HUMAN IMPACT ON TROPICAL FRESHWATER ENVIRONMENTS

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Keywords: water pollution, environmental impact, water use, watershed.

Contents

Summary

This chapter approaches a series of aspects related to anthropic impact on continental aquatic ecosystems found in tropical regions: water usage policies, water resources degradation and loss of benefits, tropical diseases, water crisis, environmental biomonitoring programs, aquatic biodiversity, watersheds as the main focus for integrated intervention acts, reference sites for biomonitoring efforts, maintenance of gallery/riparian forests as intervention actions, and litter breakdown as a tool to assess human impacts.

1. Introduction

Water is, without doubt, an essential element for life. Today, even with all the technological advances of the modern world which provide comfort and practicality to our life, water continues to be one of our main concerns. As water availability is indispensable for the colonization and permanency in any environment, the lack of it can limit the distribution of living organisms, including human beings. Like our most primitive ancestors, we are still dependant on this resource that continues to be misused and wasted despite the fact that it is getting scarcer every day.

Despite some disagreements, the estimates of the relative distribution of the water between the several planet compartments point to (Von Sperling, 2006): 97.07526% in the oceans, 1.91523% in glaciers, 0.98828% in underground waters, 0.01646% in lakes, 0.00366% concentrated as soil moisture, 0.00095% in the atmosphere, 0.00009% in rivers and 0.00007% in living organisms. Thus, the freshwater available for human consumption found in rivers and lakes represents a percentage of around 0.01% of all water on the planet. Also, sources of freshwater are not homogeneously distributed around the planet's surface. There are clearly regions of the globe where freshwater is more abundant, such as the Amazon basin, and desert areas where this resource is more limited.

Currently, 11 countries in Africa and nine in the Middle East face severe water shortage problems. The situation is also critical in Mexico, Hungary, India, China, Thailand and the United States. Asia, Africa and Europe are the regions with less water available for human consumption (Table 1). On the other hand, Latin America has the greatest water availability per person in the world. However, the inappropriate distribution of this resource has caused shortage problems in several countries. For example, Brazil possesses 11.6% of the available world's freshwater but nearly 70% of it is in the Amazon basin while the other 30%, that supplies 93% of the Brazilian population, is unevenly distributed around the country.

Table 1. Water availability per person in World regions (1000m^3).

The data found in Table 1 also show a tendency for decrease in water availability in all regions as time passes by. The superficial freshwater available (lakes, rivers and reservoirs) that is used for treatment and distribution has been suffering the effect of environmental deterioration processes (e.g. forest clearance and pollution). The intensive use of water resources has led to an adoption of measures, such as the regulation and modification of watercourses. These cause alterations in ecosystems and microenvironments as well as prejudice the fauna and flora. Increasing water pollution is one of the main characteristics of water usage around the world. In developing countries there are few cities that possess treatment stations for domestic, agricultural and/or industrial waste water, including the water contaminated with agrotoxics. As a result of spring water degradation, treatment to make it suitable for human consumption is becoming difficult and expensive.

The richness of water resources in Brazil does not imply that there is good water availability for the population. There are regions that are affected by droughts throughout almost all the year where access to the water is extremely difficult. In addition to this, in regions where water is abundant its quality can often be compromised by the lack of basic sanitation. According to the National Health Foundation (Fundação Nacional de Saúde, FUNASA), only 42% of Brazilian residences are provided with domestic waste water collection services. Besides this, the water distribution network is not evenly distributed among regions and between urban and rural population.

According to the Brazilian Institute of Statistics and Geography (Instituto Brasileiro de Geografia e Estatística, IBGE), 77.8% of Brazilian residences have water distribution services. Nearly 6.97 million residences (15.6%) use wells and springs, and 2.95 million residences (6.6%) use other types of water supplies. Data from the World Health Organization (WHO) and the Pan American Health Organization (PAHO) showed that the improvement in water supply and the adequate collection and disposal of sewage and solid waste helped to prevent 80% of typhoid and paratyphoid fever cases and reduced more than 70% of trachoma and schistosomiasis cases. These actions also helped to prevent half of the occurrences of dysentery, amoebiasis, gastroenteritis and skin infections. Beyond the concerns about its distribution, there is also a strong concern about the quality of the water offered to the population. Research performed by the IBGE showed that in 1,974 Brazilian municipalities the water supplied by the public distribution service does not have any previous treatment. That means that 7.2% of the water provided to the Brazilian population is not submitted to any treatment or any disinfection process.

