Chapter 2
Water and Health: Global and National Aspects

Ulisses Confalonieri, Léo Heller, and Sandra Azevedo

Abstract Although water is recognized as essential for the appropriate functioning of biological systems and human health, many countries and a large part of the global population are water stressed. The expected changes to the hydrologic cycle brought about by the process of global climate change will aggravate this situation. Almost 90 % of the four billion diarrhea episodes occurring globally each year are linked to deficiencies in sewage disposal and the supply of safe water. In Brazil, the most important public health problems associated to water are: diarrheal diseases, schistosomiasis and other helminth infections, leptospirosis, vector-borne diseases (e.g. malaria and dengue fever) and poisoning by Cyanobacteria toxins. It is suggested, for Brazil, the setting of quantitative goals for reduction in childhood diarrhea in the next 5 years as well as development of integrated indicators for the monitoring of water-and-sanitation-related health problems.

Keywords Climate • Cyanobacteria • Health • Indicators • Infections • Sanitation • Toxins • Water

U. Confalonieri (✉)
Centro de Pesquisas René Rachou, Fundação Instituto Oswaldo Cruz,
Av. Augusto de Lima, no 1715, 30190-001 Belo Horizonte, MG, Brazil
e-mail: pmags@ensp.fiocruz.br

L. Heller
Centro de Pesquisas René Rachou, Fundação Oswaldo Cruz,
Av. Augusto de Lima, no 1715, 30190-001 Belo Horizonte, MG, Brazil

S. Azevedo
Instituto de Biofísica, Centro de Ciências da Saúde Bloco G, Universidade Federal
do Rio de Janeiro, Ilha do Fundão, 21949-900 Rio de Janeiro, RJ, Brazil

C.E. de Mattos Bicudo et al. (eds.), *Waters of Brazil*,
DOI 10.1007/978-3-319-41372-3_2

Introduction

The importance of water for vital processes and for human health is well known. Water is essential for biological functioning at all levels, from the metabolism of living organisms to the equilibrium of ecosystems. This also applies to human biology, since it is essential to their physiology, comfort and hygiene. However, it is estimated that approximately 1.5 billion people in the world do not have access to good quality water (UN Statistics United Nations Statistics Division 2008). Approximately 80 countries suffer from water stress, defined as the situation in which there is a runoff of rain less than 1000 m^2 $person^{-1}$ $year^{-1}$ (Arnell 2004). The populations of these regions comprise about 40 % of the world's total population.

In 2002, 21 % of the population of developing countries did not have continued access to adequate sources of water (UNSD 2008). The United Nations has the objective, as part of one of their Millennium Development Goals (MDGs), to reduce in 50 %, by 2015, the proportion of the world's population in 1990, without access to good quality water for drinking and without adequate sanitation.

With the prospect of major changes in the hydrologic cycle—at local, regional and global levels as a result of global warming—societies face an enormous challenge with regard to managing water resources and the provision of drinking water. Due to this situation, this article emphasizes the relation between the quantity and quality of water and human health; and the existing challenges for improving the access to good quality water. Some global aspects are briefly taken into consideration, and emphasis is given to national and regional Brazilian problems with regard to water and its health linkages (Fig. 2.1).

Fig. 2.1 Aquidauana River during its flooding in Southern Mato Grosso (Photograph U. Confalonieri)

Water and Health

It is estimated that approximately 10 % of the global burden of diseases is due to the poor quality of water and to deficiencies in excreta disposal and in hygiene (Prüss-Ustin et al. 2008). Almost 90 % of the approximate four billion annual cases of diarrhea in the world (which cause 1.5 million deaths in children under the age of 5) are attributed to deficiencies in sanitation and the provision of good quality water. On the other hand, we know that up to 94 % of all diarrhea cases are preventable (WHO/UNICEF 2006).

