73256

# ENVIRONMENTAL MANAGEMENT IN BOLIVIA

## Innovations and Opportunities

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# ENVIRONMENTAL MANAGEMENT IN BOLIVIA

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## Abbreviations

| | |
|---|---|
| AAPS | Authority for Oversight and Social Control of Drinking Water and Basic Sanitation (Autoridad de Fiscalización y Control Social en Agua Potable y Saneamiento Básico) |
| ASM | Artisanal, Small-Scale, and Medium-Scale |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| COMIBOL | Bolivian Mining Corporation |
| DALY | Disability-Adjusted Life Year |
| DGGIRS | General Directorate for Integrated Solid Waste Management (Dirección General de Gestión Integral de Residuos Solidos) |
| EBO | Bolivian Gold Company (Empresa Boliviana de Oro) |
| FENCOMIN | National Federation of Mining Cooperatives (Federación Nacional de Cooperativas Mineras) |
| FOFIM | Financial Mining Fund (Fondo de Financiamiento para la Minería) |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GIZ | German Agency for International Cooperation |
| HU | Hydrologic Unit |
| PAHO | Pan American Health Organization |
| SERGEOTECMIN | National Geology and Mining Technology Service (Servicio Nacional de Geología y Técnico de Minas) |
| UNICEF | United Nations Children's Fund |
| WHO | World Health Organization |

# Executive Summary

Pollution management is at the top of the development agenda of Bolivia, and this program helps address it in a cross-sectoral manner. In the context of the implementation of the program "Environmental Management in Bolivia: Innovations and Opportunities" which was conducted from September 2010 until October 2012, the World Bank has implemented a technical assistance program and supported a multisectoral analysis in order to help the Bolivian government improve environmental management in four specific areas: (a) water resource pollution by mining and mitigation of the pollution; (b) evaluation of potential wastewater reuse in agriculture with case studies from Cochabamba and Tarija; (c) improvement of waste management; and (d) evaluation of health benefits through adequate water supply and basic sanitation. The program's overall objective is to help strengthen environmental management in critical areas of the pollution management agenda. The program is directed at the government and nongovernmental agencies in Bolivia, academia, and the donor community. Water, climate change, and human health are cross-cutting topics within the four areas of the program, and are dealt with in each of the chapters of the report. The program was carried out in close partnership with Bolivian government institutions and other agencies.[1]

The program included three sets of activities carried out throughout the program implementation: analytical services delivered through targeted technical studies, knowledge exchange and convening services, and specific support to project development (financial services) (table ES.1).

As part of this program, more than 12 workshops were implemented aiming at increasing capacity and strengthening knowledge exchange in the selected priority areas. This report summarizes the key finding of the analytical studies. One of the world's most mega-diverse and mineral-rich countries, Bolivia is experiencing environmental pressures with high economic costs. Bolivia is richly endowed with natural resources, minerals, and biodiversity.

Its widely ranging ecological conditions in around 16 ecological zones, a consequence of the great changes in altitude from the tropical Amazon plains to the Andean peaks, make it one of the 15 richest countries in terms of biodiversity in the world. Bolivia's history is intricately linked with the extraction of its mineral wealth and the social conflicts it has been associated with.

[1] The Ministry of Environment and Water and the Ministry of Mining and Metallurgy are the main counterparts of this technical assistance program, initiated at the request of the former. The selected topics were chosen by the Ministry of Environment and Water, assisted by discussions with the following institutions: Vice Ministry of Water Resources and Irrigation; Vice Ministry of Environment, Biodiversity, and Climate Change; Vice Ministry of Drinking Water and Basic Sanitation of the Ministry of Environment and Water; Vice Ministry of Public Investment and External Financing of the Ministry of Development Planning; Vice Ministry of Mining and Metallurgy and Vice Ministry of Mining Cooperatives of the Ministry of Mining and Metallurgy; National Federation of Mining Cooperatives (FENCOMIN); Bolivian Mining Corporation (COMIBOL); Ministry of Agriculture and Rural Development; Ministry of Health; National Irrigation Service; Social and Economic Policy Analysis Unit; and civil society organizations such as the Environmental Defense League and the Federation of the Association of Bolivian Municipalities.

**Table ES.1 Components of the program "Environmental Management in Bolivia: Innovations and Opportunities"**

| Analytical services | Knowledge exchange, study tours, and South-South cooperation | Linkages with financial services |
|---|---|---|
| WORLD BANK PUBLICATIONS<br>"Environmental Management in Bolivia: Innovations and Opportunities"<br>CONSULTING STUDIES<br>Wastewater reuse prefeasibility studies for Tarija and Cochabamba and field assessment<br>Solid waste management: best practices in the LCR<br>Clean mining technologies assessment and field studies<br>DOCUMENTARY<br>"Gold and Mercury: A Fatal Mix" (best practices in the region on clean technologies in gold mining, presented in the International Workshop on Clean Mining Technologies in La Paz)<br>INFORMATION SYSTEMS<br>Mining-Environmental Information Platform (hydrologic, mining sector, and socioeconomic georeferenced data collected over five years by this program and an earlier Bank technical assistance program) transferred to Ministry of Environment and Water and Ministry of Mining and Metallurgy | MULTI-STAKEHOLDER WORKSHOPS<br>Workshop on Environmental Health in the Water and Sanitation Sector (Bolivian agencies, European Union, UNICEF, PROAPAC-GTZ, OPS, World Bank)<br>Workshop on Mining Pollution from the Watershed Perspective (Bolivian agencies, DANIDA, GTZ, OPS, Catalan Cooperation Agency, World Bank)<br>Workshops on wastewater reuse in La Paz, Tarija, and Cochabamba (Bolivian agencies, GTZ, OPS, World Bank)<br>International Workshop on Clean Mining Technologies for Mining Cooperatives in Bolivia (Bolivian agencies, Ministry of Mining and Metallurgy, FENCOMIN, Ministry of Environment and Water, UNIDO, World Bank, with 55 participants)<br>Three workshops on solid waste management<br>STUDY TOURS<br>Study tour to Colombia and Peru on solid waste management<br>Study tour to Colombia for training on the methods of evaluation of the costs of environmental degradation | Lake Titicaca Local Sustainable Development Project 2007–2015<br>The project supports improving basic water and sanitation services as well as tourism development and cultural protection.<br>The program delivered technical assistance to the project implementation unit in the area of wastewater reuse for Viacha |

Bolivia is also one of the poorest countries in Latin America, with a 38 percent poverty rate in 2007, made worse by a range of environmental challenges that tend to exacerbate poverty: (a) indoor and outdoor air pollution; (b) water pollution from industries (particularly mining) and associated adverse health and ecological impacts; (c) vulnerability to natural disasters and climate change risks; (d) inadequate solid waste management; and (e) the expanding agricultural frontier and unsustainable land use, resulting in deforestation, loss of biodiversity, and soil erosion. As the country is now facing a period of political stability relative to the previous decade and important institutional reforms are taking place in the area of environmental management, such as the revision of the legal framework in the water and forest sectors, it is strategically important to support the efforts of the government of Bolivia to strengthen the environmental management framework.

Many of these problems have direct economic and social impacts, such as the loss of agricultural productivity and an increase in water treatment costs with soil erosion and water pollution, while others have high health costs. According to preliminary assessments, the costs of environmental degradation in Bolivia amounted to 6.2 percent of gross domestic product (GDP) in 2005, with the largest share of the costs borne by children under the age of 5, largely resulting from inadequate access to improved water and sanitation, followed by the losses from air pollution and natural disasters. Since two thirds of Bolivians already live in urban areas, and the urban population is growing at a rate 6 times higher than in rural areas since 2000 (2.4 versus 0.4 percent in 2009), urban environmental issues are likely to become increasingly important for the environment and the overall development agenda of Bolivia (World Bank 2013).

The pressures on natural resources and pollution are rising with the growing world demand for minerals and an expectation of continued urbanization in Bolivia. The need to develop roads, hydropower, and other infrastructure, and the large potential to continue developing the country's yet untapped mineral and hydropower resources, juxtaposed with high mineral prices and an expectation that they will persist in the long term, will signify continued and increasing pressures on forests and environmentally sensitive areas. In Bolivia, it is now common to see mining tailings from abandoned mines, whose processing was previously unprofitable, being brought back into operation by artisanal producers. In the rivers of the Amazon, the high gold price has increased the incentives for informal run-of-the-river gold mining by artisanal miners from Brazil and Bolivia, resulting in significant mercury pollution. Climate change may further intensify these pressures, as large amounts of gold were recently uncovered in areas formerly covered by glaciers, posing risks to water supplies from mining pollution. Within the urban landscape, the increasing urban population will likely result in rising pollution pressures and higher associated economic impacts of pollution in the future.

The government of Bolivia is implementing a series of measures to strengthen environmental management and improve environmental health. They range from a large investment program in water supply and sanitation and education and hygiene programs to the ongoing restructuring of the legal framework for the management of natural resources and the environment, culminating in the passage of the Mother Earth Law on September 5, 2012. Sustainable use of natural resources and efforts to build resilience to climate change are a cornerstone of the government development strategy. Environmental stewardship and risk management is one of six strategic guidelines underlying the current administration's 2006–2011 National Development Plan, entitled "A Dignified, Sovereign, Productive and Democratic Bolivia to Live Well," and is a central element of the new Bolivian Constitution.

This report summarizes the outcomes of the pillar of the program on analytical services and is divided into five chapters: (1) Improved water supply, sanitation, and hygiene: health impacts; (2) Innovation in solid waste management: options for the future; (3) Reuse of wastewater to mitigate water scarcity: case studies in Cochabamba and Tarija; (4) Cooperative gold mining: dynamics and challenges in a rapidly growing sector; and (5) Mining and water: the benefits of integrated water resource management at the watershed level. In every instance, the focus has been on identifying the windows of opportunity for policy action and investment in what is an often complex social and economic setting. The findings and recommendations carried out as part of the program have been consulted upon with a broad range of stakeholders in Bolivia through the series of workshops on each of the topics, and the recommendations presented in this report are limited to a range of options that are feasible and yet innovative in the current context – hence the reference in the title of this report to "innovations and opportunities."

### Improved Water Supply, Sanitation, and Hygiene: Health Impacts

Bolivia has achieved substantial reductions in child mortality, including due to diarrheal illness, but child mortality remains high. Although diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people. Therefore, the main focus of this study is on diarrheal illness resulting from inadequate water supply, sanitation, and hygiene. As estimated in chapter 1, the departments with the highest number of diarrheal deaths among children under the age of 5 are those with the lowest GDP per capita. The diarrheal mortality burden is highest among poor children under age 5: it is 3.5 times higher than among children in higher quintiles (figure ES.1).

In terms of the regional distribution of the burden of disease, this study finds that diarrheal mortality among children under age 5 is highest in Potosí, Santa Cruz, Cochabamba, and La Paz. Those regions have the highest total number of cases of annual diarrheal mortality in children under age 5 attributed to inadequate water supply, sanitation, and hygiene (figure ES.2). Spatial analysis of diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene among children under age 5 per 1,000 live births shows that the greatest burden is in Potosí, Cochabamba, and La Paz, where this indicator is at 15 to 20 annual diarrheal deaths per 1,000 live births in the rural population and 8 to 11 annual diarrheal deaths per 1,000 live births in the urban population.

Diarrheal illness imposes significant costs on the Bolivian economy and welfare of nearly 1 percent of the annual GDP, without considering the costs of diarrheal mortality. This study estimates the annual cost of diarrheal morbidity from inadequate water supply, sanitation, and hygiene at Bs. 0.93 billion to 1.10 billion (or between 0.8 and 0.9 percent of the 2008 GDP), including Bs. 0.7 billion to 0.81 billion for urban areas and Bs. 0.23 billion to 0.26 billion for rural areas. These morbidity costs include the costs of illness (medical treatment, medicines, and value of lost time due to illness or attending to sick children).

Additional costs result from "averting behavior," whereby people take such measures as purchasing bottled water for drinking, boiling or chlorinating water, or installing water purification filters in order to avert the perceived health risks.