2. Water Usage Policy: From medieval civilizations to the present

There is a historical record that indicates that, apart from small springs and wells, the Tigris River was the main direct source of water for Rome during the first 441 years after the foundation of the city (Campos and Studart, 2001). In 312 BC the Romans began the construction of the *Aqua Appia* aqueduct and four decades later this was followed by the construction of the *Anio Vetus* aqueduct. In due course there were several aqueducts built, leading to the formation of a complex hydraulic network that provided all the water supply for the city. When there were crises because of the high demand for water supplies, the government searched for new sources that could provide high quality water in good quantities. These several aqueducts are historical monuments in modern Rome. To manage the system the Romans started organizing administration structure models and in 97 AC Julius Frontinus VI was nominated Rome's Water Deputy (*Curator Aquarum*) by Emperor Augustus Nerva. Frontinus had under his responsibility the functioning of a complex aqueduct system that collected water from sources far away from the city and transported it to various reservoirs distributed around the city.

The water was classified according to its usage as *nomine Caesari*, *privatis* and *usus publici*. The *usus publici* class was further subdivided as *castra*, *opera publica*, *munera* and *lacus*. The *nomine Caesari* was water reserved for the imperial palace and the buildings that were under direct control of the emperor. The *privatis* water was for citizens who had the emperor's grant (*principis* benefit) and its concession was dependant on the payment of a fee. The *usus publici* was the water provided for public buildings, bath houses, military and paramilitary buildings and activities, ornamental fountains and for emergency water reserves (Campos and Studart, 2001).

After the Middle Ages and until the late 18th century, hygienic habits and bathing were not popular and were infrequent. The use of perfumes during this period was a sign of prosperity.

After the Industrial Revolution the growth of cities brought serious problems linked to water quality and related to the lack of an adequate system for sewage disposal. As a result a continuous increase in pollution was observed and also an increase of the costs of obtaining water for human supply. Urban rivers began to receive sewage and effluents without treatment, becoming open channels for the transportation of pollutants.

Unfortunately in several Brazilian cities the disordered growth and the lack of government investment hampered the use of concepts and techniques fundamental for the implementation of an efficient system for water supply. These were:

- Extraction of raw water from rivers, wells, lakes, reservoirs, etc.
- Transport of raw water from the source of extraction to the points of consumption using channels, adductor systems, tunnels, etc.

- Treatment of raw water to improve its characteristics regarding physical, chemical and bacteriological aspects in order to make it suitable for human consumption.
- Distribution of treated water in the places of consumption using a pipe distribution system.
- Collection of used water and sewage using pipe networks to ensure their removal to safe places.
- Treatment of the used waters in order to produce water that can be assimilated by the final receptor water body.

Thus, the establishment of a policy for the management of water resources is fundamental in order to minimize water waste, to treat raw water, to guarantee the distribution of good quality water and to adequately treat sewage and effluents. It is mandatory that investments of this nature foresee: a) the objectives to be reached; b) the fundaments or principles of this policy; c) the mechanisms to implement it; d) a law or legal measurements that support it; and e) the institutions that will execute and accompany this policy. Campos (2001) emphasizes that these policies have to be designed taking into account the geographical space and local characteristics. Ideally, national policy has to be general enough to include aspects that can be applied in all states; afterwards these states have to develop a policy based around their individual needs whilst continuing to follow the national policy guidelines. All these policies have to follow the principle of decentralization, where the basin committees have to discuss the specific needs of each basin, respecting all the hydrologic, geomorphologic, cultural and economic peculiarities of the basin.