Water is related to human health in various ways, the most important:

1. As a vehicle of microbial agents of gastroenteritis, especially due to fecal contamination, or of other infections such as leptospirosis, common in urban flooding.
2. As a vehicle of toxic agents, either natural (e.g. biological toxins, such as those from cyanobacteria; arsenic) or of an anthropogenic origin (other chemical contaminants).
3. As reservoirs of disease vectors, such as mosquitos of malaria and dengue fever and the intermediate hosts (snails) which harbors the worm that causes schistosomiasis (*Schistosoma mansoni*).
4. Direct physical impacts (e.g. flooding in populated areas) or indirect (e.g. damages to the production of food or to health infrastructures, etc.) (Fig. 2.2).

Fig. 2.2 Creek at a flooded area of Aquidauana Pantanal, MS (Photograph U. Confalonieri)

Situation in Brazil

Some classic criteria exist for defining public health priorities for intervention. In general, three main aspects are accepted:

1. Number of affected individuals.
2. Severity of disease processes (measured by mortality and disability).
3. Existence of technologies for prevention/control.

With regards to the health problems related to water, by applying these criteria, we can define the following conditions among the most important:

1. Infantile diarrhea: is still an important cause of death in the country (see page 13).
2. Vector borne diseases: especially, malaria, practically restricted to modified environments in the Amazonian region (with about 540 thousand cases in 2006) and dengue fever, most important in big cities, with about 700 thousand cases in 2008 (incidence in 2007 of 295.7 cases per 100 thousand inhabitants).
3. Schistosomiasis and other soil transmitted helminthiasis: schistosomiasis originates in the fecal contamination (by sick people) of bodies of water such as streams, lakes and reservoirs which contain populations of the *Biomphalaria* genus. It is endemic in the Northeast region and in parts of the Southeast. One estimate points to the existence of eight million carriers in the country. In the Northeast region, 43,759 new cases were diagnosed in 2004 (an incidence of 87.8 cases per 100 thousand inhabitants).
4. Leptospirosis: generally occurs as a consequence of the contamination of water from urban flooding, by urine of sewage rats, which shed the bacteria. It is therefore related to the occupation of urban land in areas deficient in drainage, sewerage and solid waste collection, which facilitates the proliferation of the rodents. Between 1996 and 2005, 33,174 cases were diagnosed in the country. The largest epidemic ever registered in Brazil was in the summer of 1996, in the city of Rio de Janeiro, with 1790 cases and 49 deaths.
5. Cyanotoxin toxicity: in our country, the work of Teixeira et al. (1993) describes a strong evidence of correlation between the occurrence of cyanobacteria blooms in the reservoir of Itaparica (Bahia) and the death of 88 people, among the 2000 intoxicated who presented severe gastroenteritis due to the consumption of water from the reservoir between the months of March and April of 1988. However, the first confirmed case in the world, of human death caused by cyanobacteria toxicity (cyanotoxins) occurred in the beginning of 1996, when 130 chronic renal patients started showing clinical manifestations, after having been submitted to hemodialysis sessions at a clinic in the city of Caruaru, State of Pernambuco, of severe hepatotoxicosis. Out of the total, 60 of these patients passed away within 10 months of the onset of symptoms. Analysis confirmed the presence of cyanotoxins in the water purification system of the clinic and in blood and liver samples of the intoxicated patients (Azevedo 1996; Carmichael et al. 1996; Jochimsen et al. 1998; Pouria et al. 1998; Carmichael et al. 2001; Azevedo et al. 2002).

