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Long-term uncertainties and potential risks to urban waters in Belo Horizonte

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Abstract
This paper addresses urban water potential risks for the next 30 to 50 years at Belo Horizonte, Brazil. Belo Horizonte is a planned city, built in 1898 to become the capital of the state of Minas Gerais. The city, located in a mountainous region of tropical soils, has a population of 2,227,400 inhabitants with a population density of 6,900 inhabitants/km^2. Long-term uncertainties and potential risks to urban waters are assessed on the base of scenarios involving demographic projections, climate change estimations, land use trends, institutional and legal possible developments, on going programmes and other factors considered relevant to urban waters in the future.

Keywords: potential risks to urban waters, demographic projections, global change, land use trends

1 Introduction

The present paper addresses long-term uncertainties and potential risks to urban waters in Belo Horizonte, a planned city, built in 1898 to become the capital of the state of Minas Gerais, Brazil. The city, located in a mountainous region of tropical soils, has a population of 2,227,400 inhabitants. Risks and uncertainties to urban water are qualitatively assessed on the base of scenarios involving demographic projections, climate change estimations, land use trends, and institutional and legal frameworks. The risk assessment is preceded by a brief description of the existing water management system in Belo Horizonte and followed by a discussion on possible developments, on-going programmes and other factors that may be relevant to the risk management of urban waters in Belo Horizonte and region, in the future.

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2 Urban waters in Belo Horizonte

Belo Horizonte (BH) is the capital of the State of Minas Gerais, which in economic terms (gross product) is the third among the 26 Brazilian states. The city lies at 20° South latitude and 44° West longitude (Figure 1) and has an altitude of 750 to 1,300 metres. It is located in a mountainous region of tropical soils that originated from the decomposition of metamorphic rock. Tropical highland weather predominates in this area, with an average yearly rainfall of 1,500 mm and an average yearly temperature of 21^{o}C. The rainy season lasts from October to March, when 90% of the total yearly rainfall occurs. The highest monthly average rainfall (315mm) takes place in December. Mean relative humidity reaches 50% during winter and 75% in summer.

Figure 1: Location map of Belo Horizonte (Nascimento *et al*, 1999)

BH has 2,227,400 inhabitants with a population density of 6,900 inhabitants/km^2. It is a planned city, built in 1898 to become the capital of the state, in an area of 330 km^2. The overall metropolitan area (RMBH; Belo Horizonte Metropolitan Area) consists of 33 distinct municipalities with an area of 9,179 km^2 and 3,900,000 inhabitants.

2.1 The Belo Horizonte water supply and wastewater systems

The water supply system (dinking water) connects to 99.7% of BH residents with an average supply rate of 286 litres per inhabitant/day. Surface sources predominate in the BH water supply system. There are four main sources, namely:

- Velhas (Velhas River Basin) with a capacity of 6.75 m^3/s;
- Manso (reservoir, maximum storage: 121,000,000 m^3) with a capacity of 4.2 m^3/s;
- Serra Azul (reservoir, maximum storage: 93,000,000 m^3) with a capacity of 2.6 m^3/s;
- Vargem das Flores (reservoir, maximum storage: 44,000,000 m^3) with a capacity of 1.2 m^3/s.

All the systems are interconnected and supply not only BH but also most of the municipalities gathered into the Metropolitan zone. The total water supply production capacity is 16.3 m^3/s, which easily meets a present demand of 11.9 m^3/s for the Metropolitan Region of Belo Horizonte. The water supply system presents high standards in terms of operation as well as water quality.

In BH, about 92% of the population is connected to the wastewater sewerage system but there is a lack of interceptor pipelines and wastewater treatment facilities. There are two relatively recent wastewater treatment plants in operation, the Arrudas and the Onça WWTP, with a total capacity to treat 4.0 m^3/s. In the future, those WWTP will have their total treatment capacity increased to 8.1 m^3/s and will then be able to treat almost 100% of the wastewater flow generated within the Arrudas and Onça catchments, including wastewater drained from the Contagem municipal area located upstream.

In Belo Horizonte as well as throughout the BH metropolitan area, a separated sewerage system has been adopted, although illicit inter-connections between the wastewater and stormwater networks and the lack of interceptor pipelines are main causes of heavily polluted receiving bodies in the urban area and in the Velhas River downstream of the city. About 56% of the required interceptor lines need already to be built. Therefore, improvements to urban creeks, detention ponds, wetlands, and to the Velhas River water quality will require important investments in wastewater interception. Alternatively, new approaches may be adopted, e.g.: combining the existing end-of-pipe WWTP with decentralised treatment facilities, or the possibility of keeping combined systems in certain areas where in fact this approach has been informally adopted e.g. in many of the shantytowns.