The basin committees are created in order to promote the management of the interventions made in each area. Usually, they are constituted by: a) representatives from the State's secretary or from organizations and entities from the administration that act in each basin and whose activities are related to water usage management strategic planning and financial management; b) representatives from the municipalities that compose the basin; c) representatives from the civil society such as universities, higher education institutions, institutions for research and technological development, water users, associations specialized in hydric resources, syndicates, regional councils and other community associations, all with headquarters inside the basin. In addition, the equal participation of all municipalities in each state has to be ensured. Usually the committees' functions are as follows:

- To approve the proposal for the basin in order to integrate the Water Resources Plan and its upgrades.
- To approve plans for upgrade, conservation and protection of the water resources of the hydrographic basin.
- To approve proposed annual and multi annual programs for the use of financial resources.
- To promote understanding, cooperation and conciliation between all users of the water resources.
- To study, divulge and debate in the region the priority programs for services and works that will be executed for the interest of the community and to define the objectives, goals, benefits, costs and the financial, environmental and social risks implied in these programs.
- To provide subsidies for the elaboration of the annual report on water resources in the hydrographic basin.
- To create an annual calendar of demands and events and to send them to the administrative organizations.
- To execute control actions at the hydrographic basin level.
- To ask, when needed, for support from the administrative organizations.

Brazilian Basin Agencies (as legal entities with administrative and financial structures of their own) are created in some hydrographic basins following the decision of the Committee and with the approval from the Water Resources Council. The Agencies' responsibilities would be to create future plans for the hydrographic basin and to manage the financial resources obtained from the financial charges imposed on water usage and other public services.

There is no consensus yet on the classification of water bodies for use as a management instrument. There is a necessity to classify water bodies in order to: a) ensure that they have a quality compatible with the uses that have been defined for them and b) to prevent over-use of financial resources in water treatment and pollution avoidance.

In Brazil, the classification of water bodies was initially instituted by the official document MINTER, GM 0013, in January 1976. It established the quality and emission standards for effluents in four classes.

This document was replaced by the Resolution of the National Council for the Environment (Conselho Nacional do Meio Ambiente – CONAMA) number 20, in July 1986. In this document, fresh, salt and brackish waters present in national territories were categorized in nine classes that were evaluated by specific parameters and indexes in order to define each class's potential main use. This is an instrument for the conservation of water quality levels in the water bodies. It states that health and well-being as well as environmental aquatic equilibrium cannot be achieved with deterioration of water quality. The classification of the water bodies is not necessarily based on their present state but on the quality levels that they have to achieve to fulfill the community needs.

The objective of this instrument is to ensure that water has a quality compatible with the purest type required, by the uses determined for it and to reduce, by implementing permanent prevention measures, the cost of the combat against water pollution. This mechanism also provides a link between water quality management and water quantity management. That is, it strengthens the relationship between water resources management and environmental management.

CONAMA RESOLUTION Nº 357, MARCH 17TH, 2005. *This determines classes of water bodies and the environmental guidelines for their classification, and establishes the conditions and standards for the emission of effluents and gives some other measures.*

Chapter II Regarding the Classification of Water Bodies

Article 3. The fresh, salt and brackish waters found in the national territories are classified according to the quality required based on the use for which they are going to be intended. There are 13 quality classes.

The better quality waters can be used for less exigent ends if they do not prejudice water quality and if they fulfill other pertinent requirements.
Section I – Regarding fresh waters
Article 4. Freshwater is classified in:
1 – special class: water appropriate for:
- a) human consumption, after disinfection;
- b) conservation of the natural equilibrium of water communities; and
- c) conservation of aquatic environments in conservation units of the integral protection type.

2 – Class 1: water appropriate for:
- a) human consumption after simplified treatment;
- b) protection of aquatic communities;
- c) leisure activities of primary contact such as swimming, skiing and diving in agreement with the CONAMA resolution Nº 274, 2000;
- d) irrigation of vegetables that are eaten raw and of fruits that grow in contact with the ground and that are eaten raw without peeling; and
- e) protection of aquatic communities found in indigenous lands.

3 – Class 2: water appropriate for:
- a) human consumption after conventional treatment;
- b) protection of aquatic communities;

c) leisure activities of primary contact such as swimming, skiing and diving in agreement with the CONAMA resolution Nº 274, 2000;
d) irrigation of vegetables, fruiting plants, parks, gardens, sports and leisure fields that will be in direct contact with the public; and
e) aquaculture and fishing.

4 – Class 3: water appropriate for:

a) human consumption after conventional or advanced treatment;
b) irrigation of trees, cereals and forage plantations;
c) amateur fishing;
d) secondary contact leisure activities; and
e) animal watering.

5- Class 4: water appropriate for:

a) navigation;
b) landscape harmony.

