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Integrated concepts in water reuse: managing global water needs

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Abstract

Communities across the world face water supply challenges due to increasing demand, drought, depletion and contamination of groundwater, and dependence on single sources of supply. Water reclamation, recycling, and reuse address these challenges by resolving water resource issues and creating new sources of high-quality water supplies. The future potential for reclaimed treated effluent is enormous. Although water reclamation and reuse is practiced in many countries around the world, current levels of reuse constitute a small fraction of the total volume of municipal and industrial effluent generated. In addition, to meet their growing water supply needs, communities are considering other non-traditional sources of water such as agricultural return flows, concentrate and other wastewater streams, storm water, co-produced water resulting from energy and mining industries, as well as the desalination of seawater and brackish groundwater. Water reuse provides a wide range of benefits for communities, which translates into creating immense value for the public and the environment. The benefits of water reuse, however, can be difficult to quantify and often go unrecognized. One of the most significant benefits of water reuse is the value created by the inclusion of water reuse in integrated water resources planning and other aspects of water policy and the implementation of water projects resulting in the long-term sustainability of our water supplies. These integrated concepts, which involve the convergence of diverse areas such as governance, health risks, regulation, and public perception, also present a significant challenge to water reuse. These complex connections can assert equal influences on both the benefits and challenges associated with water reuse. In addressing these complex integrated issues, a number of significant barriers and impediments to the widespread implementation of water reuse projects arise. Numerous examples exist of barriers experienced by current water reuse projects around the world, including: the need for innovative technologies, technology transfer, and novel applications; the need for public education and increased public acceptance; better documentation of the benefits of water reuse; the lack of available funding for water reuse projects; working with the media; and the need for support by regulators and politicians. Integrated concepts can also be factors in a number of trends affecting water reuse globally. Current trends include addressing emerging pollutants of concern, the use of advanced wastewater treatments including membranes, indirect potable reuse, public perception, understanding the economics of water reuse, groundwater recharge and aquifer storage and recovery, salinity management (including concentrate disposal), increase in the use of "alternative sources", environmental or natural system restoration, innovative uses of nonpotable water reuse, and decentralized and satellite systems. Since these trends are emerging developments in the field of water reclamation and reuse, there are a number of research needs associated with these topics. Research is needed to better understand the issues, to develop innovative technologies, and to develop tools and other assistance for communities and water agencies to implement successful water reclamation and reuse projects.

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Keywords: Water reuse; Water reclamation; Desalination; Integrated concepts

1. Introduction

Water reuse is a growing practice in many regions of the world, even in countries that are not typically considered to have problems with water scarcity. Countries and regions in which water reuse is on the rise include the US, Western Europe, Australia, and Israel.

In the US the practice of recycling/reclaiming water is a large and growing industry. An estimated 2.6 billion gallons per day (bgd) (9.8 Gl/d) are reused in the US This is but a tiny fraction of the total volume of wastewater generated, however. According to the US Environmental Protection Agency's (EPA) 2000 Watershed Needs Survey, a total of 34.9 bgd (132.1 Gl/d) is produced [1]. Thus, the proportion currently reclaimed and reused amounts to only 7.4%, suggesting that future potential for reclaiming treated wastewater is enormous.

Recycled water use on a volume basis is growing at an estimated 15% per year in the US Applications range from the irrigation of golf courses and individual lawns to edible crop irrigation, various types of industrial reuse, and indirect potable reuse, such as groundwater recharge. All evidence suggests that water recycling will play an expanded role in water management in the 21st century, not only in the semi-arid western states and "sunbelt" states, but perhaps in all 50 states. As shown in Fig. 1, at a compound annual growth rate of 15%, the volume of recycled/reclaimed water would amount to 12 bgd (45.4 Gl/d).

As in the US, water recycling/reuse is on the rise in Australia. According to a review undertaken by the Australian Academy of Technological Sciences and Engineering, a total of 166.2 Gl/y (43.91 billion gal/y) was reused in 2001–2002, up from 112.9 Gl/y (29.83 billion gal/y) during 1996–1999 [2]. The proportion of effluent recycled also increased during this period from 7.3% during 1996–1999 to 9.1% in 2001–2002.