The wastewater system is identified as the greatest deficiency in the urban water complex in Belo Horizonte. A high association between low income and lack of access to the sewerage system could be identified. The Municipal Water Supply and Sanitation Plan proposes a selection of priority areas for investments, including interventions on sewerage. In this prioritization analysis, however, the Plan includes the assessment of the policies involving water supply, wastewater, refuse collection and stormwater drainage, with strong articulation with other municipal plans.

2.2 The Belo Horizonte stormwater system

Traditional stormwater systems prevail in the city, although experiences with detention ponds have existed since the 1950s. There is a 4,300 km network of roads all equipped with gutters, inlets etc. There are some 700 km of perennial creeks in the municipal area. Parts of these creeks have been lined to the extent of nearly 200 km, most of them as culvert concrete channels. Using concrete box culverts as a “solution” to aesthetic, odour, garbage and water-borne disease problems related to heavily polluted streams demonstrates an oversimplified approach to stormwater management. The apparent simplicity of stormwater management, as perceived during most of the last century, led to the use of very simple design methods for storm water systems. Also, the BH municipality did not invest in monitoring stream discharges or water quality parameters. One of the consequences of this approach is high uncertainty in hydrologic design. A similar oversimplification also prevailed in hydraulic design; only uniform flow conditions were regularly considered in the design of channel structures, which usually resulted in underestimations of flood risk and flood effects.

The intense urban growth during the 1970s combined with inequalities in the distribution of income led to huge impacts on water quality in receiving bodies and an increase of flood risk. This is mainly due to the impacts of new urban developments causing an increase of imperviousness and also to the occupation of flood prone areas. Water pollution by wastewater discharges and diffuse pollution inputs, including solid waste and the products of severe erosion processes have caused the degradation of water quality in streams and the reduction of conveyance capacities of sewers and channels due to sediment deposits. Detention basins have also been heavily impacted (Nascimento *et al*., 1999).

3 Uncertainties and potential risks to urban waters in Belo Horizonte

Long term threats and uncertainties associated with the urban development of Belo Horizonte are first of all briefly discussed in terms of population growth and climate change. This discussion is followed by a list of potential risks associated to the water supply and sanitation infrastructure and services.

3.1 Population growth

Population growth in Belo Horizonte is virtually reaching a saturation level (Figure 2). Present average population growth rate is at 1.1 % per year (from 1990 to 2000) and nearly 95% of the municipal area is already urbanised. It is important to consider that the BH land use law still allows a considerable densification of the present urban occupation in almost all the municipal territory, with the exception of the central, very densely occupied area, and zones of restricted densification. Nevertheless, this scenario of high densification seems not to represent such a significant risk when one takes into account the mentioned present population growth rate.

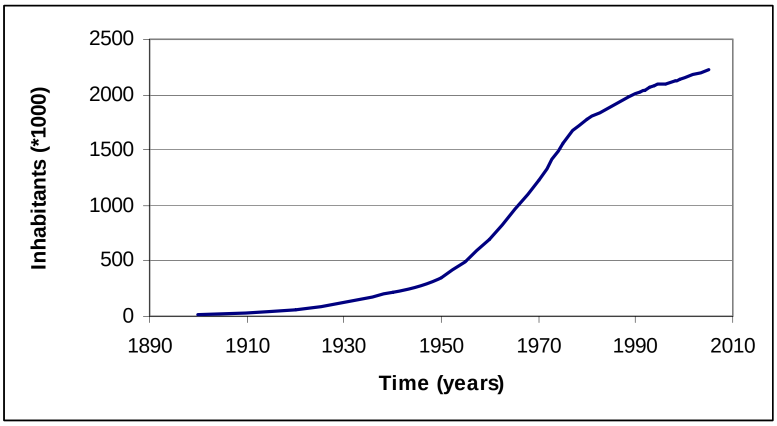

Figure 2: Population growth in Belo Horizonte.

However, pressures on water resources due to population growth as well as a variety of environmental impacts due to rapid urban expansion may be consistently expected in the metropolitan region of Belo Horizonte (RMBH), where population growth rates higher than 5% per year are still observed in certain townships. Part of this phenomenon is due to the attractiveness of industrial and commercial activities as well as to the quality of public services in townships located near to Belo Horizonte. In some suburban areas the low cost of land associated, in many cases with illegal urban developments, may also partially explain this expansion process despite poor infrastructure of public services.

