Direct industrial reuse of water from municipal wastewater treatment plants (WWTPs): groundbreaking experiments and prospects in Brazil *

Water reuse has been one of the strategies adopted worldwide to deal with water scarcity in regions with a desert climate or in watersheds where demand exceed natural and installed capacity of producing water, as well as the possibilities of water adduction from new sources.

Investment in planned water reuse, or in recycling of wastewater for drinking or non-potable uses, has been gaining ground with the diffusion of the *circular economy* concept [1], which aims at reducing the consumption of energy and natural resources and the generation of waste and effluents in production by introducing processes of recycling, reusing, maintaining, reviewing, and renewing of systems and procedures.

Reusing water means collecting and reusing wastewater from different human activities: rainwater runoff on buildings and paved areas; domestic sewage (black and gray waters); liquid effluents from industrial processes; washing of vehicles and external floors, etc. Water reuse can be done indirectly, planned or unplanned, through catching water from water bodies that dilute wastewater discharges from upstream; or directly from wastewater treatment plants (WWTPs) to consumers, through dedicated distribution water pipes.

The level of treatment required to enable water reuse depends on the wastewater quality and on the type or purpose of reuse. Potable reuse requires several processes or levels of treatment for removing different types of pollutants or contaminants; non-potable reuse, in turn, is intended for uses that are less demanding of water quality, whose quality standards can be met with conventional levels of treatment.

In urban areas, planned water reuse for non-potable purposes can be applied in: construction works; flush toilets; irrigation of parks and gardens; washing of streets and public spaces; cleaning of draining pipes; fire fighting systems, etc. Non-potable reuse also includes: recharge of surface and undergroud water sources (indirect reuse); irrigation of crops (agricultural reuse); aquaculture; environmental and

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* **2030 Water Resources Group** is a global initiative whose mission is facilitating intersectoral dialogues and actions to address water security issues in developing countries. The initiative was launched at the 2008 World Economic Forum, and since 2012 the group is headquartered at the World Bank / IFC. The present text is a result of initial discussions that 2030 WRG Brazil has been developing with public and private institutions of the sanitation sector and other stakeholders (regulatory agencies, industrial sector, NGOs), aiming to support projects and investments for expansion of the industrial reuse of effluents from public wastewater treatment plants (WWTPs), especially in the water stress areas of the State of São Paulo. The objective of this text is to identify aspects that have been sufficiently discussed throughout this preliminary stage of dialogues, as well as to raise significant issues for the advances that are necessary. It is a work material for supporting the implementation of reuse projects in Brazil, and it should not be considered as an institutional position. The text was written by Stela Goldenstein and Iraúna Bonilha, representatives of the 2030 WRG in Brazil (São Paulo).

[1] About circular economy, please check: *Delivering the Circular Economy: A Toolkit for Policymakers*. Ellen MacArthur Foundation, 2015 (available for download on the internet).

landscape improvement (maintenance of water flows, creation of lakes and wetlands, etc.); and industrial processes, such as in cooling towers and boilers (industrial reuse). [2]

According to data from the USA National Recycling Coalition (NRC, 2012), total reuse of municipal sewage worldwide in 2008 was about 50 million cubic meters per day. Most of it - 58% of the total - was untreated sewage, mainly for agricultural reuse in Mexico and China; 42% was treated wastewater, reused for several purposes in 43 countries, mainly in the United States, the largest reuser in volume (7.6 million cubic meters per day). In Israel, 75% of the wastewater collected was reused, especially in agriculture. In countries like Singapore or Kuwait, reuse water accounted for more than 10% of the water consumed for domestic use.[3]

A 2013 study [4] shows that there is a lack of up-to-date information and data on water reuse in the world; of 181 countries surveyed, only 55 had data available on the three aspects of wastewater management - generation, treatment, and use; 69 countries had information on two aspects or one only; and 57 had not provided any data. Most of the available information was out of date.

In Brazil, planned reuse of water is still a new and incipient activity. Estimated current volume of direct water reuse in the country is only 2.0 m^3/s (172,800 m^3/day). Studies for a national reuse plan [5] propose a target of 10 m^3/s of direct water reuse by 2030, being 40 to 50% only for industrial reuse, which is considered the most feasible reuse modality for Brazilian conditions.

Industrial reuse as a complementary strategy for water security in Brazil

Although Brazil owns 12% of the world's freshwater reserves, water stress is a reality in several regions of the country. Water scarcity is not a problem restricted to the states of the Northeast, where drought is historical [6], also affecting the supply of cities and economic activities in the South and Southeast regions (see **Figure 1**). The causes of this disturbing picture can not be attributed exclusively to climate variations. On the other hand, conditions tend to worsen in face of climate change scenarios.

The highly heterogeneous distribution of the population and of the water resources in the territory does not favor the traditional water use patterns. Settlement in Brazil was historically concentrated in the lands closest to the sea, far from the great rivers of the hinterland. About 70% of the national freshwater stocks are in the Northern Region (Amazon Basin), where less than 10% of Brazilians live; while in the Southeast, in the South and Northeast regions, which account for 85% of the country's population, only 15% of national water reserves are found. [7]

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[2] According to the classification presented in: *Elaboração de Proposta do Plano de Ações para Instituir uma Política de Reúso de Efluente Sanitário Tratado no Brasil.* BRASIL/ MINISTÉRIO DAS CIDADES; IICA; CH2M. 2016. p. 17 (Table 3).

[3] *In op cit.* BRASIL/MINISTÉRIO DAS CIDADES; IICA; CH2M, 2016. p. 20.