Information from a survey on water conducted by the WateReuse Foundation for the Global Water Research Coalition in December, 2004, indicates that water reuse is also a growing practice in several European Union countries. According to Wintgens [3], currently more than 200 projects exist in Western Europe while many others are in an advanced planning phase.

The indicators of growth of the practice of water reuse in these various regions of the world do not, however, speak to the challenges facing recycling. A review of the results from the aforementioned WateReuse Foundation reflects

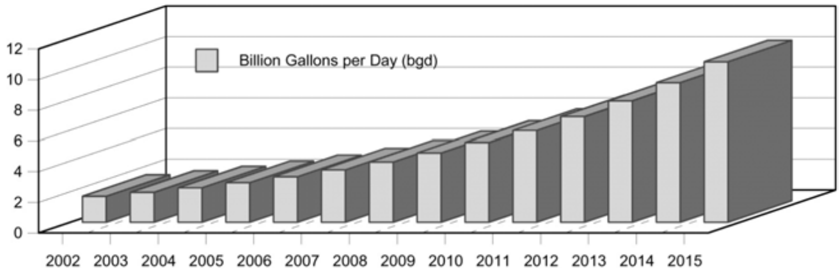

Fig. 1. Projected water reuse. Estimated growth of water reuse in the US, 2002–2015.

an amazing similarity in the challenges, barriers, and obstacles to increased water reuse in countries around the world. In the Foundation's survey, respondents were asked to enumerate "key factors of success" that would support the future development of water reuse in their respective country/region. The most frequent responses follow:

- Defining project objectives properly — Water reuse projects frequently are conceived and planned without (a) consulting stakeholder groups in the community and (b) developing clear and compelling arguments regarding how the project is going to benefit and improve the quality of life in the community.
- Public perception/public acceptance — Nearly all respondents noted that while non-potable reuse applications (e.g., landscape irrigation) are generally acceptable, as reuse moves toward indirect potable reuse, the reaction from the public — usually in the form of negative publicity in the media — becomes more negative. Respondents in both the US and UK noted the need for research into the psychological factors that lead to the public's resistance to indirect potable reuse.
- Lack of uniform regulations/standards — Around the world, regulations vary dramatically. National standards do not exist in the US. In Europe, there are no uniform European regulations (i.e., "supra-national" regulations that would apply to the entire continent).
- Pricing of recycled water — The conundrum is that if recycled water is sold at its actual cost (usually more than that of drinking water), potential users will not want it. On the other hand, if the product is discounted, inefficient uses will result.
- Technologies — Technologies should be matched with the intended application. Experience curves do not exist for recycled water since it is a relatively new phenomenon. One respondent suggested a research project that would compile the treatment trains used in the 100 most successful installations around the world and match these treatment trains with applications.
- Economics of water reuse — To date, no one has conducted a rigorous analysis in which the social and financial benefits of reuse are compared with both social and financial costs. Typically, water reuse project decisions are based on financial costs and benefits with no credit being given to non-monetizable benefits such as environmental protection.
- Chemical and microbiological safety — The biggest challenge, of course, is to apply treatment technologies that will remove exotic chemicals such as endocrine disrupting compounds (EDCs) and remove or inactivate microbial pathogens. This must be done on a continuous basis and water utilities must be able to convince the public that the recycled water is chemically and microbiologically safe for the intended application.
- Need for additional research — Several respondents cited the need for additional research on chemical and microbial contaminants, especially EDCs and pharmaceutically active compounds. Research is also needed on membrane pre-treatment and biofouling.

When water practitioners conceive of a water reuse project, they must immediately take all of the above-mentioned factors into account and weave them together into an integrated solution. Moreover, the recycled water project must make sense in the larger context of integrated resources planning and other aspects of community life. The various elements of success and barriers to implementation of water reuse are described in the following section.