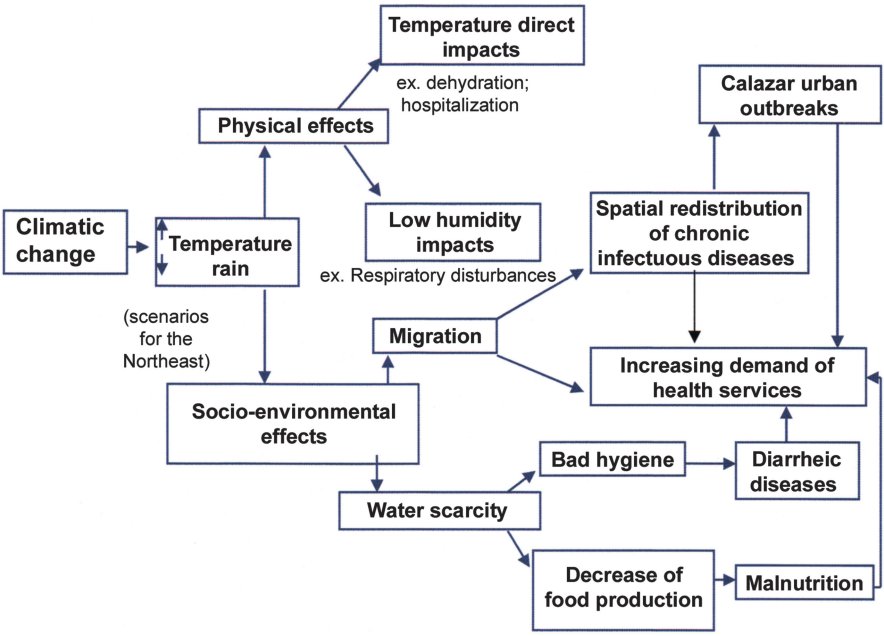

Fig. 2.3 Drought and health in Brazilian Northeast (CEDEPLAR/FIOCRUZ 2008)

6. Complex situations due to chronic shortage of water: it is important to note that the relation of water to the health conditions are generally very complex and mediated by several factors of a physical-geographical, socio-environmental, economic and cultural nature. Figure 2.3 illustrates this, showing how climatic changes can affect the water, aside from other risk factors, and contribute to diseases in the northeastern semi-arid, region of Brazil.

It shows the complex and multifactorial way in which scarcity of water in the Northeast affects health and the medical care systems. Even though high temperature and low humidity have direct impacts on human physiology, most of the health problems derive, indirectly, from socio-environmental processes caused by drought. The most important impacts are: nutritional problems, which are exacerbated by the decrease in the production of food; and the consequences of the migration process brought on by the affected economy (CEDEPLAR/FIOCRUZ 2008). These are the main mechanisms of the spatial redistribution of chronic and, infectious diseases (ex. Calazar) and the cause for the increase on the demand of healthcare systems in the destination of migrants. Although there is a certain adaptive capacity of local populations to drought, mainly through governmental actions of mitigation, scenarios indicate a considerable worsening of aridity in the region, historically unprecedented, and for which society will have to adapt.

Although Brazil has a privileged position in the world, with regards to the availability of water resources (ca. 12 % of the world's availability), there are important

regional disparities. In the Northeast region, for example, there are areas in which the availability of water per inhabitant/year is less than the minimum recommended by the UN, of 2000 L (Marengo 2008). One should also consider that the availability of water in Brazil depends largely on the weather, and projections indicate a reduction in the amount of rain in the North and Northeast regions of up to 20 % by the end of the twenty-first century (Marengo 2008). The World Health Organization (WHO) estimated that 2.3 % of the total number of deaths in Brazil (or 28,700 deaths) could be attributed to deficiencies in the quality of water, of sanitation and of hygiene (Prüss-Ustin et al. 2008).

The coverage of water supply services in urban areas of Brazil increased ca. 4.5 percentage points (from 87 to 91.4 %) and most significantly, for the rural population from 9.3 to 25.7 %, with a 16.4 increase in percentage points between the years of 1991 and 2003, according to the statistics of PNAD and the CENSO 2000. This reflects the difficulty in further advancing in the universalization of urban coverage, noting that the population that lacks these services is located predominantly in peripheral areas and in areas of informal urbanization, which indicates the need for the adoption of specific programs integrated to urban development. On the other hand, regardless of the progress in serving the rural population, coverage is still incipient. Furthermore, the data indicates the existence of 12 million Brazilians in the cities and an additional 22 million in rural areas who still need to be supplied by this service, further adding to the demands imposed by the natural increase of population. This coverage by public network of water supply has a greater concentration of municipalities with less satisfactory coverage, in the North and Northeast regions of the country. Although the statistics do not clearly reveal the way in which the water supply occurs, it may be inferred that the supply does not always meet the requirements considered adequate with regards to the continuity of the supply and with regards to the quality of the water, which is reinforced by the irregular financing of the services and by the operational limitations.

