Thematic 6: Water and Conservation

Development of socio-environmental management tools for Andean basins with mining activities

A. Pérez-Foguet. Dept. of Applied Math. Institute of Sustainability, IS.UPC.
Universitat Politècnica de Catalunya UPC – BarcelonaTech.
agusti.perez@upc.edu

C. Yacoub. Institute of Sustainability, IS.UPC.
Universitat Politècnica de Catalunya UPC – BarcelonaTech.
cristina.yacoub@upc.edu

N. Miralles. Dept. of Chemical Eng. Institute of Sustainability, IS.UPC.
Universitat Politècnica de Catalunya UPC – BarcelonaTech.
nuria.miralles@upc.edu

ABSTRACT

We present an analysis of three socio-environmental management tools developed and applied to an example of Andean basin with mining activities of significant importance. Socio-environmental conflicts related to mining activities are of increasing interest in the region. Most of them include water quality or quantity issues as a central part of the disputes. On the other hand, environmental regulations are changing from a paradigm focused on pollution control to a paradigm based on the health of the ecosystems, much more related with sustainable development and well-being than before. Some authors defend the participatory use of technical and scientific knowledge with local stakeholders in these contexts, while others report some boomerang effects of these practices. The work presented here shows that it is possible to develop and adapt management tools such as hydrological modeling, environmental monitoring and sustainability indices, to support the public debate and informed opinion to these particular contexts; and, at the same time, innovate within the water resources sector. The experience also shows the limits and requirements of the proposal. Political leadership is needed to overcome conflicts by promoting public structures for supporting water governance; technical and managerial

tools and capacities of private sector are not enough. There are local initiatives that accumulate valuable knowledge and practice these processes of change from conflict to technical cooperation and public participation in the region.

INTRODUCTION

The socio-environmental conflicts associated to mining in the Andean region are cause of concern and increasing interest, especially those related to water quality and quantity affectations (Bebbington et al., 2008; Sosa and Zwarteveen, 2012). More than 160 conflicts were registered by the end of 2012 with the Observatorio Latinoamericano de Conflictos Ambientales, www.olca.cl. However, it is difficult to find specific works dealing with the use and analysis of socio-environmental management tools in these contexts. As presented in Kemp at al. (2010), a better connection of the conflict parts through technical, scientific and engineering-based approaches to water management should be an option to explore as a mining sector strategy. Practical management tools proposed include participatory environmental surveys, technical discussions and working groups, local university research teams involvement, etc. However, other authors highlight some drawbacks of being proactive with these practices (Velásquez, 2012).

On the other hand, the global trend on the water resources management in recent years, specifically the water quality, has changed in the fundamental objectives from a management focused on control of pollutants to a vision that is based on an ecosystem and integral approach (Hering et al, 2010). Europe has lead policies that promote the protection, improvement and sustainable use of water as a whole, with an ecosystem approach through the Water Framework Directive, WFD (EC, 2000; EAA, 2012). This new paradigm is based upon the status of biological, hydro-morphological and physicochemical quality elements. All the elements should be considered to comprehensively assess the ecological status of aquatic systems.

With both ideas in mind, the debate about the role of scientific data and social participation in mining related conflicts, and the evolution to an ecosystem approach in water management, it can be easily argued that more efforts are needed to gain better understanding of how to deal with the evaluation of the impacts and pressures on the aquatic ecosystems involving the stakeholders interested in the hydrological cycle, specifically in the Andean region. This is not just a theoretical question. In fact, during recent years, several Andean countries have included some of these innovative concepts in their water and environmental policies, but a general overview rises that there is a lack of plans and measures to effectively implement them. In particular, it is hard to find academic studies assessing the environmental problems in the region and proposing methodologies adapted to mining contexts.

