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Future of water recycling – A review of the direct potable water reuse

Natalija Aleksić [#], Vanja Šušteršič

University of Kragujevac, Faculty of Engineering, Serbia

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ABSTRACT

Population growth, increasing water stress, and water scarcity have influenced the consideration of the reuse of treated wastewater as a possible alternative water source. Currently, recycled water is mainly used in industry, agriculture, and landscape irrigation, and now, in certain parts of the world, recycled water is also used as drinking water due to the limited freshwater resources. To meet the future water supply needs, the direct potable water reuse could be studied as an alternative source of drinking water. Direct potable reuse can enhance sustainability and water supply reliability. This paper analyzes direct potable water reuse as a circular principle in water sector and compares several successful cases of direct potable water reuse in Namibia, South Africa, Texas and New Mexico. Countries that use direct potable reuse are successful examples of using wastewater to form sustainable and reliable water supplies, which is of great significance for the future.

1. Introduction

From 1950 to 2020, the population living in cities increased from 0.8 billion to 4.4 billion, and it is projected that by 2050 it will reach 6.7 billion (UN, 2018). Water demand exceeds the capacity of local water resources (Fajnorova et al., 2021) - two billion people live in countries under conditions of high water stress (UN-Water, 2018), four billion people experience severe water stress at least one month per year, and 1.8 billion people at least six months per year (Mekonnen and Hoekstra, 2016). Between 2008 and 2018, only Europe, Northern America, Central Asia, and Southern Asia reduced their water stress, and in all other regions, water stress worsened (UN-Water, 2021). On a global scale, water use is constantly growing, twice more than the population increase (Mainali, 2019). With continued population growth, rising living standards, and climate change impacts, it is estimated that the global water demand will grow by around 1 % per year until 2050 and that over half of the global population will live in water-stressed regions (UN-Water, 2019). This indicates that the population is at a threat of having a shortage of clean drinking water (Mancosu et al., 2015). Water scarcity (water demand exceeds water availability (He et al., 2021)) is a matter of human, economic, and environmental insecurity (Tortajada, 2020), and it is the crucial determinant of water security (He et al., 2021). In other term, water scarcity is the number one global societal risk (Zisopoulou and Panagoulia, 2021). Also, global water scarcity is a complex and dynamic problem (Dolan et al., 2021), and solving that problem is a challenge for continued human development and sustainable development goals achievement. Population growth and urbanization increase the number of water users and water consumption and influence water pollution and water scarcity (Ghernaout and Elboughdiri, 2019). Changes in rainfall patterns threaten to worsen these effects in many areas (Tortajada, 2020). Potential solutions to water scarcity involve two aspects: increasing water availability, and reducing water demand (UN-Water, 2018). Water demands can be met through:

[#] Corresponding autor: natalija94u@gmail.com

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the development of local groundwater and surface water reservoirs, rivers, and lakes; development and implementation of inter-basin water transfer systems; desalination of brackish water and seawater; conservation; and potable reuse (WateReuse, 2020).

Currently, almost all parts of the world use the linear process of water use (Bertham and Sanahuja, 2019) - extraction, treatment, distribution, consumption, collection, treatment, and disposal/discharge into the environment. The natural environment acts as the buffer between treated wastewater and extracted drinkable water. With water scarcity and water stress all around the world, this is not an appropriate solution. Instead of a single-use process: take, treat, use, and discharge, wastewater can be reused as a valuable resource. The main goal needs to be closing the loop on water use. Recently, wastewater is recognized as a potential 'new' source of clean water for potable use (Tortajada, 2020), and this way of obtaining drinking water represents a circular water process. The process of using treated wastewater for drinking water is called potable water reuse (EPA, 2021). There are two types of potable water reuse: indirect potable reuse (IPR) and direct potable reuse (DPR). IPR uses an environmental buffer (a lake, river, or a groundwater aquifer) before the water is treated at a drinking water treatment plant (EPA, 2012). DPR involves the treatment and distribution of water without an environmental buffer. DPR can enhance the sustainability and reliability of water supplies via recuperating potable water from wastewater (Ghernaout and Elboughdiri, 2019).

This paper discusses the direct potable use of treated wastewater as a significant water source and presents the current case studies of direct potable use. This paper discusses and compares case studies of direct potable reuse in Namibia, South Africa, Texas and New Mexico. The case studies demonstrate a diversity of approaches and applied technologies. This paper provides useful information about DPR and current cases of DPR around the world. Also, this paper relies on existing literature about DPR, and it could help water planners and the local unities to analyze applying of DPR for solving current and future problems with water resources.

2. Circular principles in the water sector - potable water reuse

Lately, with the rise of environmental awareness, the circular principles have been applied in the water sector. Public water and sanitation utilities can become engines for the circular economy (IWA, 2016). To achieve circular economy goals and to close loops, the technological approach is focused on applying technical innovations for reducing water consumption, water reuse, and wastewater recycling, to keep the highest value of water, generate new inputs and material, while also optimizing production costs (UNESCO and UNESCO i-WSSM, 2020). Municipal wastewater and industrial wastewater are potential sources for wastewater recovery and reuse. Water reuse encompasses various activities with its unique characteristics based on the source water and the end-use. Figure 1 presents how different types of water reuse projects can be integrated into the urban water cycle (EPA, 2021a). Potable water reuse, water desalination, imported water, and non-potable water reuse are only some options for consideration of water reuse for many purposes (EPA, 2018a). Generally, potable water reuse in the practice involves the planned use of treated municipal wastewater for augmenting drinking water supplies (EPA, 2012). Proponents of potable water reuse and owners of water and sanitation utilities are exploring and trying to implement key strategies to accelerate the mainstreaming of potable water reuse. Also, many utilities are considering or planning to use advanced treated water as an alternative water supply for potable reuse. Potable reuse refers to recycled water people can use and drink. Currently, municipal wastewater is treated in wastewater facilities to a level where it is safe to discharge it to the environment. New principles in the water sector refer to further additional treatment of treated wastewater and its use for various applications or as a use of drinking water (WateReuse, 2021). In general, potable reuse is the process of taking treated wastewater from a wastewater treatment facility and purifying it further with advanced technologies (Water Research Foundation, 2021). Potable water reuse projects imply the use of more intensive additional treatment requirements, control, and monitoring.