2. Water reuse

Any discussion of water reuse must begin with various terminologies used and a definition of reuse. In the US, reused water is called recycled water in California, while in Florida it is known as reclaimed water. A water statute that governs water reuse projects in the US Bureau of Reclamation defines the word “reclamation” as meaning water reuse and desalination. The WateReuse Association combines all of these words in its mission statement: water reuse, recycling, reclamation, and desalination. With respect to a definition, the Association defines reuse broadly as “the reclamation and treatment of non-traditional (or impaired) waters for the purpose of beneficial reuse.” Non-traditional or impaired waters include the following: (1) municipal and industrial wastewater effluent, (2) brackish water, (3) poor-quality ground water, (4) agriculture return flows, (5) stormwater and (6) the oceans.

2.1. Applications

The early applications of water reuse were for irrigation of golf courses and landscapes; this is no longer the case, however. Other applications include industrial reuse, irrigation of edible and non-edible agricultural crops, and indirect potable reuse. Industrial reuse applications include use in cooling towers, for boiler feed, and for use in the cooling cycles of power plants. In Sonoma and Monterey Counties in California, lettuce, artichokes, strawberries, and grapes are irrigated with recycled water. There are several well known examples of indirect potable reuse around the world, including facilities in Orange County, California, the NEWater facility in Singapore, and in Windhoek, Namibia.

2.2. Benefits

Water reuse represents a viable, long-term solution to the challenges presented by growing municipal, industrial, and agricultural demands for water. Reclaimed water has numerous benefits, including the following:

- represents a sustainable alternative supply of water;
- typically uses less energy than importing water;
- this dependable supply is under local control;
- avoids construction impact of new supply development; and
- reduces or eliminates the quantity of treated wastewater discharged to sensitive or impaired surface waters.

2.3. Economics of water reuse

According to Sheikh et al. [4], water reuse projects are often undervalued when compared to other projects due to the failure to properly quantify benefits of reuse such as watershed protection, local economic development, and improvement of public health. Engineers who are evaluating project alternatives often compare only the financial costs of various alternatives and do not quantify either social costs or social benefits. As a result, the true benefits and costs of many water reuse projects have never been properly evaluated. If the non-monetizable benefits could indeed be quantified, the benefits of many water reuse projects would exceed the costs and, using benefit/cost ratio as an evaluation tool, would become economically feasible.

Providing reclaimed water frequently costs more than potable water system costs; however, many utilities price this water below the cost of service in order to promote its use. These revenue shortfalls must be subsidized as population growth in certain areas strains water supplies and water reuse gains popularity [5]. This will likely change as readily available water becomes more scarce and the public demonstrates an increased willingness to pay for dependable water supplies.

Several surveys have been conducted which show that reclaimed water costs compare favorably with those of alternative sources. Gagliardo and Strayer [6], in advocating the application of a free-market approach to recycled water system expansion, estimated that the average cost to retrofit a recycled water customer site was

US \$30,000 plus \$2635 per acre-foot (\$8.09/1000 gal) (\$2.14/m^3) of potential use at that site. The 2001 cost of potable water in San Diego was approximately \$640/acre-foot (\$1.96/1000 gal) (\$0.52/m^3), and the recycled water rate was 90% of the potable water rate, or approximately \$580/acre-foot (\$1.78/1000 gal) (\$0.47/m^3). At a 50% potable water rate, the city could recoup its expenditure if the site used over 45 acre-feet/y for 10 years.

Walker-Coleman of the Florida Department of Environmental Protection compared rates for metered reclaimed water with rates for drinking water and found that consumers can save a great deal by using reclaimed water over potable water sources. In Florida, reclaimed water prices vary from about \$0.39/1000 gal to \$0.50/1000 gal (US dollars) while the price of potable water is considerably higher.

As noted earlier, some of the benefits of water reuse are infrequently recognized and almost never calculated. Water recycling projects have the potential to extend existing water supplies, lessen the demand on sensitive water bodies, lower the cost of developing new water supplies, reduce wastewater treatment and disposal costs, lessen the discharge of pollutants to the environment, and provide a high-quality supply of water to serve a variety of beneficial uses. Another benefit is that recycled water can be developed in phased project expansions, which offers tremendous flexibility as to timing of water supply investments [7].

Reuse projects such as the proposed Ground Water Replenishment System in Orange County, California, provide safe and reliable local water supplies regardless of weather conditions (e.g., drought and reduced rainfall). This supply is available for groundwater replenishment; protects groundwater from seawater intrusion, industrial uses and landscape irrigation; reduces ocean discharges; and decreases reliance on expensive and undependable imported water purchases.

