WATER-RELATED DISASTERS IN BRAZIL: PERSPECTIVES AND RECOMMENDATIONS

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Introduction

The importance of water to sustain life and health is an undeniable statement. Nevertheless, in some situations water may cause problems and even a threat to life. The United Nations (UN) organization foresees risk of conflict in 46 countries in near-future because of water (CHADE, 2008).

When inhabited places are associated to triggering factors, such as punctual extreme events, natural (or other) disasters may take place. According to the United Nations International Strategy for Disaster Reduction - UNISDR, a disaster is "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR, 2009). Water-related disasters may happen mainly due to overabundance (floods, flashfloods, dam failure) or shortage (droughts, problems for public supply of potable water, impacts on agriculture). "Disasters are not related to averages, they are caused by extremes" (OGURA, 2013). Furthermore, other disasters may involve water resources at different ways, affecting environment, public health, urban dynamics and rural production.

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There are different and connectable risk scenarios concerning a disaster situation. An integrated approach for risk management is necessary to face this complexity, including activities related to prevention, mitigation, preparedness, response and recovery.

Prevention and mitigation must be highlighted as activities to minimize risks and make vulnerable systems more resilient, reducing human and material losses and damages.

This work aims to discuss the nexus between water resources and disasters in Brazil, pointing out the main challenges to reduce vulnerability and suggesting actions for an integrated management of water resources, public health and natural disasters.

Water and Disasters

When water excess stands for a disaster risk

Floods are a well-known disaster to Brazilians. According to EM-DAT (2014), Brazil is classified among the countries most affected by floods in the world, with high numbers of affected people and deaths (EM-DAT, 2014, TOMINAGA *et al.*, 2009).

Nevertheless, there is not a straightforward relation between floods and disasters. In some uninhabited areas, floods are just physical processes: they are not considered disasters because there are no affected people. Sometimes floods are not a natural phenomenon, as in dam failure situations. Also, climatic extremes may increase frequency and intensity of floods. But all these occurrences may not characterize disasters. Hydrological disasters do happen when their impacts hit a vulnerable community, overwhelming its ability to recover.

In urban areas, when there is an intense precipitation and the soil is not able to absorb all the water, the excessive water volume runs to the urban drainage system (TUCCI, 2008). Depending on local topography, this excess may reach areas next to rivers (TUCCI and BERTONI, 2003; GOERL and KOBIYAMA, 2005). In some Brazilian municipalities, urban expansion leads to changes in the original hydrological cycle, due to deforestation, erosion, siltation, land waterproofing through concrete and asphalt, structural interventions on rivers and irregular buildings near rivers' borders (BRASIL, 2007). Due to both socioeconomic problems and the intense urbanization process, part of low-income population occupies risk areas, increasing their vulnerability (GOERL AND KOBIYAMA, 2005).

As floods frequently reach large areas in Brazil, there are significant economic losses and many disturbances for daily life (BRASIL, 2007) legitimating the necessity of strong monitoring systems to either avoid or minimize those impacts.

In Brazil, the monitoring of floods is supported by organizations such as ANA – National Water Agency, CPRM – Geological Survey of Brazil and Cemaden – Brazilian Center for Monitoring and Warnings of Natural Disasters. Some municipalities also perform their own monitoring. The monitoring of flashfloods, however, poses a special challenge, because there is little time to provide warnings (GOERL and KOBIYAMA, 2005). Goerl and Kobiyama (2005) created an index to distinguish floods and flash floods, including environmental and social considerations, to support monitoring and warning processes. Goerl and Kobiyama (2005) also modified Stephenson's hazard index (STEPHENSON, 2002), considering that the higher the flow' speed, the lower the flow's height that is necessary to cause damage. It is also possible to consider steepness and roughness in the same index.