2.1. Indirect potable use and direct potable use

Advanced wastewater treatment is conducted after primary, secondary, and tertiary (conventional) treatment, and it is focused on the removal of organic carbon compounds, nutrients, metals, suspended solids, and pathogens. Treated water may be recycled for non-potable uses (such as gray water and irrigation) or reused via IPR or DPR as drinking water (Noibi et al., 2020). IPR relies on blending treated wastewater with other natural water sources (river, lake, etc.) via environmental buffer over enough time. Therefore, facilities must have access to environmental buffers such as a surface water reservoir, massive storage tank, and aquifer. The use of environmental buffer presents the main difference between IPR and DPR (Eden et al., 2016), figure 2.

Table 1 presents individual processes used in advanced wastewater treatment facilities for potable water treatment (IPR and DPR). Processes are combined depending on the location of facilities, available technologies, requirements, etc., to achieve water quality appropriate for potable reuse. Facilities for advanced wastewater treatment have five objectives: removing suspended solids, reducing dissolved chemicals, disinfection, water stabilization, and producing water with good quality (EPA, 2018).

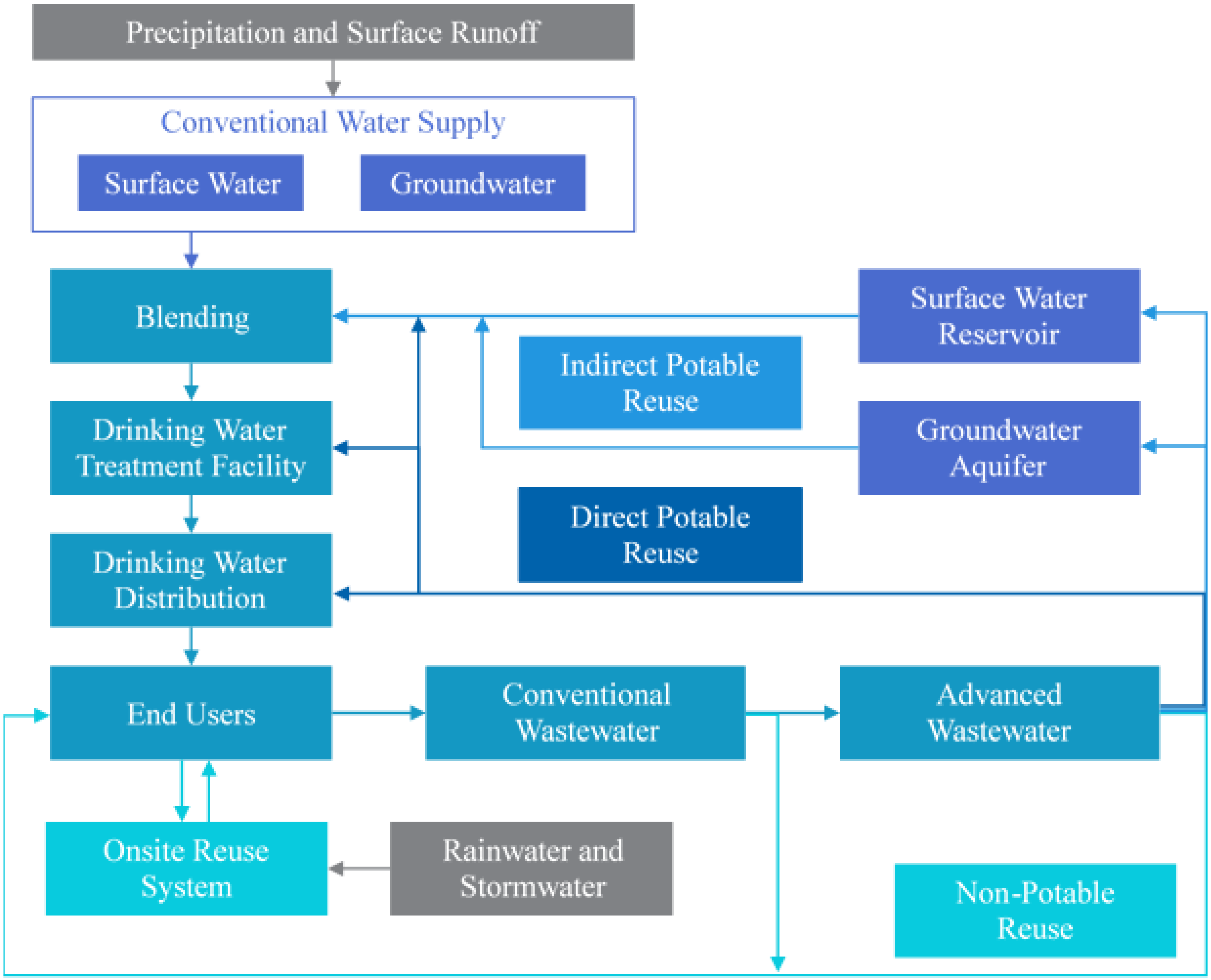

Figure 1. Examples of integrating water reuse into the urban water cycle (EPA, 2021a)