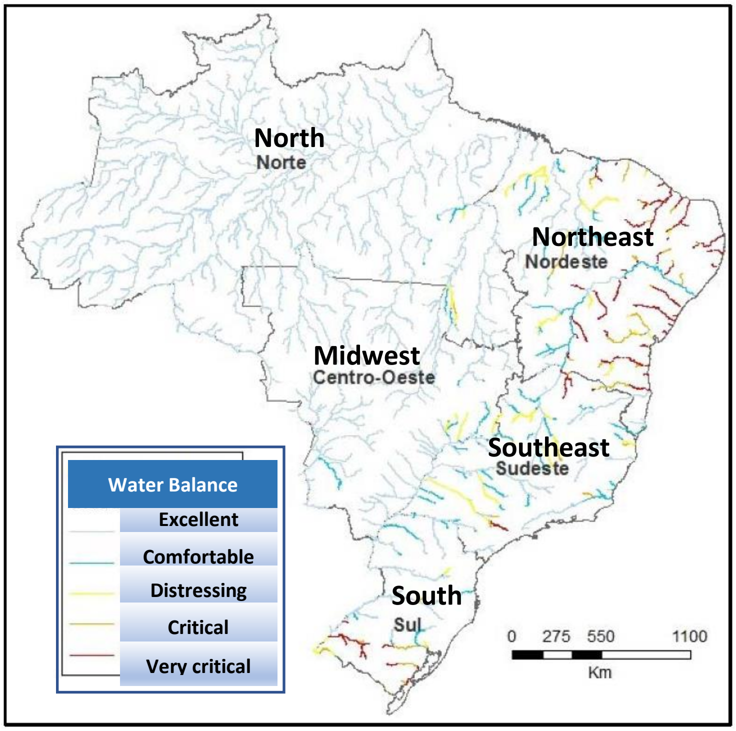
[4] *Global, regional, and country level need for data on wastewater generation, treatment, and use*. SATO, Toshio et al. In: Agricultural Water Management 130 (2013) 1–13. Elsevier, 2013 (http://inweh.unu.edu/wp-content/uploads/2017/01/2013-AGWAT_Sato-et-al_Global-Wastewater-Data.pdf)

[5] *In op. cit.* BRASIL/ MINISTÉRIO DAS CIDADES; IICA; CH2M. 2016.

[6] For more information, please see: https://super.abril.com.br/blog/superlistas/os-10-maiores-periodos-de-seca-no-brasil/

[7] Data from the National Water Agency (ANA) and the Brazilian Institute of Geography and Statistics (IBGE 2010 Census).

Figure 1. Water Balance in Brazil (2013)



Source: Adaptated from CH2M, 2016. Based on data by the Brazilian Water Resources Conjuncture (ANA, 2015)

Most of Brazilians live in cities, and the national urbanization rate tends to reach 90% in 2020 [8]. However, urban growth in Brazil has not been historically followed *pari passu* by investments in the expansion of sewage collection and treatment systems, or in policies to rationalize water use. According to data from IBGE [9], in 2017, about 85% of the Brazilian households were connected to public water supply, but only 66% were connected to sewage collection networks. In the North and the Northeast regions, respectively about 70% and 50% of the households used septic tanks or discharged raw sewage directly into the environment. This is a reality that is not Brazilian only, but continental: World Bank data show that, in 2017, 60% of the population of Latin America and the Caribbean was connected to sewage collection systems, but less than 40% of this sewage was treated.[10]

In large Brazilian cities, the widespread pollution of urban rivers and springs forced authorities to seek for protected water sources in increasingly distant areas, including by water transfers from neighboring river basins. Wastewater, untreated or under-treated, is discharged into water bodies, but often catched by other users downstream. In fact, water supply service providers themselves, as well as agricultural and industrial activities that catch water directly, practice forced reuse whenever using water

[8] *Estado das Cidades da América Latina e do Caribe*. ONU-Habitat, 2012.

[9] Brazilian Institute of Geography and Statistics. 2017 National Survey of Household Sample (Pesquisa Nacional de Amostra de Domicílios Contínua – PNAD).

[10] *Wastewater? Shifting Paradigms. From Waste to Resource. Preliminary insights for the World Water Forum 2018*. World Bank Group Water / CAF (Banco de desenvolvimento da América Latina), 2018.

from sources that receive significant pollution. This is unplanned indirect reuse, which results in poor water quality, conflicts between water users, and higher costs for water treatment.

Thus, given the characteristics of the settlement and urbanization processes; the ways in which water resources are still used and managed; and the insufficient coverage of the urban sewage collection and treatment infrastructures, the balance between supply and demand of drinking water in some river basins has been compromised, especially in the dry season.

In the State of São Paulo, public water supply is practically universalized in cities [11]. However, water stress is an increasing reality in some areas within the so-called " Macrometrópole Paulista " [12], especially in the basins of the Alto Tietê and the Piracicaba-Capivari-Jundiaí (PCJ) rivers, where the metropolitan areas of São Paulo and Campinas and other important surrounding agglomerations are located. According studies by the government of the State of São Paulo [13], the water supply systems currently existing in this macrometropolis, besides being already highly dependent on water transfers from neighboring river basins, are not able to supply the expected demand for the coming years, or to face exceptionally unfavorable hydrological conditions.

The severe drought of 2014-15, which has strongly affected the states of São Paulo and Minas Gerais, has shown that the public supply systems of large and medium-sized cities of the Southeast Region need to increase their resilience to face lasting droughts. The mitigation of water stress in Brazil, particularly in the most critical river basins, requires the systematization of a consistent set of actions, investments and changes in the current water supply and consumption patterns, including: planned water reuse; conservation of springs; recovery of native forest areas; loss reduction in the public supply networks; cleaning of water bodies; incentive for the use of water-conserving technologies and processes; increment of surface water reserves; interconnection of river basins; recharge of aquifers; desalination (brackish ground water or sea water), etc.