Beyond technical studies and research about floods and flash floods, efforts have been made to evaluate economic losses caused by floods. Corsi *et al.* (2012) adapted DaLa (*Damage and Loss Assessment*) method for the after-flood situation in the municipality of São Luis do Paraitinga, in São Paulo state countryside. The evaluation includes effects and impacts on varying economic and social sectors, infrastructure and environment, to estimate the necessary value for rebuilding, risk management support and addressing of public policies towards natural disasters risk prevention. The authors evaluated a R$ 103,63 million damage for São Luiz do Paraitinga. Housing and transport were the main affected sectors (CORSI *et al.*, 2012).

When water shortage poses a disaster risk

While floods inflict undeniable impacts to urban spaces, drought's impacts may be underrated, although it is a recurrent problem in many Brazilian municipalities.

In technical jargon, "drought is characterized by lower than average precipitation in a given area over an extended timeframe, leading to an inadequate supply of water" (McCANN *et al.*, 2011a). Nevertheless, Tuan (2005), analyzing drought's impacts, has described it as more than the absence of rain: "it is an invisible phenomenon, except for its consequent devastation: small crops, dead animals, and malnourished people".

McCann *et al.* (2011a) mention several implications for public health as consequences of the lack of water: drought often leads to decreased food production, leading to famine and malnutrition in some regions. Air quality may be affected due to prolonged particulate suspension in the air, which aggravates lung diseases (McCANN *et al.*, 2011a). Smoke from wildfires, common in droughtstricken areas, also trigger respiratory problems (McCANN *et al.*, 2011a). There can be an increased incidence of vector-borne diseases and fungal diseases – during droughts, fungal spores are aerosolized and easier to inhale (McCANN *et al.*, 2011a).

Consequences of drought may widely vary and so do the types of drought, despite the only word used to characterize the phenomenon. Kobiyama (2005) classifies droughts in three categories: (1) climatological drought, when precipitation values are below normal figures for the area; (2) hydrological drought, when rivers and reservoirs water levels are low, and (3) edaphic drought, when the soil lacks humidity. Santos (2007) quotes four types of droughts. Firstly, the (1) meteorological drought is characterized by the absence of precipitation during a period of time. The meteorological drought causes a decrease in water from rivers and reservoirs, and then the (2) hydrological drought takes place. The (3) agricultural drought implies a water deficit in soil, resulting in agriculture losses. The (4) socioeconomic drought is a consequence of the other types, bringing about poverty and economic stagnation for the affected regions.

In Brazil, population from the semi-arid region deals with difficult access to water and shortage of water and foods, resulting in increased infant mortality, poor health conditions and economic constraints (SANTOS, 2012).

Based on climate, most of Brazilian Northeast region is characterized as semi-arid, according to Thornthwite classification (AYOADE, 1988). This classification is based on an aridity index (AI): the P/PET ratio, where (P) stands for the average annual precipitation and (PET) stands for the average annual potential evapotranspiration (SOUZA FILHO, 2011). In A semi-arid region, the IA varies from 0,20 to 0,50, while in the hyper arid it is less than 0,05 and in dry sub humid regions it can achieve 0,65 (SOUZA FILHO, 2011).

There is a large spatial and time variability of water occurrence in the semi-arid region (SOUZA FILHO, 2011). The mean precipitation during a year may vary from 400 to 2000 mm (VAN OEL *et al.*, 2010). Some characteristics of this region are: intermittent rivers, periodic droughts and frequent floods, water use driven toward human and agricultural supply, reservoirs with low hydrological efficiency and small precipitation and runoff values (VIEIRA, 1995). While the specific runoff in Brazil is 21 L s^{-1} km^{-2}, in Brazilian Northeast it is just 4 L s^{-1} km^{-2} (SOUZA FILHO, 2011). There are many wells in the region, but often their use is restricted by lack of security, maintenance and operation measures.

