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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Sustainable use of low flow reaches downstream energy generation dams

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The paper describes the issues of water quality in low flow reaches downstream energy generation dams. These reaches should maintain a minimum water flow in order to guarantee adequate ecological conditions in the water body. A case study is presented with respect to the longest low flow reach in Brazil, focusing mainly on environmental and regulatory aspects. Water quality in this reach should be enhanced by the construction of some intermediate dikes, which will allow the sedimentation of particulate matter and the formation of small reservoirs for the growth of aquatic species. A concern remains only with phosphorus concentrations, since the environment will change from a lotic to a lentic condition.

Introduction

Our current civilization, characterized by a high degree of consumption, constitutes an extremely low entropic level system, which needs a huge amount of energy to keep itself stable. This level is maintained due to an intense use of the energy extracted from the environment. Thermodynamically speaking, if nothing is done, the energy resources will be exhausted in the medium run, causing serious and irreparable environmental degradation. As the cost of oil and the environmental impacts of its use as a source of energy are increasing, the path towards renewable sources of energy becomes more and more attractive and necessary. It is widely known that hydropower is the best developed and by far the most important form of renewable energy, playing also a major role in the achievement of the Kyoto targets.

Brazil is a country where the use of hydroelectric power reaches the impressing amount of 79 %, whereas the world average is around 17 % (MME, 2006). The current installed capacity in Brazil is approximately 70 GW. Under a historical point of view, the construction of dams for energy generation began in the country at the end of the 19th century. Since then a considerable amount of reservoirs has been built, mainly after the decade of 1960.

Environmental impacts from the construction of reservoirs

The construction of reservoirs is associated with several environmental impacts, both of positive and negative nature. In the first group the most relevant are: energy production, employment generation, enhancement of water quality (due to turbidity reduction, nutrients sedimentation and decreasing of eutrophication processes downstream), expansion of working posts offer during the construction of power plants; supply of reliable low cost energy to the region, substitution of diesel based thermoelectric generation by hydroelectric generation and collection of royalties yearly paid to States and cities for the use of the water resources. The main impacts of negative nature are people relocation, changes in the structure of the aquatic community, loss of genetic patrimony (flora and fauna), slopes destabilization and climatic alterations, including those related to the emission of greenhouse gases.

Case study: Capim Branco Reservoir

Capim Branco Reservoir is located in River Araguari, State of Minas Gerais, Brazil, 19o South. The filling of the reservoir was accomplished in the period from November to December 2005. Capim Branco Dam will generate 240 MW of energy through an effective head of 58 m

Hydropower plants can be classified, according to the height of effective head, in low, medium or high. There are no very accurate definitions for the classification of the types of heads. According to CERPCH (National Center of Reference for Small Hydropower Plants, 2006) high head plants are those whose heads are higher than 150 m. Those up to 15 m are low head plants and the ones whose heads range between these two values are considered to be medium head plants. Most of the hydroelectric projects in Brazil lie within the latter, including the present case of Capim Branco Reservoir.

Environmental issues

All hydroelectric projects developed in the country should present a detailed Environmental Impact Assessment before the construction/operation approval by the State Environmental Agency. This report covers the description of the project, the survey of physical, biotic and anthropogenic aspects of the area of influence of the project, the study of

the possible environmental impacts as well as the proposition of measures for their mitigation. In some hydroelectric projects, there is the need of keeping a minimum flow in the former river bed, in case the position of the dam and the power plant impose a different flow. In the present case the Environmental Agency, according to the hydrological features of the region, determined the maintenance of a minimum flow of 7 m3/s. The low flow reach of Capim Branco Reservoir has a length of 9 km and is therefore the longest one in Brazil. The hydrological characteristics of these particular water courses, including the procedures for the calculation of the required minimum flow, have been sufficiently explored in the technical literature. However there are worldwide very few studies regarding the aspects of water quality in these especial aquatic environments. Also the hydrobiological features play here a quite important role, since one of the main objectives of the study of low flow reaches is to guarantee an adequate biodiversity in a river zone that normally would be exposed to dryness.