**Figure ES.1 Poverty and child mortality (under age 5) due to diarrheal illnesses attributed to inadequate water supply, sanitation, and hygiene**

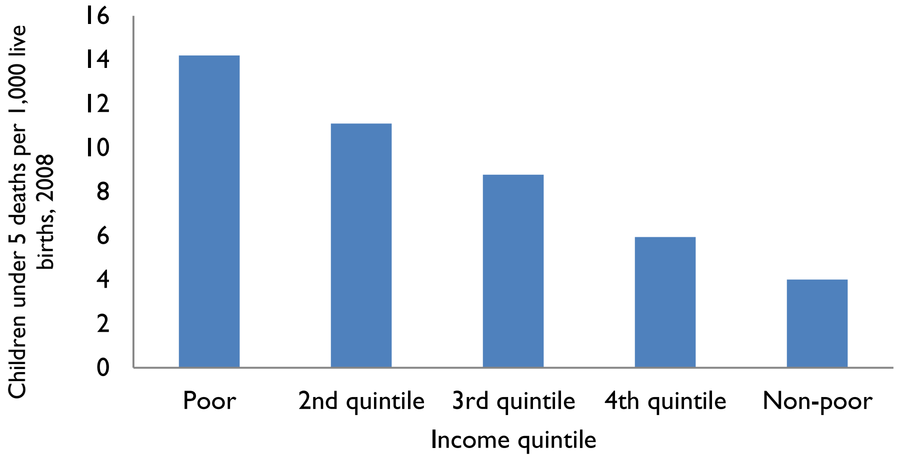
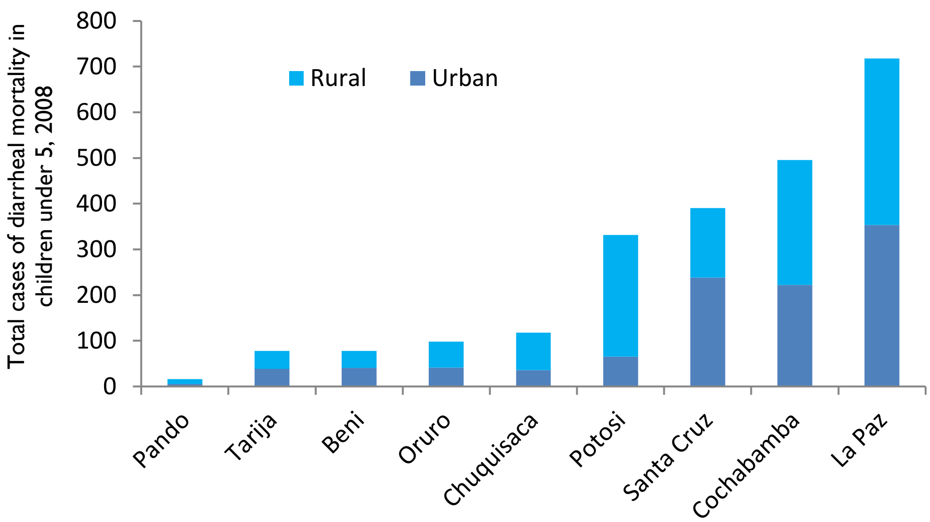



**Figure ES.2 Children under 5: annual diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene**




The study estimates that only about 11 percent of the urban population and 4 percent of the rural population in Bolivia practice water disinfection (DHS 2008). Water boiling is the dominant disinfection method, with about 80 percent of all persons who practice water disinfection boiling their drinking water. Finally, the study did not attempt to quantify the costs of diarrheal mortality in economic terms, as the feedback received during the technical workshops at the inception of the study did not favor that approach.

The investment in improving water supply, sanitation, and hygiene in particularly vulnerable areas needs to be scaled up to make a dent in Bolivia's child mortality and morbidity. Using a well-established World Health Organization (WHO) methodology for the analysis of health risks, the study estimated the expected reduction in child mortality in Bolivia that the implementation of the 2011–2014 Water, Sanitation, and Hygiene Program (of the Ministry of Environment and Water) would bring about. It is estimated that the program would make it possible to achieve an annual reduction of about 290,000 to 485,000 cases of diarrheal illness and 45 to 70 deaths in urban areas, and of about 100,000 to 250,000 cases of diarrheal illness and 30 to 45 deaths in rural areas. This equals only about 3 to 5 percent of the total cases of mortality and morbidity associated with inadequate water supply, sanitation, and hygiene.

Several key messages and policy recommendations emerge from chapter 1. First, environmental health risks impose a significant burden on Bolivia's economy – an estimated 2,300 children die prematurely every year in Bolivia due to the lack of access to water supply, sanitation, and hygiene. Second, cost-effective interventions to address these environmental health risks exist and should be prioritized in Bolivia, focusing mainly on the areas with the highest burden of diarrheal illnesses and mortality (Potosí, Cochabamba, and La Paz departments, especially in the rural areas). Third, environmental health analysis is a useful tool for assessing the ex ante impact of sectoral investment programs and policies. The scenario analysis shows that the implementation of the ongoing Water, Sanitation, and Hygiene Program in Bolivia (2011–2014) would reduce diarrheal illnesses by an estimated 390,000 to 735,000 cases per year, and would reduce diarrheal mortality by 75 to 115 cases per year. However, investment is still far short of the levels required to significantly reduce child mortality due to diarrheal illness. New ways of looking at the problem of the quality of water and sanitation services and child health can generate strong policy impetus for increased investment in the sector.

### Innovation in Solid Waste Management: Options for the Future

In Bolivia, population growth in combination with changes in consumption and production patterns have led to an increase in the generation of solid waste. This has attracted attention to weaknesses in the country's solid waste management practices. There are a number of problems in this regard, mainly related to final disposal and its repercussions on the environment. Chapter 2 provides a baseline assessment of the solid waste management sector in Bolivia and includes an analysis of the general context and the range of financing, regulation, management models, and contracts that offer viable options for strengthening the sector.

The solid waste management sector in Bolivia will be facing major challenges in the coming years. Population growth patterns and the subsequent increase in consumption as a result of economic development will be reflected in a significant increase in the production of solid waste. In the year 2010, the General Directorate for Integrated Solid Waste Management (Dirección General de Gestión Integral de Residuos Solidos, DGGIRS) of the Ministry of Environment and Water estimated that the total generation of solid waste was 1.75 million tons per year or 4.8 tons per day, of which 87 percent came from urban and 13 percent from rural areas. Considering current growth patterns in population and per capita production, it appears that by 2015 these numbers will climb to 2 million tons per year or 5.5 tons per day. The actual amount may be even higher if expected changes in consumption patterns are factored in. Although coverage in terms of garbage collection, street sweeping, and transport is good in provincial capitals and in large municipalities, weaknesses are evident in medium-sized and smaller towns, particularly those located in outlying areas. Conditions for final disposal are inadequate in most municipalities, and only half the waste produced in the country is transported to landfills.

In view of the challenges that lie ahead, the Ministry of Environment and Water has taken several significant steps. The most notable of these has been the creation of the DGGIRS as a specific unit for the solid waste management sector. For its part, the Directorate has worked hard to strengthen the sector. National planning has been strengthened through the diagnostic study for the Plurinational Program for Integrated Solid Waste Management; the legal framework has been strengthened by drafting the Solid Waste Management Law; and technical assistance has been provided to the municipal-level authorities by drafting the guide for preparing solid waste projects and other guides, manuals, and workbooks. The program has included direct technical assistance to the DGGIRS and has provided technical inputs in the preparation of the draft law and the guidance for the municipalities.

It is now important to move forward to the implementation phase of the measures proposed by the DGGIRS. The main obstacles are the scarcity of resources and the difficulty in obtaining financing; the remaining gaps in the regulation of the sector in the area of compliance with national targets and service provision; and the selection of management models and contracts for service provision by public, mixed, and private providers in a manner compatible with the existing municipal administrative models in Bolivia.

A range of options can be implemented by the government in order to deal with these challenges and scale up investment in the sector. Viable alternatives to attract resources to the cash-strapped sector include an increase in national, external, and private investment in the sector by means of different financing mechanisms, the development of a cost calculation mechanism, and the introduction of a service fee collection law to cover recurrent costs. In order to regulate the sector it is important to clearly define the actors that deliver service provision and regulate the sector, and grant them the economic and legal instruments they need to improve service delivery. Management models could be geared toward the regionalization of the service (for instance, the establishment of associations of municipalities) and the creation of decentralized solid waste management units. The relevant contractual models may vary depending on the size and type of municipality, and the degree of participation by the private sector.

### Reuse of Wastewater to Mitigate Water Scarcity: Case Studies in Cochabamba and Tarija

Wastewater reuse is an important policy priority on the environmental management agenda in Bolivia because of the growing scarcity of water resources in the Bolivian highlands, projected to increase with climate change. According to the 2008–2015 National Basic Sanitation Plan, in 2007 nationwide drinking water and sewerage services were available to 75 percent and 48 percent of the population, respectively. In urban areas, these percentages climb to 88 percent and 54 percent. The National Basic Sanitation Plan estimates that 70 percent of the wastewater collected is not treated at all, with the remaining 30 percent receiving inadequate treatment, due to difficulties with the efficacy of wastewater treatment plants.

Rapid urbanization and industrial growth in some areas of the country have led to a sharp increase in the demand for water for use in homes and for industrial purposes, and have been factors in the increase in water pollution. On occasion these sectors use up the entire supply of water, to the detriment of irrigation for agricultural uses. In such a scenario, the reuse of wastewater becomes a need and serves to compensate for the fact that very few water sources are entirely uncontaminated.

The treatment and reuse of domestic wastewater for crop irrigation is an increasingly common practice in many countries, due to the lack of freshwater for use. In Israel, 67 percent of domestic wastewater is reused for irrigation, 25 percent in India, and 24 percent in South Africa. The use of domestic wastewater for irrigation allows for achieving similar or greater yields than those obtained with the use of water from natural sources that has not been reused and avoids or reduces the use of fertilizers, as wastewater is already high in nutrients, particularly nitrogen and phosphorus. However, unless appropriate treatment techniques are used, risks to the health of farmers growing the crops as well as consumers of the harvest are high. Therefore, domestic wastewater reuse methods must follow strict treatment and control measures that allow for enjoying the advantages this practice involves, while minimizing risks to farmers and consumers.

Chapter 3 of this report presents the results of an evaluation of the potential for reusing wastewater to irrigate agricultural land in Bolivia. The main goal of this evaluation is to place the reuse of wastewater in Bolivia in a broader context and generate lessons from what has been achieved so far. The analysis undertaken in this chapter in the case studies of the potential for wastewater reuse in Cochabamba and Tarija is intended as a preliminary stage in the development of wastewater reuse projects. The study's focus is on a technical assessment of the feasibility of applying wastewater stabilization reservoir technology in Bolivia. However, it is necessary to think ahead to later stages, which will include an evaluation of the social impact that wastewater stabilization reservoirs will have on communities in the areas of influence of wastewater reuse projects.

The results of the Cochabamba and Tarija case studies illustrate the significant potential for safe reuse of treated wastewater in Bolivia as a solution to the problems caused by water scarcity in parts of the country, and show how it is truly the potential driving force behind their economic development. The case studies also demonstrate how through the use of adequate technology, such as stabilization reservoirs, it is possible to achieve the quality necessary for safe and unlimited irrigation, to optimize the use of water by maximizing the arable land area under irrigation (on occasion even tripling the area irrigated with the use of other technologies), and to simultaneously simplify the operation and maintenance work needed to ensure the long-term sustainability of the irrigation service. It is revealing that according to the data gathered for a recent study sponsored by the German Agency for International Cooperation (GIZ) and carried out by the Ministry of Environment and Water, with the solutions proposed herein for Cochabamba and Tarija, irrigation using good-quality water can be ensured for an incremental area equivalent to 67 percent of the total area currently under irrigation in the country and which uses wastewater on an irregular basis.

In order to ensure the viability of the planned treated wastewater reuse scheme, it is necessary to overcome certain barriers that put its long-term sustainability at risk. Among these is the general discontent of the population living in the vicinity of the country's wastewater treatment plants, due to the foul smells that emanate as a result of inappropriate treatment technologies, inadequate maintenance and operation of the facilities, and poor urban planning. As can be seen in the case of Tarija, this discontent translates into open opposition by broad-based sectors of the population to any type of initiative related to wastewater management.

### Cooperative Gold Mining: Dynamics and Challenges in a Rapidly Growing Sector

Another pressing issue addressed by this report is mining pollution of watersheds. The issue is first addressed by looking at the opportunities for introducing clean technologies (in chapter 4), and then by prioritizing critical watersheds (in chapter 5). Artisanal, small-scale, and medium-scale (ASM) gold mining is a key source of employment and income in rural Bolivia, often complementing traditional agricultural activities. The registration of new gold mining cooperatives has boomed in the last five to six years as the price of gold has risen. As a result, the number of gold mining cooperatives has almost doubled since 2006. Whereas many new cooperatives are located in traditional gold mining regions, others are located in new regions with limited experience or capacity to cope with the externalities from mining.

Chapter 4 analyzes the new developments in cooperative gold mining in Bolivia, and its environmental impacts. The chapter also examines how national and international best practice experiences with cleaner technology could be scaled up by introducing more appropriate and efficient processing techniques to the hundreds of new ASM gold mining cooperatives operating in fragile environments.

Mining has always played a significant role in Bolivia's economy and continues to be a key source of income, comprising 9.6 percent of GDP and 30.9 percent of total exports in 2011. Gold is the fourth most important mineral by value extracted in Bolivia, with the majority of production currently being undertaken by ASM cooperatives. These gold mining cooperatives provide new income and employment opportunities in some of the most remote and poor regions of the country, but they also lead to new environmental challenges. Therefore, there is an urgent need to identify ways to support the cooperatives to employ more appropriate and efficient processing techniques.

International and Bolivian experiences illustrate that clean technology can be introduced to ASM gold mining at relatively low cost and with significant impacts. Several of the cases reviewed in this study demonstrate win-win scenarios whereby cleaner processing techniques have reduced the use of mercury and simultaneously improved productivity. In particular, experiences from Colombia provide well-documented cases on how projects have improved productivity, reduced operational costs, and mitigated contamination from mercury and other chemicals (table ES.2). Bolivian best practice cases are also available and demonstrate the existence of local technical capacity, an important advantage in order to provide the cooperatives with technical support. One example is the Cotapata Mining Cooperative near La Paz, which in 2010 was the first Bolivian mine certified by Fairtrade/Fairmined. The Cotapata Mining Cooperative shows some of the benefits of improving existing processing techniques but it also illustrates that mining activities can coexist with conservation within a national park when the production process is well designed and takes into account the surrounding landscapes and other resource users.

These experiences reveal that it is possible to implement effective clean technology programs with ASM miners. However, the rapid assessment of the gold mining cooperative sector in Bolivia, carried out in this study, also shows that the cooperatives are a very heterogeneous group and that taking into account the multifaceted characteristics of the cooperatives is necessary in order to scale up these experiences.