Beyond the drought in the Northeast region, there are variations for the problem of water shortage. Favero and Diesel (2008) emphasize that water shortages may be a consequence of drought, but may also be artificially created, as a consequence of over--exploitation of deep and surface waters, water quality degradation, inappropriate land use and decreased ecosystem's capacity for water storage. In Brazil, groundwater is used by ~40% of population (CARY *et al.*, 2013; FOSTER *et al.*, 2013; HIRATA *et al.*, 2012; SUHOGUSOFF *et al.*, 2013). In São Paulo state, 75% of municipalities use groundwater (CARY *et al.*, 2013; FOSTER *et al.*, 2013; HIRATA *et al.*, 2012; SUHOGUSOFF *et al.*, 2013). In Recife (Pernambuco State, Brazil), due to severe droughts (such as 1998/1999 drought) and also to frequent water rationing in the city, private dug wells have been used as a supplementary source for water supply (CARY *et al.*, 2013; FOSTER *et al.*, 2013; HIRATA *et al.*, 2012; SUHOGUSOFF *et al.*, 2013). Most of the wells are irregular and not recognized by administrative agencies. Although wells ensure water safety during drought periods, many of them are affected by salinization and contamination and their illegal situation makes water management difficult in the State. As technologies against salinization are not cost-effective, many dug wells are lost or abandoned.

Dependence from aquifers is common to other Brazilian cities, such as Natal (RN), Fortaleza (CE), Brasília (DF) and São Paulo (SP) (CARY *et al.*, 2013; FOSTER *et al.*, 2013; HIRATA *et al.*, 2012; SUHOGUSOFF *et al.*, 2013). For an ideal management, water supply should sum up ground and surface water, as complimentary resources (CARY *et al.*, 2013; FOSTER *et al.*, 2013; HIRATA *et al.*, 2012; SUHOGUSOFF *et al.*, 2013).

Water-related Socio-natural hazards

According to the UNISDR Terminology on Disaster Risk Reduction (UNISDR, 2009), socio-natural hazards are "the phenomenon of increased occurrence of certain geophysical and hydrometeorological hazard events, such as landslides, flooding, land subsidence and drought, which arise from the interaction of natural hazards with overexploited or degraded land and environmental resources". Moreover, "this term is used for the circumstances where human activity is increasing the occurrence of certain hazards beyond their natural probabilities. Evidence points to a growing disaster burden from such hazards. Socio-natural hazards can be reduced and avoided through wise management of land and environmental resources" (UNISDR, 2009).

Water quality degradation

Scattered sources of pollution perform one of the hazards that link water, environment and societal matters. The process starts with waste disposal in wrong places, blocking manholes. In sequence, water from precipitation does not go through manholes, causing floods in urban spaces, where most of the surface is concrete or asphalt. Water from floods melts to animals' fecal detritus and urine, dead animals, manure and other pollutants and afterwards the surface runoff carries all this mixture to houses, rivers, lakes, reservoirs, and groundwater and also to treatment plants. Problems encompass health (increasing incidence of diseases) environment (decreasing quality in water resources) and economics (increasing treatment costs of supply services and cleaning of public spaces). In details, the consequences may include: death of fishes, water quality degradation, unsafe drinking water, aesthetic pollution, bacterial pollution, sediment deposition, dissolved oxygen depletion, eutrophication, impacts to aquatic life due to toxic material, contamination by heavy metals, decreasing of water resources self-purification.

Eutrophication and cyanobacteria blooming may appear as a secondary disaster, being a consequence of primary disasters, such as floods, but they also may represent a direct hazard. The Caruaru disaster sadly illustrates this condition: in 1996, 76 people died in Brazilian Northeast because they were submitted to hemodialysis with cyanobacteria--contaminated water (BITTENCOURT-OLIVEIRA & MOLICA, 2003). According to UNISDR (2009) criteria, cyanobacteria blooms in lakes and reservoirs can be considered as potential biological hazards: some cyanobacteria produce toxins that can be a threat for public health (ESTEVES, 1988; MILLIE *et al.*, 1992; RICHARDSON, 1996; AZEVEDO & BRANDÃO, 2003, TUNDISI, 2003; VIDOTTI & ROLLEMBERG, 2004; PITOIS *et al.*, 2001; VINCENT, 2004) because of the reactions they cause in mammals bodies, such as stomach diseases, allergic reactions, skin problems and development of tumors (PITOIS *et al.*, 2001).