Regulatory aspects

Before the approval of the Environmental Impact Assessment there is the need of the implementation of Public Audiences in order to evaluate the position of the local community with respect to the construction of a hydroelectric dam in the region. Moreover the State Environmental Agency determined, as a countermeasure for the unavoidable environmental impacts, that the energy enterprise should finance some research projects regarding hydrological, limnological and geological aspects of the disturbed environment.

Construction of intermediate dikes

In order to enhance the water quality in the low flow reach of Capim Branco Reservoir, ten intermediate dikes are planned to be constructed along the river bed. The function of these dikes is to provide successive regions of water accumulation, which should foster the development of aquatic communities and also contribute aesthetically to the local landscape. On the other hand some physico-chemical characteristics may be modified, such as a lower turbidity, enhanced transparency and lower dissolved oxygen values due to a reduced flow rate. Neverthless the balance of this intervention can be considered as positive. Actually these dikes are similar to small reservoirs, showing hence ecological structure and function comparable to those found in most lentic environments. The construction of dikes for the mentioned purposes is a pioneer example in the country and constitutes a unique form of improving the environmental use of low flow reaches downstream dams for energy generation.

Water quality

Data of water quality in the low-flow reach (still without the intermediate dykes) has been collected since July/2005 on a monthly basis. Four sampling points have been distributed along the river bed: Point 1 (beginning of LFR – Low Flow Reach), Point 2 (upstream the discharge of treated wastewater), Point 3 (downstream the discharge of treated wastewater) and Point 4 (end of LFR). The wastewater treatment is carried out by an anaerobic reactor followed by a flotation unit with the addition of ferric chloride.

Table 1. Average values of monitored water quality constituents

Parameter	P1	P2	P3	P4
BOD (mg/L)	7	5	7	6
COD (mg/L)	11	9	11	9
Total N (mg/L)	0,17	0,14	0,15	0,17
Total P (mg/L)	0,12	0,23	0,16	0,11
E. coli (MPN/ 100mL)	8	9	8	6
Temoerature (°C)	23,6	24,0	24,8	25,7

The most relevant water quality information is summarized in Table 1.

Temperature variations follow the local climatology, where the rainy and hot season extends from January to March and the colder, dry season lasts from April to December.

Peaks of BOD and COD are generally observed in the rainy season. This is due to the runoff of soil particles and organic matter. Average BOD values are slightly higher than the water quality standard set up the Federal Environmental Council – CONAMA (2005) (5 mg/L).

Nitrogen values are low. There are no Brazilian standards for N in rivers, but only for ammonia (2.7 mg/L), nitrite (1 mg/L) and nitrate (10 mg/L). From the total N values it is seen that these standards are easily met.

Phosphorus values are low, but also higher than the allowable federal standard (0.1 mg/L for lotic water bodies), but this has not been reflected in eutrophication problems in the reach.

E. coli values are low and within the standard (1.000 MPN/100mL). The populations are higher at the dry season, probably due to the lower dilution in the water body.

Water quality modelling

As part of the study, water quality of the low-flow reach (also without intermediate dikes) was modeled, in order to gain insight into its possible behaviour under different scenarios. QUAL2E equations (USEPA, 1987; Thomann & Mueller, 1987; Chapra, 1997) were used and implemented in Fortran code, without longitudinal dispersion and algae components. The model takes into account point-source pollution (discharge of treated effluent) and diffuse pollution (incremental load along the river reach). The constituents modeled were

DO, BOD, nitrogen and fractions, phosphorus and fractions and thermotolerant coliforms. The treated effluent data were obtained from the plant´s operational records. The graphs below present the simulation results (the point of the treated wastewater discharge is indicated by a triangle).

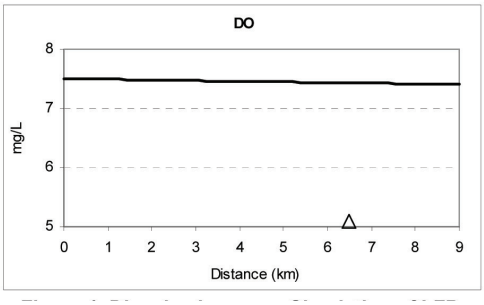

Figure 1. Dissolved oxygen. Simulation of LFR.