Plants, wildlife, and fish depend on sufficient water flows to their habitats to live and reproduce. The lack of adequate flow, as a result of diversion for agricultural, urban, and industrial purposes, can cause deterioration of water quality and ecosystem health. Water users can supplement their demands by using recycled water, which can free considerable amounts of water for the environment and increase flows to vital ecosystems [8].

When future reuse projects are implemented, municipalities will be able to reduce spending on water and wastewater infrastructure, saving nearly as much as the project cost. In some cases, the cost of the water produced by the reuse technology will be less than that of other new water supplies and will take about half of the energy currently required to bring imported water to the water district.

2.4. Technologies

The technologies used most frequently in California for treatment prior to groundwater recharge are microfiltration, reverse osmosis, and ultraviolet irradiation (UV). The Orange County Water District plans to install and utilize microfiltration, reverse osmosis, and UV in their groundwater replenishment projects. Many California experts believe that in the future, virtually all wastewater treatment plants, especially those that discharge into the Bay–Delta surface waters, will feature filtration of some type.

Groundwater recharge requires that a municipal utility purify water to a higher quality than most natural water resources. Clear, treated wastewater is subjected to three purification processes in order to produce clean water that is allowed to filter through the ground by natural filtration processes (e.g., the path that rainwater takes) into deep aquifers in an underground basin where it will be extracted by wells for drinking water after mixing with exiting groundwater supplies for at least a year. The first of these three purification processes is microfiltration (MF), which uses a low-pressure membrane that takes small suspended particles and other materials out of the water. MF efficiently prepares water for the reverse osmosis process. Currently, MF is used in commercial industries to process food, fruit juices, and sodas; in computer chip manufacturing; and to sterilize medicines that cannot be heated.

In Florida, the technologies typically used in reuse facilities are quite different than in California. St. Petersburg was the first major city in Florida to go to reclaimed water for irrigation on a large scale. Treatment installed at the city's four reclamation plants, constructed in the 1970s, feature the following treatment process: grit removal, mechanical aeration, clarification, filtration in deep-bed multimedia filters, a high level disinfection with chlorine, and storage.

The conventional treatment of wastewater in Florida currently features deep-bed, high rate multimedia filtration, and high-level disinfection using chlorine. Although Florida has more desalination facilities than any other American state, membranes are not used in water reuse due to cost considerations. The reclamation technologies of choice in Florida for the foreseeable future are likely to be deep-bed-dual or multimedia filtration and chlorination.

Technologies employed to treat recycled water in the US depend almost entirely on the application, which is called "highest treatment for highest use." In Title 22, Chapter 4, of the California Code of Regulations, bacteriological water quality standards were established based on the expected degree of public contact with recycled water. For example, if the primary application is irrigation or cooling tower water, sand or dual-media filtration after secondary treatment is sufficient to achieve a state's water quality criteria. If, on the other hand, the intended application is indirect potable reuse, sophisticated technologies such as MF, reverse osmosis, and UV must be employed to ensure chemical and microbiological safety of the reclaimed water.

2.5. Issues, barriers, and impediments to reuse

Some of the principal issues, barriers, and impediments to widespread water reuse are as follows:

- Lack of available funding — a survey of municipalities in California several years ago revealed that the major constraint to water recycling is lack of funds. Although many larger municipalities have constructed water reuse projects, smaller utilities have not, often due to lack of funding support from Federal and/or state governments. Lack of funding is probably a major constraint around the world.
- Need for public education — Local decision-makers, especially where rainfall is abundant, do not consider water reuse as an option when considering water resource alternatives. An educational campaign is needed to provide information to politicians on the success stories, costs, and benefits of water reuse.
- Better documentation of the economics of water reuse — Although several practitioners have documented the need for a complete accounting of financial and social costs and financial and social, non-monetizable benefits, such an accounting has yet to be accomplished. A well written, documented economic treatise on water reuse is needed as a resource.
- Additional support by politicians — Even in areas such as California and Florida where the public appears to be ready for even planned indirect potable reuse projects, the politicians are not. In recent years, projects in San Diego, East Valley (near Los Angeles), and Tampa Bay have been rejected by the respective communities. In all three of these cases, the public appeared to be very supportive; however, intense local politics eventually resulted in all three projects being killed or put on hold indefinitely. The WateReuse Foundation is currently funding a $250,000 study to determine the reasons why some planned indirect potable reuse projects were successful [e.g.,

Upper Occoquan Sewerage Authority (VA), Water Factory 21 (CA), Scottsdale (AZ)] while others were rejected. Another goal of the study was to provide tools to local decision makers who plan to launch such projects in the future.