As for sanitation, one can also perceive a growth and slight expansion in the coverage of the public network, having grown 13 percentage points between 1991 and 2002 (from 62 to 75 %). Even though an increase of coverage was also indicated for the rural population during the same period, only 16 % of households are actually being serviced; leaving room for discussion with regards to the most adequate technological solution for dispersed populations. In addition, the coverage indicators only supply partial information since they do not indicate the destiny of the wastewaters. Furthermore, there is an issue over the ambiguity of the indicator, since the mere existence of coverage for sewer collection does not necessarily provide for an effective improvement in health and environmental conditions. The collection network in places devoid of interceptors and sewage treatments can even cause an increase in human health problems if the solution previously prevalent, invariably the infiltration of underlying soils by different types of septic tank effluents, was kept in place. In this case, the network ends up concentrating the sewage in the water bodies of urban areas, endangering the population and increasing the

circulation of pathogenic bacteria in the environment. The presence of interceptors and treatment plants itself, is no guarantee of human health protection or of water quality of receiving water bodies, if we consider the frequently reduced efficiency of the latter in removing pathogenic bacteria.

With regards to the nature of service, PNSB (IBGE 2000) informs that 4097 (42 %) of the 9848 Brazilian districts have a collective network, but that only 1383 of them have treatment plants (14 % of the total). However, only 118 of them perform disinfection of sewage. Of the total volume of sewage collected, only 35 % receives some sort of treatment, which results in about 9,400,000 m^3 of raw sewage conveyed daily to the bodies of water of the country, taking into account only the sewage collected by network. It is also worth noting the information that 3288 districts with network (80 %) do not possess any interceptor extension, potentially causing the deterioration of the water quality of the receiving bodies of water located in urban networks.

In the assessment of the water supply and sanitation services for the population, one needs to highlight the asymmetries which occur. They can easily be identified according to various dimensions. Aside from the inequality of availability of the service being associated to the location of the household, if urban or rural, it is also surprisingly closely related to income, in other words: the poorer are the most excluded. In addition, studies have revealed that the sizes of the cities and their level of human development are positively related to the possibility of them having greater services of coverage (Rezende 2005) (Fig. 2.4).

Fig. 2.4 Lake in the Pantanal South Region, MS (photograph U. Confalonieri)

Perspectives

1. MDG: there are several interconnections between the Millennium Development Goals and water, sanitation and health. Perhaps, the one which will suffer the most direct consequences will be the reduction of infant mortality Goal 4 of the "MDGs" due to diarrheic diseases, with the improvement of access to sanitation and water supply services. The most specifically related goal, corresponds to Goal 7 (Environmental sustainability), which aims at reducing the deficit through water supply services and sanitation. With this, improvements not only to the levels of health, but also to the conservation of the ecosystems and to decreasing the pressure over the commonly scarce water resources would be attained (WHO/UNICEF 2006; Schuster-Wallace et al. 2008). It is anticipated that Brazil will manage to meet the goal related to the supply of water, but will have difficulties in meeting that which relates to sanitation. In addition, the improvement of water management, with the implementation of better systems, reduces the chances of formation of breeding sites of vector mosquitoes of dengue fever and malaria (Goal 6: Combat HIV/AIDS, malaria and other diseases).
2. Global Climatic Change: the IPCC (Intergovernmental Panel on Climate Change) indicates in its Fourth Assessment Report (2007) the reduction of rainfall, especially in dry tropics, which will increase the number of people living under conditions of water stress. There are also projections of reductions, in the next few decades, of the availability of fresh water in coastal regions as a consequence of saltwater intrusion resulting from rising sea levels (global warming effect). It is also expected that the reduction in flows of river and the increase in temperatures of water will lead to declining water quality, as the dilution of contaminants is reduced less oxygen is dissolved in water, and microbiological activity increase (Bates et al. 2008). As a conclusion, IPCC's work indicates that the changes in rainfall and in temperature caused by global climatic changes will make the provision of fresh water, drainage and sanitation, an even more difficult process. Currently, the management of the water resources has been based on knowledge about stable climates. The policies and regulations on the use of water resources need to include information about regional scenarios of climate changes. For Brazil, studies and the development of regional scenarios indicate the North and the Northeast as the regions which will probably be the most intensely affected by the processes of global climatic change (Baettig et al. 2007; Marengo et al. 2007; Ambrizzi et al. 2007; Marengo 2008).
3. Research, surveillance and monitoring: given the importance of water for human health, sectorial actions are necessary for a more complete understanding of the relation between water and health in the country. Governmental initiatives need to kept, such as the one of 2008, to encourage studies of integrated assessment of human health risk in populations exposed to contaminated water (Sector Funds of Water Resources and Health). Also important are the initiatives for the collection, organization and accessibility of data on water, sanitation and the diseases related to this subject. One should point out, in this respect, the initiative of the