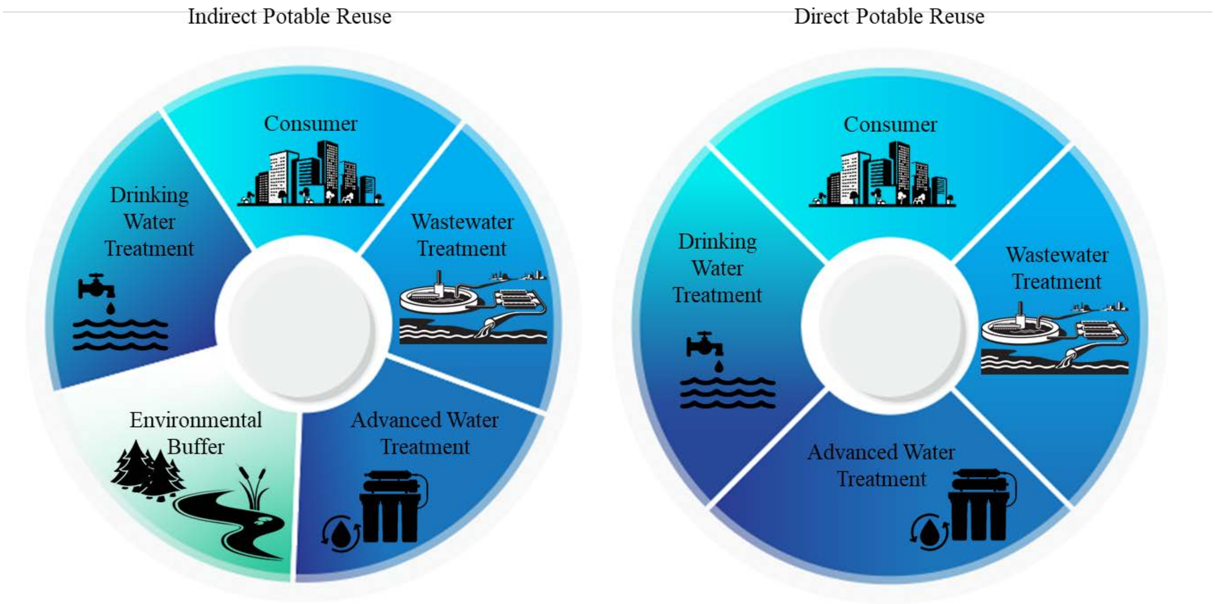

Figure 2. Illustrative representation of the difference between IPR and DPR

Table 1
Overall treatment objectives and corresponding unit processes (EPA, 2018)

Treatment objectives	Unit processes
Removal of Suspended Solids	Coagulation Flocculation Sedimentation Media filtration Microfiltration (MF)
Reducing the Concentration of Dissolved Chemicals	Reverse osmosis (RO) Electrodialysis Electrodialysis reversal Nanofiltration (NF) Granular activated carbon (GAC) Ion exchange Biologically Active Filtration (BAF)
Disinfection and Removal of Trace Organic Compounds	Ultraviolet disinfection (UV) Chlorine/chloramines Peracetic acid Pasteurization Ozone Chlorine dioxide Advanced oxidation processes (AOP)
Stabilization	Sodium hydroxide Lime stabilization Calcium chloride Blending
Aesthetics (taste, odor, and color control)	O_3/Biologically Activated Carbon (BAC)MF/RO

When evaluating the policy of wastewater recycling and reuse, it is helpful to consider what is achievable from a technology standpoint (Freedman and Colin, 2015). Figure 3 illustrates how selected technologies for IPR and DPR may be deployed as a function of water recovery needs and water quality. Table 2 compares the IPR and DPR.

Today, many utilities are transitioning to DPR (Steinle-Darling et al., 2016). The DPR refers to the additional treatment of purified water derived from municipal wastewater after extensive treatment to assure that strict water quality requirements are met at all times (EPA, 2012). There are two types of DPR. Treated water is introduced into the raw water supply upstream of a drinking water treatment facility (first type), and treated water is introduced directly into a potable water supply distribution system (second type) (WateReuse, 2020), Figure 4.

In DPR, the reclaimed water is treated to drinking water standards and then diluted with the drinking water in the water network. In other terms, implementation of DPR requires reliance on the applied technology to produce water that is safe and acceptable to consume. That is possible due to the technological progress, however, there are significant barriers that exist concerning consumer acceptance and regulations. A key part of a DPR system is the ability to provide high-quality water reliably all the time (Leverenz et al., 2011).