- Additional research — Most wastewater, especially in arid and semi-arid areas, needs to be recycled to serve growing populations. All of this water cannot be used to irrigate golf courses or for industrial applications. These highly treated reclaimed waters will need to be used to irrigate edible crops and for indirect potable reuse. The latter application necessitates substantial research to be able to assure the public of the chemical and microbiological safety of reclaimed water. Research is also needed to improve the economics of water reuse by reducing the cost of technologies, to ensure technology transfer, and to promote reuse for specific industrial applications (e.g., cooling in power plants, concrete production, etc.).
- Leadership by governments — Governments have a leadership role to play (a) in assuring adequate water resources for regional and multi-jurisdictional areas, (b) to practice water use efficiency at federal facilities, and (c) in providing funding to promote water use efficiency and conservation.

3. Managing global water needs through integrated concepts

As water professionals look forward in the 21st century, the forecasts are for increased water scarcity in many areas/regions around the globe by the year 2020. As can be seen in Fig. 2, US Filter is predicting water stress only 15 years from now in China, southeast and southwest Asia, India, the Middle East, North Africa, South Africa, and the western United States. While it is easy to discuss integrated concepts, it is much more difficult to decide, in light of the impending "water crisis of 2020" exactly how to go about

United States Filter Corporation, 1996

Fig. 2. Projected areas of water stress in the world in 2020.

averting the crisis. Since one of the truisms of water is that issues are intensely local, there can be no one formula for success that can be used by communities around the globe. It is possible, however, to define a mission and a set of long-term goals that can be used by water professionals to craft a strategy to ensure a safe and sustainable supply of water for the 21st century.

3.1. Defining the mission

The first step is to define an overall mission. Perhaps the mission statement is as follows: Take whatever actions are necessary to develop a safe and sustainable water supply for the 21st century. "Safe" and "sustainable" are hereby defined to mean adequate supplies for municipal, industrial, agricultural, and rural use. Supplies will be developed in a manner that protects the environment.

3.2. Identifying the drivers and barriers

The next step is to delineate and define limiting factors and drivers. In terms of water reuse, perhaps the single biggest driving force is droughts, such as the ones currently being experienced in the western US, western Australia, and South Africa. Droughts are water reuse's best friend. The great American statesman Ben Franklin got it right when he said, "You know the value of water when the well is dry". These words are no less true in the 21st century than when Franklin uttered them in the late 18th century.

Franklin's statement also serves to point out one of the most significant barriers to more widespread water reuse and that is public acceptance. As noted earlier, a better understanding is needed of the psychology of why the public appears to accept the "unplanned" indirect potable reuse that occurs every day when water utilities draw raw water through their intake systems from the Mississippi, Thames, Seine, Rhine, and other major rivers. Early in 2004, the WateReuse Foundation sponsored a workshop dealing with the psychology of public perceptions of water reuse. The Foundation invited a sociologist and three world class psychologists to participate in the two-day workshop. One of the psychologists explained the phenomenon of "naturalness." The public believes strongly in "things natural." Thus, if water is discharged from a wastewater treatment plant and is assimilated into a flowing river before being withdrawn again, the perception is that the water being withdrawn is "natural" and therefore okay.

Another concept explained by the psychologist was that of "contagion" — once contaminated, always contaminated. Taken together, these two phenomena perhaps explain the public's resistance to indirect potable reuse. Wastewater effluent is perceived as being irretrievably and hopelessly contaminated while water flowing in a river, no matter the quality, is natural.