Following this aim, this work focuses on the assessment of socio-environmental management tools in Andean basins that include significant mining activities. The main hypothesis behind the study is that the participatory development and use of these tools may enhance the decision makers' capacities to deal with water related conflicts and at the same time, innovate in the water management and technology sector. The research centers in a case study with information partly available and partly economically achievable and a high level of local stakeholders engagement. The action - research process conducted includes the development and use of three different environmental management tools (hydrological modeling, environmental monitoring and sustainability indices). Their main characteristics and results are presented hereinafter. An overall analysis of their contributions is included.

The Jequetepeque river basin, located at Northern Peru, is chosen as the reference case study for this work (Bebbington et al., 2008; Sosa and Zwarteveen, 2012). It has an extension of 4372.5 km^2 and a maximum height of 4150 m.a.s.l. The annual average precipitation ranges from zero in the coast to 1100 mm in the higher parts of the basin. There are mining activities in the upper and middle part of the basin, and agro-export activities in the coast. The coast part is regulated by a reservoir located at 350 m.a.s.l. The upper part of the basin is within the Cajamarca region (2.7% and 5.2% of Peru extension and population). This is one of the most impoverished regions of the country and has the second largest number of mine sites, 2.816 concessions (more than 30% of the surface). The action-research carried out within the period 2006-2011 includes the implementation of a sequence of projects involving different local stakeholders (government, universities, NGOs, etc.), these being contributors during all project cycle, analysis of the results and discussions, according to their own capacities.

METHODOLOGY

The focus of the research is on the knowledge and methodologies of analysis that can be adapted and transferred by participation and capacity building and that are expected to be used and disseminated to promote informed opinion. The proposal focuses in three specific tools: (i) hydrological models that allow the stakeholders to simulate and evaluate the water and sediment dynamics of the basins (Chung and Lee, 2009), (ii) environmental monitoring that generate knowledge about the status of the ecosystems and helps to discern between origins of the impacts (Allan, 2006), and (iii) multidimensional assessment of water poverty through composite sustainability indicators (Giné and Pérez-Foguet, 2010; Pérez-Foguet and Giné, 2011).

Small research competitive grants, university projects and international cooperation programs have supported the field and lab work. An analysis of the main characteristics and relationships between the three tools are included specifically here. The focus is on complementarity, integrability and sustained applicability of the proposals. Brief descriptions of the three management tools follow.

The dynamics of the basin are evaluated using the Soil and Water Assessment Tool, ArcSWAT (Yacoub and Pérez-Foguet, 2011, 2012). The model is properly calibrated and validated, and it has been used to assess the impacts of land use changes, from traditional uses to pine forestation and to open mining, in different extents. Hydrological impacts are evaluated by comparing maximum stream flow and average water yield of the upper subbasins.

A specific environmental monitoring including water, sediment and biota matrices has been defined and carried out (Acosta et al., 2009; Yacoub et al., 2012a, b). Four field campaigns have been done in different seasons and years for each component. Data available from other sources has been pre-processed and incorporated in the analyses. Toxicity levels have been assessed. Conclusions about actual impacts and appropriated methodologies for updating have also been elaborated.

And finally, a proposal of a sustainability index, a water poverty index, WPI, developed to better understand the links between poverty and water in basins has been defined and applied (Giné and Pérez-Foguet, 2010; Pérez-Foguet and Giné, 2011). The WPI evaluates water scarcity by taking into account physical estimates of water availability and the socioeconomic drivers of poverty. The proposal presented integrates the concept of causality through the Pressure-State-Response approach, PSR. The use of evaluation frameworks based on this concept is widespread, and they have been extensively applied for supporting catchment management (Walmsley, 2002; Chaves and Alipaz, 2007). The index uses information of different sources and routines, involving several stakeholders at basin level. It includes a measure of the socio-environmental conflicts within the index structure.

RESULTS

The main results obtained with each of the management tools are summarized in the following paragraphs. After them, the results of the analysis of their relationships are presented. The paper finishes highlighting principal conclusions of the experience and the analyses.