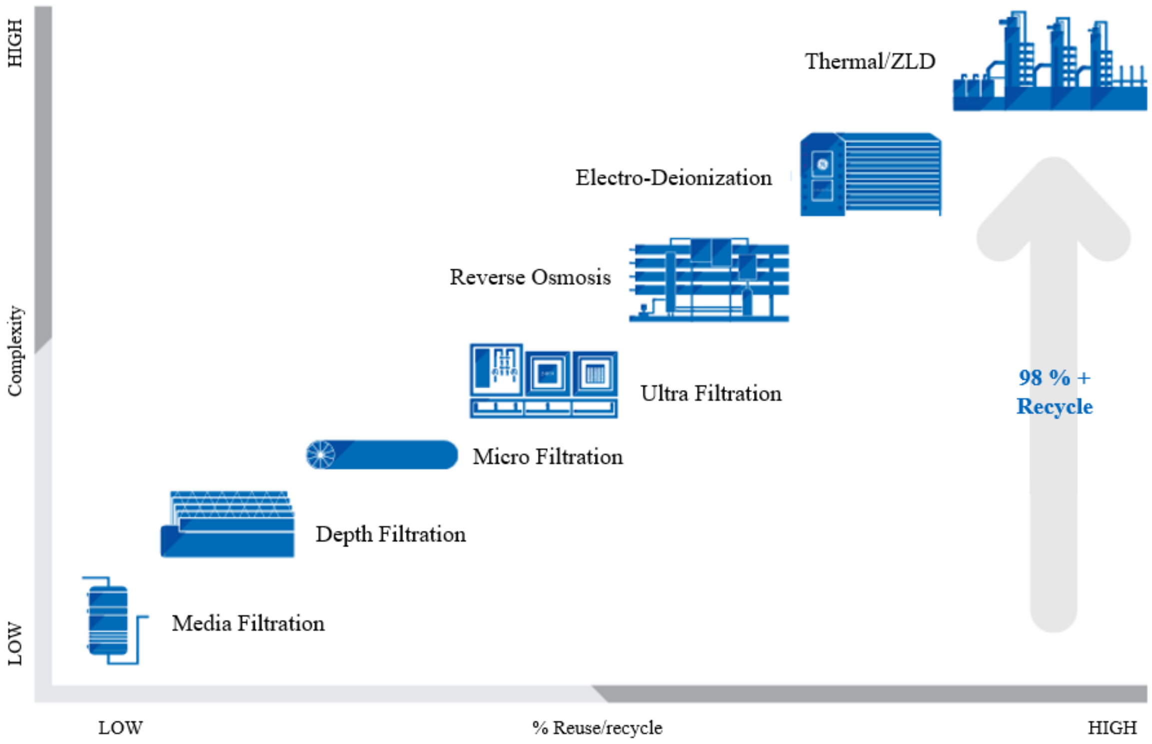

Figure 3. Reuse technology spectrum (Freedman and Colin, 2015)

Table 2
Comparison of IPR and DPR (Aravinthan, 2005; EPA, 2018)

Description	IPR	DPR
Treatment	Multiple barrier treatment before surface augmentation or aquifer injection	Demands extensive treatment of the wastewater prior to reintroduction directly to the drinking water facility.
Practicality	IPR can be impractical if the environmental buffer is not suitable	DPR requires a higher level of monitoring and treatment complexity, although elimination of an environmental buffer provides a higher level of control over the water
Treatments requirements	Several states have regulations or guidelines for IPR treatment requirements	There may be no difference in the treatment objectives between IPR and DPR; however, the level of process monitoring and control, and the total level of treatment may be more complex for DPR due to the absence of an environmental buffer
Contaminants	Fewer contaminants undergo dilution, mixing, and natural treatment in the receiving body before abstraction into the drinking water facility	Certain chemicals tend to concentrate over time when water is repeatedly recycled
Water quality	Depending on site-specific conditions, environmental buffers have the potential to either enhance or degrade water quality	DPR provides a high level of control; but, the process monitoring and control may be more complicated than IPR
Water rights	Water rights issues can complicate IPR potential	Water rights issues can complicate DPR potential
Community reactions Public perception	Newly introduced IPR, though highly treated than unplanned discharge, tends to upset the communities	Very negative
Discharge	Wastewater effluent is normally discharged upstream	No discharge outside
Costs	Environmental buffers can incur significant costs to protect, maintain, operate, and monitor.	DPR may require a higher level of operator training and may involve additional treatment steps beyond IPR
Regulations	Several states in the USA have regulations or guidelines governing IPR	DPR facilities are currently considered on a case-by-case basis, and to date, no states have formal regulations or guidelines governing DPR

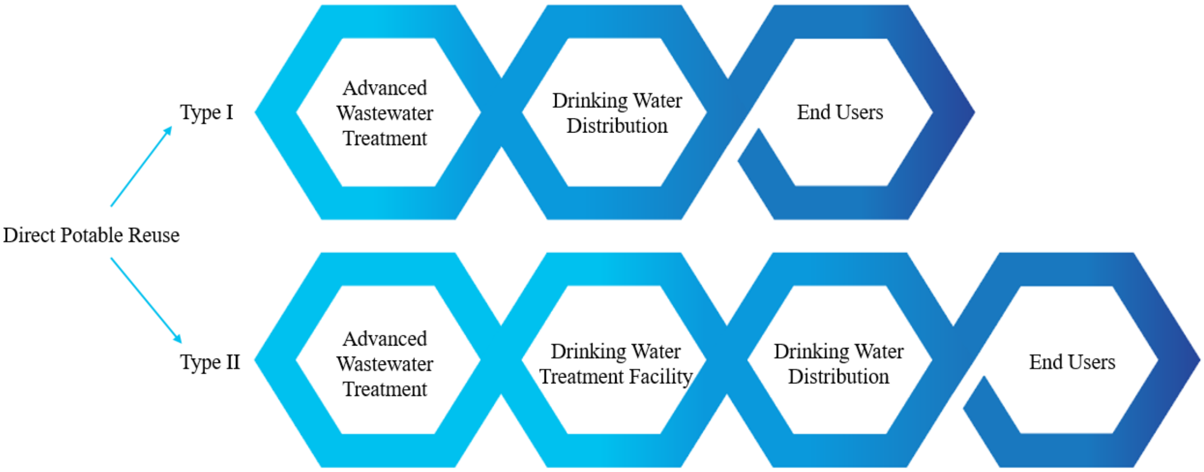

Figure 4. Two types of DPR (WateReuse, 2020)

The DPR systems have their advantages and disadvantages. Some of the advantages and disadvantages are listed in Table 3. The advantage of the DPR system is that the facility for wastewater treatment and the facility for advanced water treatment are located at one place or in the immediate vicinity, which directly affects the reduction of operating costs, water transport costs, and energy needs. Water is transported over short distances so that a small number of external factors can affect its transport. The lack of these systems is based on public outrage, the absence of law, and the constant need to monitor water quality and safety.