Nevertheless, eutrophication and cyanobacteria blooms are closely related to other hazards and disasters. Most of Brazilian reservoirs receive a great discharge of nutrients, such as phosphorus and nitrogen and there are high temperatures and constant solar radiation during most of the year. Consequently, there is an ideal environment for the growing of blooms. As a large number of people depend on those reservoirs for water supply, it poses a risk for human health and causes financial losses for professionals that depend directly on reservoirs for fishing and touristic/recreational activities.

There are two main driving factors for cyanobacteria blooming dynamics: phosphorus and nitrogen concentrations and water column stratification. Phosphorus and nitrogen concentrations in water are determined in particular by land use conditions in reservoirs borders. The stratification often happens after either frontal systems occurrence or specific conditions of wind and precipitation (TUNDISI, 2010; MORAES *et al.*, 2010, IZYDORCZYK *et al.*, 2005). Undoubtedly, current weather forecast applications should be extended to monitor cyanobacteria blooms.

Erosion

Other example of water-related socio-natural hazard is the hydric erosion. Inappropriate land use and irregular allotments in steep hills and river borders expose large areas to erosive processes. In São Paulo metropolitan region, the average soil loss through erosion is estimated in 13,5 m^3 of soil during a year, which means a sediment load in both natural and constructed drainage systems, worsening floods (SANTOS, 2012).

In the countryside, intense erosion may cause environmental degradation and lead to soil impoverishment and water resources pollution (ANDREANI JUNIOR *et al.*, 2013). Brazilian permanent protection areas (APPs), such as riparian vegetation, either prevent or minimize sediment movement from erosive processes in agricultural areas and therefore hold pesticides and pollutants (buffer zones) (ADDISCOTT, 1997).

Agricultural processes

Agricultural processes are one example more about interactions involving water, climate, weather, economics, population and environment. Together, these factors may amount to a disaster. Agriculture has become a contributor to global environmental changes through land use change and irrigation, changing the global hydrological cycle concerning both quality and amount (GORDON, 2010). Studies suggest we will need from 70% to 100% more food in 2050 to feed 9 billion people (WORLD BANK, 2008; ROYAL SOCIETY OF LONDON, 2009; GODFRAY *et al.*, 2010). Agriculture accounts for ~85% of global consumptive use of water (GORDON, 2010; FOLEY, 2005) and irrigation is responsible for 66% of water consumption in general (GORDON, 2010; FALKENMARK & LANNESTAD, 2005). It has changed river flows patterns, downstream and costal ecosystems and wetlands and lead to river depletion in many places (GORDON, 2010). Charles (2010) mentions that food producers deal with increasing competition for water, land and energy and that there is a clear necessity of inhibiting the negative effect of food production on environment.

Human health

As an additional remark on the aspects involving water-related socio-natural hazards, we must consider that unsafe water poses serious threats to human population health. According to Confalonieri (2011), "there is an interface between water and health, linked through the biophysical system of water (ecosystem), the socio-economic and political system of water (the hydro-social cycle) and human health". Confalonieri (2011) categorizes infectious diseases transmitted through water, as follows: they "can be directly waterborne, such as giardiasis, cryptosporidiosis and cholera; water-washed, such as schistosomiasis; or water-related, where water is an essential component of the transmission cycle, for example as a mosquito-breeding habitat for malaria, dengue fever, chikungunya fever and lymphatic filariasis".

In a post-disaster situation, the disaster still happens: risk of post-flood diseases

Many diseases are directly linked to water quality, even in the absence of other disasters occurrence, characterizing a biological disaster. After natural disasters, such as floods, some of these diseases may characterize a secondary disaster. This relationship is specially known concerning leptospirosis. A technical note from the Brazilian General Coordination for communicable diseases (BRASIL, 2011) illustrates this context. A piece of this document, reproduced below, highlights guidance and directions for epidemiological surveillance institutions under Health secretariats:

> "1. Every year during summertime, an increase in number of leptospirosis cases is one of the main epidemiological occurrences after floods. To warn epidemiological surveillance institutions from Municipal and State Health Secretariats about their expected conduct in natural disasters situations, such as floods, the Health Surveillance Secretariat under the Health Ministry (SVS/MS) informs:
> a. In natural disaster situations, such as floods, individuals or groups of people who had contact with contaminated water may infect themselves and show symptoms of the disease" (BRASIL, 2011).