**Table ES.2 ASM clean technology experiences in Colombia**

| | Mercury reduction | Productivity | Additional benefits |
|---|---|---|---|
| Global Mercury Project II: Antioquia | 10 tons of mercury | Processed minerals increased from 95 tons to 126 tons per day | Recovery of gold increased by 31% |
| Green Gold (Oro Verde): Pacific Coast | No use of mercury | Premium of 2% over official prices of gold | Improved access to local decision-making |
| Rio Surata Project: Vetas and California regions | 67% reduction in the use of mercury | 76% increase in recovery of gold | Operational costs of processing reduced by 62% |

The gold mining cooperatives in Bolivia include both hard rock and alluvial mining, which are carried out from extreme altitudes (5,000 meters above sea level) to barge dredging in the Madre de Dios River in the Amazon basin. Even neighboring cooperatives differ significantly in size, productivity, processing techniques, organizational capacity, and access to equipment. Moreover, their widespread dispersion makes monitoring and regulating their activity very costly and difficult.

Targeting this heterogeneity faces an additional challenge in that no database of the cooperative mines currently exists. Therefore, considerable time was used in this study to collect basic data from different institutions to establish an overview of where cooperative mining operates, the number of environmental licenses, and the types of minerals the cooperatives exploit. A more complete database is crucial in order to propose adequate technological improvements, in a tailored manner, considering the different characteristics of the gold mining cooperatives. From a technical perspective, it would be relatively straightforward to establish such an information system as most of the cooperatives are already registered, but it should be done in close coordination with the mining federations to ensure a constructive collaboration.

The rapid assessment of the cooperative mining sector also illustrates that there appears to be a growing willingness to mitigate some of the environmental impacts from mining. This was clear in the dialogue with cooperatives during the field visits carried out as part of this study, but it is also evident in examining the growth of environmental licenses issued since 2000. More than 80 percent of the environmental licenses were issued from 2009 to 2011, possibly indicating a new environmental awareness (MMM 2011). The alluvial mining cooperatives appear to be front-runners, as they presented 72 percent of the registered environmental documents. However, the mining cooperatives stressed in the dialogue that rigid technical requirements, high costs, and relatively complex and time-consuming bureaucratic processes are barriers for many cooperatives, especially the smaller ones with limited resources to contract technical support. More flexibility and technical support by the Ministry of Mining and Metallurgy to comply with the environmental regulations were requested by the cooperatives.

The review of the international and regional experiences also detected some gaps that need to receive more attention in the future. Whereas significant results have been demonstrated in reducing the use of mercury and other chemicals, limited methodological progress has been observed regarding innovative processing techniques to protect and restore landscapes, natural vegetation, biodiversity, rivers, and river catchments. Furthermore, many projects have been implemented in a relatively isolated manner with the ASM miners, with a more integrated approach engaging other stakeholders being employed to a lesser extent.

Given the limited focus on natural resource degradation and multistakeholder planning in the ASM sector in Bolivia, this study proposes strengthening this area through the integrated watershed management policy framework. This approach could be well integrated in the National Watershed Plan, which aims to engage all local stakeholders and establish long-term and sustainable management plans of local natural resources. As shown in chapter 5, hydrologic resources are critical for multiple uses (agriculture, livestock rearing, drinking water) but are highly vulnerable to mining activities, making this framework even more important. Furthermore, impacts are not just restricted to vulnerable watersheds but many protected areas are also highly vulnerable to mining. For example, in the Apolobamba and Cotapata National Parks, 206 and 37 mining operations are registered, respectively, which indicates that integrated territorial planning should involve multiple institutions and sectors.

The following policy recommendations have emerged from the analysis of and consultations held with the cooperative mining sector in Bolivia. Cooperative gold mining has received relatively limited attention the last few years, but the rapid growth of the sector calls for immediate action to mitigate contamination and natural resource degradation. Though donor agencies and government institutions face difficulties providing such rapid responses, it is an important advantage that relatively simple and low-cost technologies already exist that can reduce the use of mercury and improve the recovery of gold. It is a potential win-win situation and it has proven possible to change the processing techniques of ASM miners. The essential conditions have been identified in this study in order to scale up these pilot experiences in the gold mining regions of Bolivia. As revealed through consultations with the National Federation of Mining Cooperatives (Federación Nacional de Cooperativas Mineras, FENCOMIN) and other stakeholders, those conditions include the need to develop tailored approaches to working with different cooperatives, establish credit mechanisms, and creating an adequate institutional space for dialogue between miners, communities impacted by mining operations, and other stakeholders. The National Watershed Plan could potentially fill this void and promote an integrated development approach.

Despite these five challenges, cleaner and more efficient technology could be a win-win solution for most stakeholders and an acceptable approach for the government to engage more with the cooperative mining sector without triggering conflict, as has happened when relying exclusively on the enforcement of environmental regulations.

### Mining and Water: The Benefits of Integrated Water Resource Management at the Watershed Level

The 2006–2011 National Development Plan, which is a key instrument guiding the country's development and strategic investments, recognizes the importance of integrated water resource management at the level of the watershed as being the indispensable condition for participatory sustainable development in Bolivia. The government of Bolivia has been promoting integrated water resource management since 2007. So far, considerable progress has been made in promoting cross-sectoral coordination in the planning of water resources for irrigation, drinking water, and sanitation. As regards water resources and mining, there still persists a sectoral vision of planning and management. The environmental impact assessments for mining activities often fail to measure impacts from a basin perspective. Impacts on the quality of water for downstream users, on the environmental services provided by ecosystems, and on agriculture, and issues of water stress and its impacts at basin level, are usually overlooked. Bolivia is among the countries with the highest per capita water availability in the world (approximately 38,000 cubic meters per inhabitant in 2010). However, the distribution of this supply of water is not homogeneous, either in space or time, and there are parts of the country that enjoy good availability while others suffer from a water deficit. The mining sector uses 3 percent of Bolivia's water resources, but knowledge concerning the sector's demands for water and an understanding of its environmental impacts on the resource is limited. This study finds that approximately 17 percent of the watersheds, covering some 41 percent of the country's surface, receive contributions of water that has passed through zones with mining activity and could potentially be at risk of pollution from mining. Approximately 63 of the population uses water coming from areas in which there is mining. Furthermore, 6 percent of dams have drainage areas that are possibly exposed to pollution from heavy metals associated with mining activities.

In general, it is recognized that there is a need to act, and therefore political will exists to define a country strategy that promotes the sustainable use of water resources by the mining sector. For this reason, the government of Bolivia, nongovernmental actors, and other development partners have selected water and mining with a watershed perspective as a priority environmental issue, and requested that research on this subject be included in this Strategic Country Environmental Study.

The work carried out on this topic, the results of which are summarized in chapter 5 in this report, strives to identify the priority basins and sub-basins in terms of ongoing or future mining activities, using an integrated water resource management approach. Currently there are many studies that have attempted to evaluate the impacts of mining activities on water resources. Unfortunately, they fail to provide a countrywide overview of the most important basins in which the mining sector plays a predominant role. In trying to fill this knowledge gap, this study also contributed to the assembling of all available geographic databases relevant to evaluate the impacts of mining activity on water resources in a Mining-Environmental Information Platform compiled through the program and transferred to the Ministry of Environment and Water and the Ministry of Mining and Metallurgy (box ES.1).

This study reveals the necessity for integrated watershed management through coordination of national guidelines and policies and sectoral plans at the watershed level, and putting in place environmental management systems for mining activities. Further, the study reveals the need to define the areas in which mining activities are prohibited, such as the drainage areas of reservoirs, not only to counteract the possible impact on the quality of water used for drinking and irrigation, but also to avoid the sedimentation and siltation of dams.

The study further reveals the need to restrict mining in protected areas, especially those that contain rain forests and wetlands. The use of these rapid diagnostic tools does not, however, replace the need for a strategic environmental and social assessment of the watershed or environmental impact assessments of mining projects. Finally, the study demonstrates how valuable it is to have on hand systematized spatial information.

**Box ES.1 Methodology to prioritize watersheds using Mining-Environmental Information Platform**

The study used an evaluation matrix to prioritize watersheds according to the economic and social pressures resulting from mining pollution. The matrix took into account the relative importance of watersheds with respect to population density, agricultural production, poverty index, and land area under a protective regime. A value was assigned to each variable, and a weighted average of the values was used as an indicator of the level of priority of the watershed. The priority watersheds from a mining perspective and a watershed protection perspective are located in the Lake Titicaca and Lake Poopó macrobasin, and at the headwaters of the macrobasins of the Beni, Pilcomayo, and Grande Rivers. It is in these hydrologic units that close coordination between the Ministry of Mining and Metallurgy and the Ministry of Environment and Water needs to be promoted, for the purpose of planning sustainable use of water resources and developing specific programs.

## Toward a Policy Action Agenda

Through a combination of analytical studies and technical and consultative workshops carried out throughout the implementation of the program a series of policy recommendations have emerged, all of which are socially and economically feasible as short- and medium-term options. They include the need to scale up investment (and some proposed ways of doing so), strengthen the implementing regulations, adopt integrated planning approaches, and strengthen information systems, as summarized in table ES.3.

**Table ES.3 Priority policy recommendations**

| Priority area | Recommendations for short-term policy and investment action |
|---|---|
| Environmental health | Link the environmental health and water supply, sanitation, and hygiene sectoral agendas closely in policy discussions and scale up investment in the water supply, sanitation, and hygiene sector to significantly reduce child mortality and morbidity from diarrheal illness<br>Improve the efficiency of the investments by targeting areas with highest environmental health costs<br>Strengthen the monitoring and evaluation framework in the water supply, sanitation, and hygiene sector by bringing in environmental health-related indicators |
| Solid waste management | Scale up investment in the solid waste management sector by strengthening the existing and exploring new financial and contractual management models, appropriate to the context of the Bolivian municipal administration models<br>Develop an action plan and earmark funding to implement the new National Solid Waste Management Plan |
| Wastewater reuse | Pilot alternative models of wastewater reuse in practice, and carry out a social evaluation of the implications of alternative reuse scenarios |
| Promotion of clean technologies in the cooperative mining sector | Develop and implement a technical assistance program on clean technologies for the cooperatives, with joint implementation by the Ministry of Mining and Metallurgy and Ministry of Environment and Water<br>Create a shared information platform at the watershed level, possibly by institutionalizing the Mining-Environmental Information Platform with inputs from the program, and accessible to the Ministry of Mining and Metallurgy, Ministry of Environment and Water, and other relevant agencies |
| Mining from a watershed perspective | Establish a practical prioritization system on the basis of an information platform to define critical areas for the protection of water sources under highest pressure from pollution from different sources, including mining |

# Chapter 1. Improved Water Supply, Sanitation, and Hygiene: Health Impacs

## 1.1 Introduction

Bolivia is a mountainous, multiethnic, and diverse South American country with rich mineral deposits and energy resources, but with one of the continent's highest percentages of people living in poverty and least developed economies. Of the 9.9 million inhabitants, 34 percent live in rural areas and are mainly dependent on agriculture (World Bank 2009). The population grew about 2 percent during 2000–2009. The per capita gross domestic product (GDP) ($1,758) is one of the lowest in South America and grew 1.7 percent during 2000–2009. GDP has been growing at an average rate of 3.7 percent[2] over the last decade, significantly lower than the corresponding growth rates in other Latin American countries, for example Ecuador and Peru. Bolivia also encounters a large development deficit in relation to other selected development indicators, such as water supply and sanitation (table 1.1).

This chapter provides estimates of the costs of inadequate water supply, sanitation, and hygiene in Bolivia. These costs are mainly reflected by the impact of microbiological water contamination. The cost of chemical water pollution in this analysis is only captured in terms of waterborne illnesses (diarrhea). Other costs, such as the potential health impacts of heavy metals and chemicals and recreational value, are not estimated due to data constraints.Monetary valuation of environmental damage and quantification of environmental damage involve many scientific disciplines, including physical and biological studies, health sciences and epidemiology, and environmental economics. More precisely, environmental economics relies heavily on other fields within economics, such as econometrics and welfare, as well as public and project economics. New techniques and methodologies have been developed in recent decades to better understand and quantify the preferences and values of individuals and communities in the context of environmental quality, conservation of natural resources, and environmental health risks. The applied results from these techniques and methodologies can then be – and often are – utilized by policy makers and stakeholders in the process of setting environmental objectives and priorities.

Moreover, because preferences and values are expressed in monetary terms, the results can provide an additional guiding principle for the allocation of public and private resources across diverse socioeconomic development goals. For this purpose, the estimation of inadequate water supply, sanitation, and hygiene costs presented in this chapter is accompanied by an assessment of interventions for environmental improvements so that the benefits and costs of such interventions can be better understood.

The cost of environmental degradation comprises economic as well as other costs. Economic costs include medical treatment cost and workdays lost due to illness associated with environmental pollution; and losses in tourism revenues due to pollution and natural resource degradation. Other costs are associated with reduced well-being and quality of life, and include pain and suffering from poor health and disability; and the loss of recreational quality and natural heritage due to degradation of natural resources.

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[2] Average GDP growth rate at constant prices over the 2000–2007 period (Banco Central de Bolivia, 2008).