In Brazilian cities, a considerable amount of the drinking water supplied by public networks is consumed by activities that do not require potability quality standards. Therefore, this reduces the availability of treated water for drinking, which must comply with rigorous sanitary quality standards established by law, besides resulting in unnecessary water treatment costs. At the same time, in certain river basins, it has become increasingly difficult to find new water sources that can be delivered at viable costs and deadlines.

As shown by international experience, investment in non-potable direct reuse - planned reuse of treated wastewater, conducted directly from the generation site to consumers, without prior dilution or disposal in water bodies - can help reducing the pressure and the competition exerted by economic activities on surface or underground water sources that are of strategic interest for public supply.

Specifically regarding non-potable reuse for industrial purpose, four types of planned reuse of water can be distinguished: direct internal reuse to companies (recirculation in closed-loop); direct reuse

[11] *Atlas Esgotos: despoluição de bacias hidrográficas*. Agência Nacional de Águas; Secretaria Nacional de Saneamento Ambiental. Brasília, 2017.

[12] The São Paulo ('Paulista') Macrometropolis is one of the largest urban sprawls in the Southern Hemisphere; it includes the Metropolitan Area of São Paulo (MASP) – amongst the six largest in the world, with over 20 million inabitants – and other four institutionalized metropolitan areas – Baixada Santista, Campinas, Sorocaba, and Vale do Paraíba and North Coast –, besides the Agglomerations of Jundiaí and Piracicaba, and the Bragantina Regional Unit (not institutionalized yet). For further information, please visit: https://www.emplasa.sp.gov.br/MMP

[13] Plano Diretor de Aproveitamento de Recursos Hídricos para a Macrometrópole Paulista. SP; SSRH; DAEE. São Paulo, 2013.

between companies (the effluent from one is an input to another); recharge of surface water sources and aquifers of interest for industrial use, in a controlled and monitored way (indirect industrial reuse); and direct reuse of treated effluents from municipal wastewater treatment plants (WWTPs) operated by public or private sanitation utilities.

Currently, industries in Brazil have water supply in two ways: direct catchment of surface or underground water; or supply thorugh public network. Directly, or indirectly, the industrial sector consumes part of the water available in a river basin and may even compete with domestic consumption and other productive activities, especially if there are large industrial consumers and water availability is quite limited. However, as water demand keeps growing, public supply must be prioritized, not only for domestic use, but also for other economic activities that do not catch water directly and depend on the supply from public networks to keep operating. Consumptive uses tend to grow with an increasing population and ecomomic activity; therefore, any help in saving drinking water, or reducing the pressure on water availability to ensure essential uses in emergency situations, is welcome and should be encouraged.

From the point of view of the industrial sector, the costs associated with water insecurity can be an important factor influencing strategic decisions related to the location of investments or to the implementation of water reuse systems to ensure the sustainability of investments already made. In that sense, aware of the economic risks associated with water crisis, most of industries that need large amounts of water have already reduced water consumption in their production lines and introduced internal reuse in closed-loop whenever possible. On the other hand, the current volume of industrial reuse of treated effluents from external sources (municipal WWTPs) is still very little in Brazil, estimated only around 1.0 m^3/s [14].

Data from the National Confederation of Industries (CNI) indicate that, in 2014, installed sewage treatment capacity in the country - estimated at less than 40% of the total volume of sewage generated – amounted to 1/3 of the total industrial water demand, which first indicates a significant potential for expansion of the activity of industrial reuse of water. [15]

In the State of São Paulo, the most industrialized of Brazilian states, 28% of the total water withdrawal in the state was used for industrial purpose in 2017 [16]. However, this consumption was highly concentrated in the Macrometrópole Paulista, following the geograhical location of industries: in the basins of the Alto Tietê and the Piracicaba-Capivari-Jundiaí (PCJ) rivers, there were respectively around 40 and 16 thousand industrial plants, but 38% of the industrial jobs were concentrated in 10 municipalities, nine of them belonging to the Macrometrópole, and four, to the Metropolitan Area of São Paulo (RMSP).

In the Alto Tietê river basin, estimated industrial demand for water in 2017 was 4.5 m^3/s, against a total production capacity of treated sewage of 18 m^3/s in five operating WWTPs [17].

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[14] *In op cit.* BRASIL/MINISTÉRIO DAS CIDADES; IICA; CH2M, 2016.

[15] *Reúso de efluentes: metodologia para análise do potencial do uso de efluentes tratados para abastecimento industrial*. Confederação Nacional da Indústria - CNI. Brasília, 2017.

[16] Data by CNI and FIESP (Federation of Industries of the State of São Paulo), presented during the seminar "Prospects on the Reuse of Effluents by the Industry in the Piracicaba, Capivari, and Jundiaí (PCJ) River Basins", held on June 15th, 2018. The seminar was organized by the 2030 WRG/World Bank together with the Committees and Agency for the PCJ Rivers Basins, with the support of SANASA, FIESP, and the UN Global Compact.

[17] *In op. cit*. Confederação Nacional da Indústria - CNI. Brasília, 2017.

In the PCJ rivers basins, the estimated total water demand in 2016 was about 37.0 m^3/s, being the industrial sector responsible for around 25% - a participation that has remained stable since 2010, placing the sector as the second largest water consumer in the region [18]. Data from the PCJ Basin Agency also show that only 10 major industries account for almost 60% of the total water withdrawal for industrial use. In the last fifteen years, the industries installed in the region reduced water demand by 47%, through the modernization of equipment and processes, including the introduction of internal reuse in more than 60% of the plants. However, the PCJ River Basin Plan estimates that, in 2016, the total surface water demand accounted for 84% of the reference flow (minimum drought flow, or $Q_{7,10}$), a critical situation in terms of water availability.