Santos *et al.* (2012) studied the data from the Brazilian region of Vale do Itajaí during 2008 to draw scenarios for risks of leptospirosis outbreak in post-disaster situations. Based on the monitoring of precipitation, and River Itajaí´s water flow and level, the authors point the possibility of providing leptospirosis warnings 3 weeks before the disease peak. The re-building of hydrological events and association to spatial and time distribution of diseases are important factors for an effective monitoring (SANTOS, 2012; SANTOS, 2013).

Also concerning the link between water quality and human health, the "Special Report for Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (IPCC, 2012) conducted a study case for cholera, emphasizing that the prevention of contact between a hazardous exposure and susceptible host includes promoting access to clean water and reducing the likelihood of population displacement.

Furthermore, some specific types of disasters, such as floods, modify *Aedes* and *Anopheles* mosquitoes' ecosystems, leading to dengue fever and malaria outbreaks (IPCC, 2012).

Diseases outbreaks are caused either by a disruption on water supply and sanitation systems after a disaster or by deficient hygiene conditions, as in people conglomerates. Other diseases are also related to disasters, although this relation may not be straightforward. Among diseases associated to inappropriate sanitation conditions, we can mention cholera, gastrointestinal infections, typhoid fever, giardiasis, schistosomiasis and shigellosis, poliomyelitis, remembering that in Brazil poliomyelitis was eradicated during 1990 decade (MENDONÇA & MOTTA, 2007).

Expected Scenarios and main challenges

The World Commission on Water, supported by the UN and the World Bank, estimated that the increase of population till 2025 will demand an increase of 17% of water for irrigation and 70% more water for urban supply (Ramos, 2007; World Water Council, 2000). These demanded increases, associated to other water destinations, mean a 40% addition on total demand for water. The World Commission on Water states the necessity of doubling global investments in water and sanitation to comply with the increasing demand and to reduce the number of people without clean water (1 billion) and sanitation (3 billion) (Ramos, 2007; World Water Council, 2000). Involved resources, that currently amount for US$ 70-80 billion per year, should evolve to US$180 billion to reduce lack of sanitation to 330 million people till 2025 (Ramos, 2007; World Water Council, 2000).

In addition to an increasing demand for water, the expected scenario for next decades includes impacts of global environmental changes on water systems. A single event can produce effects on local, regional, national, and international levels. These effects could have been the direct result of the event itself - as a consequence of the event - or through indirect impacts such as a reduction in food production or a decrease in available resources (IPCC, 2012).

Some of the global projections for future pointed by the IPCC's report (IPCC, 2007) include an increase on diarrhea incidence due to deficient access to good quality water and changes in spatial distribution and population dynamics of infectious and parasite endemic disease vectors, such as mosquitoes related to dengue and malaria. Brazil would be further impacted in relation to infectious endemic diseases, such as malaria, leishmaniosis, leptospirosis and dengue; and problems concerning water supply, due to the salinization of natural depositions underground, as a consequence of sea level raise (IPCC, 2007).

Brazil concentrates approximately 12% of world´s surface water, with 8 large watersheds (SUASSUNA, 2004; ISA, 2005)). Nevertheless, in Brazilian Southeast region, where most of population lives, there is only 6% of available water resources and a high demand for those resources for industry, agriculture, irrigation, hydroelectric energy generation and public supply (ISA, 2005) (Water resources distribution in the country points to more frequent shortages (with related impacts) in near future. It poses the challenge to improve management programs to prevent disasters accordingly.