Droughts, along with demand due to growth, wastewater management (i.e., effluent disposal), and ecological protection, are the principal driving forces behind reuse. On the barriers side, public perception is easily the greatest impediment. Others are lack of funding for local projects, flawed or unevenly applied regulations and standards, and concerns over the unknown long-term health effects of chemical contaminants such as EDCs.

One could add the concept of a flawed "price signal" that we send to the public on water. The public perceives water to be free and a public good, not a commodity to be sold such as oil and its derivatives (e.g., gasoline, heating oil). We in the water industry perpetuate the myth of free water by not charging for excess use. Consider the fact that one can go into virtually any hotel room anywhere in the world and use as much water as one wants; there are no restrictions and there is no surcharge above, say, 40–50 GPD, for excess usage. Compare that with gasoline; one cannot obtain 1 L, 1 gal or any other volume without paying. This flawed price signal sent to the public on water keeps the price artificially low, not reflecting the true value of this liquid that is essential to life.

3.3. Developing a portfolio of alternative water supplies: new sources of water for the 21st century

Utilizing and accessing traditional sources of water will not be sufficient as populations grow and water demand increases. Water managers of the 21st century need to develop a "water portfolio," similar to a portfolio of stocks. The concept is the same: increasing value while diversifying risk.

Historically, local water agencies could augment available water supplies by drilling a new well field, increasing withdrawals from nearby rivers, or purchasing water from a wholesale agency. Those options are becoming increasingly unavailable. Local water agencies — even in water-rich areas — often must consider alternatives such as water reuse, desalination, and inter-basin transfer to meet the demands of growth.

In the US, water reuse is increasingly bundled with other so-called alternative sources of new water supplies. In legislative and policy circles, these new sources of water for the 21st century are defined as water reuse, desalination, aquifer storage and recovery, and water use efficiency (a new term for water conservation). When one speaks of integrated concepts, the reference is typically to the myriad of factors that water professionals must address in order to design and construct a successful project. Combining or "bundling" water reuse with other new sources of supply is yet a different, although completely legitimate, means of integration.

One statement heard often these days in meetings of water professionals is that water reuse and desalination are "two essential tools in the demand management toolkit of the water utility manager of the 21st century." The two are not competing alternatives, but are complementary and necessary elements in a long-term water supply plan and portfolio.

Water reuse and desalination actually have much in common. Both involve taking an impaired source of water and utilizing advanced water treatment technologies to remove the impurities. The technology of choice for developing water reuse for high water quality applications and desalination is often the same, namely membranes. When using reverse osmosis membrane technology to remove solids and other impurities, both water reuse and desalination confront a similar set of challenges: (1) reducing the concentrations of total dissolved solids, organic chemicals, and inorganic chemicals to extremely low levels; (2) accomplishing this task as inexpensively as other competing alternatives; and (3) disposing of the concentrate generated during the removal process.

3.4. Desalination

Desalination, like water reuse, has enormous potential. Desalination is really one method of reusing water by removing salts (or salinity) to meet purification standards for the intended use (whether drinking water or other uses such as oil refinery boiler feed water). The economics of desalination have changed dramatically over the past two decades with improvements in membrane efficiency. Desalination is a necessary component of future water supplies. Desalination does not just mean ocean desalination. Desalting brackish groundwater is a growing practice in the US. The El Paso Water Utilities, working collaboratively with the US Army's Ft. Bliss base, currently is constructing the world's largest inland brackish groundwater desalination facility.

On a global basis, the practice of desalination is growing rapidly. According to the International Desalination Association (IDA) [9], there were 15,000 desalting units globally with installed capacity of 6 bgd in 2002. Twenty-five percent of this capacity was added in the period 2000–2002. IDA projected at the time that an additional 3 bgd capacity would be added during the period 2002–2004.

In early 2003, Sandia National Laboratories (part of the US Department of Energy) and the US Bureau of Reclamation, carrying out a directive from the US Congress, completed a report entitled, “Desalination and Water Purification Technology Roadmap”. The Technology Roadmap identifies areas of research necessary to develop cost-effective technological “tools” that can be used to help solve the nation’s water supply challenges. According to the Technology Roadmap, “ ‘the Achilles Heel’ of ... desalination technologies ... is cost — they are currently expensive to purchase and operate.” Costs have limited the application of desalination to regions that (a) have no choice but to employ them and (b) can afford them.