3.2 Climate and climate change

The main climate characteristics of the Belo Horizonte area are the relatively small thermal amplitude and a high seasonal variation of precipitation with very dry winters and wet summers. Regionalisation studies on rainfall intensity, duration and frequency recently carried out for the BH metropolitan region (RMBH), based on precipitation data from more than 20 recording rain gauges having time series longer than 30 years did not detect any tendencies associated to climate change for precipitation depth or precipitation intensity (Pinheiro and Naghettini, 1998). In contrast, increasing temperature trends can be identified (Figure 3). However, one has to recognise the difficulties in isolating global change effects from anthropogenic impacts at a local scale, as urban heat islands can develop due to increases in impermeable areas and changes in vegetation cover and in wind patterns.

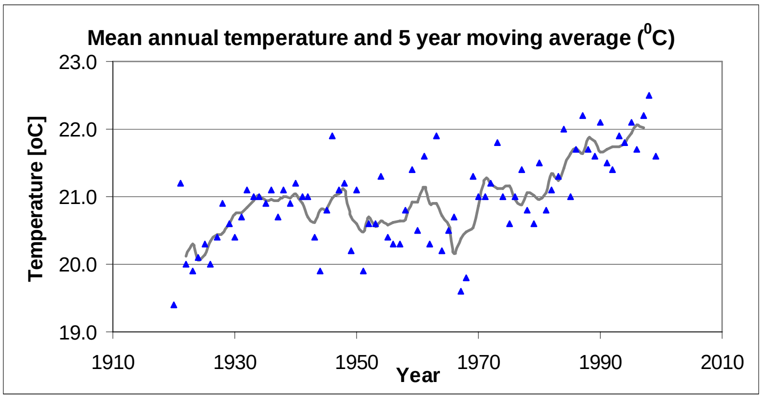

Figure 3: Belo Horizonte mean annual temperature and 5-year moving average

A particular concern with respect to climate change is the possible synergistic combination of global with regional changes due to local anthropogenic impacts caused, for instance, by deforestation and/or urbanisation. Studies assessing regional and local impacts of climate change are not numerous in Brazil. Nevertheless, according to Nobre et al. (2005), the existing studies suggest that an increase of 2^0 C to 3^0 C in average temperature may lead to a reduction of trees by up to 25% in the "cerrado" area (savannah) and by up to 40% in the Amazonian forest, before the end of the 21^{st} century. These kinds of vegetation changes may, in turn, result in a warmer and drier climate, which may lead to water shortages, among other possible impacts on water resources. The IPCC (2001) report on possible impacts of climate change on urban areas, cited by Bigio (2003), suggests regarding water:

- Expected increases in the scale, intensity, and frequency of rainfall resulting in periodic flooding of flood prone areas and in landslides on geologically unstable slopes.
- Sewage treatment systems and solid waste disposal areas could be affected by flooding, with possible contamination of water supply sources.
- An evolution to drier climates which compromises the replenishment of the water tables and reduces minimum flows, possibly implying a water shortage.

Although assessments of these kinds of risks are not so far available for Belo Horizonte, they are likely to happen in the future provided that forecasts on global change are confirmed.

3.3 Risks to the water supply system

Water quality degradation and water shortage:

- Accidental contamination of drinking water sources through the discharge of toxic substances, causing the interruption of water treatment plant operation for a certain period of time;
- Toxic algae bloom in reservoirs due to catchment environmental degradation;
- Operational failures;
- Thermal inversion in reservoirs leading to the mobilisation and mixing of previously settled toxic components; higher risk for the less protected catchments;
- High level of emergent pathogen occurrences in water supply sources due to environmental disruption.
- Flow reduction during dry seasons due to global change and local anthropogenic impacts on the hydrological regime;

- Higher demand due to population growth and changes on *per capita* consumption standards;
- Difficulties in ensuring protection of water resources and risk of water shortage or water quality degradation due to conflicting interests at the river basin scale (e.g: agricultural activities, mining and other industries, urbanisation).

3.4 Risks to the wastewater system

Persistent and chronic pollution of receiving waters:

- Implementation of planned interceptors is postponed possibly due to lack of investments as well as to political and social difficulties associated with removing informal settlements from riparian areas thus posing problems for the building of interceptors;
- Persistence of illicit connections between stormwater and wastewater sewerage systems possibly due to technical difficulties in locating and reducing connections, need for training and information in order to avoid new inadequate connections between the two systems;
- Lack of investments to increase WWTP treatment capacity;
- Operational failure or poor operation of WWTP leading to poor treatment performance possibly due to poor operational qualifications; WWTP disturbed by wet weather transient flows due to illicit connections between stormwater and wastewater sewerage systems;
- WWTP not equipped to remove nutrients (nitrogen and phosphorous) and emerging pollutants such as endocrine-disrupting chemicals.