Ministry of Health (General Coordination of Environmental Surveillance) and of the Oswaldo Cruz Foundation, for the creation of the digital atlas "Water Brazil". Containing indicators on health, water quality and sanitation, on a municipal level, in the entire country, the atlas allows for a visualization of water supply problems, standards of consumption and the epidemiological profile of water-borne diseases (http://www.aguabrasil.iact. fiocruz.br).

4. Universalization of sanitation services: the need to increase the coverage of water supply and sanitation services, aiming at placing Brazil at the level of development pursued by the country and intensity the impact on populations health, is very clear. There are big challenges to reach a situation of universality and equity for services, ensuring access to the entire urban and rural population, to the quality of services and its support over time. The inclusion of populations from the periphery of large cities and rural areas, the assurance of safety of water supplied and the implementation of means of adequate disposal of the residues consist of important challenges. Real progress in this direction will require a combination of efforts, in other words, a public policy adequately designed and implemented, the enabling of financial resources and the improvement of the management of the services. These initiatives, effectively, have the need for an integrated adoption, eliminating the idea that only financial resources are needed to overcome the problems in this area. In a way, there is an acknowledgement of the importance of prioritizing the actions of sanitation and that the success of the public policies, require the adoption of a long term integrated vision, acknowledging the role of different social actors with the new federal legislation approved in the Country (Brazil 2005, 2007). However, a political desire of overcoming these predicted obstacles for this progress will be indispensable for the success of the implementation of these legal instruments.
5. Protection of human health from exposure to toxic agents: while the cyanobacteria are natural components of any aquatic ecosystem, paying attention to the occurrence of these microorganisms in public water supply is relatively new. The increase of eutrophication of reservoirs has been produced mainly by the discharge of domestic and industrial sewage from urban centers and by the diffuse pollution originating in agricultural regions. This artificial eutrophication produces changes in the water quality, including the increase of the incidence of blooms of microalgae and cyanobacteria, with negative consequences on the efficiency and the cost of water treatment. In our country, the problem of blooms is intensified by the fact that the majority of the water supply reservoirs present the necessary characteristics for the intense growth of cyanobacteria throughout the year. It is impossible to consider the cyanobacteria as pathogenic microorganisms in the classical sense, because although several lineages of different species of this organism can produce bioactive and toxic secondary metabolites for cells of several animal groups, a large part of these compounds are only liberated into the water after the cell lysis of cyanobacteria. The quality of water may be more compromised by the presence of toxins in their dissolved form, than by viable forms of cyanobacteria that, potentially, should be in the most part removed during the conventional treatment of water. In turn, these can lead to the