This level of criticality, which reaches all types of use of water, was put to the test at the height of the water crisis of 2014-2015, when several industries, agricultural activities and urban areas in the Macrometrópole Paulista suffered with the lack of water supply. Although large industries have greater capacity to absorb the economic loss caused by the temporary halt or reduction of production, this severe water crisis forced the industrial sector to also look at the needs of its value and supply chains, and the contingency plans have become more consistent and broader, including suppliers and customers, also due to the requirement of guarantees from the financing institutions.

It is also important to remind that water scarcity, by compromising the level of important reservoirs used for power generation in the Southeast Region, can affect the production of hydroelectric power and consequently impact economy and industrial activity. According to estimates by Itaú Bank for 2015 and 2016, the probability of electricity rationing due to the low levels of the Southeast reservoirs was 70% in 2015 and 75% in 2016. A reduction of only 10% in energy consumption would represent a decrease of 0.8 to 1.0% in the Brazilian GDP.[19]

Thus, available information indicates that there is an underused potential in the country for industrial reuse of water from municipal WWTPs, and particularly in the State of São Paulo. On the other hand, the realization of this potential still depends on overcoming hurdles of technical, economic, legal, regulatory, and cultural nature, which inhibit initiatives and investments aimed at water reuse in general (see later in this article).

Despite the hurdles and uncertainties, non-potable direct reuse for industrial purpose already has a groundbreaking experience of great size and relevance in Brazil, which is Aquapolo, in the São Paulo Metropolitan Area (RMSP). It is important to draw some lessons from this case, especially from the point of view of the consumers of reuse water.

The Aquapolo case and other initiatives in progress in the State of São Paulo

The Aquapolo enterprise (see **Figures 2 and 3**), operating since 2012, is the result of a partnership between BRK Ambiental (formerly Odebrecht Ambiental, acquired in 2016 by the Brookfield Group, which operates in 12 Brazilian states) and the Sanitation Company of the State of São Paulo, SABESP (a mixed-capital company operating in the State of São Paulo), under a 41-year contract.

[18] *Relatório de Gestão das Bacias PCJ 2016*. Comitês e Agência das Bacias PCJ. São Paulo, 2016.

[19] *Brasil: a escassez hídrica e seus impactos econômicos*. Itaú Asset Management. São Paulo, 2015.

Aquapolo currently provides 650 L/s of reuse water to the Mauá Petrochemical Complex, in the Great ABC region (RMSP). Total installed capacity, however, is 1,000 L/s [20]. The input effluent comes from the ABC Wastewater Treatment Plant (ETE ABC), operated by SABESP. After the standard treatment process, Aquapolo submits the effluent to a complementary procedure (polishing), to adapt it for industrial reuse. The water quality standards to be met at the end of the process were determined by the industries at the Petrochemical Complex.

Figures 2 and 3. The ABC WWTP/Aquapolo complex, in the São Paulo Metropolitan Area

Source: Aquapolo image database (nov/2018).

Once treated, the effluent is transported by a 17-kilometer pipeline that cuts through the municipalities of São Paulo, São Caetano do Sul and Santo André, and feeds a distribution reservoir at the Capuava Petrochemical Complex, in the municipality of Mauá. From this point on, a distribution network (3.6 kilometers) delivers the reuse water to the industries at the complex, which use it mainly in cooling towers, steam generation and boilers. The reuse water pipe was designed to allow derivations as to enable serving possible new clients along the route.

The reuse water from Aquapolo replaced the raw water that was previously catched superficially in the Tamanduateí River by Petrobras' Capuava Refinery (RECAP), which treated and distributed this water to the petrochemical complex. In addition to releasing more water for the dilution of the sewage poured into the Tamanduateí river downstream, the substitution allowed users to guard against the losses resulting from the effects of a water crisis. It is estimated that the sale of treated effluents to the petrochemical hub of Mauá through Aquapolo allowed industries to stop using a total volume of about 900 million liters per month of raw water.

Braskem, a petrochemical industry that operates three plants at ABC's Pole, has signed a 40-year contract with Aquapolo to guarantee water security of its operations. Thanks to this initiative, Braskem's units crossed the 2013-15 water crisis without any productive constraints; on the contrary, production has still been increased. Since the beginning of operations with reuse water, Braskem’s plants stopped buying the water collected and treated by RECAP - a monthly flow of 212 million liters of water, equivalent to a city of 35 thousand inhabitants.

[20] For further information, please check: http://www.aquapolo.com.br.

From the perspective of Braskem as a consumer of reuse water, the implementation of the project in the ABC region avoided a potential historical loss, which could have reached more than BRL 200M in 2015, when the water crisis severely affected the Alto Tietê river basin. This calculation, developed by the company itself, has considered a scenario of an annual restriction to the granted water flows of around 30% - average restriction determined by regulators in situation of serious shortage - which would affect the production and consequently, company's profits. Applying an internal pricing model for water risk, Braskem has identified that, under a critical hydrological series such as 2013-2017 and a 15-20% constraint to water catchment over a period of three months, the impact on production would be such that it would compensate the company to pay more for the cubic meter of water, to the point of making feasible a long-term contract like that signed with Aquapolo, or the investment of another third-party interested in building and operating a plant of water reuse to meet Braskem's demand.[21]

In addition, since the water quality previously provided by RECAP was of a lower quality than that of Aquapolo's treated effluent, this still saved some tens of millions of BRL per year in the operation of the Braskem units, as it was possible doubling the number of cycles in cooling towers, increasing internal water recirculation, and reducing the maintenance and replacement of equipment such as heat exchangers, further generating the additional benefit of reducing the health and safety risks associated with maintenance services.

Aquapolo is the largest reuse project installed and operating in the country, in a region where water stress is structural and may affect public supply and economic activities in large-scale. However, contrary to expectations and the initial planning, more than five years passed since the beginning of its operation, the enterprise has not yet generated and sold the estimated volume of 1,000 L/s of treated effluents, despite of the worsening supply restrictions during the water crisis of 2013-2015.