Table 3
Advantages and disadvantages of DPR (National Research Council, 2012; ATSE, 2013)

Advantages	Disadvantages
Water security: conserves drinking water and contributes to a sustainable water supply; Environment benefits: reduces the amount of treated wastewater going into local waterways, uses an otherwise resource, reduces energy requirements, reduces carbon footprint, and reduces chemical consumption and/or waste production; Infrastructure: improved flexibility of water supply, cost savings; Water quality: maintenance of high water quality produced by advanced treatment processes/improved water quality control.	Regulatory framework: lack of political will, lack of regulatory framework and/or regulatory competency or regulatory acceptance; Industry: lack of industry competency; Water quality: poor water quality, water quality incident and loss of 'time to react', loss of advantage from using environmental buffer as a means of transporting or distributing water; Security and monitoring: the constant need for real-time monitoring; Community: safety concerns, resentment; Costs: high costs associated with DPR.

3. Review of DPR systems

This paper presents some DPR systems that are currently in operation and/or under construction. All DPR systems are unique because they apply different processes of additional treatment of treated wastewater and use various technologies for drinking water production. Figure 5 presents DPR systems that are currently in operation and/or under construction around the world.

3.1. Africa

3.1.1. *Goreangab reclamation plant, Windhoek, Namibia*

Namibia is one of the most arid countries in the world. In Namibia, heat causes about 83 % of rainwater to evaporate, and the ground only absorbs about 1 % of rainwater (Veolia, 2021). The water supply of Windhoek, the city in Namibia, depends on boreholes and three dams located 60 and 200 km away. Without nearby water sources and due to water shortages, the city has sought alternative solutions to secure its water supply. In 1968, it was decided to design and construct the facility for treated wastewater recycling for drinking purposes. Since 1969 (when the facility was constructed), Windhoek has reused treated wastewater to satisfy drinking needs (City of Windhoek, 2021). Today this plant provides over a quarter of the total water supply, and for 55 years, people have been drinking reused treated wastewater. This is the first city in the world that started to use DPR and reuse its domestic wastewater for drinking purposes. DPR plant uses technologies that mimic natural water cycles to eliminate all possible health hazards and to ensure drinking water quality. Domestic effluents are first treated in the City wastewater treatment plant. After that, the treated wastewater passes into the DPR plant. The multiple barrier technique reproduces the natural water cycle in several phases: pre-ozonation, coagulation/flocculation, floatation, sand filtration, ozonation, filtration, activated carbon adsorption, ultrafiltration, and chlorination (City of Windhoek, 2021). The resulting potable water is subjected to permanent quality controls, and to date, there have been no negative health impacts connected with the consumption of recycled water. In total, it takes around 10 hours from the moment wastewater arrives at the treatment plant to the moment it leaves as drinking water. The plant was designed to treat 27,000 m^3, however, today, during the peak hours, it treats about 41,000 m^3/day (Maquet, 2020). The DPR plants produce 35 % (350,000 inhabitants) of the water for Windhoek. Today Windhoek DPR plant has become a global benchmark and a model for innovative and sustainable water management.

3.1.2. *Beaufort West, Karoo, Durban, South Africa*

Beaufort West Municipality is located in central Karoo, in South Africa. It is one of the driest parts of South Africa and approximately has 51,000 residents (Western Cape Government, 2020). DPR plant was built in 2010 when the town's main water supply dried (the Gamka Dam). The plant uses the next steps for treatment: pre-chlorination, sedimentation, intermediate chlorination, rapid sand filtration, ultrafiltration, reversed osmosis, advanced oxidation process, and final chlorination. The reclaimed water is blended with the borehole and treated dam water in a storage tank before being pumped into the distribution system. The construction of the plant cost about 1.37 million euros, and the plant became operational at the beginning of 2011 (Visser, 2021). Although the Gamka Dam was refilled and reached 100 % capacity by September, the DPR plant continued operating.

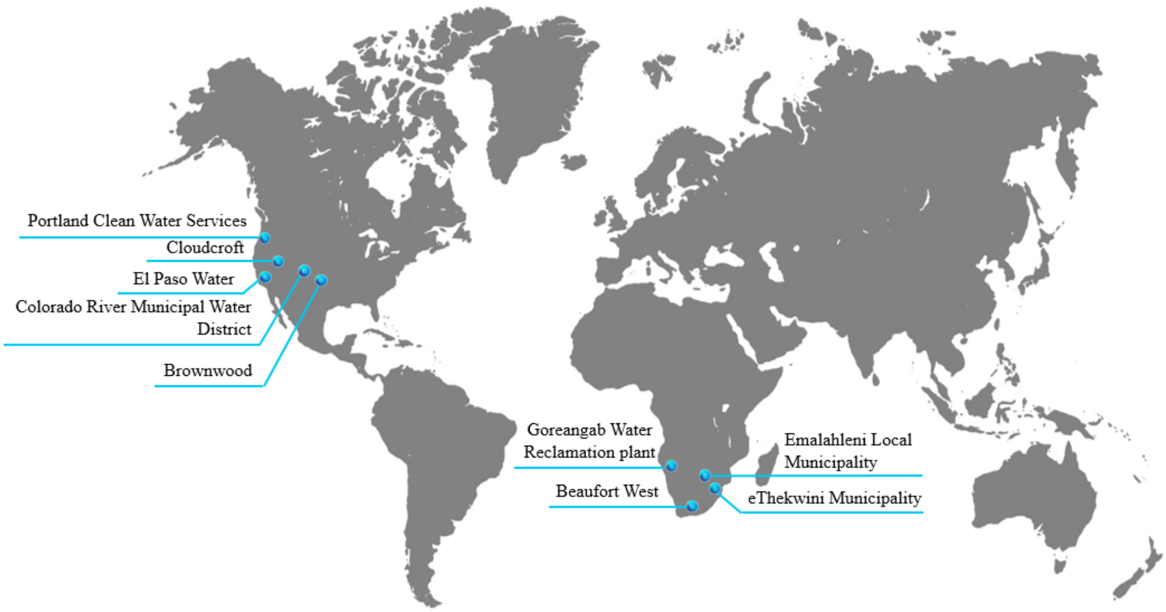

Figure 5. Planned and constructed DPR systems over the world (EPA, 2018)

3.1.3. *eThekwini, Durban, South Africa*

eThekwini Municipality has about 3.6 million inhabitants (Municipalities of South Africa, 2021), it has an industrial zone (Toyota Motor Corporation), and it is the second-largest municipality in the Republic of South Africa (The official website of the eThekwini Municipality, 2021). Because of the economy and population growth, water demands increase every year. In preparation for the shortage in 2019, eThekwini Municipality started planning two wastewater reclaimed water projects for drinking water (Japan International Cooperation Agency, 2016). The treatment process consists of the next steps: flocculation, ultrafiltration, reverse osmosis, stabilization, and ultraviolet disinfection. The plant currently purifies 30 m^3/day to potable quality (Direct Water Reuse in eThekwini, 2021). To maintain the proper level of water quality, the DPR plant is fitted with online instrumentation for constant monitoring of water quality.