rupture of the cells of these microorganisms due to the use of chemicals during the several stages of this process. Cyanobacteria are also often associated to the production of compounds that provide taste and odor to drinking water. Although these compounds cannot be considered toxic, their presence cause concern to health authorities, seeing that frequently it results in the population rejecting the potable water, leading them to seek alternative sources of water supply, thus creating an added risk to public health. Proven records of the occurrence of toxic blooms in Brazil began in the 1980s. Aquatic environments located in areas of strong anthropogenic impact had a high percentage of dominance of cyanobacteria and occurrences of blooms. In at least 11 of the 26 states of Brazil, toxic species of cyanobacteria have been identified, of which the majority of the records are from multiple use reservoirs (Azevedo 2005). In many of the cases, the cyanobacteria which cause damage disappear from the reservoir before health authorities consider the bloom as a possible risk, for they are usually unaware of the possible damages which result from the occurrence of cyanobacteria blooms and, therefore assume that the common water treatments are capable of removing any potential problem. Yet, several cyanobacteria toxins are, when in a solution, not removed by means of a conventional treatment process, being even resistant to boiling. With the frequent appearance of cyanobacteria blooms in public supply reservoirs, environmental authorities try to, in general, control the blooms by applying copper sulphate or other algaecides. This method causes the lysis of these organisms, releasing the toxins often present in cells, into the raw water of fountains. Such actions can cause severe exposure to toxins. In addition, there is evidence that populations supplied by reservoirs that contain extensive blooms can be exposed to low levels of toxins for prolonged periods (Hilborn et al. 2008). This prolonged exposure should be considered a serious health risk, since the microcystins, precisely the most common toxins of cyanobacteria, are potent promoters of tumors, and therefore, the continuous consumption of small doses of hepatotoxins can lead to a higher incidence of liver cancer among the exposed population. The chronic or episodic exposure to cyanobacteria toxins is, without a doubt, the main cause of human exposure to these compounds, especially orally, through the supply of water. On the other hand, studies developed in Brazil by Magalhães et al. (2001) and Magalhães et al. (2003) demonstrate that fish (tilapias) and crustaceans are also capable of accumulating microcystins in their muscle tissues, sometimes even at levels way above the limit recommended by WHO, which represents a serious risk for the population that consumes this fish. The impacts causes by toxic cyanobacteria in Brazilian aquatic environments have been intensified by fish farming in tank networks, even in multiple use reservoirs which are used for public supply, and by the intensive cultivation of shrimp in reservoirs and estuaries.

6. Heavy metals and organic micro contaminants: the concentration of heavy metals in the environment occurs due to anthropogenic releases associated with the effluents from metallurgical and chemical industries or mining activities that target in most cases, aquatic environments. Only a few years ago, did the scientific community start to pay attention to human exposure to certain heavy metals, such as

methyl mercury (MeHg), cadmium (Cd) and lead (Pb), among others that, even in moderate and continued doses can cause irreversible toxic effects to human health, especially to the central nervous system. The aquatic systems are particularly sensitive to pollutants because they have longer food chains, which may favor biomagnification phenomena, in other words, the increase in the concentration between two successive trophic levels. Reservoirs are environments which are more susceptible to contaminations by metals and other micro pollutants, due to their mobilization from flooded soils. Tropical dams are again, examples of this (Kehrig 1999). One of the important potential consequences of damming is the intensified production of methyl mercury, associated to the anaerobic degradation of flooded organic matter, as has been amply documented in reservoirs located in regions of temperate and boreal climates (Guimarães et al. 2000). In tropical reservoirs, it is expected that the methylation process of Hg be favored due to: the elevated and irregular temperatures, the intensified microbiotic activity and due to the frequency and duration of the stratification of the water column, with the development of reducing conditions in the hypolimnium. Most recently, the problem of environmental contamination by organic micro pollutants (pesticides and polychlorinated biphenyls or PCBs) and polycyclic aromatic hydrocarbons (PAHs) are also being investigated in aquatic systems. The majority of these compounds are banned from being used or are controlled, and their production is controlled in most developed countries in the world. Despite DDT (dichlorodiphenyltrichloroethane) being prohibited in most developed countries, this product was, has been and probably will continue to be used in the control of vector diseases by insects and in the control of agriculture pests in underdeveloped and developing countries. The PCBs, widely used in large electric transformers in the past, also had their production and use restricted, yet some equipment still uses them. However, for tropical environments there is very little information regarding the behavior and the final destiny of this class of substances (Fig. 2.5).

Recommendations

It is suggested, as an element to guide public policies, that goals be established to reduce morbidity and mortality from diseases related to lack of access to good quality drinking water. In this sense, by the direct relationship with the quantity and quality of water and with the adequate disposal of excreta, infant diarrhea stands out as the greatest problem and as an adequate indicator, the reduction of which is possible through easily executed interventions. One proposes the establishment of a goal of reducing the percentage until the year 2014 (period of 5 years) in mortality cause by diarrhea in children under the age of five in Brazil.