Identifying the reasons why this has not yet occurred can help to devise safer strategies for the expansion of industrial reuse of water in the state and in the country. Among likely difficulties, it can be assumed that there was no involvement of other localities in the surroundings, where there are potential industrial consumers of reusable water. Some industries have access to raw water from surface or underground water sources at a flat cost of water catchment rights, while smaller plants have access to drinking water from the public supply at competitive prices. Another reason is that many companies still make an overly simplistic and timely analysis, comparing the current deployment and operating costs with water reuse, which would be more expensive in a short-term assessment. However, this kind of analysis fails to consider the water risk factor in the financial valuations, and the potential loss in a scenario of scarcity, which is highly likely. This kind of vision makes it difficult to prove the feasibility of projects such as Aquapolo, because this "more expensive" water should be considered as insurance, a value to be paid to prevent a potential loss.

Aquapolo's experience indicates that the expansion of water reuse for industrial purpose in Brazil depends heavily on a more adequate alignment between the spheres of government, as well as on the rationalization of the criteria for charging of water use rights and for supplying drinking water to users that do not require potability standards. Independently of such, water risk should be more consistently introduced as a relevant factor of cost analysis and investment planning by companies.

Concerned with the risks and losses associated with the water crisis, the Committee and the Agency for the Piracicaba, Capivari and Jundiaí Rivers Basins (PCJ Basin Committee and Agency) - which

[21] Information kindly provided by André Villaça Ramalho, of Braskem's Sustainable Development department.

are responsible respectively for planning the uses of water resources and for applying the financial resources arising from charging water use rights in the region of the PCJ basins - introduced the practice of water reuse as one of the planning guidelines for dealing with water stress.

In 2016, the hydrographic region corresponding to the Water Resources Management Unit called UGRHI-5 (PCJ basins) had an estimated total population of 5.7 million inhabitants, mostly concentrated in the municipalities of the metropolitan area of Campinas and of the neighboring regions of Jundiaí and Piracicaba. Owning the country's second largest industrial park, the PCJ region accounted for a 5% share of the national GDP in 2016. In view of the continuing downward trend in per capita availability of surface water in the region, the urgency for investments to ensure water security for the near future is a challenge to the sustainable management of the regional water resources, as well as of economy and employment.

In this context, the discussion on water reuse has been emphasized in a broader basin planning scenario. The PCJ Basin Committee, through its Technical Chamber for the Use and Conservation of Water in Industry, understood water reuse as a potentially feasible measure in view of the worrying situation of the regional water balance - as indicated in the 2016 Management Report of the PCJ Basins - and assumed the responsibility of giving effective referral to the industrial reuse of treated effluents from municipal WWTPs. Through a partnership between the 2030 WRG / World Bank and the PCJ Basin Committee and Agency, a detailed Reference Term was drawn up for contracting a Regional Water Reuse Plan for Industrial Purpose, which will should also include a feasibility study for the implementation of water reuse pilot projects.[22]

The necessity of this regional study is evidenced by the backs and forths related to the investments of SANASA Campinas, the public company responsible for the sanitation of the city of Campinas.

According to the Sustainability Report of SANASA Campinas (GRI 2016), the concessionaire operates a sewage collection and treatment system that currently serves about 92% of the urban population, including more than 4 thousand kilometers of pipes, 88 lift stations, 24 sewage treatment plans, and a Reuse Water Production Plant, so-called EPAR Capivari II. This plant uses a biological treatment process at the tertiary level, removing nitrogen and phosphorus from the sanitary effluent, followed by an ultrafiltration membrane system, capable of removing numerous contaminants, such as most viruses, bacteria and protozoa, without the use of chemical disinfectants, also removing the solids. The EPAR Capivari II (see **Figures 4 and 5**) produces a high-quality effluent in physical-chemical and biological terms, which may even allow direct reuse for public supply in the future through simple chlorination so to meet the potability parameters stipulated by the Ministry of Health.

SANASA has already discussed with interested parties to enable the commercialization of reusable water, but, so far, no supply contract has been firmed. There is a project of a dedicated network for supplying Viracopos Airport from EPAR Capivari II, which is expected to be extended to the next Industrial District (Mercedes Benz Avenue). The pipeline to Viracopos would have been about 8.0 kilometers long, but the potential customer, facing difficulties of its own, did not want to bear the costs of implementation, so SANASA seeks to fund this project autonomously. Another project of the company is a reuse water line to reinforce the supply of REPLAN, Petrobrás refinery located in the city of Paulínia. However, SANASA is still assessing the legal requirements for a municipal sanitation concessionaire being able to invest in infrastructure or to sell reuse water to another municipality where it has no concession of public services.

[22] The study is currently in the procurement phase under the PCJ Basin Agency.

Figures 4 e 5. SANAS's Reuse Water Production Plant - EPAR Capivari II

Souce: Portal Brasil Engenharia

Source: CBN Campinas

According to SANASA experts, water for non-potable reuse tends to cost half the value of investments required to produce treated water to meet potability standards. Currently, SANASA delivers 1000 liters in each residence for less than 10 reais (current prices). There are different and progressive tariffs per consumption range, and depending on the size of an industry, the tariff may vary. It should also be noted that the prices charged for sanitation services in the PCJ basins are variable, since there are municipalities in the Campinas metropolitan area (RMC) that charge sewage treatment as 100% of the price of treated water, while others charge 80%.

Thus, in the metropolitan basins of the State of São Paulo that are considered as critical or water-stressed, there is a concentration of population and large industries on one hand, and on the other hand, the production of sanitary effluents, which characterizes a latent potential for direct/planned water reuse projects. Therefore, it is necessary to investigate what are the technical, economic, and legal requirements to make feasible reuse projects aimed at the industrial sector; what are the barriers that hinder or discourage initiatives in this direction; and to what extent the development of this potential could effectively aid in the strategy of reserving water availability for public supply and recharge of water sources, in view of the regional water balance.