First result is the assessment of the ability of the hydrological models. After a good calibration, they are capable of quantifying the hydrological cycle dynamics and relationships, and evaluate the possible impacts on water cycle from different soil uses, in Andean basins. They are helpful for the analyzing large scale engineering impacts, as those from land and water modifications due to extensive open mining. Influence of the terrain slope as a spatial discretization criterion on the calibration and simulation of the model has been analyzed. Some rules for practical calibration and use of this kind of models have been devised. The influence of the upper sub-basins in the hydrology response of the basin has been characterized. Current land use is the most sustainable scenario tested, featuring the largest amount of water stored, but pine forestation presents almost no changes. Severe impacts on the hydrology of the overall basin can be expected if the open mining is developed to the full extent, changing 40% of the land use in the upper sub-basins.

Second result includes the assessment of the state, hazards and toxicity levels present in the basin, as well as the proposal of an updating methodology. Results have been useful for discussions and better understanding of pollutant sources and remediation challenges. Specifically water quality results covered an area up to 10 km from emission points and show that several trace elements are present over healthy standards in different places, and that high hazards levels of some of them are also present. Typical composition of acid waters is found in coherent places. Sequential Extraction Scheme processes from sediments and kinetics analysis highlighting metal mobility have also been performed from different locations within the basin. High hazards and toxicity levels of some metals have been found downstream of emission points. Multivariate statistics help indicating similarities in the origin of the samples and in the characterization of mining activities impacts depending on their operational status. The monitoring program is enhanced with the ecological monitoring developed, that includes the analysis of the ecosystem. It includes the assessment of the fluvial habitat, the riparian zone and the macro-invertebrates index (Acosta et al 2009). The idea of an appropriate "smart" environmental monitoring has emerged. It should be adapted to the specificity of the social context of the region and the possible environmental impacts due to mining, and include the ecosystem approach and methodologies for the posterior application for local surveillance. It is important to devise low cost and participatory methodologies as the environmental monitoring developed for posterior application by local communities and stakeholders, further than the standard monitoring programs, which in any case should focus in sediments characterization rather than in surface waters. First proposals reporting biota updating by communities and with toxicology backup tests by institutions in charge have been formulated.

A third result is related with the holistic approach of sustainability indices. Because of its simplicity, in contrast with complexity of raw data, it appeals to water managers and decision-makers for planning, performance monitoring, and resource allocation. The WPI with a PSR approach offers an adequate framework to management at basin level. Analysis of information sources, routines and availability with multiple partners has been done for supporting the proposal. Information data and routines of the health system, the environmental management system and the local and regional authorities has been properly processed and integrated. As river basins are the natural territorial planning unit, such policy tools need to be applied at this geographic scale, which usually involves administrative units with different boundaries making management more complex. An adequate governance structure facilitating participation of stakeholders is needed to sustain the update of information and follow up analysis; and of course to take informed actions to improve basin situation.

After the results of each management tool, the relationships between the three are analyzed. The links of the sustainability index with the information involved in hydrological modeling and environmental monitoring has been analyzed with the aim to assess their complementarity and integrability. Five categories of data define the WPI, each of them linked to a different source of data and information system. Table 1 presents the indicators of the different components of the index and the category of data. Several links between the hydrological modeling, the environmental monitoring and the indicators of the WPI are found. On the other hand, in order to be put in practice, all this information needs to be regularly updated. Depending on the topic the updates needs to be recorded daily (i.e. hydrology), monthly (health centers and ecological monitoring) or even annually or with the census (WASH data and socio-economical, demographical and geographical data).

Thus, we conclude that the three tools are complementary and updatable. Something like a shared information system could be defined, although a lot of previous work is needed to reach that point. First off, the establishment of proper water authorities in the basin must be set up. With respect to sustainable applicability, participation in the preparation and start up of proposals adapted to local context is crucial. Some tools, as models and lab chemical essays require technical capacities, which are directly present in the local university system, but also indirectly available by civil society, profit and government organizations. Others, such as environmental surveillance need the direct local participation of communities. From the three management tools, the one with a higher requirement for practical implementation is the sustainability index, which to be used for supporting local governability of the basin, needs a proper governance structure and mandate.