Given the multisectorial nature of the “water problem” and its close links with health, one suggests the development, refinement and implementation of a composite index related to “water/health/environment/society”, capable of serving as a tool for the monitoring of access, of quality and of use of water and their relations, as specific

Fig. 2.5 Storm over Belo Horizonte, MG (photograph U. Confalonieri)

indicators of health. The idea is to have a quantitative indicator which allows for comparisons and which can be applied at different levels (ranging from communities to national levels), as a comprehensive instrument, capable of capturing the relations between social life, water, and the impacts of their uses in health. A possible alternative would be an adaptation of the "Water Poverty Index" (Sullivan 2002; Sullivan and Meigh 2007; Lawrence et al. 2002).

References

Ambrizzi, T., Rocha, R. P., Marengo, J. A., Pisnitchenko, I., Alves, L. M., & Fernandez, J. P. R. (2007). Cenários regionalizados de clima no Brasil e América do Sul, para o século XXI: Projeções de clima futuro usando três modelos regionais. Relatório 3. IAG/USP, CPTEC/INPE, 112 p.

Arnell, N. W. (2004). Climate change and global water resources: SRES emission scenarios and socioeconomic scenarios. *Global Environmental Change, 14*, 31–52.

Azevedo, S. M. F. O. (1996). Toxic cyanobacteria and the Caruaru tragedy. IV Simpósio da Sociedade Brasileira de Toxinologia. Recife. 83 p.

Azevedo, S. M. F. O. (2005). South and Central America: Toxic cyanobacteria. In G. A. Codd, S. M. F. O. Azevedo, S. N. Bagchi, M. D. Burch, W. W. Carmichael, W. R. Harding, K. Kaya, & H. C. Utkilen (Eds.), *Cyanonet: A global network for cyanobacterial bloom and toxin risk management* (pp. 115–126). Paris: IHP-Unesco.

Azevedo, S. M. F. O., Carmichael, W. W., Jochimsen, E., Rinehart, K., Lau, S., Shaw, G., et al. (2002). Human intoxication by microcystins during renal dialysis treatment in Caruaru, Brazil. *Toxicology, 181*, 441–446.

Baettig, M., Wild, M., & Imboden, D. M. (2007). A climate change index: Where climate change maybe most prominent in the 21st century. *Geophysical Research Letters, 34*, L01705.

Bates, B., Kundzewicz, Z. W., Wu, S., & Palutikoff, J. (2008). Climate change and water. IPCC/TSU, Technical Paper. 210 p.

BRASIL. (2005). Lei 11.107. Dispõe sobre normas gerais de contratação de consórcios públicos.

BRASIL. (2007). Lei 11.445. Estabelece diretrizes nacionais para o saneamento básico.

Carmichael, W. W., An, J. S., Azevedo, S. M. F. O., Lau, S., Rinehart, K. L., Jochimsen, E. et al. (1996). Analysis for microcystins involved in outbreak of liver failure and death of humans at a hemodialysis center in Caruaru, Pernambuco, Brazil. IV Simpósio da Sociedade Brasileira de Toxinologia.

Carmichael, W. W., Azevedo, S. M. F. O., An, J. S., Molica, R., Jochimsen, E., Lau, S., et al. (2001). Human fatalities from Cyanobacteria: Chemical and biological evidence for cyanotoxins. *Environmental Health Perspectives, 109*, 663–668.

CEDEPLAR, & FIOCRUZ. (2008). Migrações, mudanças climáticas, saúde segurança Pública: Cenários para o Nordeste brasileiro, 2000–2050. Relatório de Pesquisa, Belo Horizonte, CEDEPLAR/FICRUZ, March 2008, 775 p.

Guimarães, J. R. D., Meili, M., Hylander, L. D., Castro e Silva, E., Roulet, M., Mauro, L. B. N., et al. (2000). Net mercury methylation in five tropical flood plain regions of Brazil: High in the root zone of floating macrophyte mats but low in surface sediments and flooded soils. *Science of the Total Environment, 261*, 99–107.