**Table 1.1 Comparison of selected economic and social indicators in Latin America and Caribbean (LAC) countries (2007–2009)**

| | Bolivia | Peru | Ecuador | LAC (developing countries) |
|---|---|---|---|---|
| Literacy rate, adult total (% of people aged 15 and above) | 91 | 90 | 84 | 91 |
| Urban population (% of total) | 66 | 72 | 66 | 79 |
| Improved sanitation facilities (% of population with access) | 25 | 68 | 92 | 79 |
| Improved water source (% of population with access) | 86 | 82 | 94 | 93 |
| Malnutrition prevalence, weight for age (% of children under age 5) | 4.5[a] | 2.1[a] | 6.2[a] | 4 |
| Mortality rate, under age 5 (per 1,000) | 51 | 21 | 24 | 23 |
| Population growth (annual %) | 2 | 1 | 1 | 1 |
| Population, total | 9.9[b] | 29.1[b] | 13.6[b] | 572.5[b] |
| Gini index | 57 | 51 | 54 | |
| Income share held by highest 20% | 61 | 55 | 59 | |
| Income share held by lowest 20% | 3 | 4 | 3 | |
| Poverty headcount ratio at national poverty line (% of population) | 38 | 52 | 38 | |
| GDP per capita (current US$) | 1,758[b] | 4,469[b] | 4,202[b] | 6,980[b] |
| GDP per capita growth (annual %) | 1.3 | 5.7 | 2.7 | 1.7 |

a. 2004–2008; b. in 2009.

*Sources:* World Development Indicators, 2007–2009; http://www.tradingeconomics.com; WHO database for 2007–2008.

When the cost of environmental degradation is estimated, a distinction is made between financial and economic costs. To the extent feasible, economic cost should be applied, because it captures the cost to society as a whole and the reduction in its well-being. For instance, the financial cost of health services that an individual pays may be substantially less than the cost of providing those services. It is therefore important to estimate the real cost to society of providing those services. Another example is time lost due to illness or to caring for sick family members. If the sick person or caregiver does not earn income, the financial cost of time losses is zero. However, if the person is normally engaged in activities that are valuable for the family, and time losses impair these activities or reduce the amount of time available for leisure activities, the family incurs an economic loss. In economics and welfare analysis, this is normally valued at the opportunity cost of time, that is, the salary, or a fraction thereof, that the individual could earn if he or she chooses to work for income.

## 1.2 Water Supply, Sanitation, Hygiene, and Poverty

The methodology for estimating the cost of environmental damage can be broadly classified in three categories:

Estimating the impacts on health of inadequate water supply, sanitation, and hygiene

Valuing or estimating the cost of illness resulting from these impacts (mortality and morbidity)

Estimating averting expenditures (additional to the costs of illness in the previous step)

First, the impacts of the lack of access to water supply or sanitation on health are estimated in this report by using the relationships established by the World Health Organization (WHO) in a broad range of countries. Second, those impacts, expressed in terms of premature mortality and morbidity primarily within the most vulnerable population group of children under 5 years old, are translated into the number of children that become ill and die prematurely. The premature deaths and the burden of disease are expressed in terms of disability-adjusted life years (DALYs), a concept broadly used in the medical literature to express the severity of disease impacts. One case of premature mortality translates into 34 DALYs and one episode of diarrheal illness into 0.01 DALYs. Theoretically, a monetary value could be assigned to premature deaths and morbidity. However, based on the inputs from the workshops carried out during the implementation of this study in Bolivia and the reluctance by the agencies consulted to carry out such valuation, this method was not used in this study. Last, averting expenditures – or expenditures that households undertake to reduce the risk of the disease, such as purchasing bottled water – were estimated. The averting costs are the additional costs above and beyond the cost of illness due to premature mortality and morbidity and thus they are additive with the costs of illness and mortality.

The country's departments reveal a range of results for different demographic, geographic, economic, and social indicators (table 1.2) Per capita GDP, for example, ranges from Bs. 8,000 to 11,000 in Beni, Chuquisaca, Cochabamba, Potosí, and La Paz to over Bs. 27,000 in Tarija.

The water and sanitation sector in Bolivia is faced with the following problems:

- Inadequate water service quality;
- Inadequate sanitation service quality, particularly relating to wastewater treatment;
- Inadequate coverage, especially in the poorer rural and peri-urban areas.

WHO suggests that the health impact with regard to inadequate drinking water supply and sanitation is correlated with the coverage of improved water supply and sanitation (JMP 2008). Box 1.1 presents WHO's definitions of improved and unimproved drinking water supply and sanitation, which are applied in this chapter.

**Table 1.2 Selected basic indicators by department in Bolivia**

| Department | Land area km$^2$ | Population 2005 (000) | Population density per km$^2$ | Urban population share | GDP per capita 2009 (Bs.) | Child mortality rate 2008[a] |
|---|---|---|---|---|---|---|
| Chuquisaca | 51.5 | 0.65 | 13 | 49% | 8,410 | 56 |
| La Paz | 134 | 2.84 | 21 | 69% | 10,784 | 81 |
| Cochabamba | 55.6 | 1.86 | 33 | 65% | 9,971 | 85 |
| Oruro | 53.6 | 0.45 | 8 | 62% | 15,180 | 69 |
| Potosí | 118.2 | 0.79 | 7 | 35% | 10,548 | 126 |
| Tarija | 37.6 | 0.52 | 14 | 69% | 27,168 | 48 |
| Santa Cruz | 370.6 | 2.79 | 8 | 78% | 11,869 | 46 |
| Beni | 213.6 | 0.45 | 2 | 71% | 7,990 | 56 |
| Pando | 63.8 | 0.08 | 1 | 53% | 13,588 | 62 |
| National | 1,098.5 | 10.4 | 9 | 66% | 11,671 | 63 |

*Sources:* Montes de Oca 1997; PAHO 2006; World Bank 2011; http://www.ine.gob.bo.

a. Adjusted with regard to PAHO 2006, World Development Indicators 2006 estimates.

Data related to access to improved water supply and sanitation in Bolivia vary by data source. For example, table 1.3 presents different coverage estimates for improved water and sanitation from different sources. According to the WHO and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) for Water Supply and Sanitation (JMP 2008), 96 percent of the urban population and 67 percent of the rural population in Bolivia have access to water supply piped into dwellings or yards; 34 percent of the urban population and 9 percent of the rural population have access to improved sanitation (connection to public service or septic tank). Pit latrines and shared facilities are excluded from improved sanitation facilities, since there is no evidence that pit latrines are protected, and shared facilities in general are considered unimproved. The Bolivia Demographic and Health Survey (DHS 2008) provides estimates similar to those of JMP. Both focus on the human health dimension – how improved water supply and sanitation reduce the transfer of harmful pathogens. In contrast, shared water supply and sanitation facilities are included in the definition of basic water supply and sanitation services applied by the Ministry of Environment and Water. This definition is premised on the availability of the service, and does not focus on the health impact.

**"96 percent of the urban and 67 percent of the rural population in Bolivia have access to water supply piped into dwellings or yards; 34 percent of the urban population and 9 percent of the rural population have access to improved sanitation."**

## Box 1.1 Definitions of improved drinking water supply and improved sanitation

**Improved sources of drinking water**

- water piped into dwellings (household connection)
- water piped to yards/plots (yard connection)
- public taps or standpipes
- tubewells or boreholes
- protected dug wells
- protected springs
- rainwater

**Unimproved sources of drinking water**

- unprotected springs
- unprotected dug wells
- carts with small tank/drum
- tanker trucks
- surface water
- bottled water

**Improved sanitation**

- flush toilets
- piped sewer systems
- septic tanks
- flush/pour flush to pit latrines
- ventilated improved pit latrines (VIP)
- pit latrines with a slab
- composting toilets

**Unimproved sanitation***

- flush/pour flush to elsewhere
- pit latrines without slabs
- use of buckets
- hanging toilets or hanging latrines
- open defecation

* Sanitation facilities that are shared among households – whether fully public or accessible only to some – are not considered "improved" facilities. Although the use of shared sanitation does reflect demand, limited data confirm the widely held perception that many of these facilities, especially public ones, fail to ensure hygienic separation of human excreta from human contact. Serious concern has also been expressed about the actual accessibility of such facilities throughout the day and about the security of users, especially at night. Further research is needed on the nature and acceptability of shared facilities.

*Sources:* JMP 2008; WHO website http://www.who.int/water_sanitation_health/monitoring/sanitation.pdf.

**Table 1.3 Access to water and sanitation**

| | JMP | DHS | Ministry of Environment and Water |
|---|---|---|---|
| Access to improved water (% of urban population) | 96% | 94% | 88% |
| Access to improved water (% of rural population) | 67% | 73% | 54% |
| Access to improved sanitation (% of urban population) | 34% | 31%[a] | 50% |
| Access to improved sanitation (% of rural population) | 9% | 6%[b] | 37% |
| Wastewater treatment (%) | | | 30% |

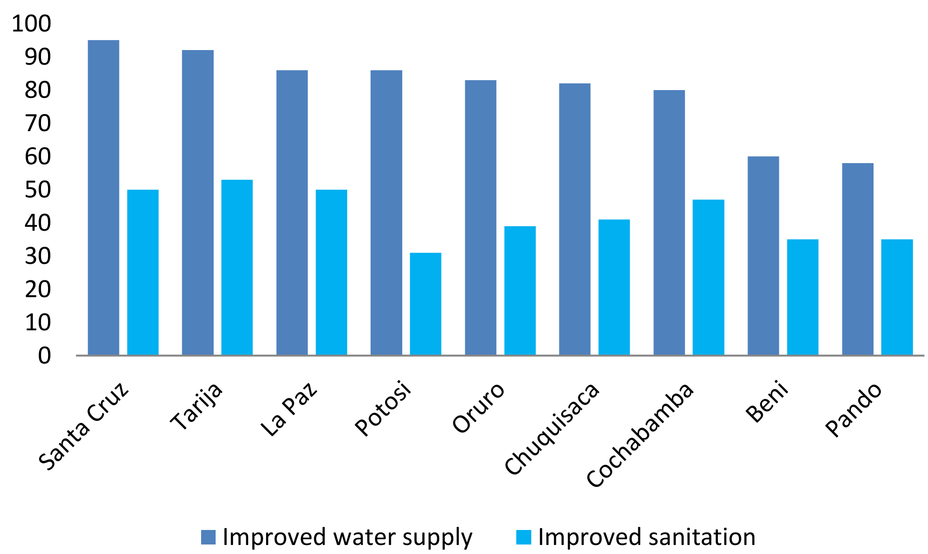
*Sources:* Ministry of Environment and Water 2009; JMP 2008; DHS 2008.

a. Excluding 60% of urban population with shared sanitation facilities, which are "unimproved" by WHO definition.

b. Excluding 38% of rural population with shared sanitation facilities, which are "unimproved" by WHO definition.

Using the data from DHS 2008, the percentage of the population with water connection, water drainage, and sanitation by department is presented in figure 1.1. Access to improved water ranges from over 90 percent in Santa Cruz to 60 percent in Pando, while access to improved sanitation ranges from just over 50 percent in Tarija to about 30 percent in Potosí.

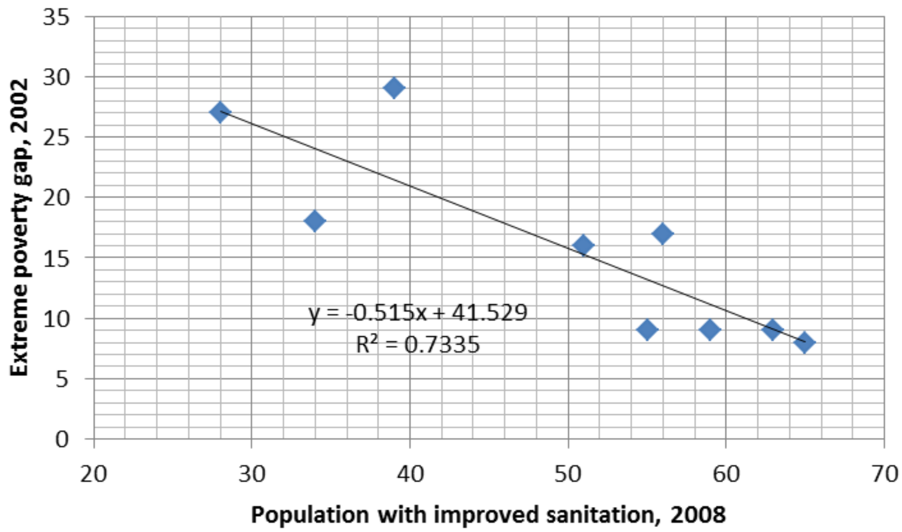
**Figure 1.1 Percentage of population with improved drinking water supply and sanitation (2008)**




*Source:* DHS 2008.

The data show that those living in poverty in Bolivia are particularly disadvantaged by low rates of access to improved water and sanitation services (figure 1.2). There is a statistically significant correlation between the poverty level in a department and the share of population with no access to improved sanitation.

**Figure 1.2 Correlation between poverty level and inadequate access to basic sanitation**




*Source:* DHS 2008; Klasen et al. 2004.

# 1.3 Annual Cost of Inadequate Water Supply, Sanitation, and Hygiene

## *1.3.1 Burden of Diarrheal Disease from Inadequate Water, Sanitation, and Hygiene*

The following section presents estimated health costs related to inadequate water supply, sanitation, and hygiene in Bolivia and averting expenditures that the population must undertake to reduce excessive health risk.

Inadequate quantity and quality of potable water supply, sanitation facilities and practices, and hygiene conditions are associated with various diseases both in adults and children. Esrey et al. (1991) provide a comprehensive review of studies documenting this relationship for diseases such as schistosomiasis (bilharzia), intestinal worms, and diarrhea (box 1.2). Fewtrell and Colford (2004) provide a meta-analysis of studies of water supply, sanitation, and hygiene; this meta-analysis updates the findings on diarrheal illness by Esrey et al. Although diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people.