Recommendations for prevention and mitigation of water-related disasters

In this item we suggest some structural and non-structural measures to improve risk management of water-related disasters in Brazil, especially for prevention and mitigation issues.

Planning for integrated inter-institutional actions

Natural phenomena which may cause disasters may increase in frequency and intensity in some regions (IPCC, 2011). Increased problems are also expected concerning urban expansion, overexploitation of water supplies, agricultural losses, erosion, and pollution. Establishing an effective risk management is crucial to deal with disaster triggers and amplifiers. The UNISDR (2009) defines disaster risk management as "the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster".

Administrative directives and organizations for disaster risk management have evolved last years in Brazil, mainly through Brazilian Law 12.608 (Brasil, 2012). Nevertheless, there are different (and separated) institutions dealing with water resources, environment, urbanization, health and disasters in Brazil. It is necessary to analyze the interrelation of various responding organizations (HEIDE, 1989) and to promote coordination among the various agencies involved in risk management. It is not advisable to wait for a disaster outbreak to plan inter-institution communication when the event is happening. All aspects concerning this communication must be planned beforehand and, whenever it is possible, through formal signed agreements. During emergence situations, information must flow quickly and clearly and decisions must be immediate.

Adjusting different communication strategies to specific groups or agencies performs a crucial task in water-related disaster management. Even when enough information has been collected, much of it is published in specialized journals, not easily accessible to emergency responders and disaster planners (HEIDI,1989; QUARANTELLI, 1998). In addition, many reports use jargons addressing science professionals, resulting in either misunderstandings or insufficient understanding from members of emergency response organizations.

An appropriate planning must include efficient communication strategies in one side and efficient capacity building programs on the other side. Operational skills and capacities must be fostered to recognize vulnerabilities, identify solutions and gather efforts to minimize disaster risks and face disaster events. Determining predictable and recurrent problems is essential to draw a preparedness disaster plan (HEIDI, 1989).

Strategies, policies and improved coping capacities must objectively analyze disaster characteristics, such as location, type, duration, and foresee possible difficulties and solutions. Ideally, policies have to integrate sanity, housing, environmental issues and civil defense. In Brazil, the Ministry of Cities tackles territorial exclusion and environmental degradation in Brazilian municipalities: an advance towards socio-environmental disasters policy (Brasil 2007). In addition, the Brazilian Ministry of Science, Technology and Innovation supports Cemaden and the Ministry for National Integration supports the Brazilian Centre for Management of Risks and Disasters – CENAD. It is expected that these agencies strengthen their interactions to work synergistically.

Other strategies should target: water management to create multifunctional agricultural ecosystems with better understanding of landscape ecology processes and acknowledgement of ecosystems services beyond food production (GORDON, 2010); land use policies beyond restrictive actions, suggesting uses compatible to water conservation and articulated protection guidelines (Santoro *et al.*, 2009).

Knowledge and information integrated management

Heidi (1989) points that "organizations evolve to take care of common community problems. Disasters, however, pose unique problems often different even from the more routine emergencies that organizations face on a day-to-day basis."

To deal with this unfamiliar condition imposed by disaster situations, a risk management must be, first of all, a knowledge management, including technical-scientific knowledge, risk scenarios and geographic database.

Data collection concerning disasters in Brazil encompasses meteorological, hydrological and geotechnical data. Government agencies, such as ANA, INMET and Cemaden are working at the enlargement of current observational system, through installation of automatic and semi-automatic pluviometers, hidrometeorological stations and meteorological radars.

