

Brazil



View of Sao Paulo, Brazil, from Ibirapuera Park. The Ibirapuera is one of Latin America largest city parks.
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“It is estimated that about 12% of the world’s surface water resources are located in Brazil, which has always been considered a country rich in water. But the fast urbanization process in the last decades produced several problems and challenges that the country now needs to face”

Urban Waters in Brazil

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Summary

In Brazil, the accelerated urbanization process in the last decades has brought many challenges such as higher demands for water, solutions to treat high volumes of wastewater adequately, alternatives for disposal of solid waste, and access to urban water facilities for the population as a whole.

An Integrated Urban Water Management plan is needed for every town, especially in metropolitan regions. This plan should address issues as the integration of investments and action plans of urban regions in the same watershed, capacity building of professionals that control urban water facilities and manage watersheds, recovery of green areas that are crucial for groundwater recharge and for the maintenance of water quality and quantity. It is also essential to monitor the quality of the water distributed, in order to prevent threats to human health like gastroenteritis and cholera.

Due to growing water demands and increasing water pollution, and to prevent the deterioration of unpolluted water sources in metropolitan regions, water reuse has become a potential solution in order to avoid import of water from other watersheds. On the other hand, water transport may be the best alternative for semi-arid regions, where there is scarcity of water sources.

1. Introduction: Challenges for Strategic Management of Cities in the 21st Century

At present more than 60% of the world population is concentrated in urban regions. The large urban expansion in the last decades of the 20th Century and in the first decade of the 21st Century brought innumerable problems of water availability and distribution, soil waste disposal, soil use and drainage.

Cities are the engine of economic and social development in this 21st Century. In the whole planet we have, at present, 600 cities that represents a Gross Product of 65 trillion dollars; more than half of the World Gross Product of 113 trillion dollars. Those cities are poles of technological, commercial, industrial and services development. In Latin America, 57 cities have this fundamental role in the economy of the South American continent.

Urbanization demands more water, more energy, produces more waste (solid, and wastewater) and degrades forest areas. Air, soil, and water pollution are consequences of this urban growth. This results in economic pressures on the municipality in order to solve the problems of impacts, with consequences on the economy and human health.

The management of cities, in general, do not have strategic nor integrated plans. These should be expressed in a Master Plan that should be the locus where aggregation of all plans –economic, infrastructure, social, environmental with a systemic view– is summarized. For a sustainable economic growth there is a need for team work, considering the city as a complex and dynamic system; integrating economic development with social and environmental processes and promoting innovations in public health, education and access to information.

Basic sanitation combined with 100% distribution of water, providing adequate access to all inhabitants is another challenge. Periurban areas of small, medium or large cities are vulnerable to the problems of water distribution, wastewater treatment, and need improvement in sanitation.

Water issues in urban areas have a direct and relevant link to human health and quality of life of the population. Human health problems caused by water borne diseases have an economic impact in the cities. Sanitary education of the population, individual and collective practices of sanitation and prevention are the best attitudes to promote a healthy environment in the cities.

The use of green spaces as Forest Parks or Ecological Stations is another public policy that can help considerably in the maintenance of the water cycle and the water availability. Water treatment of protected sources is much cheaper and economic, than water treatment of unprotected sources.

By combining projects of water protection, water distribution, wastewater treatment and

reforestation with native species, the water cycle in the urban regions could be much improved considering water supply and water quality. This includes surface water and groundwater.

Water reuse is fundamental for the improvement of the water cycle in cities. Reuse of treated wastewater for several purposes can alleviate the pressure on natural water sources. Finally, the mobilization of the urban population in order to actively participate in the reduction of water demand, improvement of water quality and protection of water sources is fundamental.

Therefore, the integration of structural measures (urban river restoration, reforestation) with non-structural measures, such as environmental education, is a fundamental process in the urban water management in Latin America.

The management of cities can be advanced and creative if a true development agenda and a modernization approach are combined to promote a sustainable growth. The continuity of programs of infrastructure, education and environmental issues is a fundamental measure with social and economic long term consequences. The water problems of urban regions are at the center of this agenda.

2. Urban Systems

2.1 Concepts of Urbanization Processes and Urban Waters

Urban systems are primordially areas of consumption and housing. It is bounded by areas of high population density, sustained by biophysical systems of larger coverage than the urban area (Rees, 2003). An urban system has different sizes or integrates various urban-rural spaces such as a Metropolitan Region.

In 1900, 13% of the global population was urban; in 2007 it increased to 49.4%, occupying only 2.8% of global territory. In 2050 it was forecasted to be 69.6% of the world's urban population (UN, 2009). The world is becoming increasingly urban as a result of economic development and jobs distribution. In developed countries the population is stabilized and urban population is already large, but in developing countries the population is still growing and in 2050 the world population will be about 9 billion and most of its growth will be in the cities (UN, 2009).

Urban development accelerated in the second half of the 20th century with the concentration of population in reduced spaces. Countries such as Brazil moved from 55% of urban population in 1970 to 86% nowadays, occupying only 29% of the country area with a mean urban density¹ of 65 persons per hectare (6,500 per km²) (Embrapa, 2008). However, the two largest countries in population, India and China, respectively, are below 40% of urban population and are moving up in this urbanization scenario (UN, 2009).

Urbanization increases the competition for the same natural resources (air, land and water) in a small space for human needs on living, production and amenities. The environment of natural resources and population (socio-economic and urban) is a living and dynamic being that generates a set of interconnected effects, which if not controlled, can lead the city to a chaos.

In the urban environment the driving force is the urbanization. Urban water infrastructure generally includes both water supply & sanitation facilities (WSS). Sanitation refers to domestic and industrial sewage collecting and treatment. It does not include urban stormwater or solid waste management systems. Urban water related facilities provided by the cities include water supply, sanitation, stormwater and solid waste. They are components of a sustainable urban environment which includes the environment conservation, health and social-economic aspects of the urban development.

The main problem related to the city and its elements has been the fragmentary way through which management is developed. The Urban Master Plan usually does not take into account all the infrastructures such as urban waters. Urban water facilities are also fragmented, since usually there is not one institution covering all services nor integration between institutions. The outputs are poor and there are no indicators of efficiency.

Urban Water facilities should deliver safe water to the population (water supply); collect and treat the sewage produced by the city before it is delivered back to the rivers, in order to protect the environment and its source of waters (conservation

for the future) avoiding the spread of diseases (sanitation); develop stormwater systems for the rain water after the urban occupation and mitigate its effects; collect the solid waste and dispose it in adequate places, avoiding the spread of human waste in the natural system by the drainage (solid waste). As it can be seen the main objectives of these services are related to security (urban drainage flood control), health and environment conservation. Environment in an urban ecosystem is also related to other environmental actions in the relation of soil and air which are also related to water management.

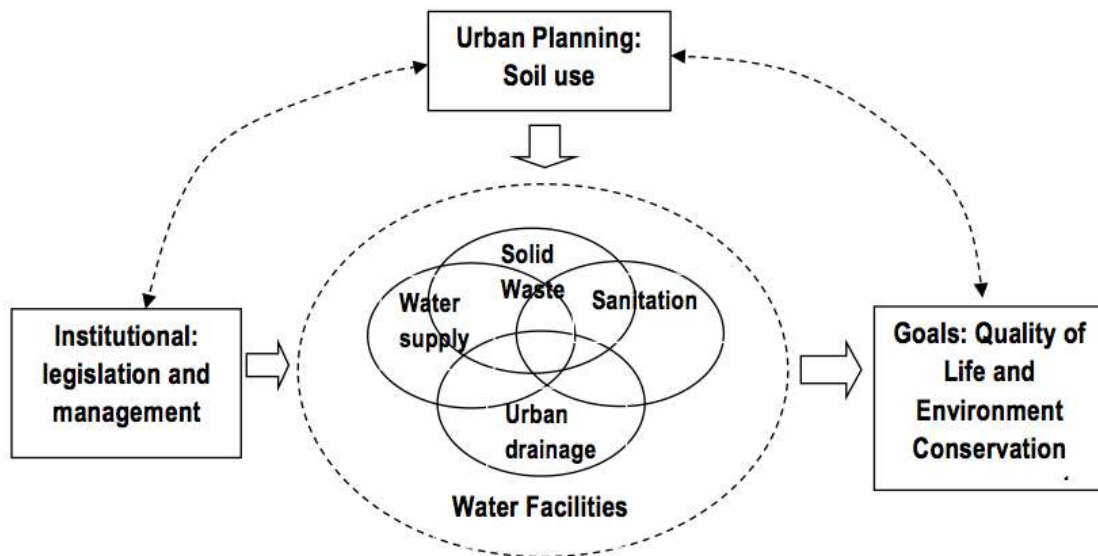
Integrated Water Resource Management has been the main tool for sound development of water management at a basin level. The city is part of a large basin or includes several small basins in its space. The city uses water from upstream in the basin for its supply and sends its effluent downstream in the basin. These are external components of the city which should be managed together with the main basin which support these boundaries.

In urban environment, IUWM is referred to specifically as **Integrated Urban Water Management (IUWM)**. IUWM includes the management of the water facilities and their interactions (Figure 1). These interactions include urban development (driver based on economic and social development of the city), environment and health (main goals) and the Institutional components, represented by the legal framework, management, capacity building and monitoring.