3.5 Risks to the stormwater system

Risk of flooding and of pollution of receiving waters by wet weather diffuse pollution:

- Significant changes or increases in the occurrence of floods, in damage caused by floods and in wet weather diffuse pollution possibly due to:
  - Increases in imperviousness;
  - Lack of investments to correct the present hydraulic functioning problems;
  - New developments (legal and illegal) in flood prone areas;
  - Lack of proper maintenance;
  - Technology update is not sufficient to face emerging risks;
  - Wet weather pollution is not properly considered;
  - Failures in other sanitation sectors,
  - Climate change alters storm frequency and intensity.

Persistent and chronic pollution of receiving waters (see item 3.4 on wastewater):

Risks associated to a generalised use of BMPs:

- Failures on flooding control and wet weather pollution abatement;
- Health risks, soil pollution associated to the use of BMP devices;
- Reduced public acceptance of BMP.

3.6 Risks shared in common by all the urban water systems

Accident, failures and criminal actions:

- Disruption of wastewater systems due to natural hazards like flooding or landslides;
- Failures of operating units due to lack of maintenance or ageing of infrastructure and associated equipment;
- Leakage of water within the drinking water distribution system is still high in BH;

- System failure induced by terrorism or criminal actions, e.g.; contamination of drinking water system, vandalism against measuring equipments in the stormwater systems;

Increasing costs:

- Increasing costs imposed by different causes:
    - Water resources pollution leading to higher treatment costs;
    - Water shortages for the present sources implying higher capital and operational costs for the withdrawal of water from remote sources;
    - Investment for the modernisation of ageing systems;
    - Costs associated to final sludge disposal;
    - Maintenance and operational costs;
    - Costs imposed by vandalism;
    - Energy costs.

3.7 Risk and uncertainties associated to governance and institutional development

In addition to the risks mentioned above, and part of the reasons for the emergence of these risks, are institutional and governance issues. These may concern the requirements for integrated planning and management that must be developed at different territorial and institutional scales:

- territorial scale: district, city, metropolitan, river basin, state, national;
- water supply and sanitation sub-sectors: water supply, wastewater, storm water, solid waste;
- sectors of the urban policy development: urban planning, urban development major projects, housing, industrial development, road system and transport.

For some of the sectors, water issues are not currently included in the decision-making procedures or in the legislation. The implementation of an effective IUWM system will, therefore, require considerable improvements on governance and institutional development, in order to ensure effective co-operation among different sectors of decision-making, policy formulation and management within the urban sphere as well as within the river basin sphere.

One part of the required institutional development for IUWM is capacity building. IUWM implementation implies considerable changes in technical and managerial methods, including monitoring, modelling, planning, decision-making on the basis of indicators, adopting new legislation, communication, facilitating public participation, etc. These changes require well-trained professionals in new methods and techniques, which will require the training of existing staff as well as the hiring of new professionals.

Therefore, uncertainties and risks related to governance and institutional development refer mainly to concerns on the difficulties of implementing those new policies, methods and legal requirements.

4 Conclusions

The present paper suggests a prospect of high risks and uncertainties associated to urban waters in Belo Horizonte and region. These risks are mainly related to local environmental impacts of urban, industrial and agricultural land use, institutional and financial challenges caused by the increasing complexity imposed by the IUWM requirements, as well as to global change effects on natural processes and on the man-made water management systems.

In order to deal with these kinds of risks and to deal with current water management problems, the BH municipality is carrying on different programs, the majority of them gathered in the on-going Stormwater Strategic Plan (Champs et al, 2005) and the Water Supply and Sanitation Strategic Plan (GGSAN, 2004, 2006). Examples are:

- the program of creek restoration in the urban area, which involves not only the restoration of polluted creeks but complete sanitation, risk management (risk of flooding, risk to public health …), and a housing programme addressed at people living in risk prone areas;
- the stormwater monitoring programme, with the set up and operation of a rainfall, discharge and water quality measurement network focused on the identification of BH stormwater problems at the present time and to contribute to the future evaluation of the efficiency of control measures implemented according to the stormwater plan. This programme will also contribute to impact assessment of urbanisation on water resources and to the statement of land use regulatory measures aiming at the mitigation of those kinds of impacts;
- the research and technological development programme: the main programme goal is the development of stormwater management technologies to deal with the main stormwater problems here described;
- the institutional and managerial development programme: this programme aims to provide a statement of legal, economic, institutional and managerial measures in order to improve storm water management in the BH municipality.

These planning efforts, associated to initiatives taken at the state and federal spheres, as the recent approval (December 2006), by the federal legislative, of a federal legislation for environmental sanitation (Heller, 2007) and the water resources management law (Federal Law 9433/97) may constitute relevant instruments for the risk management at the water sector in local (municipal) and regional (river basin) scales.

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