Enabling industrial reuse of water from municipal WWTPs in the State of São Paulo: difficulties and potentialities

Considering that water reuse is a new activity in the country, which involves health and environmental risks, different types of reuse, and new forms of relationship between sanitation utilities and consumers, the establishment of legal requirements and restrictions became a necessity as to solve legal uncertainties and remove risks to potential players in the water reuse business.

In 2005, the Ministry of the Environment, through the National Council of Water Resources (CNRH), approved Resolution no. 54/2005, which establishes modalities of water reuse for urban, agricultural / forestry, industrial, environmental, and aquaculture purposes, as well as guidelines and general criteria for non-potable direct reuse of water - including the proposition by the River Basin

Committees to invest funds derived from the charging of water use to stimulate the practice of reuse. Within the framework of government planning, regional plans at the state and the river basin levels, as well as local/city sanitation plans, can support systematic processes for implementing water reuse projects.

Currently, there are bills on the subject in Congress, but the prevailing orientation so far is that each state establishes its own policy and regulation on water reuse, in line with the guidelines of the national policy of reuse in preparation, without the need for approval of a national law to regulate water reuse uniformly.[23]

Some Brazilian states that are particularly affected by water stress have already passed regulations that discipline water reuse, such as the State of Ceará's Law No. 16.033 / 2016, which provides for the state policy of non-potable water reuse, and the State of São Paulo's Joint Resolution SES / SMA / SSRH Nº 01/2017 [24], which disciplines the direct non-potable reuse of water from WWTPs for urban purposes. Especifically regarding the São Paulo resolution, it took ten years of discussions until it was approved, but the norm still poses requirements considered by the industrial sector as excessive and does not solve legal uncertainties that negatively impact the viability of the activity, raising insecurity to potential investors.

In a Memorandum of Understandings (MoU) signed in 2017, the São Paulo State Department for Sanitation and Water Resources (SSRH) and the 2030WRG / World Bank Support defined support for addressing the hurdles to investment opportunities in planned direct reuse of water in the state as a priority. In addition to studying adjustments to the current water reuse regulation for urban purposes, the 2030WRG, along with sanitation companies and state regulatory agencies in the areas of sanitation, environment and public health, has been promoting debates and supporting initiatives that may result in the implementation of new industrial reuse projects in the state.

From the economic point of view, the financial equation that allow investments in projects of direct industrial reuse of effluents from external sources (public WWTPs) implies the evaluation of three main factors: (i) the necessary investments in the logistics of transport and delivery of the reuse water (infrastructures of adduction and distribution); (ii) the costs of supplementary treatment (polishing) to adapt the reuse water to the needs of each industrial user, which depend on the quality of the sanitary effluent from the public WWTP; (iii) the comparative evaluation of these costs against the value charged to industrial users for the granting of the right to catch raw water, which is still very low, even considering the episodic insecurity in the water supply.

In most cases, the largest investment to make reuse projects feasible lies in logistics infrastructure, that is, the installation of water adduction and distribution pipes from the WWTP directly to consumers. However, as to make the whole business feasible, it is necessary to establish an attractive

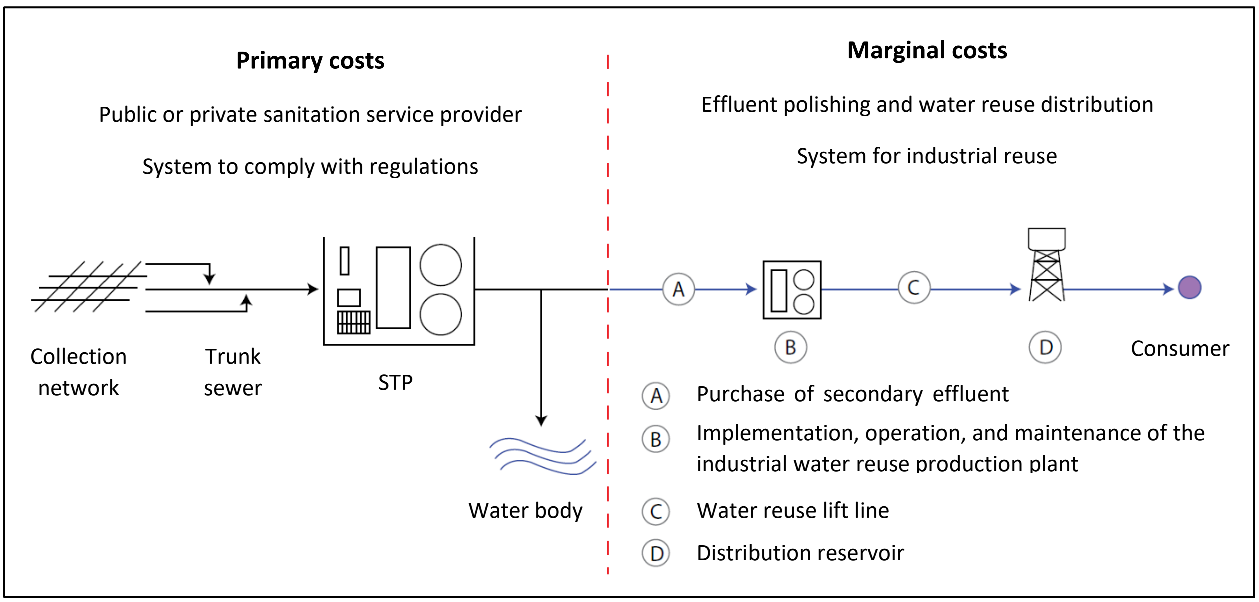
[23] The Ministry of Cities, now extinct by the current Federal Government, was coordinating the preparation of a policy for the reuse of treated sanitary effluents, whose studies were carried out by CH2M / Jacobs do Brasil. So far, the consequences of the extinction of this ministry for the continuity of the studies are unknown. For further information on the studies so far, please see: *Elaboração de Proposta do Plano de Ações para Instituir uma Política de Reúso de Efluente Sanitário Tratado no Brasil*. BRASIL/ MINISTÉRIO DAS CIDADES; IICA; CH2M. 2016.