2.2 Urbanization in Developing Countries

Urbanization increases with economic development, since jobs and incomes change from agriculture to services and industry, together with the improving facilities for education, shopping, housing and overall facilities. Large cities have been developed since the last century such as the Metropolitan area of São Paulo in Brazil, which had about 200 thousand inhabitants in the beginning of the twentieth century and 17 million in the end of the century, which represented a mean year rate of 8.5%. There are 388 cities in the world greater than 1 million inhabitants (McGranahan and Marcotulio, 2005) and 16 above 10 million. It was forecasted that in 2010 there would be 60 cities with population greater than 5 million.

1. Urban density is the amount of population in the urban areas and population density of a state, country or region is total population divided by its area.

Figure 1. Components of Integrated Urban Water Management (IUWM)

Source: Tucci, 2009.

There is a strong correlation between population density and economic production, which explains the urban areas as centers of producers, buyers, sellers, firms and workers. The country GDP grows with the population increase in large settlements. High-income countries have 52% of its population in large settlements (>1 million) and low-income countries only 11%. When the country grows its GDP, the tendency is to increase the proportion of the urban population share of consumption vis-à-vis total population (World Bank, 2009).

In developing country cities, part of the population lives in irregular or informal areas usually called slums. The growth in slums has been significant, and their increasing density is the cause of concern, since the greatest rate of population growth occurs particularly among the low income population. Slums are overcrowded with dwellings of poor quality of low income population which occupy unregulated areas without property rights. Therefore, there is the formal and the informal city. Urban management usually reaches the former. This population is lacking most of the services such as water supply, sanitation, drainage and solid waste disposal. These places are environments favorable to the development and spreading of diseases.

The main problems related to infrastructure and urbanization in developing countries are:

- Large population concentrations in small areas, with inadequate transportation systems, inadequate water supply and sanitation, water, air pollution and flooding. These unsuitable environmental conditions reduce health conditions and the quality of life of the population, cause environmental impacts and are the main limitations for sustainable development;
- Increase of the city's boundaries in an uncontrolled manner by rural migration in search of employment. For instance, Manaus in the Amazon basin, in Brazil, received about 40,000 migrants in 2004, attracted by jobs. This occupation causes impacts on the basins which usually supply the city and increase risks to contaminate this source. These neighborhoods generally lack security, traditional infrastructure for water, sewage, drainage, transportation and collection of solid waste and are dominated by criminal groups usually linked to drug trafficking.
- Urbanization is spontaneous and urban planning is conducted for the portion of the city occupied by the middle and upper income popu-

lation. The slums are developed by an informal market for public areas or area without control, which is invaded by the poor. These can develop into areas of risk such as those with flooding and mudslides, with frequent deaths during rainy periods.

- Urban planning is conducted for the formal city, while the informal city is developed in a spontaneous way, usually near to the source of jobs or market for low income population.
- Limited institutional capacity of the communities with lack of: legislation, law enforcement, maintenance of the facilities, technical support and economical funds. Usually the cities manage the areas of economic income where legislation is enforced and property rights are regulated, called here as regulated city. On the unregulated city usually there are not enough services and facilities for the population. The cities are not prepared to plan and manage this complex human development;
- Lack of Integrated Urban Water Management: most of the Water & Sanitation Management in the cities do not take into account all components of Urban Water Facilities, resulting in: interconnection of stormwater and sewage networks, lack of domestic sewage treatment or inefficient sewage treatment, increased floods on the urban drainage², losses in the water distribution systems, solids in the drainage, erosion and occupation of risky areas of flood plains and hill sides (which has been the main causes of deaths during storm events), limited garbage cleaning and education, among others.

2.3 Urban Waters in Developing Countries

2.3.1 Overview

Water is supplied by sources from upstream basins, neighboring basins or groundwater (or combination of these options). After the water is used by the population it is delivered to the streams or treated by septic tanks and delivered into the groundwater which may overspill to drainage and rivers. This

system of treatment is highly inefficient, leaving a very important load to the rivers and groundwater. In that way, the water from polluted rivers cannot be used as a source for water supply. The water supply and sanitation practices use clean water upstream (not so actually!) and deposits polluted water downstream. Since the urban development spreads upstream, most of the upstream basin is or will be polluted and the source of clean water will be lost. In addition, the urbanization could also compete with agriculture for space and for water.

Since the city, in many scenarios, does not have capacity to supply all the water, the population finds its own solution by pumping from groundwater which creates risks of pumping contaminated water (shallow aquifer) or salty (in coastal areas).

The urbanization increases impervious areas and channelization which increases the flood peak and the flood frequency for the same rainfall. The urbanization also increases the flow velocity and solids production (sediments and solid waste). Due to the lack of services, most of the solid waste arrives in the rivers, decreasing its flow capacity (and increase flood frequency) and increasing the pollution since most of the storm water pollutants arrive in the rivers together with the solids. Pumping groundwater, together with the reduction of infiltration due to impervious areas, could create subsidence in low land areas which decreases its drainage capacity by gravity and increases flood frequency. In this scenario the area can be flooded by upstream and by the sea (in coastal cities).

In summary, the urban waters in many developing countries are in a contamination cycle and the main issues are (Figure 2):

- Contamination of water supply sources (streams and groundwater) by the developments and untreated sewage and diffusion loads. Deterioration of water quality due to lack of sewage treatment has created potential risks to the water supply for the population in various conditions, and the most critical has been the occupation of areas that contribute to the urban supply reservoirs, which suffering from eutrophication, present health risks to the population.
- Lack of sewage treatment: a large part of the cities do not have sewage networks nor treatment plants. The sewage is released into storm sewers, which flow into urban streams;

2. These floods are created by the urbanization due to poor outdated engineering, corruptions related to high cost design and lack of institutional measures.

- The urbanization increases the impervious areas which increases floods and decreases the infiltration to aquifers. Impervious areas and channelization of urban rivers, increase flood flow (about seven times) and its frequency, increase the erosion and degraded areas, the amount of solids to downstream affecting the quality of urban streams;
- Occupation of risk areas such as flood plains and hill slopes, suffering frequent floods and mudslides with frequent deaths. In Santa Catarina State in Brazil 110 persons died in a sequence of events in November of 2008.
- Water contamination from stormwater and agricultural areas;
- The use of groundwater by the population and the reduction of infiltration increases the land subsidence increasing flood conditions to low areas;
- The lack of management of total solids decreases the river flow capacity due to sedimentation, which then increases flood frequency;

The results of all these are the high impact on the basin environment, coastal areas and the health of the population. The combination of all these

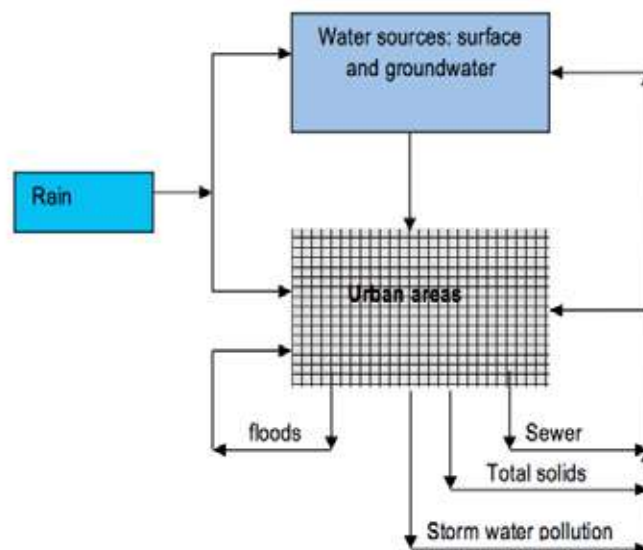
factors keep this metropolitan region under risks for the future. Since the urban area is the economic engine of a country, these unsustainable conditions are likely to create an important risk to its future development.

2.3.2 Main Risks

This condition shows that the source of the problems is the uncontrolled and unsustainable way that the urbanization is developed in the city. The main risks are:

- I. Health of the Population: some of the risks are:
 - the lack of effluent treatment and appropriate solid waste collecting and disposal create an internal source of contamination which could help the spread of many types of diseases or even an epidemic scenario;
 - the contamination of water sources such as reservoirs by nutrients creates the spreading of algae and the risk of toxicity in the water supply;
 - spreading diseases related to eutrophication of reservoirs and toxins in the water; in floods events diseases such as leptospirosis and hepatitis;

Figure 2. Contamination cycle on urban waters in developing countries



Source: Tucci, 2009.

Table 1. Relations of causes and impacts in urban waters

Main cause	Specific aspects	Impacts
Unsustainable Urban development	High density, impervious areas, unprotected surfaces and sediments	• Increase on flood frequency; • Higher sediment production; • Reducing river conveyance;
Lack of urban water Services	Population without water supply; lack of sewer collection and treatment; lack of solid waste services; lack of urban drainage and flood control management	• Water sources contamination; • Use of unsafe water and diseases; • Reducing river conveyance; • Environmental losses; • Land subsidence.
Bad management	Unsustainable works such as canal, conduits, etc. Lack of institutional management arrangements	• Transferring floods; • Losses in investments; • Lack of urban water services

Source: Tucci, 2009.