3.1.4. *Emalahleni Local Municipality*

Emalahleni Local Municipality is located in the Highveld region, has an extremely varied climate, and is situated on the western side of Mpumalanga province. Emalahleni Local Municipality is a water-stressed mining town and faces a challenge of ever-growing water demand. The main source of surface water supply to the municipality is the Olifants River. This river supplies more than 70 % of municipal water provision capacity.

Direct reuse of treated mine water for domestic purposes has increased over the last decade. Emalahleni Water Reclamation Plant, owned and operated by Anglo American Thermal Coal, uses advanced treatment technology and disinfection to supply drinking water to the Emalahleni Local Municipality (Water research commission, 2013).

3.2. The United States

In the past decade, several major DPR projects were implemented in Texas: the Colorado River Municipal Water District (2013), and the City of Wichita Falls (2014). Moreover, El Paso Water Utilities conducted pilot-scale testing for an advanced water purification facility (2016), and Brownwood received a building permit.

3.2.1. *The Colorado River Municipal Water District, Big Spring, Texas*

This facility is one of two DPR plants currently in operation in Texas to provide a necessary capacity for water supplies in the face of drought conditions. The Colorado River Municipal Water District (CRMWD) constructed the nation's first DPR plant to reclaim and clean previously used water for municipal use. It was the first facility of its kind in the country. The plant treats tertiary effluent from the neighboring City of Big Spring Wastewater Treatment Plant with a combination of microfiltration, reverse osmosis, and ultraviolet disinfection (EPA, 2016). The water is then added to a raw water pipeline. The mixed water (50 percent recycled, 50 percent raw water) is distributed to five water treatment plants where water is treated again using conventional drinking water cleaning techniques in the region that serve 250,000 people (CRMWD, 2021). The treatment process has proven highly effective in removing contaminants, cleaning the water to drinking level quality. The DPR plant started operating in May 2013, and the construction of the plant cost about 12 million euros (CRMWD, 2021). The plant can produce just under 9000 m^3/day of advanced-treated water.

3.2.2. *The advanced water purification facility, El Paso, Texas*

Drought has always been a challenge for the desert community of El Paso, Texas. Water utility serves nearly 685,500 people (World Population Review, 2021). With an average total rainfall of about 0.23 meters a year and a drought at least once every decade, there is awareness of water scarcity among residents of El Paso. Because of that, the advanced water purification facility (DPR plant) was designed. The pilot facility was designed to treat the effluent from the local wastewater treatment plant (Guerrero, 2016) through a four-step technology process: membrane technology, reverse osmosis, ultraviolet disinfection with advanced oxidation, and granular activated carbon filtration (El Paso Water, 2021). About thousands of water samples from the pilot facility were analyzed, and the results showed that the purified water met required standards.

The facility will treat up to 27,300 m^3/day. It is expected that this project will be completed in near future. The project of the DPR plant is estimated to cost around 95 million euros to 130 million euros. As the first large US city to embrace DPR, El Paso would contribute about 4 % of potable reuse capacity additions over the next five years. DPR project is an example for the nation and the world of how a forward-thinking utility can use the latest technology to create a safe, sustainable, and locally controlled water supply to sustain and grow a community in an increasingly arid climate. Currently, about 30 percent of the facility is constructed.

3.2.3. *Wichita Falls, Texas*

In 2014, the City of Wichita Falls started its DPR project to provide the required amount of water. This project was temporary until a longer-term IPR project was completed. This project involved the reconfiguration of two existing water treatment plants. One of them was a conventional surface water treatment plant (coagulation, softening, flocculation, clarification, filtration, and chloramine disinfection), and the other one was designed to treat brackish surface water and consisted of conventional surface water treatment (i.e., disinfection, coagulation, flocculation, and clarification) followed by microfiltration and reverse osmosis (Steinle-Darling et al., 2016). The DPR plant was treating about 19,000 m^3/day effluent (Steinle-Darling, 2015). The process involved a seven-step process for treating water. First, the water was treated in MF/RO plant, and after that, the water was blended with 50 % existing surface water supplies and then treated in the conventional surface water treatment plant (Aquino and Brears, 2021). The DPR project's overarching goal was to supply 50 % of the city's needed water resources (Freese and Nichols, 2016).

Due to the record rainfall in 2015, the water reservoirs were returned to 100 % capacity, and the city decided to shut down the DPR plant and transit to the IPR as it was previously planned. In late 2015, the DPR pipeline was disassembled and repositioned to the wastewater treatment plant for IPR operations (Nix et al., 2021).

3.2.4. Brownwood, Texas

The Brownwood is in western Texas, and this area began experiencing drought in 2007. By 2011 severe water rationing and mandatory conservation were enforced, making the public acutely aware of water scarcity. Water utility serves a population of 18,679 (Data USA, 2021). In 2012, Brownwood became the first city in Texas to obtain approval for DPR (Scruggs et al., 2020). Although the project was approved in December 2012, it was put on hold due to sufficient spring rainfall in 2015 to satisfywater requirements.