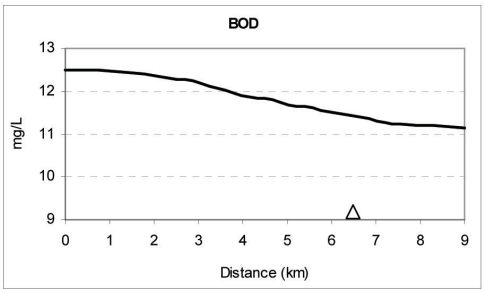

Figure 2. BOD. Simulation of LFR.

From Figures 1 and 2 it is seen that the influence of the discharge of treated wastewater is negligible in terms of BOD and DO, partially because the wastewater flow is small compared with the river flow, and partially because the effluent concentrations are low.

However, nitrogen concentrations (Figure 3) tend to increase along the LFR (non-point sources) and, especially, downstream the wastewater discharge point. The reason for the latter is that the wastewater treatment has no provisions for N removal. Nevertheless, even with this increase, the Brazilian environmental standards for the N fractions are met.

Phosphorus values are not influenced by the wastewater discharge, the reason being associated with the high dilution and the P removal by precipitation with ferric chloride followed by flotation. However, the resulting values are higher than the Brazilian standards for lotic water bodies.

The influence of the wastewater discharge on the coliform counts is clearly seen in Figure 5. Since the treatment plant has no disinfection stage, even with the high dilution provided by the LFR, the coliform counts have a step increase in the point of discharge. But even with this increase, the environmental standards are still achieved.

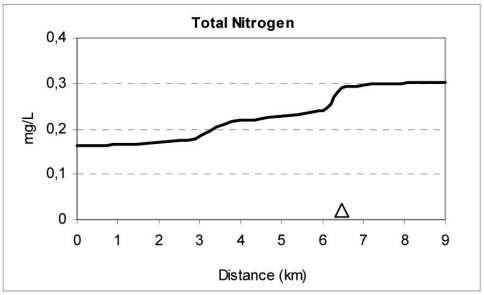

Figure 3. Nitrogen. Simulation of LFR.

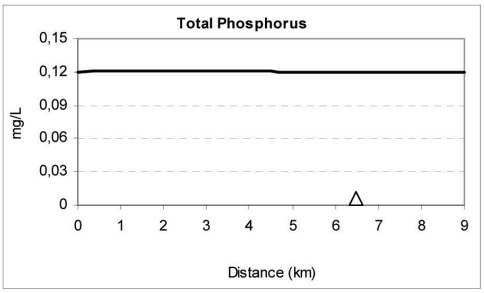

Figure 4. Phosphorus. Simulation of LFR.

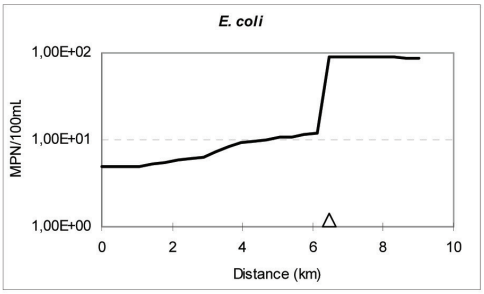

Figure 5. Coliforms. Simulation of LFR.

Conclusions and recommendations

The environmental and sustainable use of low flow reaches has been explored in this paper. Especial attention has been dedicated to the aspects of water quality in these relatively new and unique ecosystems. The monitored data indicate, in general, a good water quality and compliance with most water quality standards established in the Brazilian legislation. This conclusion is also supported by the simulation studies carried out before intermediate dykes have been built. The future construction of these dikes will probably be an efficient technique for the maintenance of the good water quality and especially for the improvement of the ecological and aesthetical value of the aquatic environment. A concern remains with the phosphorus concentrations, since the environment will change, from a lotic water body, to a series of lentic bodies.

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