- contamination of groundwater and the water supply of the population which uses this type of water;
- II. Flood: increase in the flood risk, frequency and the damage for the population, mainly the poor. This vulnerability decreases the economic conditions of the region and the country;
 - III. Environmental deterioration: degraded areas by erosion, environments of the river and the coast are decreasing the resilience capacity due to so much load deposit into the system. Usually the population pays for the environmental deterioration. The population is receiving environment subsidy;
 - IV. Decrease of safe water: the lack of safe water from upstream and the capacity of distribution leaves no alternative to the population, which will try to find their own solutions which are usually more risky and more expensive. The international price of 1 m³ of safe water in the pipes usually is about US \$ 1 to 3. In bottled water of 20 liters this amounts to US\$ 200 to 300/m³ and in a bottle of ½ liter in Amsterdam Metro, US\$ 7,500/m³;
 - V. Overall: Population vulnerability is increasing and the resilience to urban waters issues is decreasing with this type of unsustainable development.

2.3.3. Relationship Between Causes and Impacts

Urban development usually occurs without control in many cities of developing countries. The urban occupation has been developed without an Urban Master Plan which takes into account the urban water sustainability. It is developed from downstream to upstream compromising water sources and increasing flood conditions. Table I shows some relations of urban development and impacts.

The management of urban waters is fragmented by many institutions in Metropolitan Areas. There are many different plans and projects which are in conflict with each other. The institutional development is complex because of the governance changes, enforcement of water law and its implementation by water resources authorities in the basins. It is a combination of institutions at various levels: central, state and local government levels, without integration. As a result, the planning and development in the basin have been fragmented by isolated actions distributed in the area.

The management had the following issues:

- Lack of institutional arrangements which allow integrated solutions in urban water in the metropolitan area and in the basin which supply the region;
- There were many fragmented investments in flood management taking into account only

one type of solution (and expensive) of transferring peak floods to downstream without taking into account future urban growth. Lack of strategic integrated investments for water supply and sanitation in the overall metropolitan area.

- Lack of knowledge: among the population and professionals in different fields who do not have suitable information about the problems and their causes. Therefore, the decisions made result in high costs, and some companies take advantage of this to increase their profits;
- Poor conceptual knowledge among engineering professionals for the planning and control of the systems: an important portion of the engineers who act in urban areas do not have up-to-date information about environmental issues and generally seek structural solutions that alter the environment, creating an excess of impermeable areas and a consequent increase of temperature, flooding, pollution and other problems;
- Sectorial views of urban planning: planning and development of urban areas are conducted without considering factors related to the different components of water infrastructure. An important portion of professionals who act in this area have a limited sectorial view;
- Lack of managerial capacity: municipalities do not have structures for planning and management of the different aspects of water in the urban environment.

2.4 Recommendations for Integrated Urban Water Management

2.4.1. Goals and Targets

The urban water goals should be the following:

- Deliver safe water for human, animal, industrial and commercial use;
- Improve conservation, avoid degradation of areas by erosion, treatment of sewage and storm-water effluents, minimize solids in the streams coming from urban settlements;
- Reduce vulnerability to diseases and floods.

The main actions to develop a sound strategy for an integrated urban water management are:

- **Sustainable urban development.** Development of new urban development standards taking

into account the sustainability on water issues: (i) limits for densification and impervious areas; (ii) reserve of areas for parks and flood management; (iii) restrictions and economic incentives for conservation of urban source basins;

- **Protect the water supply sources.** Regulate the occupation of the water supply basin; control the load of water supply basin; improve its water quality;
- **Improve the water supply distribution.** Development of a program of investment in order to increase the water supply network and improve the water supply quality;
- **Develop a system of waste treatment.** Investment in the collection and treatment systems for all urban areas;
- **Flood Control Management.** Develop regulation for new development, controlling the future flood increase; develop flood management plans for each basin;
- **Total Solids Management.** Develop sound services for total solids in order to decrease the amount of solids in the drainage system;
- **Water and environmental conservation.** Storm water pollution control, environment recovery of selected areas;

These targets have to be achieved by an integrated management and interrelated actions inside of a space which covers more than a basin. The development of this integrated plan requires a review of strategies over the three major water sources and the metropolitan area, together with large investments over a longer period. Every component of the plan requires specific goals and strategies.

In order to achieve these goals the following steps should be taken:

- **Assessment of the urban water issues:** identification of the problems in urban waters and the integrated aspects;
- **Plans and Strategies:** development of the planning for solution of the problems in the urban water services in the city;
- **Action Plan:** implementing strategies in urban waters in time, taking into account the needs and the economic and financial aspects of the investments.

3.2 Urbanization and Sources of Water

The fast urbanization process of Brazil in the last 50 years produced several problems in all stages of the water supply, water treatment and wastewater treatment: supply of adequate water for the urban population, distribution of water and wastewater treatment. The urban development in Brazil has increased the frequency of flooding, production of sediments and deterioration of water quality. As the urbanization progresses, the impact increases due to the fact that the urban infrastructure is not organized during the process: problems of urban drainage, construction of roads, bridges and channels, deforestation, are not included in the evaluation of urban plans (Tucci, 2006). The significant impact on the maximum discharge is one of the important consequences of the urbanization along with changes in the soil cover, increase of floods and environmental deterioration in general. It is in this general picture that the water supply services occur in Brazil.

The sources of water for public supply in Brazil from surface waters, in most cases, are located in the periurban regions, or groundwaters located in the urban area or in the rural areas. In general, the urban demand for domestic supply is usually sufficient from the small watersheds around the urban area. Small watersheds (<500 km²) in the South East of Brazil have specific discharges of 15 to 25 liters/sec/km² (Tucci, 2006). This is sufficient for the domestic use of 200 liters/inhabitants/day. However as urbanization develops, the water quality of surface and groundwaters deteriorates; therefore, it is necessary to use other sources of supply.

These sources can be far from the water treatment stations, generally located in the urban center. Therefore, this increases the need for more energy for the pumping of the water from the sources. There is an additional problem that increases the cost of treatment: if the water source is well preserved with gallery forests, wetlands, or mosaics of vegetation, the cost of treatment for producing potable water is low. The figure is around 2 or 3 US dollars for 1.000 m³ treated. This is the case when there is no need for chemical treatment. If the supply source is contaminated, the chemical treatment (coagulants, activated charcoal, and others) increases the cost to US\$ 200 or US\$ 300/1.000m³ treated (Tundisi and Matsumura

Tundisi, 2010). This is the cost of the deterioration of the supply source. Official statistical data inform that in Brazil, 90% of the population receives treated water in their residence. The remaining 10% uses groundwater usually from local wells at each house or village. In the South and part of the South East, deep wells (120-500m) pump water from the Guaraní underground reserve, a huge water resource (43.000 km³) shared by Brazil, Paraguay, Uruguay and Argentina. These are groundwaters of high quality, so the cost of pumping is compensated by the small cost of water treatment.

The loss of the water supply services in Brazil is approximately 30% in the pipelines after treatment. However there are cities where 60% loss is common. This is due to the old infrastructure of the pipelines. In some cases this infrastructure has more than 100 years of age. It is also to be noted that there is no information about the water quality in the pipelines after treatment and in the distribution process.

3.3 Threats to Water Supply (Quantity and Quality)

3.3.1 Competitive Uses of Water

In Brazil 70% of the water available in the watersheds is consumed by agricultural activities. In some regions (E. G. South East, South, Center West) competitive uses for agriculture and industry threatens the water supply for domestic use.

3.3.2 Water Quality Degradation

The water quality degradation is one of the biggest problems of Brazil in the beginning of the 21st Century. The main causes of water quality degradation are:

- **Deforestation.** The lack of vegetation cover is a cause for the deterioration and loss of quality of surface and groundwaters. Deforestation also impairs recharge to the aquifers.
- **Lack of wastewater treatment.** In Brazil, only 47 % of the wastewater is treated. This produces an enormous amount of organic matter that deteriorates the water quality of surface and groundwater.
- **Surface drainage.** The surface drainage of waters in most cases is full of solid waste residues (plastic, papers, glass, and organic matter). This is another source of deterioration.
- **Transport of sediment.** Due to erosion in the soil

Table 2. Classes of uses of water supplies for human consumption, and protection of water sources and ecosystems

Level 1	Level 2	Level 3	Level 4
Water supply for human consumption	Water supply for human consumption (Conventional treatment)	Water supply for human consumption (advanced treatment)	Navigation
Water supply for protection of aquatic life	Protection of aquatic communities	Irrigation of trees (fruits) or food for animals	Landscape
Water supply for recreation	Recreation with primary contact	Fisheries	Harmony
Irrigation of vegetation	Irrigation of vegetables	Recreation of secondary contact	
Protection of aquatic communities in indigenous lands	Aquaculture and fisheries	Water supply for animals	

of the urban area, a large amount of suspended sediment can be transported. This suspended sediment carries particulate phosphorus and nitrogen aggregated into the particles of the eroded soil which causes impacts on the water chemical composition and the physical characteristics of the water (temperature, light penetration and conductivity).