WHO studies show that improvements in access to safe water and adequate sanitation, along with the promotion of good hygiene practices (particularly handwashing with soap), can help prevent childhood diarrhea. Fewtrell and Colford (2004) provide a systematic review and meta-analysis of water, sanitation, and hygiene interventions on diarrheal illness. The review estimates that 70 to 90 percent of diarrheal deaths and morbidity are attributable to unsafe water, inadequate sanitation, and poor hygiene if the share of improved sanitation is less than 98 percent. This excessive 2 percent of improper excreta disposal creates favorable preconditions for oral-fecal pathogens in the environment to affect drinking water supply and sanitation (see annex A1).

**Box 1.2 Relation between child mortality, water conditions, and sanitation**

Water supply, sanitation, and hygiene factors influence child mortality. In their review of studies, Esrey et al. (1991) find a 55 percent median reduction in child mortality from improved water and sanitation. Shi (1999) provides econometric estimates of the impact of potable water and sewerage connection on child mortality, using a dataset for some 90 cities around the world. Literacy and education levels are also found to be important for parental protection of child health against environmental risk factors. In their study in Malaysia, Esrey and Habicht (1988) report that maternal literacy reduces child mortality by about 50 percent in the absence of adequate sanitation, but only by 5 percent in the presence of good sanitation facilities. Literacy is also found to reduce child mortality by 40 percent if piped water is present; this suggests that literate mothers take better advantage of water availability for hygiene purposes to protect child health. Findings from the Demographic and Health Surveys (DHS) around the world further confirm the role of literacy in child mortality reduction. Rutstein (2000) provides a multivariate regression analysis of infant and child mortality in developing countries, using DHS data from 56 countries from 1986 to 1998. The study finds a significant relationship between infant and child mortality rates and piped water supply, flush toilets, maternal education, access to electricity, medical services, oral rehydration therapy, vaccinations, dirt floors in household dwellings, fertility rates, and malnutrition. Similarly, Larsen (2003) provides a regression analysis of child mortality using national data for the year 2000 from 84 developing countries, representing 95 percent of the total population in the developing world. A statistically significant relationship between child mortality and access to improved water supply, safe sanitation, and female literacy is confirmed.

Source: Author.

### *1.3.2 Baseline Diarrheal Health Data*

Bolivia has achieved substantial reductions in child mortality and diarrheal child mortality. Baseline health data for estimating the health impacts of inadequate water supply, sanitation, and hygiene are presented in the table in box 1.3. WHO data (2010) estimate that about 15 percent of child mortality was due to intestinal diseases in 2010. The Pan American Health Organization (PAHO) (2009) reports that in 2003, 7.3 percent of all registered deaths were due to diarrheal diseases, but 45 percent of all deaths had ill-defined or unknown causes. The first estimate is applied in this chapter.

The mortality rates in children under the age of 5 in Bolivia are presented in table 1.4, and are seen to vary substantially across departments. This analysis applied DHS data (2008) and estimated that child mortality from diarrhea ranges from about 38 to 39 per 100 live births in Chuquisaca, Tarija, and Santa Cruz (urban areas), to 113 to 146 in La Paz, Cochabamba, and Potosí (rural areas).

**Table 1.4 Mortality rates in children under age 5 per 1,000 live births (2008)**

| | Urban | Rural |
|---|---|---|
| Chuquisaca | 39 | 70 |
| La Paz | 63 | 113 |
| Cochabamba | 65 | 116 |
| Oruro | 52 | 93 |
| Potosí | 81 | 146 |
| Tarija | 38 | 68 |
| Santa Cruz | 38 | 69 |
| Beni | 44 | 80 |
| Pando | 44 | 79 |

*Source:* DHS 2008.

For diarrheal morbidity, poor reporting makes it very difficult or nearly impossible to identify all cases of illness. Underreporting includes both the substantial share of cases that do not require treatment at health facilities and those diarrheal cases that are treated by private doctors or clinics and are not reported to public health authorities. Therefore, household surveys provide the most reliable indicator of total cases of diarrheal illness. However, most household surveys only contain information on diarrheal illness in children, and only reflect diarrheal prevalence at the time of the survey. Because there is often high variation in diarrheal prevalence across seasons of the year, extrapolation to an annual average sometimes results in either an overestimate or an underestimate of total annual cases. It is often difficult to correct this bias without knowledge of seasonal variations.

**Box 1.3 Basic information to estimate the health burden**

The table in this box presents baseline data for estimating the health burden associated with inadequate drinking water supply and sanitation. This table also presents the DALYs per case of diarrheal illness, which are used to estimate the number of DALYs lost due to inadequate water supply, sanitation, and hygiene. The disability weight for diarrheal morbidity is 0.119 for children under age 5 and 0.086 for the rest of the population; the duration of illness is assumed to be the same (i.e., three to four days) for both age groups.

The DALYs per 100,000 cases of diarrheal illness are much higher for the population over age 5. This is because DALY calculations involve age weighting, which attaches a low weight to young children and a higher weight to adults, corresponding to physical and mental development stages. For diarrheal child mortality, the number of DALYs is 34 and reflects an annual discount rate of 3 percent of life years lost.

**Baseline data for estimating health effects**

| | Baseline | Source |
|---|---|---|
| Under-5 child mortality rate in 2008 | 55–99 | DHS 2008 |
| Diarrheal mortality in children under 5 years (% of total child mortality) | 15% | WHO 2010 |
| Diarrheal 2-week prevalence in children under 5 years | 23.6–29.1% | DHS 2008 |
| Estimated annual diarrheal cases per child under 5 years | 4.9–6.1 | Estimated from DHS 2008 |
| Estimated annual diarrheal cases per person (> 5 years) | 3–4 | Estimated from DHS 2008 and Egypt and Colombia surveys |
| Hospitalization rate (% of all diarrheal cases) | 2% | Ministry of Health |
| Percent of diarrheal cases attributable to inadequate water supply, sanitation, and hygiene | 85–88% | Author estimates |
| DALYs per 100,000 cases of diarrhea in children under 5 | 30–40 | |
| DALYs per 100,000 cases of diarrhea in persons > 5 years | 100–130 | Estimated from WHO tables |
| DALYs per case of diarrheal mortality in children under 5 | 34 | |

Source: Author.

DHS 2008 provides data on diarrheal prevalence in children under the age of 5. It reports a diarrheal prevalence rate (the preceding two weeks) ranging from 23.6 percent in urban areas to 29.1 percent in rural areas for Bolivia. Data by department are presented in figure 1.3. This rate is used to estimate annual cases of diarrhea per child under age 5, and total annual diarrheal cases in all children under age 5. The two-week prevalence rate is multiplied by 52/2.5 to approximate annual diarrheal cases per child.[3] With this methodology, figure 1.4 presents the estimated annual number of diarrheal cases (urban and rural areas) in each department. Santa Cruz, La Paz, and Cochabamba have the highest burden of diarrheal disease (estimated annual cases), especially among their rural populations. Cochabamba has a nearly equal amount of urban and rural cases, although only 35 percent of the population lives in rural areas. Given the estimated diarrheal burdens in these departments, drinking water, sanitation, and hygiene interventions are expected to bring higher benefits.

**"Santa Cruz, La Paz, and Cochabamba have the highest burden of diarrheal disease, especially among their rural populations."**

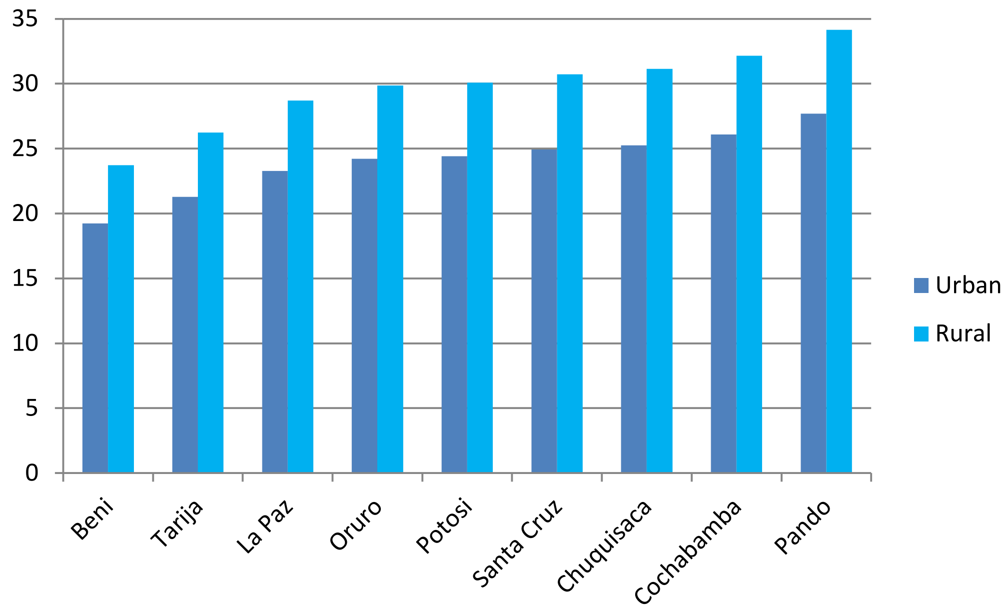
Figure 1.5 presents the per capita annual number of diarrheal cases in Bolivia by department (urban and rural areas) in children under age 5. The rural estimates exceed six cases of diarrhea per child less than 5 years of age in seven departments (Pando, Cochabamba, Chuquisaca, Santa Cruz, Potosí, Oruro, and La Paz). These departments should potentially be targeted for interventions to improve the situation with drinking water, sanitation, and hygiene.

DHS 2008 does not (nor does any other household survey in Bolivia) provide information on diarrheal illness in the population over the age of 5. Several household surveys and public health databases in other countries indicate that the incidence of diarrhea per child under age 5 relative to the incidence for the rest of the population is around 7 to 8. The annual cases of diarrhea per person among the population over age 5, presented in table 1.1, is therefore estimated as one seventh of the annual cases per child under age 5 in rural areas and one eighth in urban areas.

Diarrheal illness sometimes requires hospitalization, but there are no readily available centralized records in Bolivia that provide data on the annual number of diarrheal hospitalizations. Information from Bolivia's Ministry of Health (2009) on the total number of intestinal disease hospitalizations was used, corresponding to about 2 percent of diarrheal cases.

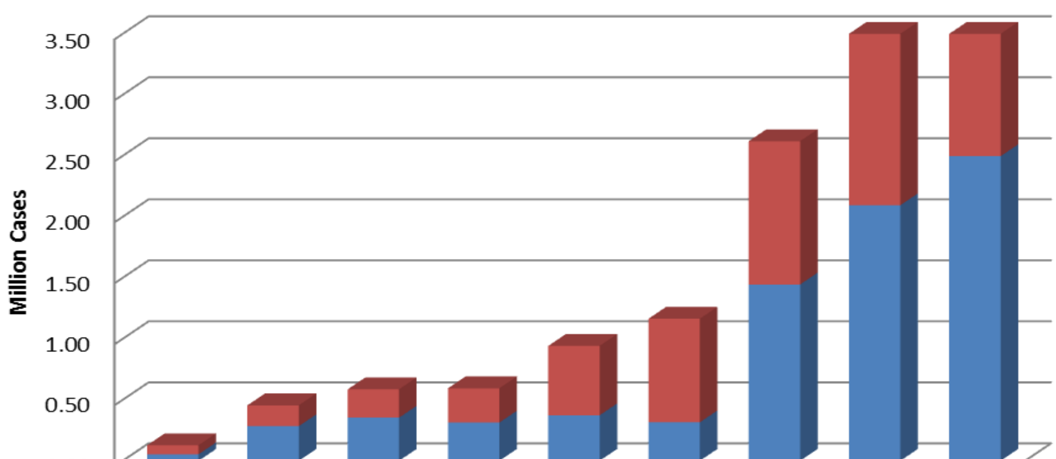
[3] The prevalence rate is not multiplied by 26 two-week periods (i.e., 52/2), but multiplied by 52/2.5 for the following reason: the average duration of diarrheal illness is assumed to be three to four days. This implies that the two-week prevalence captures a quarter of the diarrheal prevalence in the week prior to and a quarter in the week after the two-week prevalence period.

### Figure 1.3 Diarrheal prevalence (preceding two weeks) in children under age 5




*Source:* DHS 2008.

