB (Germany) is currently developing a pilot prototype for this treatment which “aims to link wastewater treatment to energy production as an efficient means of managing dairy industry effluents". (REWAGEN, 2014).

4.6. Poland

The Polish acts are in compliance with the EU Water Framework Directive for proper water protection and cost recovery of water services. The fee for water depends on the water quantity, quality and source (surface or groundwater). Council of Ministers defined the maximum rates taking into account: water source and quality, the amount of resources available for use in the particular river catchments and the costs of derivation water from these resources, availability of resources, environmental requirements and degradation level of particular areas and resources, and requirements of special protection of groundwater resources and lakes. (HELCOM PITF, 2001)

Water conservation is a predominant approach in the Polish alike in the European politics. Water management is seriously considered in construction projects, where roof gardens and rain water collection are a part of new designs. Building Research Establishment’s Environmental Assessment Method (BREEAM) is currently the world most widely adopted environmental assessment method for new structures. Leadership in Energy and Environmental Design (LEED) is currently the world’s second most widely adopted method. The LEED is more popular in American continent. LEED’s water efficient irrigation credit offers a higher number of points with stricter requirements and a specified threshold, i.e. a minimum 50% reduction in potable water use for irrigation. BREEAM’s water efficient equipment credit requires specified water efficient strategies/systems but does not quantify a required reduction in water use. The standard BREEAM method determines water efficiency (measured in L/P/day and m^3/P/yr) for a building based on the building's actual components. At the real estate fair MIPIM in Cannes, BREEAM Excellent certificate was given to the project of Warsaw Spire, which is being built in the quarter of Grzybowska, Łucka, Wronia and Towarowa Streets in Warsaw. Besides, Royal Wilanów, located also in Warsaw, obtained BREEAM Very Good certificate for its design stage. Furthermore, Business Garden Poznań, which consists of the office and service space for rental, has obtained LEED - Pre-Certification Classification category: Born to be green. It seems that the majority of new structures in Poland considers water-friendly solutions and competes for international certificates. (BREEAM, 2011; LEED, 2009)

In spite of available engineering techniques, EU promotes water conservation (eventually rainwater harvesting) instead of wastewater reclamation and gray water reutilization as it is done overseas.

5. Conclusion

Nothing changed over millennia; water is still a source of conflicts and a tool of a political pressure. Furthermore, a dynamic development of emerging countries, industrialization and population growth have not yet eliminated scarcity of water. Population settlement patterns change and society evolves from rural and agrarian to urban and industrial, which requires preserving equity and the primacy of the right to quench thirst. Rapidly growing populations mean that that more water will have to be allocated for domestic purposes.

Water, food and energy is in a short supply, therefore, an identification of sustainable solutions that meet local demands based on culture and perceptions of users is an expected approach.

There is shortage of policies encouraging the population to produce and use reclaimed water although engineering solutions exist. To optimize the available water within urban areas, municipalities have to undertake a range of demand management options. Along with demand management measures to optimize the available water in urban areas, inter-sectorial water markets have been suggested as a means to transfer freshwater from rural areas to urban areas. Recycling the water has to be an additional and unavoidable option. This must be accompanied by expanded wastewater treatment and reuse in agriculture, particularly in peri-urban agriculture.

An infrastructure system should be in place to transfer water from buyers to sellers, without extraordinary transaction costs. Finally, the regulation related to withdrawals, consumption, changes in water quality, etc. requires sophisticated legal and monitoring systems that do not yet exist in most underdeveloped and emerging countries. In some cases, laws exist but the government ability to monitor or overcome corruption is hard.

Traditionally, solutions focus on water resource protection under centralized management. However, new engineering solutions, which are capable to treat water on-site, might change such approach, for example, implementation of the membrane submerged electro-bioreactor system to produce high quality water for agriculture as well as for other purposes. Investments in such sustainable projects generate obvious economic, environmental and social benefits.

Water users' associations may be able to play a crucial role, even acting as substitutes for formal legal action and serving as pressure groups to enhance the efficiency of the administration as well as promoting new engineering solutions.

Continuing improvements in technologies should be accompanied by innovative water and infrastructure managements. Then, governmental support for "technology transfer" from research lab to industry has to be substantial. There is a serious shortage of water professionals, more in developing countries where there is still a low enrolment at universities.

Finally, more closer and much often interactions between water professionals and policy makers, land user and city planners should be promoted since their vision with regards to water is not convergent.

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