- **Industrial wastewater.** Clandestine discharge of industrial wastewater can contaminate surface and underground sources of water supply and produce new challenges and needs for water treatment.
- **Agricultural land discharges.** Discharges of wastewater from agriculture (pesticides, herbicides, fertilizers) are another important threat to water supply systems. These are especially complex because these are non-point sources and therefore, very difficult to control.
- **Persistent organic pollutants.** Persistent organic pollutants (POPs) have several origins but the major sources are those related with the human population as residues of hormones, cosmetics, antibiotics and substances of several origins (organic). These dissolve in the water and are not retained in the traditional technology of water treatment. They need special detection equipment and general studies to promote a better knowledge of their impact on human health (Jorgensen, Tundisi and Matsumura Tundisi, 2012).
- **Contamination of areas of recharge of the aquifers.** In many urban areas the recharge of the

aquifers is impaired due to the destruction of green cover (forests, wetlands, riparian forests) by roads, house, and condominiums. Besides this, the contamination of the remaining recharge areas is another problem: deposits of solid waste (open solid waste deposit), residues of construction, fuel/tanks.

3.4 Legislation

The resolution 357 of 17 march, 2005 of the National Council of Environment of Brazil (CONAMA) establishes the classification of freshwater, saline and brackish waters in Brazil. This classification is based fundamentally in the water uses. Table II summarizes the classes of use.

This legislation is reinforced by the environmental laws of Brazil –at the federal level– that considers protection of forests, gallery forests, forests corridors, wetlands and regulates the pollution of coastal and inland waters (Tucci, 2006).

At each municipality there are specific laws regulating soil uses, urban development and construction processes. The integration of federal, state and municipal legislation is one of the main challenges to control the water supply services in Brazil.

3.5 Management of Urban Watersheds

The management, control, and recuperation of urban watersheds is of fundamental importance to the water supply services. The Master Plan of the municipality has to incorporate the integrated

3.6 Policy Recommendations

management of the urban water resources taking into account the watersheds where urbanization occurs. The planning and protection of the water sources and optimization of services should control and interfere with the following processes:

- Evaluation of the water quality of sources, their state of conservation or degradation;
- The relationship water availability/water demand has to be considered in the planning;
- Conservation of the water sources and analysis of future tendencies of urbanization (geographic location) in order to develop priorities for expansion and at the same time protect water sources (surface and underground) (Tucci, 2006);
- Control of land use, monitoring of soil contamination or preservation, monitoring of the water quality and permanent measurement of water availability and demand;
- Improve or introduce new legislation at the municipal level in order to prevent excessive soil use and occupation, presence of water sources, protect and develop urban forests and green spaces in order to maintain an adequate balance between urban and natural areas;
- Mobilize the population, schools, private initiative in order to develop a participatory approach to integrated watershed management. Education at all levels is fundamental;
- The capacity building of manager's, technicians and other participants of the municipal administration is also extremely relevant. The lack of a systemic vision of the municipality and its urban region, the lack of knowledge between protection of natural resources of the municipality and the areas of expansion is one of the problems that impair an efficient management of the water supply services in many urban regions of Brazil;
- Financial resources and stimulus to promote a better institutional organization in the urban regions of Brazil are other initiatives that certainly will have an effect in the management of water resources. The administration and maintenance of good governance depends upon the integration of several administrative departments such as housing, environment, science, and water services.

The deterioration of the water sources in Brazil is a reality. Although Brazil has a competent and up-to-date legislation and available technological resources to solve the complex problem of protection of water sources and distribution, this was not achieved with the necessary efficiency to improve the water quality at the source and to decrease the vulnerability of populations (Bicudo et al., 2010). The populations of the periurban areas of large metropolis or even medium size cities are the most affected and vulnerable. Since there is a strong link between quality and distribution of water, human health and economy, it is necessary to develop a strategic vision in the evaluation of the main problems to be solved (Tundisi et al., 2012).

At present, the following issues related to the water supply services are fundamental in Brazil:

- **Protection of surface and underground sources.** Reforestation, urban forests and parks, gallery forests in urban regions should have highest priorities. Channelization should be banned. The construction of channels in the urban environment decreases biodiversity and causes loss of ecological services;
- **Improve the legislation at the urban level.** The payment for ecological services could be introduced as a complementary measure for the protection of the sources (Heide et al., 2013);
- **Improve the water treatment and technology** in order to analyze and remove the organic pollutants from the water;
- **Improve and increase the efficiency and frequency of monitoring at all levels** (from the source to the tap). Appropriate use of indicator parameters;
- As a large scale priority **wastewater treatment** is fundamental for Brazil. The wastewater treatment technology should consider advanced methods as well as new projects such as the use of wetlands to improve the process and lower the costs of treatment. Ecohydrology and ecotechnologies should be implemented;
- Another priority is to include in the Master Plan of each town or city **projects for the protection of water sources, control of urban drainage, and soil use regulation** (Tucci, 2006, 2010). Water resources should be part of an integrated management plan for the whole city;

- **Develop a statistical data bank for Human Health and Water Supply Quality** in order to establish and consolidate an integrated policy for the urban areas;
- **Vulnerability assessment of urban populations** exposed to risks of water shortage and degradation of water quality;
- The **adoption of new advanced technologies** such as the ecohydrology principles as introduced and discussed by Zaleswky (2014) in the recovery and management of urban water sources should improve considerably the new vision of water and watershed management in urban areas in Brazil;
- **Reintroduce, at the urban level, the concept of mosaics of vegetation** in order to improve the landscape, increase self-purification potential, reduce soil erosion and improve water quality;
- **More efficient water delivery infrastructure and technology** with decreasing water consumption per capita;
- Finally, one of the greatest problems for adequate water supply in Brazil is the implementation and execution of ideas projects and plans. There are sufficient financial resources. There are plans and projects. The execution is not adequate, or fails or is too slow. There is a strong need for **capacity building of managers to implement projects and plans** with great efficiency and rapidly, with a systemic and integrated vision, of the future.

4. Water and Health

4.1 Overview

Together with the problems of water supply in non-planned urban systems, probably one of the biggest challenges in the management of water resources in large Brazilian metropolitan regions is related to the impacts of waterborne diseases as a consequence of the low rates of sewage treatment and due to a very deficient legislation and parameters for monitoring microbiological quality of water (Hupffer et al., 2013).

The methods used to monitor the quality of raw water used for catchment and distribution in Brazil may partly explain the gastroenteritis as the major threats related to water contamination in Brazil.

Disease outbreaks linked to classical waterborne diseases, such as cholera for example (last great outbreak occurred in 1999 in the north of the country), are sporadic or localized in specific regions, like in the mouth of the Amazon River. It is well established that the classical microbiological indicators, namely faecal coliforms, have good relationship with the presence of *Vibrio cholerae* and *Salmonella typhi* (Sobsey and Meschke, 2003). However, as mentioned, these diseases are infrequent in the present Brazilian reality. Moreover, the absence of coliforms, the main parameter for microbiological water quality officially used in Brazil, does not necessarily reflect the safety of the drinking water for the presence of pathogens resistant to water treatment systems, such as enteric viruses and intestinal protozoa (Sobsey and Meschke, 2003; Hupfer et al., 2013).

4.2 The Burden of Gastroenteritis in Brazil

In Brazil, the main threat to human health among other waterborne diseases is gastroenteritis, which is characterized by vomiting and diarrhea, and is caused by viruses, protozoa or bacteria. Gastroenteritis represents more than 80% of diseases related to inadequate environmental sanitation in Brazil (IBGE, 2011). These diseases are a great burden to the health care system, occupy thousands of hospital beds, and affect more often children.

The World Health Organization (WHO) claims the poor sanitation as a serious threat to human health. Although widespread in the world, the lack of sanitation is still very much associated with poverty affecting mostly low-income people, vulnerable to malnutrition and often by improper hygiene (WHO, 2008). Diseases related to water and sewage systems deficiencies with inadequate hygiene cause the deaths of millions of people every year, with prevalence in low-income countries (GDP per capita of less than U.S. \$ 825.00). According to the World Health Organization (WHO, 2008), 88% of deaths from diarrheal diseases in the world are caused by inadequate sanitation. From these deaths, approximately 84% are children (Kronemberger, 2012). It is estimated that 2 million children die each year, especially in developing countries, due to diarrhea. There is a lack of studies about the number of cases of fecal-oral transmitted diseases in Brazil, but in a survey conducted by the Fundação Getúlio

Vargas, it was demonstrated that near 54,400 persons were admitted to hospitals presenting clinical signs of diarrhea in the 100 biggest Brazilian cities during the year 2011 (Kronemberger, 2012). From these, 28,594 were children under 5 years of age. For the whole country, 396,048 people were hospitalized due to gastroenteritis during this same year (138,447 children). This same study showed that for the 20 cities with higher rates of sewage treatment, 14.6 cases/ 100,000 inhabitants versus an average of 363 cases/ 100,000 inhabitants in the 10 with the lower levels of sewage treatment, when analyzing the data for the 100 biggest cities. It means that the average hospitalization in the cities with the worst level of sewage treatment was 25 times greater (Kronemberger, 2012). It is noteworthy that overall many cases are not included in the reports by the hospitals and many others are not attended in the public health service, thus are not included in the statistics.