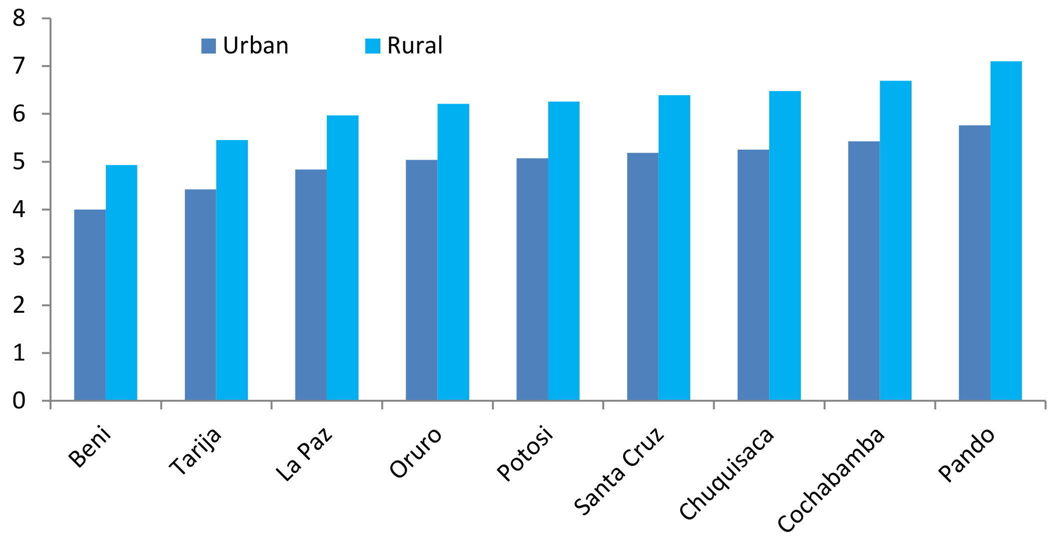
### Figure 1.4 Annual number of cases of diarrhea by urban and rural area




| | Pando | Beni | Tarija | Oruro | Chuquisaca | Potosi | Cochabamba | La Paz | Santa Cruz |
|---|---|---|---|---|---|---|---|---|---|
| Rural | 0.07 | 0.17 | 0.23 | 0.28 | 0.57 | 0.85 | 1.17 | 1.43 | 1.05 |
| Urban | 0.05 | 0.28 | 0.35 | 0.31 | 0.37 | 0.32 | 1.45 | 2.10 | 2.50 |

*Source:* Author estimates.

**Figure 1.5 Annual number of cases of diarrhea (per child under age 5)**




*Source:* Author estimates.

Table 1.5 presents the estimated health impacts from inadequate water supply, sanitation, and hygiene. These estimates are based on the data from the table in box 1.3, taking into account that 85 to 88 percent of diarrheal illness is attributable to water, sanitation, and hygiene (see above). DALYs from diarrheal illness (morbidity only) also are presented in table 1.5, based on the estimated cases and an average duration of diarrheal morbidity of three to four days.

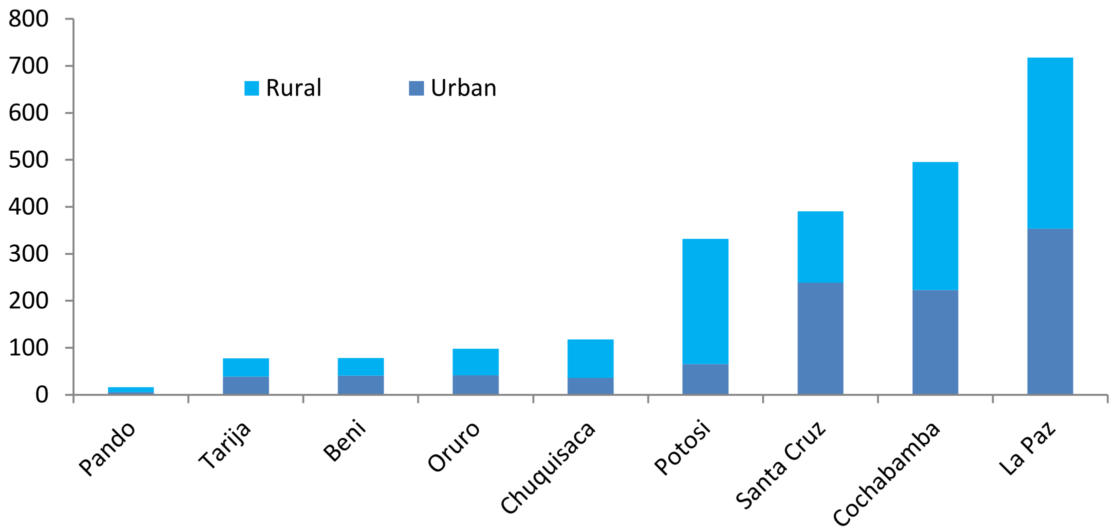
**Table 1.5 Estimated annual health attributable to inadequate water supply, sanitation, and hygiene**

| | Mortality cases, children under 5 | | Morbidity cases, total, million | | DALYs loss, total | |
|---|---|---|---|---|---|---|
| | Urban | Rural | Urban | Rural | Urban | Rural |
| Chuquisaca | 36 | 82 | 0.3 | 0.5 | 206.1 | 325.1 |
| La Paz | 353 | 364 | 1.8 | 1.3 | 1,157.6 | 817.2 |
| Cochabamba | 222 | 273 | 1.2 | 1.0 | 798.6 | 671.8 |
| Oruro | 42 | 56 | 0.3 | 0.2 | 173.0 | 160.7 |
| Potosí | 65 | 266 | 0.3 | 0.7 | 174.3 | 485.6 |
| Tarija | 39 | 39 | 0.3 | 0.2 | 195.4 | 132.8 |
| Santa Cruz | 238 | 152 | 2.1 | 0.9 | 1,379.6 | 602.9 |
| Beni | 41 | 37 | 0.2 | 0.2 | 157.0 | 97.6 |
| Pando | 5 | 11 | 0.0 | 0.1 | 29.7 | 42.2 |
| Bolivia total | 1,042 | 1,281 | 7 | 5 | 4,271.3 | 3,336.0 |

*Source:* Author estimates.

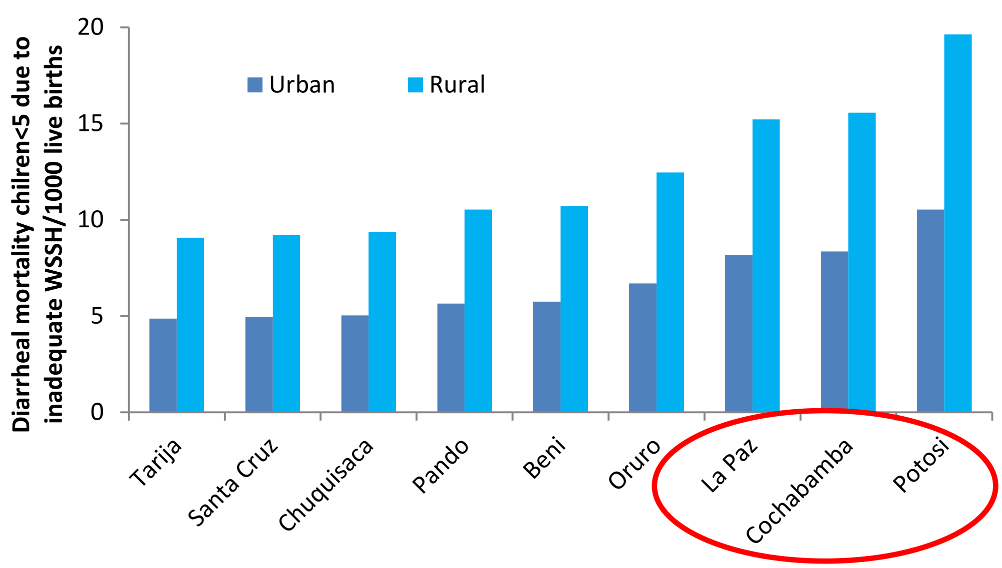
Figure 1.6 presents total annual diarrheal mortality in children under age 5 attributed to inadequate water supply, sanitation, and hygiene. In absolute numbers, diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene among children under age 5 is higher in Potosí, Santa Cruz, Cochabamba, and La Paz. The greatest burden of diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene among children under age 5 per 1,000 live births is found in Potosí, Cochabamba, and La Paz, where this indicator is at 15 to 20 annual diarrheal deaths per 1,000 live births in the rural population and 8 to 11 annual diarrheal deaths in the urban population (figure 1.7).

**Figure 1.6 Total children under age 5: diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene**




*Source:* Author estimates.

**Figure 1.7 Children under age 5: diarrheal mortality attributed to inadequate water supply, sanitation, and hygiene per 1,000 live births**

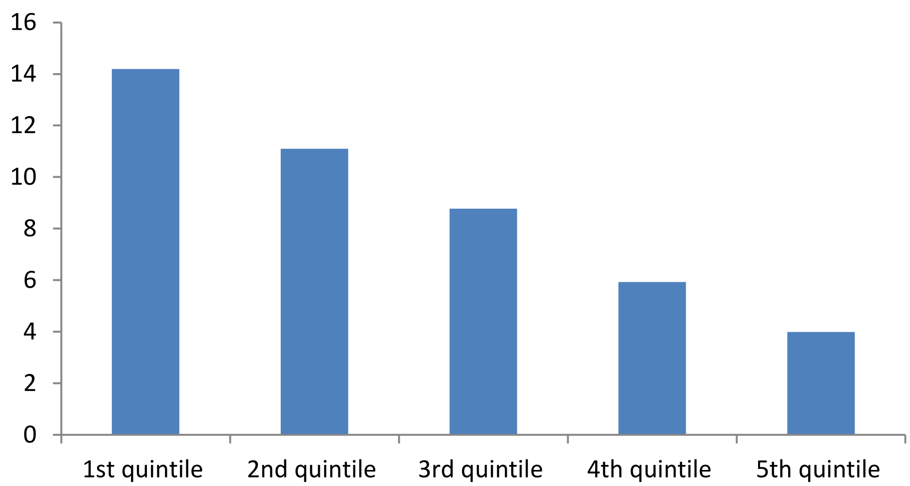



*Source:* Author estimates.

**"The departments with the most diarrheal deaths among children under age 5 are those with the lowest per capita GDP."**

The departments with the most diarrheal deaths among children under age 5 are those with the lowest per capita GDP. DHS 2008 presents the estimate of mortality among children under age 5 by income quintile in Bolivia. The estimated diarrheal mortality among children under age 5 by income quintile associated with inadequate drinking water supply, sanitation, and hygiene is presented in figure 1.8. The diarrheal mortality burden is especially heavy among poor children under age 5: it is 3.5 times higher than among children in higher quintiles.

**Figure 1.8 Estimated diarrheal mortality among children under age 5 associated with inadequate water supply, sanitation, and hygiene, by income quintile**




*Source:* Author estimates using 2008 DHS data.

WHO recently revised the burden of disease estimates, taking into account malnutrition-mediated health impacts associated with inadequate provision of water and sanitation and improper hygiene practices (Blössner and de Onis 2005). The new WHO estimates reveal that the environmental health burden in children under age 5 is substantially higher when all linkages through malnutrition are incorporated, especially in those subregions where malnutrition and poor environmental conditions coexist. In a study of the linkage of the global disease burden and the environment, it was estimated that 50 percent of malnutrition is attributable to the environment, essentially to water supply, sanitation, and hygiene (pooled expert opinion based on literature review) (see annex A6).

### *1.3.3 Estimated Cost of Health Effects*

The annual cost of diarrheal morbidity from inadequate water supply, sanitation, and hygiene is estimated at Bs. 0.93 billion to 1.10 billion (tables 1.6 and 1.7), including Bs. 0.7 billion to 0.81 billion for urban areas and Bs. 0.23 billion to 0.26 billion for rural areas. These morbidity costs include the costs of illness (medical treatment, medicines, and value of lost time). The cost of illness related to diarrheal morbidity is presented in table 1.6.[4] About 35 to 55 percent of these costs is associated with the cost of

[4] These costs do not include the valuation of DALYs.

treatment and medicines, and 45 to 65 percent is from the value of time lost to illness (including caregiving) (see box 1.4 and annex A2). The share of time lost to illness is higher in urban areas than in rural areas (60 to 64 percent versus 45 to 50 percent), since average urban wages are significantly higher than rural wages.

**Table 1.6 Estimated annual cost of diarrheal illness (Bs. million)**

| | Urban | | Rural | |
|---|---|---|---|---|
| | "Low" | "High" | "Low" | "High" |
| Morbidity | | | | |
| Children under age 5 | 375 | 445 | 135 | 160 |
| Population over age 5 | 325 | 365 | 90 | 100 |
| *Total annual cost* | *700* | *810* | *225* | *260* |

*Source:* Author estimates.

**Table 1.7 Estimated annual cost of illness (morbidity) (Bs. million)**

| | Urban | | Rural | |
|---|---|---|---|---|
| | "Low" | "High" | "Low" | "High" |
| Cost of medical treatment (doctors, hospitals, clinics) | 140 | 145 | 75 | 80 |
| Cost of medicines | 135 | 145 | 50 | 55 |
| Cost of time lost to illness | 425 | 520 | 100 | 125 |
| *Total annual cost* | *700* | *810* | *225* | *260* |

*Source:* Author estimates.

**Box 1.4 How to estimate the value of time?**

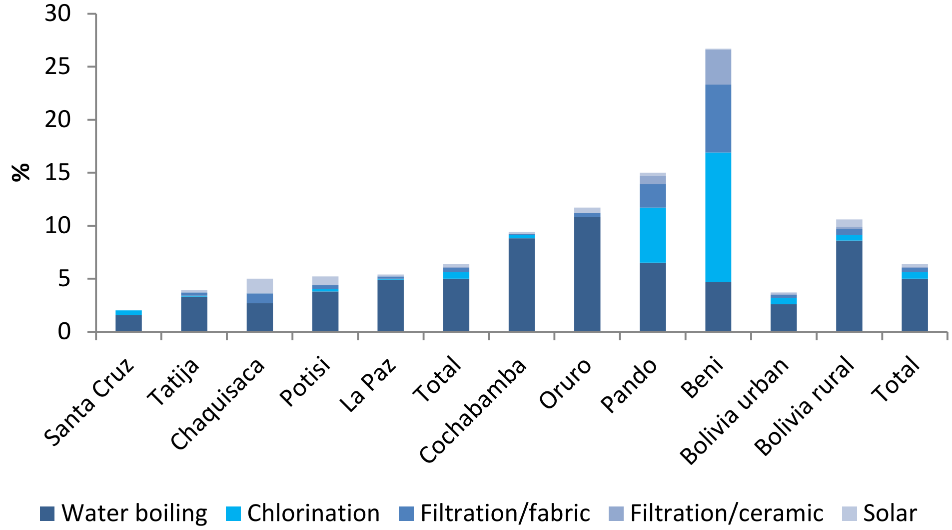
The value of time for adults is based on national average wages. Economists commonly apply a range of 50 to 100 percent of average urban and rural wage rates to reflect the value of time. The hourly rates of Bs. 2.5, or about Bs. 30 per day in rural areas, and Bs. 7.5, or about Bs. 60 per day in urban areas, reflect around 75 percent of the average weighted wage in Bolivia. These rates for value of time are applied to both income-earning and non-income-earning adults. There are two reasons for applying the rates to non-income-earning adults. First, most non-income-earning adults provide a household function that has a value. Second, there is an opportunity cost to the time of nonworking individuals, because they could choose to join the paid labor force.