Water bestowal is an instrument for command and control, where a proportion of the water availabilities is conceded for a specific use, during a limited time, to a specific user. The main objectives of this bestowal are to ensure the qualitative and quantitative control of water usage and to provide the right to use the water.

Among the discussions and deliberations around water bestowal, the maximum bestowed values (volume or output, or both) have to be considered and also how the water will be allocated in times of drought. These decisions have a strong regional character and depend on the pluviometric regime in the basin and its affluents. Therefore, care has to be taken in the establishment of national general policies and the decision has to be based on the knowledge of different hydrologic and geomorphologic aspects, as well as on knowledge of the aquatic biodiversity found in different eco-regions, biomes and parts of hydrographic basins.

Countless dams were built during the twentieth century in tropical regions. In Brazil, since the 1950s and after the industrialization of the country, the use of hydroelectric dams was considered the most viable way to produce electric energy (Bortoleto, 2001). Today, reservoirs are used for several purposes such as water storage for public usage, fish farming, tourism and leisure, contributing also to regional development (Tundisi and Matsumara-Tundisi, 2003).

Modification of reservoir discharge alters the natural hydrologic regime of water bodies located downstream. It reduces the mean annual discharge rate and the seasonal discharge rate, alters the time of occurrence of extreme discharge volumes, reduces the magnitude of floods and/or inflicts non-natural outflows. These changes interfere with abiotic factors that are important for aquatic organisms (water speed, substrate type, temperature and oxygen). The consequences of these changes include variation in water quality, decrease in dilution and natural capacity for purification, exposure of the river bed, and interference with input of allochthonous material originating in vegetation at the margins (Poff *et al*. 1997; Limno-Tech and Slivitzky, 2002). Thus, these changes in reservoir discharge rate modify the structure of aquatic communities and interfere with spawning of migratory species, reducing the chance of larvae and eggs reaching developmental habitats (such as oxbow lakes). They also decrease the diversity of habitats and food available for invertebrates, amphibians, fish, birds and mammals.

The residual or remnant discharge of a river is the one that has to be guaranteed, downstream from any hydroelectric enterprise, in order to satisfy all the uses determined by the Water Resources National Policy. In other words, the residual discharge has to satisfy the following: sanitation, ecologic discharge (see below), human and industrial supply, animal watering, production of electrical energy, irrigation, navigation and leisure, among others.

After the 1990s, there has been an increase in the number of studies aiming to determine the volume of discharge that satisfies the socio-economic needs of rivers and reservoirs while maintaining viable habitat conditions essential to the preservation of the structure of natural biological communities related to the aquatic ecosystems.

In this context, the ecological discharge, also called residual or remnant discharge, is the volume of water needed to ensure the maintenance and conservation of natural aquatic ecosystems and their biota, the scenery characteristics and other economic, scientific and cultural interests (Alves and Bernardo, 2000).

The limitation of the methodologies used in the ecological discharge concept is that they focus on a minimal discharge without giving importance to other aspects related to ecosystem maintenance. The methods most used to determine ecological discharge were based on the need to maintain fish populations (especially those with economic importance) downstream from the reservoirs. These methodologies are based on the belief that if habitat conditions are suitable for fish populations to survive then they must be appropriate for the survival of other aquatic organisms. However, the reduction of the discharge downstream from reservoirs causes several impacts on aquatic communities and ecosystems that might not be detected by monitoring fish populations. Moreover, it is important to note that the response of fish communities might not represent responses to local alterations since these organisms are very mobile and can avoid unfavorable situations.

3. Water resources degradation and loss of benefits

The increase in anthropic impacts over aquatic ecosystems in recent decades is an aggravating circumstance that has demanded the attention of researchers and environmentalists. Every day there is an increase in freshwater extraction for diverse uses, as well as an increase of pollution in rivers and lakes caused by pouring of non-treated domestic and industrial waste into these water bodies. Water bodies have also suffered other types of impact such as margin modification, clearance of riparian vegetations, channeling of river beds and deposition and accumulation of sediments that can lead to river clogging (Table 2). This problem requires more attention in developing countries within tropical regions where population growth is higher and where fewer practical actions have been undertaken in order to minimize these impacts. Below, we will raise and discuss the main aspects related to anthropic impacts in tropical freshwater ecosystems.