Viruses are the most frequent etiological agents of gastroenteritis in human beings. There are more than 100 different types of viruses found in human waste and all are potentially transmitted by water (Brunkard et al., 2011). The types and concentrations of the viruses detected in sewage or sites contaminated by releases of untreated sewage demonstrate the flow of the virus in the population and reflect the most prevalent viral infections in the community and the level of water pollution (Vieira et al., 2012). It is known that enteric viruses such as poliovirus, rotavirus, calicivirus, adenoviruses and hepatitis A virus are present in the gastrointestinal tract of infected individuals, are eliminated through feces in large quantities (10⁵-10¹¹ / g of feces) and are capable of directly or indirectly contaminate water (Rigotto et al., 2010). As mentioned before, the current applied techniques to measure the microbiological safety of water in Brazil does not include the detection of viral (or protozoan) pathogens (Vecchia et al. 2012). Contamination of water sources can occur due to the lack of sewage treatment, inadequate maintenance of the pipe network, reservoirs and landfills, which in turn can contaminate groundwater. Another remarkable problem is that the technologies for monitoring and the processes currently applied to the treatment of drinking water in Brazil are not effective to avoid the risk of viral contamination (Hupfer et al., 2013).

The monitoring of viral particles is usually neglected by water companies due to the difficulty and complexity of the procedures involved to accomplish this task. However, a wide variety of viruses responsible for various diseases such as acute gastroenteritis and hepatitis have been detected in different matrices of aquatic studies in many countries, including Brazil (Vieira et al. 2012). The absence of routine analysis by virological monitoring services and supply of drinking water has been characterized as a problem worldwide (Vecchia et al., 2012). A number of different reports showed the presence of viruses and protozoa in Brazilian surface water. In many of these studies, it is recurrent that the rates found in different regions are higher than those found in surface water for the north hemisphere or even in Latin American countries with higher levels of sanitation. A survey conducted in the state of São Paulo revealed enteric viruses in 85% of 60 untreated raw water samples analyzed, of which approximately 25% were due to adenoviruses (AdV) and enteroviruses (EV) (Cetesb, 2011). In a study performed with conventional PCR on water samples collected from the Arroio Dilúvio, a water stream that crosses the city of Porto Alegre, Brazil (Vecchia et al. 2012), AdV was detected in 21.4% of samples while EV in 64.3%. In a different study carried out in Florianópolis, Brazil, 84 samples of water from different sources, collected from 2007 to 2008, were analyzed by molecular methods and integrated cell culture-PCR procedure. AdV genome was detected in 64.2% of samples. The study showed that in viral samples positive for AdV, 88.8% were infectious (Rigotto et al. 2010). A survey conducted by Vieira et al. (2012), in which 144 water samples from Rodrigo de Freitas Lagoon in Rio de Janeiro, Brazil, were analyzed by qualitative and quantitative polymerase chain reaction assays, AdV virus was less prevalent (16.7%), while group A rotavirus was the most prevalent (24.3%) followed by Norovirus (18.8%). Another study undertaken in Manaus, Brazil, analyzing water from natural streams by conventional PCR, revealed that in 52 samples collected from 13 different sites, 44.2% contained rotavirus genome, followed by AdV (30.8%), astrovirus (15.4%) and norovirus (5.8%) (Miagostovich et al., 2008).

4.3 Recommendations

Considering the high rates of detection of these viral agents in water matrices, the number of cases of diarrhea and the absence of correlation between the presence of fecal coliforms and viral or protozoan agents, the Brazilian guidelines for the quality of drinking water should be revised. Another urgent goal is to improve the levels of sewage treatment in Brazilian cities to minimize the discharge of contaminated wastewater into the water bodies used for production of drinking water. These strategies should be prioritized to diminish the burden of gastroenteritis in Brazil.

5. Conservation and Water Reuse as Management Tools

5.1 Overview

As part of the Integrated Urban Water Management, water reuse and conservation actions should be planned and implemented to protect water supplies from deterioration, protect human and ecosystem health, reduce costs of water treatment and to make water demands and uses of urban systems as sustainable as possible.

Water reuse is an urgent solution that copes with the problems of limited availability of water sources and water pollution mainly in Metropolitan Regions.

5.2 Water Availability and Reuse

Following the UN's World Conference on Water and Environment in 1992, held in Dublin, Scotland (ICWE, 1992), water began to be seen as an economic good that should be used sparingly. In Brazil, the National Policy on Water Resources (Law N. 9433, January 1997) was instituted, which established the "charging for the use of water resource subject to licenses." This law also established the legal and administrative structure of the National System of Water Resources (Law N. 9984, July 2000) and created the National Water Agency in addition to a resolution that established general criteria for granting rights to using water resources (CONAMA Resolution N. 16, May 2001).

Charging for the use of water is an extremely beneficial tool for both the conservation of water, since it induces the management of the demand, as well as for the protection of the environment, promoting the reduction of effluent discharge into water bodies. However, due to the trend of population and industrial growth, especially in large conurbations, water availability tends to decrease over time, while the available water resources are kept relatively constant in terms of flow, but not in terms of quality (Hespanhol, 2008).

The Metropolitan Region of São Paulo (MRSP) is an example of the problem of water availability. This region is supplied by approximately 74 m³/s of surface water and 10 m³/s of groundwater sources, totaling 84 m³/s. Since the MRSP is located in the headwaters of the Alto Tietê Basin, the local availability of water is not sufficient to provide water to the 20 million inhabitants and to one of the largest industrial areas in the world. Therefore, it imports water from other watersheds, such as the Piracicaba-Capivari- Jundiaí Hydrographic Basin, which contributes with a reversal of 33 m³/s to the waters of the MRSP. The adducted 84 m³/s generates a flow of approximately 67 m³/s. Since the capacity installed in the sewage treatment plants of the MRSP is of 16 m³/s, the remaining 51 m³/s of raw sewage is dumped, untreated, into the receptor bodies of water in the region, rendering them increasingly polluted.

Sustainability of water supply systems should be viewed based on the probability in which the water supply system will be able to permanently meet demands, in satisfactory condition. The most important variables that determine (or not) a condition of sustainability are: (i) robustness, reflecting consistent performance and the ability to meet increasing demand, even under several types of stress; (ii) resilience, the ability of the system to regain its appropriate state following negative impacts, such as losing service capacity from supply sources; and (iii) vulnerability, the magnitude of the failing of a supply system (Hashimoto et al., 1982).

The system that supplies the MRSP is therefore unsustainable, seeing that it is not robust and due to the fact that it presents a practically null resilience, as it remains dependent on resources from basins which are also subjected to extreme

conditions of water stress. The systematic transfer of large volumes of water from distant sources, generating additional volumes of sewage that are not treated, can no longer be accepted, both in an economical and environmental point of view. This will tend to become increasingly restrictive based on popular awareness, regimentation of professional associations and due to the institutional development of watershed committees who are affected by losing their water resources. The costs associated with new supply systems, tend to be much larger than the costs of existing systems due to nearby, less polluted water sources having already been previously exploited. A study conducted by the World Bank, analyzing the resources invested in projects of international water supply, showed that the cost per cubic meter of drinking water from a new water supply system can be equivalent to two or three times the cost of an existing system (World Bank, 1992). It would be of great importance from a humanistic point of view, to eliminate the discharge of raw sewage into water bodies in the metropolis. These bodies of water should revert into amenities, integrating the population into parks and gardens and establishing conditions for leisure and the development of aquatic sports.

Modern and sustainable solutions that will significantly enhance the robustness and resilience of the water supply system in the MRSP, consists in the management of the demand and the treatment and reuse of water, available in the form of sewage in the MRSP area, to complement public supply. The management of demand consists in the control of losses, especially from public water distribution systems, user awareness through environmental education programs and the implementation of tariff allowances programs. The management of supply is related to the search for alternative sources of provision, including treated domestic and industrial sewage water, use of harvested rainwater and groundwater, supplemented by managed recharge of aquifers. The benefits related to the use of treated water for beneficial uses, as opposed to the disposal or discharge, include the preservation of sources of high quality, environmental protection and economic and social benefits (Asano, 2007).

Water reuse is not exclusively applicable to arid and semi-arid regions or areas with difficult access to water, but also applicable to regions with abundant

water resources which are however, insufficient to meet their specific high demands, as in the case of the Metropolitan Region of São Paulo.

Foreseeing at an early stage, the need to modify orthodox policies of water management, particularly in deprived areas, the Economic and Social Council of the United Nations, proposed in 1958 that “unless there is great availability, no good quality water should be used for purposes that tolerate lower quality of water” (United Nations, 1958). The waters of lower quality, such as sewage from households, residues from waste water treatment and industrial effluents, agricultural drainage waters and brackish waters should, whenever possible, be considered as alternative sources for less restrictive uses. The use of appropriate technologies for the development of these sources is today, together with the improvement of the efficiency in use and the management of the demand, the basic strategy for solving the universal problem of water shortage.

The potential for reuse depends on local factors (political decision, institutional agreements and technical availability), and economic, social and cultural factors. The basic principles that guide the practices of reuse are: the preservation of health of groups that are at-risk, the preservation of the environment, consistently meeting quality requirements related to the intended use, and the protection of materials and equipment used in water reuse systems (Hespanhol, 2002, 2008).