[24] At the time of the approval of the Resolution: SES – State Department of Health; SMA – State Department of Environment; SSRH – State Department for Sanitation and Water Resources.

price for the service. Cost estimates by CNI [25] indicate that the value per cubic meter decreases as treated volumes increase, making systems of 500 L/s economically more viable than those of 50 L/s, for example.

As most of sewage treatment systems use conventional secondary activated sludge biological systems, the most feasible option is to adapt these systems to produce effluents of quality suitable for most of reuse types, practically not involving civil works, through the installation of ultrafiltration membrane units in the aeration chambers of the activated sludge systems, or in small chambers adjacent to them. In addition to the costs associated with the remodeling of WWTPs, costs related to water adductors and distribution tanks to meet demand in specific areas should also be considered. The primary costs associated with conventional sewage treatment systems for activated sludge can not be attributed to water reuse, as they are required to comply with the emission standards established by CONAMA Resolutions No. 357/2005 and No. 430/2011. Therefore, the costs of reusable water are only the marginal costs associated with the necessary supplementary treatment units and the intake and reservoir system, as shown in **Figure 6**.

Figure 6. Primary and marginal costs associated with water reuse



Source: CNI, 2017; Fukasawa, 2016.

From a technical point of view, some WWTPs operated by public or private sanitation companies are already able to generate effluents of enough quality for their systematic reuse, at least for industrial purpose. However, most of treatment plants require investments in the modernization of their installations and processes, as to generate final effluents of better quality. In the RMSP, the Municipal Indicator of Sewage Collection and Treatability of Urban Population (Ictem), published by the Environmental Agency of the State of São Paulo (CETESB), which measures the performance of WWTPs,

[25] *Reúso de efluentes: metodologia para análise do potencial do uso de efluentes tratados para abastecimento industrial.* Brazilian National Confederation of Industry (CNI). Brasília, 2017.

is considered “reasonable” to “very poor” in a large part of the municipalities, even to meet the quality standards defined by law for effluent discharge. Due to water scarcity, to the need to improve the quality of water bodies, and to the increasing costs of treatment, it is also necessary to discuss in which situations the investments needed today to increase capacity and improve the performance of WWTPs could be partially funded by the commercialization of treated effluents for reuse.

At the same time, these are large investments, which introduce issues for which it is necessary to guarantee full legal compliance and institutional security, as they demand new standards of contracting and commercial relationship between sanitation service providers and water users; the revaluation by licensing agents of water use permits for water withdrawal and effluent discharge; and the introduction of ancillary gains to sanitation service contracts.

From the point of view of industrial users, reducing risks in the purchase contracts is a priority. The private sector needs guaranteed supply and legal certainty in contracts to invest in industrial reuse projects. In view of the current situation, it is the supply of reusable water under attractive conditions that could generate demand from potential consumers. Therefore, the identification and evaluation of anchor companies - that is, potential consumers of large volumes of reuse water - seems to be the key to make projects of direct reuse of effluents from municipal WWTPs feasible.

The discussions held with stakeholders through technical meetings, seminars and workshops have raised some of the uncertainties that have been repeatedly mentioned as reasons that exclude private sector investments in reuse projects, such as:

- Contract terms: the terms of the purchase contracts of reusable water need to be long as to provide sustainability to the business and stimulate industries to give up on a part of their current water catchment rights already granted (water use permits);
- Political risks: despite contracts, there is a diffuse perception that, in government changes, there may be a risk of termination of concession contracts by the municipality, which creates institutional insecurity;
- Supply capacity: there is doubt, or at least unpredictability, about the capacity of the public authorities or the sanitation service providers to meet a growing demand over time, especially under an extremely critical scenario that may imply the reduction of domestic consumption, and therefore, sewage generation;
- Conflicts between inspecting authorities: the standards of environmental, health, and water resources authorities are different, so that each one requires a different type of monitoring and analysis of the effluent quality, which frequently creates extra costs and legal compliance risks against environmental and sanitary standards;
- Regulation of reuse water quality standards: it is still not clear for intervening institutions that quality standards regarding industrial reuse without physical contact of workers should be jointly determined by producers and consumers, without any stiffening by regulation or need for inspection by the health agency;
- Lack of integration between local and regional water resources and sanitation plans.

Developing the reuse of effluents from WWTPs as an alternative to supply the industrial sector involves identifying gaps, difficulties, and opportunities; changing mindsets; and actions by sector leaderships that adopt water reuse as a strategy, which would help to create benchmark and an institutional matrix at different levels of government. Water reuse is clearly not a solution for all cases, each region demands specific solutions, since in many localities there is not even a significant industrial park that justifies reuse projects aimed at the sector. In these cases, if there is a satisfactory treatment of sewage, the most feasible is planning indirect reuse as to recharge surface water sources and aquifers. Whenever logistics involves vast distances, water reuse is not always economically feasible and preliminary feasibility studies are mandatory.

Regarding the uncertainties pointed out by the industrial sector to invest in water reuse systems, it is essential to see that there is already significant insecurity to meet water demands using licensed surface and ground extractions. In water crisis, water catchment grants will always be more precarious, from the viewpoint of commercial security, than the contracts for the supply of reusable water from public WWTPs, as shown by the Braskem-Aquapolo case and other contracts with industrial consumers that SABESP manages in the RMSP. There is no way to avoid risks in a situation of structural scarcity, and it is worthwhile recalling that the work for implementation of reuse systems may take three years or more, so waiting for more certain scarcity scenarios may be ill-advised and lead to major losses.