3.2.5. *Clean Water Services, Portland*

Clean Water Services produced a batch of high purity water that far exceeded safe drinking water standards and provided it to local brewers to make beer. The treatment facility treats more than 0.09 billion m^3 of water. Water quality nearly meets drinking water standards. Most of the cleaned water is released into the Tualatin River, while some (more than 0.24 million m^3) is reused for irrigation, and some is used in the beer industry (Clean Water Services, 2021).

3.2.6. *Cloudcroft, New Mexico*

Cloudcroft is located in the mountains of southern New Mexico. The population often more than doubles on weekends due to tourism. Drought conditions have reduced the supply to below demand, and exploration for additional groundwater found no new supplies, and because of that, in 2006, Cloudcroft decided to implement DPR. Construction of the DPR facilities began in 2009 (Scruggs et al., 2020). DPR scheme has been developed, and it (379 m^3/day) consists of an MBR followed by RO and AOP. The reclaimed water is then blended with ground and spring water (>51 %) and stored in an engineered storage buffer. Further, the water is treated by an advanced water purification system (UF, UV disinfection, GAC, and chlorination) (Lahnsteiner et al., 2018).

3.3. Comparison of DPR projects and discussion

Table 4 provides an overview of DPR projects and includes information concerning the location, year of installation, current status, type of water reclamation plant (WRP) inlet (source water), reclamation plant capacity, blending with other water sources, and the additional treatment of the blended water. Figure 6 provides an overview of applied technologies in DPR plants.

Technologies used in the listed DPR projects are similar. It is crucial to treat treated wastewater to the desired quality for effective and safe reuse for drinking purposes. The efficacy of the treatment processes is also enhanced, and the water quality is guaranteed with the development in technology. Efficient treatment technology for the treatment of treated wastewater increases the public acceptance of reclaimed water. The water is therefore thoroughly processed to remove all particles, pollutants, and pathogens. The degree of treatment depends on the level of treated wastewater, and because of that DPR plants use different treatment options. The degree of the treatment is directly related to the cost and intended use of water. That means that the higher quality of water requires higher treatment costs. Comparing to regular water supply plans in cities, planning reuse of wastewater for drinking use in cities make additional costs, which can result in the fact that reclaimed water is more expensive.

Table 4
Comparison of DPR project (Gisclon et al., 2002; Hutton et al., 2009; EPA, 2018; Lahnsteiner et al., 2018)

Facility Name/ Project Name	Location	Year of installation	Status	water reclamation plant inlet	water reclamation plant, Q (m^3/day)	Blending - reclaimed water/ ‘natural water’(%)	Additional treatment
Goreangab Water Reclamation plant	Namibia Windhoek	1969 expanded in 2002	Operational	Secondary domestic effluent	27,000 - 41,000	25/75b (treated dam water þ groundwater); Pipe-to-pipe blending in the distribution network	None
Beaufort West	South Africa Western Cape province	2011	Built	Secondary municipal effluent	2,000	20/80 (treated dam water þ ground water); max. 30% of reclaimed water; blending in a storage tank	None
eThekwini Municipality	South Africa Mpumalanga province	2001	Operational	Treated domestic and industrial effluent	47,500	-	-
Emalahleni Local Municipality	South Africa	2007	Operational	Mine water	-	Water is sent to nearby Anglo American mines and to the eMalahleni Local Municipality.	-
Colorado River Municipal Water District (Big Springs)	USA Texas	2013	Operational	Disinfected tertiary municipal effluent	7,600	50/50 (treated water/raw water)	Conventional WTP
El Paso – Advanced Water Purification Facility	USA Texas	Future	Undergoing regulatory approval	Tertiary municipal effluent	27,300	Straight to distribution system	None
Wichita Falls	USA Texas	2014-2015	Closed	Secondary municipal effluent	19,000	50/50 (untreated lake water); blending in a splitter box	Conventional WTP
Brownwood	USA Texas		Construction approval	Tertiary municipal effluent	5,700	Blending in the distribution system with treated lake water	None
Cloudcroft	USA New Mexico	2016	Built but delayed	Secondary effluent from MBR	379	49/51 (spring/well water); blending in an engineered storage buffer	Advanced WTP (UF, UV, GAC, NaOCl)

Also, depending on the local circumstances (location, domestic water demands, available water, climate changes, etc.) DPR is not always a possibility and good option. Depending on factors like wastewater quantity and quality, type of treatment and distribution system, cost, public awareness, etc., there are several feasible options for the reuse of treated wastewater. City planners should check which option for water reuse is possible in the city. The DPR refers to designing the water scheme where the aim is to reuse treated wastewater for drinking purposes. DPR consists of proper treatment of wastewater and overall optimization of treatment and distribution scheme for reclamation and reuse of water. People understand the environmental and economic importance of reusing treated wastewater, but also have some concerns that could affect their acceptance of the DPR scheme. Concerns are related to the quality of the drinking water, health reasons, and lack of trust in the treatment process. With the shortage of freshwater availability, growing populations, and increasing water demands, the circular approaches towards the use and reuse of water have emerged as a priority. The circular economy approach of reusing treated wastewater has potential benefits for people, such as that the reused wastewater can provide a reliable water source for drinking purposes.