Reuse may be intended for urban potable and non-potable purposes, agricultural irrigation, fertilization of lakes in aquaculture practices, industrial purposes, managed recharge of aquifers, restoration of river flows and recreation.

Reused water for urban non-potable purposes, or utilities water, is already being used in the MRSP and in several Brazilian metropolitan regions. The sewage effluents that have gone through biological treatment systems undergo further physical-chemical treatment and are distributed to restricted areas with controlled or uncontrolled access, with special attention given to avoid direct contact with the public (USEPA, 2004; Hespanhol, 1997). The possible uses of water from reuse are: irrigation of parks and public, residential and industrial gardens, sports centers, soccer fields and golf courses, green areas of industries, schools and universities, lawns, trees and decorative bushes along avenues and

highways; reserves in the event of fire; decorative aquatic systems, such as fountains and small shallow artificial lakes; washing of vehicles, such as cars, trucks, buses and trains; washing of floors, garages and parks; sanitary flushing in public restrooms and in public and private residential and commercial buildings; cleaning of sewer pipes and rainwater pipes; dust control; construction, for washing aggregates, for preparation and curing of concrete and for moisture control of soil compaction.

Water reuse for urban potable purposes may result from direct or indirect reuse systems. In the indirect use systems water catchment occurs from lakes or river flows that receive treated or untreated sewage (Figure 4). This system is extensively practiced in Brazil, as for example, along the Rio Tietê and the Paraíba do Sul River, and requires efficient management from the environmental agencies in order to avoid adverse impacts on the human health and the environment.

Ideally, this system of indirect potable reuse should be carefully planned, with a secondary sewage treatment unit, normally with activated sludge, and more modernly, with units of submerged biomembranes (IMBRs), followed by advanced treatment systems, and if necessary, followed by a chemical balance prior to being released into surface or groundwater receiving bodies, termed “environmental attenuators” (Figure 5). The purpose of the environmental attenuators is to, by means of dilution, sedimentation, adsorption, ion exchange, among other processes, attenuate the low concentrations of pollutants that still remain following the advanced treatment systems previously used.

The planned indirect potable reuse system would be difficult to be implemented in Brazil today, because the bodies of surface water that could act as environmental attenuators are almost all polluted and therefore would be unable to operate as secondary cleansers. The managed recharge of confined aquifers, as environmental attenuators, is rejected by environmental legislators.

Another system, would be the direct potable reuse, which consists in the advanced treatment of effluents and its direct introduction into a Water Treatment Plant (WTP) that distributes the water in the public system, or into a mix tank upstream of the WTP in which additional flows of surface or groundwater make up the total flow to be treated in

the reuse system. In this system, water does not go through environmental attenuators (Figure 6).

In addition to the advanced treatment system and a chemical balancing reservoir, the system contains a retention and certification reservoir, whose goals are to compensate the variability between production and water demand; compensate the variability of the quality of the produced water (practically unnecessary with the advanced treatment systems) and, to provide a sufficient detention time to detect and act upon any possible deficiencies within the process, before the release of the treated water into the distribution system.

In view of the current situation, we are faced with the challenge of substituting orthodox mechanisms of water management, in order to address the sustainability of water supply in the urban sector. This needs to be done through the universal practice of water reuse, more specifically through the practice of direct potable reuse using existing networks of water distribution and their expansions. Many countries with localized water stress have been using this practice: Namibia, Australia, South Africa, Belgium, Singapore and the United States.

Among the factors that contribute towards changing the dogmas regarding water management in Brazil are, the pollution of the possible bodies of surface receptors, which prevents their action as environmental attenuators; the rarity, distance from and pollution of potential sources for water supply; and the lack of technical acknowledgement regarding the managed practice of aquifer recharge. The systems of water distribution and their existing extensions can be used and there is no need for building new systems, seeing that there are advanced technologies that remove traces of organic and inorganic contaminants and pathogenic organisms that are not removed in traditional water treatment systems. An assessment conducted in the United States (Tchobanoglous et al, 2011) concluded that the total cost of a parallel distribution system for drinking water, treated at an advanced level would range between R\$ 0.7/m³ to R\$ 4.00 R\$/m³ (0.32 US\$/m³ to 1.70 US\$/ m³), whereas a typical advanced treatment system, including membranes systems and advanced oxidation processes would range between 1.3 R\$/m³ to R\$ 2.2/m³ (US\$ 0.57/m³ to 0.97 US\$/m³). Investments

Figure 4. Typical scenario of unplanned indirect reuse systems occurring in a series

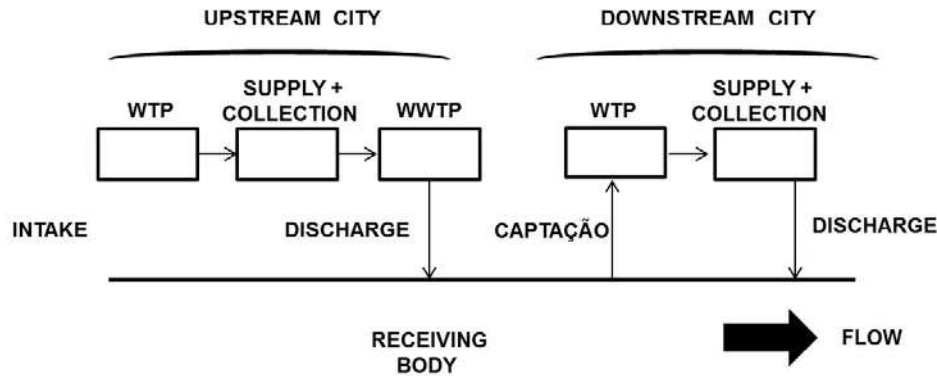
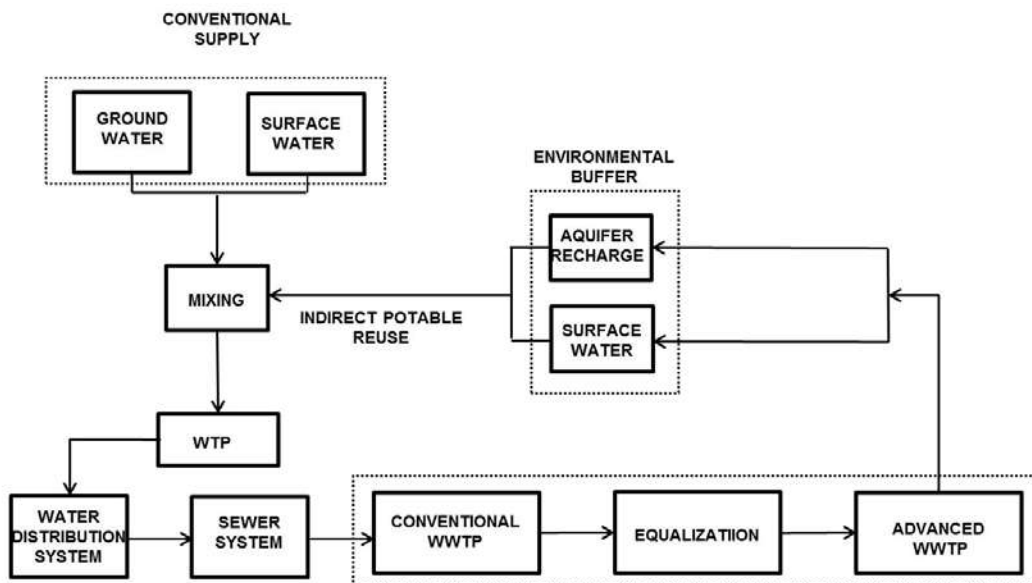


Figure 5. Basic diagram of a planned indirect potable reuse system



Source: adapted from Tchobanoglous et al., 2011

made towards the implementation of an advanced treatment, outweighs the investments for the construction of a parallel distribution network of water with conventional treatment. In the case of the MRSP it would avoid the costs of construction and maintenance of pipelines for raw water coming from other basins in addition to not jeopardizing the supply of water in basins under water stress, such as the PCJ Basin.