Data integration should be made with computing systems able to deal, represent and extract information from this big, growing and heterogeneous dataset (Big Data). This challenge requires standard protocols, following international interoperability standards, such as the Open Geospatial Consortium (OGC) (Open Geospatial Consortium - OGC Reference Model, 2011) and also national interoperability standards, under the National Space Data Infrastructure (INDE[i]). Soler *et al.* (2012) rise an important question in computational resources for natural disasters monitoring: how to retrieve and mine data - usually Big Data (LONDE *et al.*, 2013) - on a friendly approach to decision makers from different backgrounds? The first step towards water-related risk management must be the integration of water data with health, social and environmental datasets. Most of the efforts to standardize disaster data do not account for impacts on health and environment, due to lack of formally collected and analyzed information. Despite the lack of information, disasters with consequence to health and environment cause high rates of deaths and affected people. It is important not only to collect, but also to centralize information regarding these issues, keeping a common pattern for all registers. Moreover, data integration, as well as any actions concerning disaster risk, implies the involvement of varying institutions.

Global change perspectives pose the need for greater information on risks before the events occur, that is, early warnings (IPCC, 2012). The "Special Report for Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" (IPCC,

2012) mentions this necessity as a common factor for analyzed case studies. Furthermore, the report states, the importance of investments in knowledge and information as a recurring theme, and includes observational and monitoring systems.

The major challenge, though, is to foster studies about the interactions of water, environment, population, urban problems, weather, climate and health and plan accordingly.

Actions for mitigation of floods and droughts

Effective strategies for prevention and mitigation of disasters are thought to reduce the impacts and risks of hazards through proactive measures taken before an emergency or disaster occurs. According to Ayala-Carcedo (2004, p. 288):

" Anti-hazard and anti-vulnerability measures are usually called structural measures, and may be classified in active measures (anti-hazard) and passive ones (anti-vulnerability); anti-exposures measures are called non-structural. Structural measures include, (...) for floods: dams, channels, fluvial dykes, dwelling with basement. Main non-structural measures are: warning for evacuation or avoidance of risk, land-use planning based on risk maps or special procedures, training for risk, insurance."

Specific structural measures to minimize floods must include a proper architecture of drainage systems, construction of reservoirs to slow rainwater (large pools and individual reservoirs in buildings), incentive to reduce land waterproofing (through permeable floors, green roofs, enlargement and maintenance of green areas in parks and gardens), recovery of river margins, desilting of rivers, desocupation of security areas next to rivers´ margins, and monitoring of urban housing.

Concerning droughts, structural measures must include construction of legal dug wells, inspection of dug wells, and catchment and treatment of groundwater.

For the semi-arid region, the challenge is developing a strategy for adaptation of semi-arid communities to its nature. It includes the investment on infrastructure, the management of water resources, and, moreover, the management of climatic risks (SOUZA FILHO, 2011). In details, we should ensure rural population access to water, effective use of water in production processes, inclusion of social actors in decision making systems, conflicts management and infrastructure operation (SOUZA FILHO, 2011).

Concerning global change impacts, the IPCC´s Report (IPCC, 2007) states that it is necessary to modify structural constraints of population vulnerability to impacts of climate on health, such as housing in risk areas, poor basic sanitation; exposition to social violence, climate influenced transmission of epidemics; and development and improving of early warning systems against climatic extremes (IPCC, 2007).

As general recommendations, it is advisable to improve the elaboration of hazard mappings, the adoption and enforcement of land use and zoning legislation, the mapping of flood plains(with housing areas and risk areas), inspection of homes in flood-prone areas, creation of disaster mitigation public awareness programs and enforcement of insurance programs.

Actions for mitigation of disasters related to water quality

Considering the possibilities of biological disasters either triggered or worsened by floods and droughts, actions to minimize these events (item 5.3) appear as indirect mitigation actions for disasters related to water quality.

Specific actions to mitigate disasters related to water quality must include water quality monitoring in reservoirs, wetlands and drought regions, distribution of sanity kits (containing tablets or devices for water disinfection), fostering basic sanity systems in municipalities, and monitoring and regulation of pollutants and sediments carried to water bodies. Chemicals from agriculture or industry must undergo a strict supervision, as they may cause water contamination during floods or through discharge in water bodies.