Table 1. Categories, indicators and data systems involved in the Water Poverty Index. Indicators given by Pérez-Foguet and Giné (2011). Data systems: Meteorology (M), Agriculture (A), Environmental & Regional planning (ER), Urban water cycle & Health (UH), and Socio-economical and Public administrative systems (SP).

Indicators	Variable - Pressure	Variable - State	Variable – Response
Resources			
Water availability	Population growth rate (SP)	Per capita water availability (M) Aridity Index (M)	
IWRM	Annual variation in the HDI-Education (SP)	*Institutional framework in IWRM (SP)*	Adequacy of programmes to support IWRM (SP)
Access			
Access to safe water	Annual variation in safe water accessibility (UH)	Access to safe water (UH) Continuity of service (UH) Operational status of water supply (UH)	Improvement in water supply infrastructure (UH)
Access to sanitation	Annual variation in improved sanitation accessibility (UH)	*Access to improved sanitation (UH)*	*Improvement in sanitation facilities (UH)*
Equity in access	*Population living in non-durable dwellings (UH)*	*Inequality index in terms of access to basic services, water and sanitation (UH)*	
Capacity			
Human Development	Annual variation in the HDI (SP)	HDI (SP)	Educational level of household head (SP)
Institutional Capacity	% water supplies managed by water committees (UH)	% of water committees with qualified staff (UH)	*% technicians in relation to the labour force (SP)*
Gender Issues	*Annual variation in the women HDI-Education (SP)*	*Equally distributed index, in relation to educational level (SP)*	
Use			
Hygiene promotion	% households with point-of-use water treatment (UH)	Prevalence of water-related diseases (UH)	
Agricultural water use	% irrigated land with proper technological approach (A)	Agricultural water use, expressed as the ratio of irrigated land to total cultivated land (A & M)	Improvement in agricultural water-use efficiency (A & M)
Environment			
Environmental Preservation	Arable land as a % of potential arable land (A) *Grazing land as a % of potential grazing land (A)* Soil erosion (M) Reports of environmental conflicts (ER)	% of area with natural vegetation (A) *% of area under protected status (A)*	*Adequacy of the environmental institutional framework (ER)* % of prioritized protected area (A)
Drinking Water Quality	*% water systems correctly treated (UH)*	% water systems with faecal contamination (UH)	% water systems regularly treated (UH)
Agricultural Water Quality		*Agricultural water quality (ER)*	*Surface water quality surveillance (ER)*

Note: In italics, variables removed based on correlation criterion.

The main hypothesis formulated at the beginning of this work is confirmed, at least, to some extent. It is possible to improve knowledge and capacities of stakeholders to take informed decisions related to mining and water resource management through participation in applications of hydrological modeling and simulation, surveys and data analysis. At the same time, innovative contributions to water management sector can be devised. The approach followed has facilitated innovative work and better knowledge about water basin state and dynamics from a socio-environmental point of view. Tools are complementary and can be integrated into a Decision Support System or to be used separately. Of course, in any case, in order to be successfully used the parts involved should share appropriated governance structures to manage and put in practice decisions.

The case study presented cannot be considered a best practice in the sense of successfully and sustainably applied proposal, but it can in the sense of participatory research-action approach example within a complex and conflictive social context. The main positive externality is that the experience has been useful for analyzing and supporting real proposals with arguments. As a principal drawback, the sustainability index has not been put in practice. The main challenge is that the basin management lacks a basin authority or another institution in charge of it. On the other hand, we cannot think that conflicts improve management; they limit the development of capacities. All works of the case study would have been more helpful without social conflicts around. And finally, an opportunity that is specifically arising in the case study analyzed is that the Peruvian Government is pushing an Integrated Water Resources Management plan with support of international agencies. Political leadership is the key to facilitate the link between scientific and technological knowledge and governability. Experiences, procedures and capacities are available in the field.

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