On the other hand, economic crisis scenarios, and the lack of public initiatives to foster water reuse, may discourage investments, making the companies prefer to keep the water grants they already have - even if they are, by definition, precarious instruments - and maximize internal reuse systems instead of investing in new enterprises for external reuse of water.

The experience in California (USA), where reuse of effluents from WWTPs is well developed, shows that the companies need to be motivated to participate in river basin planning. Traditionally, private sector focus on business models and aspects such as economic, efficiency, security, competitiveness, and swiftness. Industry also tends to focus on individual and short-term solutions, whereas governments need to work on longer planning horizons with collective solutions agreed between different sectors that use water. Participating in long-term planning, companies may also find support for their own projects and overcome the distrust in relation to the efficiency of the public sector.

In Brazil, the productive sector has formal representation in the river basin committees that are responsible for preparing the river basin plans, but the articulation between these plans and private strategies for water security is still often incipient. Sanitation and water resources plans have been prepared based on a conventional perspective, always focusing on actions such as: bringing in water from more and more distant sources; building centralized and expensive sanitation systems, such as the RMSP system; simply discharging the effluents treated by the WWTPs downstream, etc. Several plans mention the need to increase water reuse volumes for several activities but fail to establish guidelines or action programs for that purpose. The lack of social participation, including of industrial users, as well as insufficient integration with other medium and long-term sectoral views, make the implementation of these plans more difficult.

One of the aspects that mostly hinder the logistics to deliver reusable water is the lack of land use planning and control by municipalities. The location of new industrial districts in the municipalities should consider the vicinity of WWTPs, as they are potential sources of reusable water. The regional plans for ecological-economic zoning (EEZ), as well as the municipal sanitation plans under development, should consider this as a decision factor when defining the location of industrial zones. The Economic and Ecological Zoning Plan for the State of São Paulo, being drafted by the State Secretariat for the Environment (SMA-SP), promises to incorporate guidance for the decision on the location of industrial zones because of the discussions promoted by the 2030WRG on water reuse.

From the point of view of the water security of a river basin, the evaluation of the results that the reuse can have on the water balance is a fundamental aspect. The impacts of water reuse on the water balance of a river basin should also be assessed as part of the feasibility analysis of water reuse pilot projects, especially if there are basins diversions, since part of the volume that currently participates in the indirect reuse, through discharge of effluents into water bodies, would cease to do so, either because it is incorporated into the producst, or due to the launch in a different place from the original grant. It is necessary to study each pilot project so to evaluate the institutional and legal risks identified, as well as the extent to which the reuse could help mitigating water insecurity.

The water reuse business is still at its early stages, and it is proving to be feasible depending on factors such as the scale of the demand and the logistics costs involved. Therefore, there is a need for more in-depth studies per basin, especially in those in critical situation. It is necessary to study pilot projects per sub-basin to assess the institutional and legal risks pointed out and the potential for mitigation of the water insecurity that industrial reuse can provide for each basin and for the companies installed in it.

At the same time, 2030WRG believes that it is important to go further with studies and debates for the definition of fair prices for charging of water uses, as well as for selling drinking water for industrial use. The water pricing is lawfully defined as one of the management tools incorporated by the State and National Water Resources Policies, whose goals are to enable users to recognize the actual value of water, promote its rational use, and obtain financial support to recover river basins. In situations of water stress the price of the licenses still does not reflect this reality, nor it is a factor that promotes the rational use of water. The frequent undervaluation of the price of treated water for non-essential uses results that the basin is increasing its risk level, since the public authority is not appropriately considering the priorities in the water use in the license pricing.

The discussion about the feasibility of industrial reuse of water aims at introducing aspects of rationality in a market that currently presents distortions, since municipalities provide drinking water for non-potable uses, even in water stress regions. In addition, the debate helps to bring about cultural change in the business sector and in sanitation companies, leading them to take a broader view of water risk and to participate more actively in river basin planning and management, as well as in feasibility studies for new planned direct reuse projects.

General questions to guide initiatives oriented to promote planned industrial reuse of treated sanitary effluents in Brazil:

- Does the potential for direct non-potable reuse of WWTPs effluents in the context of the basin lack mapping and determination?
- Why are there jst a few cases of companies that reuse effluents from WWTPs or inter-companies?
- What are the conditioning factors that make reused water a strategic alternative in the basin?
- What are the limit distances that make distribution of reused water from WWTPs logistically competitive? How can we write the equation using the variables that define this competitiveness?
- What are the environmental and sanitary regulations that regulate the reuse of WWTPs' final effluents, and what are the procedures to get health and environmental licensing for new projects? Do these regulations support the industrial reuse?
- How to create a correspondence between the criteria for pricing the licenses and for regulating the water rates for the supply generating reuse competitiveness, making it significant within the matrix of sources in the regions facing structural water stress?
- What is the potential for expansion of reuse projects, considering the current prices to license and to sell water by concessionaire and local utilities?
- In terms of reused water extraction and distribution licensing rights, to whom they will belong, and what the operation regulations will be like?
- What are the possible institutional relationship patterns and the business models involving producers (sanitation concessionaires), distributors (reuse operators) and consumers?
- What are the relations to be established with the granting local authorities to promote changes in the economic-financial balance of the concession contracts when new businesses to trade water for reuse are added?
- What are the regulating agencies' duties and procedures towards legal security of such investments?
- How can technological and innovation motivating standards be introduced in the concession contracts, so to guarantee the quality of effluents and increase its reuse potential?
- How to face the cultural obstacles involved, such as the lack of technical knowledge by the decision makers (insufficient scientific dissemination); the technical and institutional mindsets against the reuse; the society's distrust in relation to the quality of the reused water; and the lack of knowledge about the unplanned reuse as a current practice?