Source: Author.

### *1.3.4 Averting Expenditures*

In the presence of perceived health risks, people often take averting measures to avoid these risks. If people perceive there is a risk of illness from the municipal water supply or from other sources of water supply on which they rely, some of them are likely to purchase bottled water for drinking purposes, boil or chlorinate their water, install water purification filters, or use solar disinfection. Economists usually include these measures as a cost-of-health risk. In Bolivia, only about 11 percent of the urban population and 4 percent of the rural population practice water disinfection (DHS 2008). Water boiling is the predominant disinfection method (about 80 percent of all who practice water disinfection boil their drinking water) (figure 1.9).

**Figure 1.9 Water disinfection at point of use in Bolivia**




*Source:* DHS 2008.

In an unpublished report by UNICEF (2011), the percentage of the population that disinfects water is about 5 times higher, including a 2.5 times higher share of the population that boils water for disinfection. The quality of the primary data in this report is unclear. Estimates of water disinfection from DHS 2008 are applied in this report (see annex A3).

## 1.4 Methodology of Cost-Benefit Analysis of Interventions in Bolivia's Water Supply, Sanitation, and Hygiene Sector

**"Environmental degradation reduction is an equivalent to the benefits that society would enjoy if environmental quality were improved to a condition with no environmental risks to health, no negative impacts on productive assets from environmental degradation, and no damages to health, infrastructure, and housing from natural disasters."**

The annual health costs, including annual diarrheal mortality, morbidity costs, and averting expenditures, attributed to inadequate potable water supply, sanitation, and hygiene in Bolivia are estimated in the previous section.

Environmental degradation reduction is an equivalent to the benefits that society would enjoy if environmental quality were improved to a condition with no environmental risks to health, no negative impacts on productive assets from environmental degradation, and no damages to health, infrastructure, and housing from natural disasters. The estimates of health damage presented above can therefore be used as a starting point to rank interventions aimed at improving environmental quality and reducing environmental damage. From a socioeconomic standpoint, the welfare of society will improve if those interventions that provide greater benefits than the cost of the interventions or interventions with the least cost per unit of health benefits are implemented. Therefore, the logical next step from this evaluation of costs of environmental degradation is to carry out cost-benefit *or* cost-effectiveness analyses for each of these health risks in the context of Bolivia (boxes 1.5 and 1.6).

These interventions have been selected due to international evidence of the effectiveness of various interventions; problems with municipal water supply reliability in many urban areas; public perceptions of health risks from the municipal water supply; and the low coverage of improved water supply and sanitation in rural areas in Bolivia. All interventions are expected to provide health-related benefits in terms of reduced damage from diarrheal illness (table 1.8) in proportion to the cost of each intervention.

**Box 1.5 Cost-benefit analysis and cost-effectiveness analysis**

A cost-benefit analysis or cost-effectiveness analysis of potential interventions to improve water supply, sanitation, and hygiene, in terms of quality and population coverage, can serve as an instrument to establish priorities and guide resource allocation. However, the costs of interventions and the benefits of these interventions (a reduction in the cost of inadequate water supply, sanitation, and hygiene) are often difficult to quantify in a comprehensive and accurate manner. Therefore, it is useful to provide a range of estimates, with transparent assumptions, that reflect diverse situations in order for such estimates to be of value and serve as guidance to decision makers. A cost-benefit analysis or cost-effectiveness analysis of the following interventions could be considered:

- Hygiene improvement (for example handwashing with soap);
- Point of use household drinking water disinfection (for example boiling of water);
- Municipal water supply rehabilitation and improved sanitation expansion in urban areas;
- Improved rural water supply and sanitation expansion (for example pour-flush or VIP toilets).

Source: Author.

**Box 1.6 The methodology of cost-effectiveness**

Cost-effectiveness analysis is a tool that helps decision makers to identify the project or policy that will achieve reduction of a selected health indicator (for example DALYs from diarrheal illness) with the least possible costs and thus in the most efficient manner. After compiling a list of possible interventions (Ministry of Environment and Water 2009), the costs associated with each of those interventions are calculated. Finally, decision makers can identify the minimal-cost solution for the given environmental indicator reduction by comparing the costs of all available policies or projects. The approach adopted here is to first use data on annual diarrheal cases or corresponding DALYs lost before and after investment. Water supply and sanitation investment project costs should be analyzed to estimate annualized project costs. These estimates are used together with a relative risk reduction approach in each department (separately for urban and rural areas) before and after investments.

The differences in annual DALYs lost or diarrheal morbidity before and after investment equaled the reduction in health impacts due to investment. These reductions are compared to the annualized costs of the investment projects. Water supply and sanitation investments are then ranked from an environmental health perspective based on their cost-effectiveness ratio of different investment projects. Local decision makers are provided with information about the most cost-efficient option of health risk reduction.

Source: Author.

**Table 1.8 Categories of benefits of interventions**

| Interventions | Benefits |
|---|---|
| Handwashing with soap | Reduced cost of diarrheal illness |
| Boiling of drinking water | Reduced cost of diarrheal illness |
| Municipal water supply and sanitation | Reduced cost of diarrheal illness |
| | Reduced expenditure on water disinfection |
| | Reduced water losses in municipal systems |
| | Time savings from improved access to toilet facility |
| Improved rural water supply and sanitation | Reduced cost of diarrheal illness |
| | Reduced expenditure on water disinfection |
| | Time savings from improved access to toilet facility |

Source: Author.

The estimated cost per person in rural areas is somewhat lower than in urban areas when conservative valuation methods are used. This is because of the lower wage rates in rural areas, and therefore the lower cost of time losses from illness.

Despite the important reductions that Bolivia has achieved in child mortality from diarrheal illnesses, the prevalence of diarrhea in adults and children remains high. Poor households in rural areas are most severely affected, because their relatively low income and education levels, compounded by a lack of access to basic services, result in a very high risk of diarrheal illness. An analysis could focus on the costs and benefits of major water supply, sanitation, and hygiene interventions, including:

- Handwashing by mothers or caretakers of young children in rural and urban areas;
- Improved water supply in rural areas;
- Safe sanitation facilities in rural areas;
- Drinking water disinfection at point of use in urban and rural areas.

Previous studies have demonstrated that benefits would exceed the costs of most of these interventions and that they could substantially reduce the costs of environmental health effects.

## 1.5 Health Benefits of Water Supply, Sanitation, and Hygiene Program

In 2011 the Ministry of Environment and Water published the performance evaluation framework, which identified critical objectives for improvement of water supply, sanitation, and hygiene in Bolivia in 2011–2014. In Ministry of Environment and Water 2011, tables 1.9 and 1.10 present indicators for improvements in drinking water supply and sanitation, respectively. Table 1.9 includes revised national goals for the increase in coverage of drinking water supply services in 2011–2014. The goals for each of these years are split into three columns according to the size of the settlements or towns: communities with fewer than 2,000 inhabitants, towns with populations ranging from 2,000 to 10,000, and cities with populations over 10,000. It is important to note that, according to Bolivian practices, communities with fewer than 2,000 inhabitants are considered rural communities; those with populations over 2,000 are considered urban.

In the rows, the increase in coverage is divided into two parts: increase of coverage employing "conventional systems," and increase of coverage employing "nonconventional systems." Nonconventional systems include technology to adapt to or mitigate climate change. However, conventional/nonconventional grouping would not have a direct impact on health benefits. Both improvements are regarded as the provision of improved water supply. Data on the increase of coverage using conventional systems are divided by target groups in urban and rural areas who obtain benefits from regular "new" connections and "improved" water supply in terms of protecting the source from contamination (especially fecal coliform), separately for the three sizes of settlements. New connections would provide piped water in dwellings, supplying more than 50 liters per person per day, or a public tap at a distance of less than 1 kilometer and supplying more than 20 liters per person. Table 1.10 uses the same definitions for the provision of sanitation.

A set of scenarios are defined in this analysis, following the World Health Organization methodology, depending on the conditions of access to water supply and sanitation, which represent different risks of illness. Due to the absence of information on the current water and sanitation services provided to the target population, the reasonable assumption is that water supply service is provided to the population with no improved drinking water and no improved sanitation (scenario VI) (see table 1.11 for the definition of the scenarios). The target population could obtain access to improved water supply, or obtain a new piped water connection (scenarios Vb, IIId or IIIc). At the same time, the target population can be assumed to practice or not practice drinking water disinfection (see annex A5).

### Table 1.9 Indicators for drinking water supply improvement in Bolivia

| Description | 2011 Number of additional inhabitants | | | | 2012 Number of additional inhabitants | | | | 2013 Number of additional inhabitants | | | | 2014 Number of additional inhabitants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total |
| Conventional systems | 84,464 | - | 30,580 | 115,044 | 81,950 | 22,000 | 63,550 | 167,500 | 94,760 | 17,644 | 5,471 | 117,875 | 100,804 | 10,764 | - | 111,568 |
| A=New | 13,915 | - | 30,580 | 44,495 | 10,648 | 11,000 | 57,786 | 79,434 | 8,058 | 8,250 | 5,471 | 21,779 | 4,334 | 9,114 | - | 13,448 |
| B=Improved | 70,549 | - | - | 70,549 | 71,302 | 11,000 | 5,764 | 88,066 | 86,702 | 9,394 | - | 96,096 | 96,470 | 1,650 | - | 98,120 |
| Non-conventional systems | 4,246 | 1,414 | - | 5,660 | 7,464 | 2,486 | - | 9,950 | 10,010 | 3,333 | - | 13,343 | 37,703 | 12,568 | - | 50,270 |
| C=Conventional with improved treatement (ACCL) | 4,246 | 1,414 | - | 5,660 | 7,464 | 2,486 | - | 9,950 | 10,010 | 3,333 | - | 13,343 | 37,703 | 12,568 | - | 50,270 |
| Subtotal | 88,710 | 1,414 | 30,580 | 120,703 | 89,414 | 24,486 | 63,550 | 177,450 | 104,770 | 20,977 | 5,471 | 131,218 | 138,507 | 23,331 | - | 161,838 |
| **Total** | | | | | | | | | | | | | | | | **591,208** |

*Source:* Ministry of Environment and Water 2011.

**Table 1.10 Indicators for sanitation improvement in Bolivia**

| Descripción | 2011 Number of additional inhabitants | | | | 2012 Number of additional inhabitants | | | | 2013 Number of additional inhabitants | | | | 2014 Number of additional inhabitants mop0-o9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total | >10000 | 2000-10000 | <2000 | Total |
| Conventional systems | 73,579 | 2,844 | 33,118 | 109,544 | 91,317 | - | 46,203 | 137,519 | 110,154 | 30,250 | 22,917 | 163,321 | 172,854 | 19,250 | - | 192,104 |
| A=New | 65,148 | 2,844 | 33,118 | 101,109 | 72,028 | - | 46,203 | 118,031 | 80,460 | 30,250 | 22,917 | 133,626 | 97,994 | 19,250 | - | 117,244 |
| B=Improved | 8,432 | - | - | 8,432 | 19,289 | - | 200 | 19,489 | 29,695 | - | - | 29,695 | 74,861 | - | - | 74,861 |
| Sistems with improved treatment (ACCL) | - | 5,407 | 1,153 | 6,560 | 446 | - | 7,939 | 8,385 | 3,861 | 4,950 | - | 8,811 | 29,425 | 1,309 | - | 30,734 |
| C=With treatment plants or wastewater reuse | - | 5,407 | - | 5,407 | 446 | - | 5,500 | 5,946 | 3,861 | 2,750 | - | 6,611 | 29,425 | - | | 29,425 |
| D=With ecological sanitation treatement | - | - | 1,153 | 1,153 | - | - | 2,439 | 2,439 | - | 2,200 | - | 2,200 | - | 1,309 | - | 1,309 |
| Subtotal | 73,579 | 8,250 | 34,271 | 116,100 | 91,762 | - | 54,142 | 145,904 | 114,015 | 35,200 | 22,917 | 172,132 | 202,279 | 20,559 | - | 222,838 |
| Total | | | | | | | | | | | | | | | | 656,973 |

*Source:* Ministry of Environment and Water 2011.

**Table 1.11 Description of the scenarios**

| Scenario | Description |
|---|---|
| VI | No improved water supply and no basic sanitation |
| Vb | Improved water supply and no basic sanitation |
| Va | Basic sanitation but no improved water supply |
| IV | Improved water supply and basic sanitation |
| IIIc | IV and improved access to drinking water (generally piped to household) |
| IIIb | IV and improved personal hygiene |
| IIIa | IV and drinking water disinfected at point of use |
| II | Regulated water supply and full sanitation coverage |
| I | Ideal situation |

Source: Author.