Table 2: Main types of environmental impacts in tropical aquatic ecosystems (modified from Callisto et al., 2005)

Lasting recent decades, freshwater ecosystems have been altered on varying scales and have registered various negative consequences of anthropogenic activities (e.g. mining, dam construction, artificial eutrophication, river canalization, and recreation). The detection of resulting impacts on streams depends on the use of biomonitors combined with physical (e.g. temperature, suspended solids) and chemical (e.g. nutrient levels, concentrations of potential toxins) data.

Water quality provides two broad classes of economic benefits: withdrawal benefits and instream benefits. Withdrawal benefits include municipal water supply and domestic use (e.g. household consumption, cooking, washing, and cleaning) benefits, agricultural irrigation and livestock watering benefits, and industry process waste benefits. If water quality is low, withdrawn water must be treated before it can be used and the economic benefits (net treatment costs) associated with its usage are lower. Instream benefits (i.e. the benefits of water quality arising from water left “in the stream” and not withdrawn) include two subcategories: usage benefits and non-usage benefits. Instream usage benefits include swimming, boating, and sport-fishing benefits. These type of benefits are associated with direct human interaction with water in the stream/river. Other instream usage benefits include the aesthetic value of water quality that may accrue to nearby picnickers, streamside trail hikers, and streamside property owners. Instream non-use benefits of water quality include stewardship value, altruistic value, bequest value and existence value. Non-use benefits accrue to individuals regardless of whether or not they have direct interaction with water. The stewardship value arises from a belief (often moral or religious) that humans are responsible for maintaining some level of water quality even in cases where no withdrawal or instream usage benefits result. The altruistic value arises from the enjoyment some people receive from simply knowing that other people enjoy withdrawal or instream use benefits. The bequest value arises from a belief that current human generations are responsible for maintaining some level of water quality to “bequest” to future human generations. Finally, the existence value arises from the enjoyment some people receive from simply knowing that some level of environmental quality exists. If water quality is allowed to deteriorate, then stewardship, bequest, and existence goals may not be met, and associated benefits fall (Dumas et al., 2005).

The impacts of urbanization on water quality benefits are mediated by aquatic ecosystems. Increases in stream nutrient levels that lead to algal blooms can reduce swimming and boating benefits while reductions in dissolved oxygen that lead to fish death can reduce fishing and streamside property value benefits. Meanwhile, the increases in disease-causing bacteria due to urban and suburban storm water runoff can increase water treatment costs and reduce swimming, fishing, and boating benefits. The reductions in aquatic species populations or diversity caused by stream sedimentation or toxic chemical discharges can reduce stewardship, altruistic, bequest, and existence values. Economic valuation methodologies typically trace changes in water quality variables through changes in aquatic ecosystem parameters to changes in economic benefits. Often, it is a change in an aquatic ecosystem parameter, such as a fish population, algae population, or disease-causing bacteria population, that is the ultimate cause of a change in economic benefits.

Conversions of rural and forested lands to urban areas degrade streams by altering the composition, structure and function of their aquatic ecosystems. Landscape changes associated with urbanization include terrestrial habitat loss, landscape fragmentation, increased impervious surface area, increased storm runoff, reduced groundwater recharge and riparian habitat loss. The urbanization process is consistently linked to stream degradation, which results from increased peak flows, stream power and stream sedimentation, reduced base flows, and modified instream habitat and substrate complexity. Riparian areas are particularly susceptible to urbanization impacts and habitat fragmentation. The loss of riparian vegetation can destabilize stream banks, increase summer water temperatures and daily fluctuations, alter the recharge of shallow aquifers, and reduce the effectiveness of these natural filters. This loss also results in increased surface runoff, increased erosion and sedimentation and reduced debris and leaf litter deposition. These organic matter deposits are used by many aquatic organisms for food and shelter. Declines of native fish, amphibian, and aquatic invertebrate assemblages have been linked to deterioration of riparian habitats (Kennen et al., 2005).

Linking the effects of landscape fragmentation in a spatial context to ecological consequences is often a difficult task for aquatic ecologists. Moreover, translating the effects into procedures that can be used in management is even more complicated because ecological complexity tends to blur results with patterns and processes that can be difficult to distinguish because of the high level of variability inherent in aquatic ecological data (Kennen et al., 2005).

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