Hilborn, E. D., Fournie, J. W., Azevedo, S. M. F. O., Chernoff, N., Falconer, I. R., Gage, M., et al. (2008). Human health effects workgroup report. In K. H. Hudnell (Ed.), *Cyanobacterial harmful algal blooms: State of the science and research needs* (pp. 589–616). New York, NY: Springer.

IBGE. (2000). *Pesquisa Nacional de Saneamento Básico*. Brasília: IBGE.

Jochimsen, E. M., Carmichael, W. W., An, J. S., Cardo, D., Cookson, S. T., Holmes, C. E. M., et al. (1998). Liver failure and death following exposure to microcystin toxins at a hemodialysis center in Brazil. *The New England Journal of Medicine, 36*, 373–378.

Kehrig, H. A. (1999). Investigação dos níveis de metilmercúrio em amostras ambientais e humanas. Tese de Doutorado, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Lawrence, P., Meigh, J., & Sullivan, C. (2002). The Water Poverty Index: An international comparison. Keele Economics Research Papers, 24 p.

Magalhães, V. F., Marinho, M. M., Domingos, P., Oliveira, A. C., Costa, S. M., Azevedo, L. O., et al. (2003). Microcystins (Cyanobacteria hepatotoxins) bioaccumulation in fish and crustaceans from Sepetiba Bay (Brasil, RJ). *Toxicon, 42*, 289–295.

Magalhães, V. F., Soares, R. M., & Azevedo, S. M. F. O. (2001). Microcystin contamination in fish from the Jacarepaguá Lagoon (RJ, Brazil): Ecological implication and human health risk. *Toxicon, 39*, 1077–1085.

Marengo, J. A. (2008). Água e mudanças climáticas. *Estudos Avançados, 22*, 83–96.

Marengo, J. A., Nobre, C. A., Salati, E., & Ambrizzi, T. (2007). Caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI. Ministério do Meio Ambiente, SBF/ProBio, Brasília. 54 p.

Pouria, S., Andrade, A., Barbosa, J., Cavalcanti, R., Barreto, V., Ward, C., et al. (1998). Fatal microcystin intoxication in haemodialysis unit in Caruaru, Brazil. *The Lancet, 352*, 21–26.

Prüss-Ustin, A., Bos, R., Gora, F., & Bartram, J. (2008). *Safer water, better health. Costs, benefits and sustainability of interventions to protect and promote health*. Geneva: WHO. 53 p. Retrieved from http://www.who.int/quantifying_ehimpacts/publications/saferwater/en/index.html.

Rezende, S. C. (2005). Utilização de instrumentos demográficos na análise da cobertura por redes de abastecimento de água e esgotamento sanitário no Brasil. Tese de Doutorado, Universidade Federal de Minas Gerais, Belo Horizonte.

Schuster-Wallace, C., Grover, V., Adeel, Z., Confalonieri, U. E. C., & Elliot, S. (2008). *Safe water as the key to global health*. Canada: United Nations University, INWEH. 28 p.

Sullivan, C. (2002). Calculating a Water Poverty Index. *World Development, 30*, 1195–1210.

Sullivan, C., & Meigh, J. (2007). Integration of biophysical and social sciences using an indicator approach: Addressing water problems at different scales. *Water Resources Management, 21*, 11–128.

Teixeira, M. G. L. C., Costa, M. C. N., Carvalho, V. L. P., Pereira, M. S., & Hage, E. (1993). Gastroenteritis epidemic in the area of the Itaparica Dam, Bahia, Brazil. *Bulletin of the Pan American Health Organization, 27*, 244–253.

United Nations Statistics Division. (2008). Millennium development goals indicators. Retrieved from http://mdgs.un.org/unsd/mdg/default.aspx.

WHO/UNICEF. (2006). Protecting and promoting human health. In *Water, a shared responsibility. The UN Water Development Report 2* (pp. 202–240). Paris: UNESCO.

http://www.springer.com/978-3-319-41371-6

Waters of Brazil
Strategic Analysis
de Mattos Bicudo, C.E.; Galizia Tundisi, J.; Cortesão Barnsley Scheuenstuhl, M. (Eds.)
2017, XII, 191 p. 46 illus., 32 illus. in color., Hardcover
ISBN: 978-3-319-41371-6