According to the Technology Roadmap, “by 2020, desalination and water purification technologies will contribute significantly to ensuring a safe, sustainable, affordable, and adequate water supply for the United States.” For this to happen, however, a substantial research investment will be needed to find a way to reduce capital and operating costs. Although desalination has several advantages (not the least of which is a stable, virtually unlimited supply in coastal regions of the world), it will always have two huge technical challenges: (1) removal of as much as 35,000 mg/L of salt and other impurities; and (2) disposal of the brine concentrate that is a by-product of the treatment process. The WateReuse Foundation, working in conjunction with the US Bureau of Reclamation, Sandia National Laboratories, and other research institutes, is heavily engaged in conducting research on innovative, cost-effective methods of concentrate disposal.

3.5. Aquifer storage and recovery (ASR)

Many water purveyors in the US and Australia have turned to ASR as an alternative water supply source. The most prevalent practice is to use ASR as a means of storing treated drinking water. In recent years, however, increasing attention has focused on the potential for storage of reclaimed water, which is often the most reliable source of “new” water available.

In ASR, either treated or reclaimed water is injected into an aquifer storage zone, which is typically several hundred feet in depth. Water is injected during wet weather periods, and then is withdrawn for use during dry weather periods. ASR thus allows a balancing of supply and demand to minimize the impacts of seasonal weather patterns. ASR is a viable and proven water resource management tool. ASR can be used to accomplish the following objectives:

- seasonal and long-term water storage;
- emergency water storage;
- help maintain minimum flows and levels;
- help control salt water intrusion;
- aquifer recharge and conveyance; and
- help to reduce costs of water management and facilities expansion.

The long-term vision for ASR is that aquifers will be used for the storage of drinking water, reclaimed water, stormwater and groundwater to meet a wide variety of seasonal, long-term water banking, emergency and other water management needs [10].

3.6. Water conservation

Gleick, of The Pacific Institute, believes that “the largest, least expensive, and most environmentally sound source of water to meet California’s future needs is the water currently being wasted in every sector of our economy [11]. That is the core message of a major new report on urban water use in California recently released by the Pacific Institute entitled “Waste Not, Want Not: The Potential for Urban Water Conservation in California”. “Waste Not, Want Not” estimates that up to one-third of California's current urban water use — more than 2.3 million acre-feet — can be saved using existing technology. And at least 85% of this savings (over 2 million acre-feet) can be saved at costs below what it will cost to tap into new sources of supply and without the social, environmental, and economic impacts that any major water project will bring.

Although water usage in California may be excessive compared to other parts of the world, given the huge savings potential through conservation, this is obviously one means of assuring adequate future water supplies that cannot be ignored. There are numerous opportunities to improve water use efficiency, ranging from the use of low flush toilets to mandating the installation of dual-piping systems in all new government buildings that are constructed; dual-piping systems allow reclaimed water to be used in urinals and in the HVAC systems.

4. Conclusions

Water reuse already represents an important water supply in many areas of the world. Reuse is growing in importance in the US, Australia, Europe and other regions. Its potential is largely untapped, however, due to a number of barriers, including lack of support from governments and the public's resistance to planned indirect potable reuse. Water reuse should not be viewed as simply the reclamation and reuse of wastewater effluents. Rather, a broader definition, encompassing the recovery and reuse of brackish ground waters, use of stormwater and agriculture return flows, and desalination of the oceans, should be embraced.

Water reuse should be viewed as one of several alternative sources of new water, all of which will be important tools in the toolkit of the water manager of the 21st century. Some of the other alternative sources include desalination, ASR and conservation.

Both water professionals and the consuming public need to view water differently in the 21st century. It is incumbent upon the consuming public that it develop more trust in the ability of water utilities to treat any poor-quality (impaired) water to a drinking water or higher standard. Similarly, water professionals must earn that trust. Water will finally be recognized for its inherent great value in the 21st century as demand grows and readily available and inexpensive supplies remain at virtually the same level. The water community should strive to convey the value of water through whatever means available, including education of the public and elected officials. Water is more than a valuable commodity or a necessary public good: water is essential to life itself.

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