"The political and social will must be fostered to invest in long-term improvements in water and sanitation facilities that will subsequently mitigate much of the human misery associated with disasters" (McCANN *et al.*, 2011b)

Concluding remarks

A whole planning for a water-related disaster risk management should consider all disaster risk management phases: prevention, mitigation, preparedness, response and recovery. Also, roles and actors must be identified according to Brazilian context. A detailed discussion targeting water-related disaster in each phase of risk management is being prepared for a subsequent paper, following this one.

We must highlight that any disaster mitigation plan will depend on communities participation to be effective. It is not different for specific water-related disaster management. People should understand how the monitoring and warning systems operate, when and why it is necessary to evacuate a risk area, what to do during a disaster situation. Also, they must be able to distinguish different roles and organizations related to Civil Defense and to identify who they can count on, where they should go, what they should take. In addition, concerning water-related disasters, it is essential that risk areas residents be informed about hygiene procedures to take during and after disasters.

In a disaster situation, water becomes the most precious good for affected people, in spite of contamination, shortage and spread of diseases. Those people will depend on safe water to be healthy and then be able to act towards full recovery. Water resources, then, must be a priority in stake holders' agenda: to ensure monitoring, preservation and appropriate supply should be an important part of an effective water-related disaster planning.

Note

i http://www.inde.gov.br

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WATER-RELATED DISASTERS IN BRAZIL: PERSPECTIVES AND RECOMMENDATIONS

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Abstract: Water-related disasters in Brazil are frequently connected to floods, which are responsible for high numbers of affected people and deaths in the country. Nevertheless, there are other aspects to be considered about the relationship between water and disasters. Droughts and erosion, for instance, affect many regions in the country. Moreover, water management implications also relate to environmental, societal and natural disasters. The consequences and secondary effects of the hydrological disasters are also an important aspect to be evaluated: epidemic diseases and unsafe water for human consumption are two problems in the post-disaster phase. In this article we target vulnerability linked to water resources and disasters, point out the main challenges to reduce it and suggest actions for an integrated management of water resources, public health and natural disasters.

Key Words: natural disasters, water resources, vulnerability

Resumo: Quando se fala em desastres relacionados à água no Brasil, faz-se uma associação direta com as inundações, que são responsáveis por muitos registros de mortes e pessoas afetadas no país. Entretanto, há outras extensões da interface entre água e desastres que merecem atenção. O extremo oposto das inundações, por exemplo, se traduz em seca efetiva e seca agrícola (seca verde), ambas com sérias consequências para a população atingida. A erosão hídrica e as implicações do manejo da água em questões de fragilidade ambiental, por sua vez, relacionam-se a desastres de caráter ambiental. Outro aspecto importante são os desdobramentos do desastre hidrológico em si, pois há efeitos que surgem e se mantêm no período pós-desastre, como epidemias e ingestão de água imprópria para consumo humano. Neste artigo foram apontados os principais desafios para diminuir os riscos relacionados a desastres e recursos hídricos e sugerimos ações para um gerenciamento integrado de recursos hídricos, saúde pública e desastres.

Palavras-chave: desastres naturais, recursos hídricos, vulnerabilidade.

***Resúmen*:** Los desastres relacionados al agua en Brasil en general son asociados a inundaciones, pues estos eventos son responsables por 59% de los desastres registrados en el país. Sin embargo, hay otras relaciones importantes entre agua y desastres y hay que tomarse en cuenta los efectos de estas relaciones. Las sequías, por ejemplo, afectan varias regiones en Brasil. Además, la erosión hidrológica y la gestión del agua en el ambiente tienen relación con desastres ambientales. Las consecuencias de los desastres hidrológicos, así como sus efectos secundarios, también son un aspecto importante para análisis: las enfermedades epidémicas y el consumo de agua no adecuada constituyen graves problemas en las situaciones que se siguen a un desastre. En este trabajo se buscó relacionar vulnerabilidad y los recursos hídricos, apuntando los principales retos para reducir los efectos de los desastres relacionados a estos temas y sugiriendo acciones para una gestión integrada de los recursos hídricos, la salud pública y los desastres naturales.

***Palabras clave*:** desastres naturales, agua, vulnerabilidad.