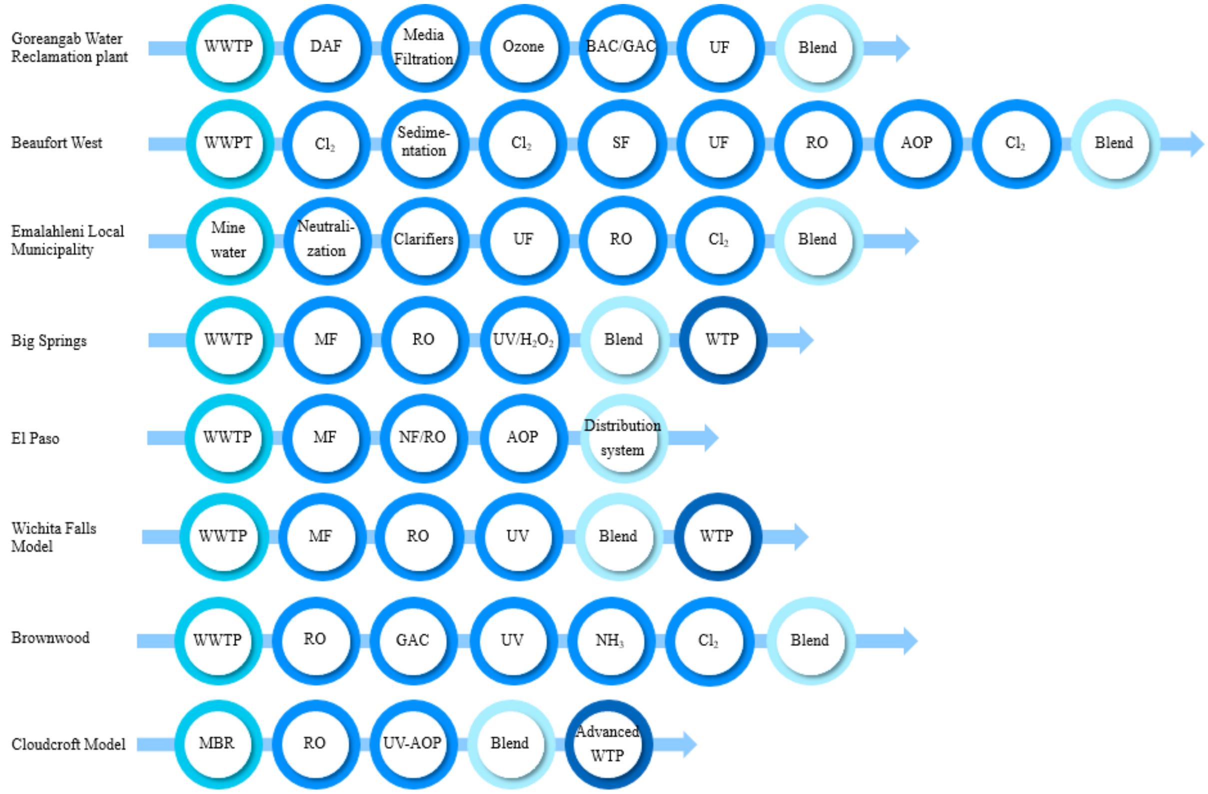

Figure 6. Applied technologies in DPR plants (Hutton et al., 2009; Lahnsteiner et al., 2018; AWWA, 2021)
AOP – advanced oxidation process, BAC – biological activated carbon filter, DAF - dissolved air flotation, GAC - granular activated carbon filter, MBR – membrane bioreactor, MF – microfiltration, NF – nanofiltration, RO – reverse osmosis, SF – sand filtration, UF – ultrafiltration, UV – ultraviolet disinfection, WTP – water treatment plan, WWTP – wastewater treatment plant

4. Conclusion

Climate change, combined with increasing urban growth and existing water stress, creates additional strain to already limited water supplies and compounding water availability challenges. Water is a resource under pressure, and the first response to reduce that pressure is to optimize consumption. Today that is not enough. Reduction of the pressure is possible if the reduction of water consumption is combined with the establishment of a closed circular water loop through potable water reuse. Recycled wastewater is increasingly used to meet increasing water demand and to provide more reliable water supplies. DPR is a time, resource, and money-intensive process, but it is already widespread in many cities across the globe. This paper offers a review of successful examples of the DPR projects. Residents in these cases were affected by dry conditions and water scarcity, and they understood the need to reuse wastewater for drinking purposes, notably because there were no additional water supplies. Various global studies present that, shortly, most countries will be affected by water stress and that water supplies will be reduced and, therefore, learning about DPR and presenting successful examples of DPR can help communities consider new circular and innovative programs for drinking water supply. Also, this paper presents and compares the technologies used in DPR, however, to understand the DPR, it is necessary to conduct further research on water quality before and after treatment, legislation, necessary financial resources, and public acceptance of this system.

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Budućnost reciklaže vode – Pregled primera direktne ponovne upotrebe pijaće vode

Natalija Aleksić [#], **Vanja Šušteršič**

Univerzitet u Kragujevcu, Fakultet inženjerskih nauka, Srbija

INFORMACIJE O RADU

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Pregledni rad

Ključne reči:
Direktna ponovna upotreba vode za piće
Recikliranje vode
Otpadne vode
Voda za piće

IZVOD

Stopa rasta stanovništva i nestašica vode su uticali na razmatranje upotrebe prečišćene otpadne vode kao potencijalnog alternativnog izvora vode za piće. Trenutno se reciklirana voda uglavnom koristi u industriji, poljoprivredi i za navodnjavanje. Danas se reciklirana voda, u određenim delovima sveta, koristi i kao voda za piće zbog ograničenih resursa. Da bi se zadovoljile buduće potrebe vodosnabdevanja, direktna ponovna upotreba pijaće vode bi se mogla uzeti u obzir kao mogući izvor vode za piće. Direktna ponovna upotreba vode za piće može poboljšati održivost i pouzdanost vodosnabdevanja. U ovom radu je analizirana ova tehnika kao kružni princip u vodosnabdevanju i, takođe, je upoređeno nekoliko uspešnih primera primene ove tehnike u Namibiji, Južnoj Africi, Teksasu i Novom Meksiku. Države koje koriste ovu metodu predstavljaju uspešne primere korišćenja otpadnih voda za formiranje održivog i pouzdanog vodosnabdevanja, što je od velikog značaja za budućnost.