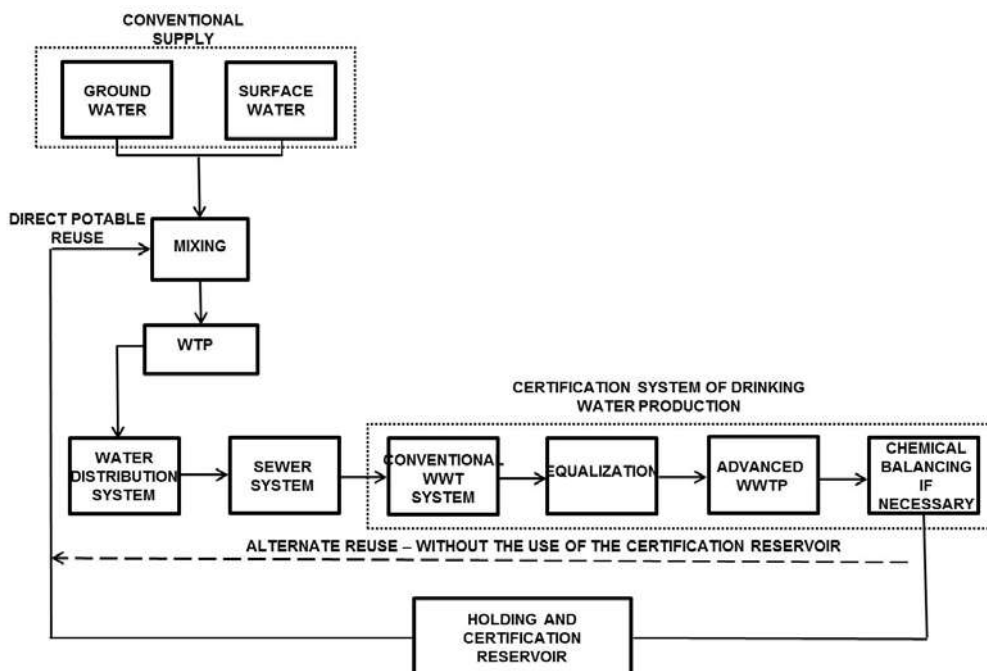
The factors that delay and inhibit the practice of reuse are the inadequate regulation of restrictive norms that do not represent the actual Brazilian conditions and do not protect the environment and the public health of the groups at risk. There

is also a negative perception with regards to the use of recycled water and a lack of trust towards in governmental proposals.

5.3 Recommendations

Even though Brazil has a significant percentage of the world's water resources, many regions face water resources that are less than 200 cubic meters per inhabitant per year, which generates critical supply conditions and conflicts in uses of water. In cases like the MRSP, where water is imported from other water basins, it is necessary to **observe whether the regions considered apt for undergoing reversal**

Figure 6. Direct potable reuse



Source: adapted from Tchobanoglous et al., 2011

practices, possess the water resources compatible to their needs and if the additional volumes of sewage that are generated, are adequately treated and disposed of.

It is necessary to **adopt a new management paradigm** based on the keywords conservation and water reuse. The industries of the state of São Paulo are already investing financial resources in the implementation of conservation and water reuse programs, reducing their consumption between 40 to 80%. Agriculture, which accounts for approximately 70% of the water consumption in Brazil, has been assessing the benefits of reuse, which provides nutrients and micronutrients for crops, eliminating the need for the use of synthetic fertilizers. The reuse of water for aquaculture, for managed recharge of aquifer and recreation, still do not exist in Brazil.

The indirect potable reuse systems are not very viable in Brazil, since the underground springs and the bodies of surface water do not possess the technical conditions or are so heavily polluted that they cannot be used as environmental attenuators. It is inexorable that, within a maximum period of a decade, the practice of direct potable reuse, using modern treatment technologies and advanced

systems for risk management and operational control, will be, despite the psychological, legal and institutional reactions that constrain it, the most plausible alternative for actually providing real drinking water. In addition to solving the problem of quality, direct potable reuse would be strongly associated with supply security, since it would use available sources of supply within the locations of consumption, eliminating, for example, the need for long and costly construction of pipelines, which usually transfer water to urban centers collected from areas affected by water stress

In order to universalize the practice of reuse in Brazil it is necessary to: (i) develop a realistic legal framework to regulate, guide and promote the practice of water reuse, including norms, water quality standards, codes of practice and institutional responsibilities for the different means of reuse, especially for urban and agricultural use; (ii) encourage reuse of water by creating awareness of the values and benefits of the practice, by creating research and development programs, by implementing demonstration programs and projects, by introducing specific credit lines, and by establishing specific criteria for funding reuse

projects. The initiative for these actions could come from the National Water Agency – ANA, the Department of Water Resources of the Ministry of Environment, the state departments of water resources, the basin committees and the local and state sanitation companies.

The sanitation companies should develop studies and surveys, in conjunction with certified research centers to: (i) assess, technically and economically, operations and individual processes, as well as advanced treatment systems for direct potable reuse within Brazilian conditions; (ii) study the dimension and establish operational criteria for reservoirs and certificates of the quality for reused water; (iii) assess the possibilities and the technical and economic implications for the use of existing networks and their extensions, for the distribution of potable reuse water; (iv) develop educational and awareness programs to promote public acceptance of the practice of direct potable reuse. Relevant arguments refer to the security of supply and the provision of safe water to consumers of the public water supply systems; and (v) overcome the self-protectionist and immediatist procedures of the regulatory bodies, who should be guided towards developing realistic norms, standards and codes of practices based on studies and research and not through copying aliens rules and guidelines that do not represent our technical, cultural, environmental and public health conditions.

6. Cities in Dry Zones and How the Water Supply is Organized

Brazilian dry zones present particular characteristics of precipitation, deterioration of surface and groundwaters and great distance in relation to other watersheds, so that specific actions of Urban Water Management must be implemented concerning the water supplies and distribution of adequate water for the semi-arid population.

6.1 Characterization of the Brazilian Semi-arid

The driest area in Brazil, classified as semi-arid, extends across eight states of the Northeast (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe) in addition to

the North of Minas Gerais, totaling a territorial extension of 980,133.079 km². Proportionally to the area of the states, 93.0% of the territory of Rio Grande do Norte, 87.6% of Pernambuco, 86.7% of Ceará, 86.2% of Paraíba, 69.3% of Bahia, 59.4% of Piauí, 50.7% of Sergipe, 45.3% of Alagoas and 17.5% of Minas Gerais are included in the semi-arid region.

The term semi-arid usually generically describes the climate and the regions where the average annual rainfall is between 250 and 500 mm, and where vegetation is composed mainly by shrubs that lose their leaves during the driest months or by pastures that dry up during the dry seasons. Typical biomes of the semi-arid regions are the steppes like those in Kazakhstan, the Australian outbacks and the caatinga, which is typical of the Brazilian Northeast.

The interannual variation of precipitation in the Northeast is very large and depends mainly on two phenomena of the ocean-atmosphere system, the El Niño / Southern Oscillation (or anti-El Niño / Southern Oscillation) and the Atlantic Dipole. The El Niño is the warming of the sea water in the tropical Pacific from the coast of Peru / Ecuador up to the west of the Pacific. La Niña is the opposite, in other words, the cooling of sea water in the Tropical Pacific from the coast of South America to the west of the Pacific. The El Niño phenomenon has been identified as being responsible for the most severe droughts in the region.

6.2 Demographic Distribution

The results of the Population Census conducted by IBGE – Brazilian Institute of Geography and Statistics indicated that the population living in the Brazilian semi-arid reached a total of 22,598,318 inhabitants in 2010, representing 11.85% of the Brazilian population and 42.57% of the population residing in the Northeast.

The five most densely populated municipalities of the semi-arid are Feira de Santana – BA (556 642 inhabitants), Campina Grande – PB (385 213 inhabitants), Caucaia – CE (325 441 inhabitants), Caruaru – PE (314 912 inhabitants) and Vitória da Conquista – BA (306 866 inhabitants). According to analysis of the INSA – National Institute for Semi-Arid, of the 1,135 municipalities of which the semi-arid is composed of, the vast majority (93.4%)

Table 3. Classification of municipalities in the Brazilian semi-arid region according to the size of the resident population

Population	Number of Cities	Classification	Sum of the population of all cities in the group
Up to 5,000	190	Small	697.046
5,001 to 10,000	264	Small	1.882.695
10,001 to 20,000	373	Small	5.323.977
20,001 to 50,000	233	Small	6.836.496
50,001 to 100,000	57	Medium	3.723.683
100,001 to 500,000	17	Large	3.577.779
500,001 to 900,000	1	Large	556.642
Total	1135		22.598.318

Source: INSA, 2014; classification proposed by the Ministry of Social Development and Fight Against Hunger, 2004.

is considered small, followed by 5.0% medium and 1.6% large as can be deduced from Table III. Of the total population of the semiarid, 65.2% reside in small municipalities, 16.5% in medium sized municipalities and 18.3% in large municipalities.

6.3 Water Supply

In 2006 ANA – The National Water Agency concluded the Northeast Urban Water Supply Atlas. The study performed a diagnosis of the water supply, consisting of an analysis of the watersheds and water producing systems of 1256 municipalities within the Brazilian semiarid region. From the total of the 1256 municipalities, 737 (58.7%) are supplied by Isolated Systems and 519 (41.3%) by Integrated Systems (a single system serving more than one municipality).

In the ATLAS study area, the quality of surface and groundwater is shown to be compromised in most watersheds, due to human activities related to improper disposal of solid waste, indiscriminate use of agricultural inputs, the deficiency or absence of sewage treatment systems, the carrying of inorganic fillers from mining and processing of ores and deforestation and improper soil management, which results in erosion and siltation of rivers.

ANA's study took into account three different time spans in order to quantify the demands over water – short (by 2005), medium (by 2015) and long term (by 2025), taking into account two distinct scenarios: (1) Trend Scenario, in which you project the use of water resources following a historical background; and (2) Optimistic Scenario, in the event that goals are met related to the reduction of

losses of water supply systems; management of the demands deriving from development poles; increase in irrigated area with smaller individual demands.

The study conducted by ANA concluded that 72% of the municipalities located within the study area show a population growth trend until 2025 (24.3% with strong growth and 51.2% with moderate growth), while 22.9% will possibly suffer population loss (3.2% with significant losses and 17.2% with moderate losses). A total of 4.9% of municipalities were identified with a tendency towards stagnation.

Assuming the optimistic scenario for 2025, the Atlas concludes that:

- The total water demands of the studied cities is 734 m³/s;
- The demands for water, for irrigation purposes represent 58% of this total (427 m³/s);
- The demands for human supply correspond to 27% (198 m³/s);
- Water supply for industries will require 73 m³/s, 10% of the total estimated demand;
- The demand for watering livestock will correspond to approximately 5% of the total (36 m³/s).

Of the expected demand for water supply in 2025, 185.4 m³/s will be required to supply the urban areas (93.5%) and 12.9 m³/s to supply the rural population (6.5%).

6.4 Identification of the Problem

In order to identify the supply difficulties, the municipal headquarters were classified by ANA as follows:

- Satisfactory supply –the water sources and the water production system are sufficient to supply the demands within the planning prospects;
- Critical situation per system –the capacity of water production of the system is not sufficient to meet the demands within the planning prospects;
- Critical situation per water source –the availability of water of the water sources is not sufficient to meet the demands within the planning prospects;
- Critical situation per water source and system –both the water sources and the production system indicate a deficiency regarding the balance of supply and demand within the planning prospects.

For the Optimistic scenario and prospects for 2025, the Atlas concluded that, of the 1256 analyzed municipalities, 26.8% will be adequately served by supply systems, corresponding to a population of 8.4 million inhabitants, 2.7% will be supplied by means of a deficit water source, 52.8% will be supplied through critical water production systems and 17.7% through production systems and water sources both classified as critical.

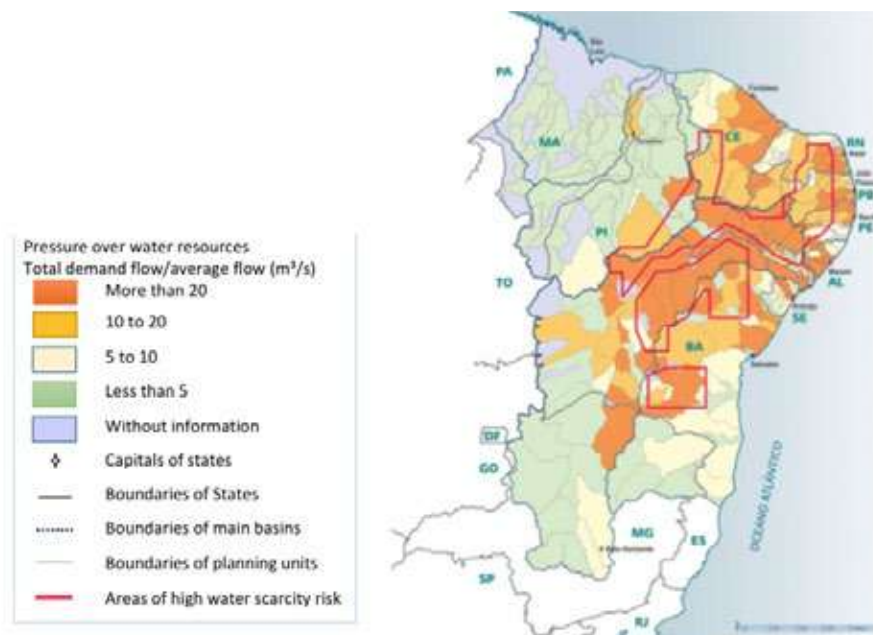
Such data indicate that if adequate solutions are not implemented, and even if actions to reduce urban water demands in 2025 are considered, 41 million people in the region will still have no guarantees of a water supply for human consumption.

Figure 7 classifies the studied cities by level of criticalness of supply, for the scenario described.

With regard to the supply of water to people in semiarid cities that do not have water sources nearby, the construction of pipelines is the most appropriate solution, whether from larger reservoirs, or from wells in sedimentary areas (with greater restriction so that the potential of these reserves can be identified, particularly in regards to their mechanisms of recharge), or from more distant reservoirs and rivers, even those located in other watersheds, thus creating the so called transpositions of water between basins.

Great water projects for water transport have already been completed, or are under construction or have already been designed over the last years, to supply water to the cities of the semiarid and provide support to the productive activities. This is the case, for example, of the Integration Channel in Ceará, destined to carry water from the Castanhão reservoir –the biggest of the Northeast located

Figure 7. Pressure over water resources under the optimistic scenario of 2025



Source: ANA

outside of the São Francisco River basin (capacity of 6.7 billion m³) all the way to the Fortaleza region, capital of the state, over a 225 km extension. Another example is the network of 500 km of pipeline in the state of Rio Grande do Norte. In both cases, it reflects the exploitation of water reserves within the territory of each state. The main ongoing strategy for increasing water infrastructure of the semiarid region is linked to the projects to transfer water from the São Francisco River toward the states of Ceará, Rio Grande do Norte, Paraíba and Pernambuco, through two large channels called axes North and East.

According to the Ministry of National Integration, by the end of the project there will be a continuous withdrawal of 26.4 m³/s of water, equivalent to 1.4% of the total water flow of 1850m³/s ensured by the Sobradinho, in Bahia, in the stretch of the river where the water will be captured. This flow is

intended for consumption for the urban population of 390 municipalities in the Agreste and the Hinterland of the four states of Northeast. In years when the Sobradinho reservoir surpasses its accumulation capacity, the collected volume could increase to up to 114m³/s on average, contributing towards ensuring water supply for multiple purposes.

When crossing the state of Pernambuco, the North and East axes, will serve as a source of water for the existing or proposed pipeline systems currently responsible for supplying water to the Hinterland and the Agreste. For the agreste in Pernambuco, considered one of the most inhabited semiarid regions of the planet, 1300km of pipelines are being implemented, destined to complement the supply of water, using the São Francisco River to provide water to 68 cities and 80 localities.

7. Conclusions

The rapid degree of urbanization in Brazil has brought innumerable environmental problems such as an increasing demand for water supply, energy, food and transportation. Urban ecosystems produce a considerable amount of solid and liquid waste that impact the natural environment downstream the cities. The urban ecosystem is a dynamic and complex system and as such the Integrated Urban Water Management has to be considered for these ecosystems. The components of this IUWM include legislation, urban planning and soil use, urban drainage and quality of life and environment conservation (Tucci, this paper).

The water supply services present innumerable problems in urban areas. Despite that 90% of the population receives water in their houses, the treatment of wastewater is only 45% of the total sewage produced. This impairs the uses of water downstream to the cities and produces many problems of Public Health and dissemination of water borne diseases. Another problem that is common in Brazil is the loss of treated water in the distribution networks that is an average of 30% (Tundisi, this paper). The urban water quality degradation in Brazil is dependent upon deforestation, discharge of industrial

wastewater, agricultural discharges and transport of sediment due to the erosion of soil in urban areas, as well as lack of wastewater treatment.

The water quality in the sources of supply also varies: if the source is well protected by forests the water quality is good and the costs of treatment are as low as U\$ 5,00 / 1.000 m³ of water. If there is a degradation of the source, the costs of water treatment can be as high as U\$250.00 per 1.000 m³ of water (Tundisi, this paper).

In Brazil, the main threat to human health among the waterborne diseases is gastroenteritis caused by viruses, protozoa and bacteria. This disease represents more than 80% of diseases related to poor sanitation and is a great burden to the health care system (Spilk, this paper). The current applied techniques to measure the microbiological safety of water in Brazil do not include the detection of viral or protozoan agents. The process applied to the treatment of water in Brazil is not effective to avoid the risk of viral contamination.

The driest area in Brazil, called by the specialists as semiarid region (rainfall between 250 and 500 mm/ year) has a population of approximate 22.600.000 inhabitants, distributed in 1135 mu-

municipalities with a majority of small cities (from 5,000 to 50,000 inhabitants) (Cirilo, this paper). In a study carried out by ANA (National Water Agency of Brazil) it was shown that the quality of surface and groundwater was impaired by the disposition of solid waste, use of agricultural fertilizers, the absence of sewage treatment systems, and deforestation with erosion and siltation of rivers as a consequence. The construction of pipelines for water transportation between watersheds is one of the adequate solutions for water supply of these municipalities in the semiarid area. Another solution is to improve and invest heavily on the management of water in the municipalities (Cirilo, this paper).

Finally, one fundamental question in the urban water management system in Brazil, is the technology of water reuse. Today the water availability for the supply of urban population in Brazil is approaching a critical level, due to extensive changes in rainfall in the last two years (summers of 2012/2013 and 2013/2014). An

overall reduction of 30% occurred increasing the vulnerability of urban populations; one possible solution is the re-use of treated wastewater that only in the metropolitan region of São Paulo could bring another 56m³/s to be used in other activities. Treatment of water for re-use would be a formal component of the water resource management. The quality of water for reuse should have a permanent monitoring assessment, established standards for different uses, and an evaluation of the benefits of the re-use in urban and metropolitan regions (Hespanhol, this paper).

The concept of green cities as presented by Tundisi (this paper) should be included in all programs for integrated water management of urban regions. Forests are a vital and dynamic component of the water cycle and the implementation of municipal parks, ecological stations and other forested areas amidst the urban environment is a step forward in water conservation and quality of life in the urban ecosystem.

8. References

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