The reduction of annual diarrheal cases for each group of the target population is estimated from tables A5.1 and A5.2 in annex A5, and results are presented in table 1.12.

**Table 1.12 Estimated annual reduction of diarrheal incidence in Bolivia (number of cases reduced)**

| | Provision of improved or piped water supply | | | |
|---|---|---|---|---|
| | Urban/no disinfection | Urban with disinfection | Rural/no disinfection | Rural with disinfection |
| VI to Vb | 138,827 | 104,120 | 2,882 | 1,729 |
| VI to IIId | 115,679 | 72,300 | 93,856 | 75,085 |
| VI to IIIc | 130,139 | 72,300 | 112,627 | 75,085 |
| *Provision of sanitation* | | | | |
| VI to Va | 92,594 | 66,139 | 180 | 100 |
| Vb to IV | 123,893 | 82,595 | 43,992 | 21,996 |

*Source:* Author estimates.

Table 1.13 presents the range of estimates of annual diarrheal reduction for the urban and rural population after provision of water supply, sanitation, and hygiene, depending on different combinations of scenarios.

**Table 1.13 Range of estimates of annual diarrheal reduction for urban and rural population (number of cases reduced)**

| Scenario combinations | Urban/no disinfection | Urban with disinfection | Rural/no disinfection | Rural with disinfection |
|---|---|---|---|---|
| VI to IIIc (WS) + VI to Va (S), and VI to Vb (WS) + Vb to IV (S) | 485,453 | 325,153 | 159,681 | 98,910 |
| VI to IIIc (WS) + Vb to IV (S), and VI to IIId (WS) + VI to Va (S) | 462,305 | 293,333 | 250,655 | 172,265 |

*Source:* Author estimates.

WS for water supply scenarios, S for sanitation scenarios.

**"In urban areas, the total number of diarrheal cases may be reduced by about 290,000 to 485,000 cases annually and in rural areas by 100,000 to 250,000 cases."**

In urban areas, the total number of diarrheal cases may be reduced by about 290,000 to 485,000 cases annually and in rural areas by 100,000 to 250,000 cases. Applying the diarrheal fatality rate for diarrheal illness in Bolivia,[5] diarrheal mortality reduction among children under age 5 is estimated at 45 to 70 deaths in urban areas and at 30 to 45 deaths in rural areas.

Thus, applying the WHO framework analysis, as in Fewtrell and Colford 2004, it is estimated that the Water, Sanitation, and Hygiene Program in Bolivia 2011–2014 (Ministry of Environment and Water 2011) would make it possible to achieve a reduction of about 290,000 to 485,000 cases of diarrheal illness and 45 to 70 mortality cases in urban areas, and about 100,000 to 250,000 cases of diarrheal illness and 30 to 45 mortality cases in rural areas. These represent about 3 to 5 percent of the total mortality and morbidity cases associated with inadequate water supply, sanitation, and hygiene.

## 1.6 Conclusions

Several key messages have emerged from the process of carrying out this study and its results: (a) environmental health risks impose a significant burden on Bolivia's economy, with an estimated 2,300 children dying prematurely every year in Bolivia due to the lack of access to water supply, sanitation, and hygiene; (b) cost-effective interventions to address these environmental health risks exist and should be prioritized in Bolivia, focusing mainly on the areas with the highest burden of diarrheal illnesses and mortality (Potosí, Cochabamba, and La Paz departments, especially in the rural areas); and (c) environmental health analysis is a useful tool for assessing the ex ante impact of sectoral investment programs and policies. The scenario analysis shows that the implementation of the ongoing Water, Sanitation, and Hygiene Program in Bolivia over 2011–2014 would reduce diarrheal illnesses by an estimated 390,000 to 735,000 cases, and would reduce diarrheal mortality by 75 to 115 cases per year. This is still far short of the required investment levels to significantly reduce child mortality attributed to the unmet sectoral needs.

[5] The fatality rate of diarrheal illness is 0.0145% for the urban population and 0.0219% for the rural population in Bolivia.

# Chapter 2. Innovation in Solid Waste Management: Options for the Future

## 2.1 Overall Context and Status of the Solid Waste Sector in Bolivia

In Bolivia, population growth in combination with changes in consumption and production patterns have led to an increase in the generation of solid waste. This has attracted attention to weaknesses in the country's solid waste management practices. There are a number of problems in this regard, mainly related to final disposal and its repercussions on the environment. This chapter is divided into three sections: the first section offers an analysis of the general context concerning solid waste management in Bolivia and highlights the weaknesses and challenges facing the sector; the second depicts some of the basic issues in solid waste management, such as financing, regulation, management models, and contracts; and the third examines future options to address each of these issues. The ultimate objective of this chapter is to propose viable alternatives for strengthening the solid waste management sector in Bolivia.

### *2.1.1 Volume and Types of Solid Waste*

In the year 2010, the General Directorate for Integrated Solid Waste Management (DGGIRS) estimated that the total generation of solid waste was 1,745,280 tons per year or 4,782 tons per day, of which 87 percent came from urban and 13 percent from rural areas. Current growth patterns in population (as estimated by the National Statistics Institute) and production per capita suggest that by 2015 these numbers will climb to 1,999,155 tons per year or 5,477 tons per day. The actual amount may be even higher if expected consumption patterns are factored in. Today consumption in many parts of the country is relatively low by international standards, resulting in average per capita solid waste production of 0.5 kilograms per person per day in urban areas and 0.2 kilograms per person per day in rural areas. However, as incomes increase and standards of living improve, it is expected that there will be a substantial increase in the amount of solid waste generated.

**"It is expected that there will be a substantial increase in the amount of solid waste."**

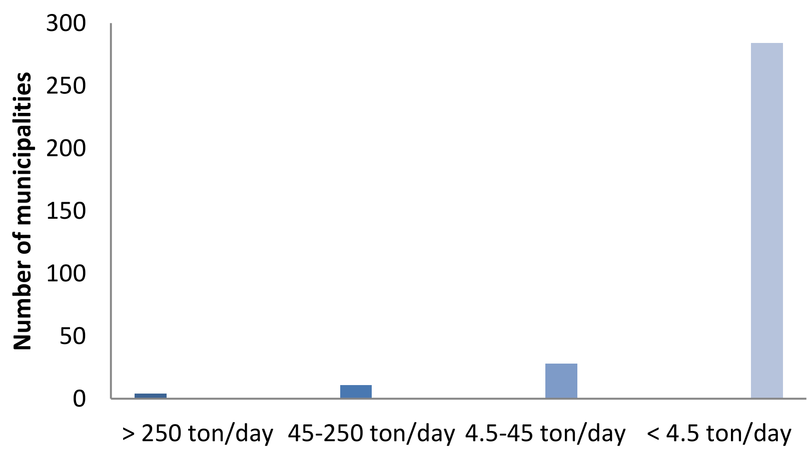
Not surprisingly, solid waste production is concentrated in the most populated departments (Santa Cruz, La Paz, and Cochabamba), which together generate 75 percent of the country's total waste (table 2.1). Most Bolivian departments lack large cities producing significant amounts of solid waste (more than 250 tons per day). In fact, most municipalities have a population of less than 10,000 inhabitants, and these produce less than 5 tons per day of solid waste (figure 2.1).

**Table 2.1 Solid waste distribution by department (tons per day)**

| Department | Urban | Rural | Total (%) |
|---|---|---|---|
| Santa Cruz | 1,344 | 120 | 1,464 (30.6%) |
| La Paz | 1,160 | 151 | 1,311 (27.4%) |
| Cochabamba | 697 | 126 | 823 (17.2%) |
| Potosí | 187 | 91 | 278 (5.8%) |
| Chuquisaca | 193 | 56 | 249 (5.2%) |
| Tarija | 219 | 29 | 248 (5.2%) |
| Oruro | 152 | 29 | 181 (3.9%) |
| Beni | 173 | 24 | 197 (4.1%) |
| Pando | 23 | 6 | 29 (0.6%) |
| Total | 4,148 | 632 | 4,780 |

*Source:* Adapted from Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2010).

**Figure 2.1 Distribution of municipalities based on solid waste production (total municipalities: 327)**

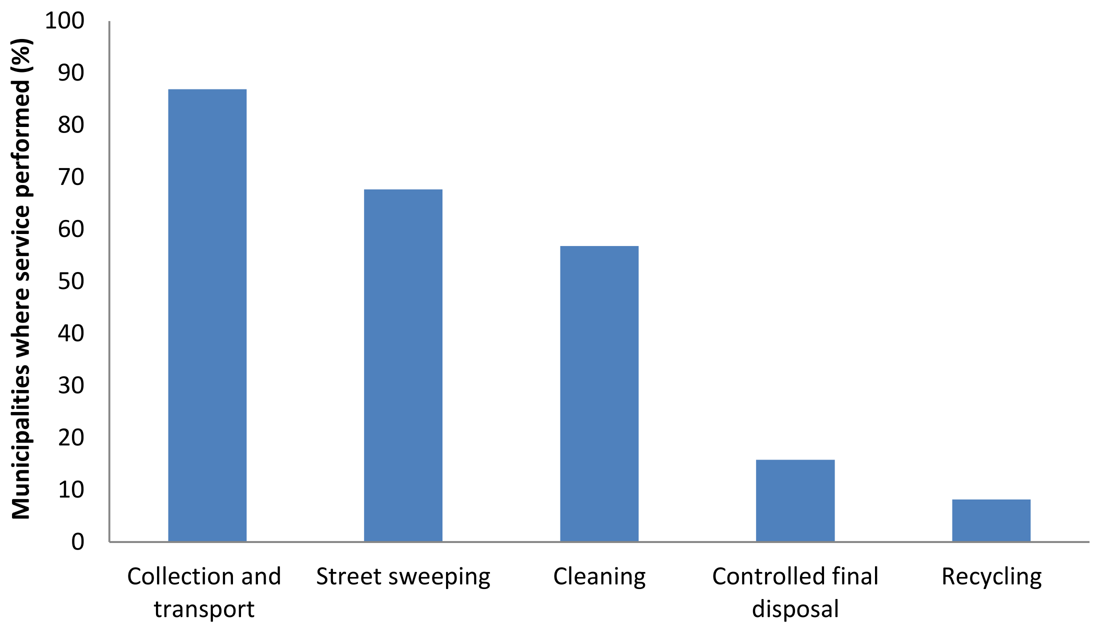



*Source:* Adapted from Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2011).

### *2.1.2 Operational Management of Urban Sanitation Services*

Solid waste management regulations define urban sanitation as a cleaning service undertaken in human settlements and consisting of street sweeping, collection, transport, transfer, treatment, and final disposal of solid waste according to technical criteria. This definition describes the various stages involved in adequate management, from the initial activities until final disposal. In relation to figure 2.2, the municipalities tend to pay more attention to street sweeping and garbage collection than to final disposal measures. This is due to political reasons and because citizens lose interest once the garbage leaves their home or its vicinity, and no longer constitutes an eyesore. Even when the municipalities run only a waste collection and transport service, they are in general prone to operational deficiencies. This is particularly the case regarding vehicles, as most are in poor condition. The result is low coverage, the proliferation of small garbage dumps, and social problems.

**Figure 2.2 Percentage of municipalities with sanitation services (among the 183 analyzed by DGGIRS)**



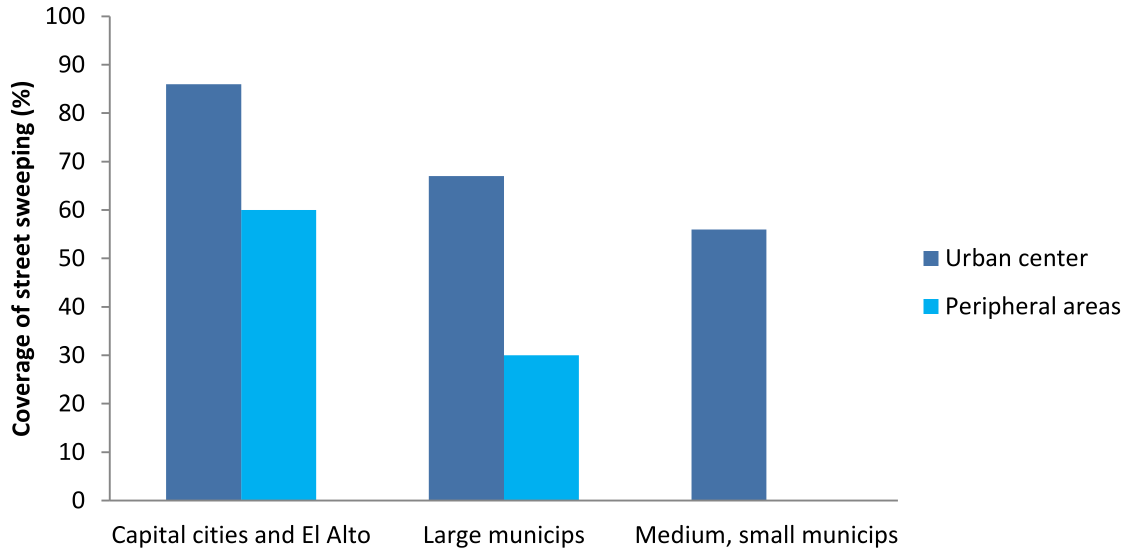

*Source:* Elaborated from Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2011).

## Sweeping of Streets and Public Areas

In 68 percent of the municipalities, and mainly in the provincial capitals, large towns (more than 100,000 inhabitants), and medium-sized towns (between 10,000 and 100,000), there exist street-sweeping services, the efficacy of which varies depending upon factors such as population, resources, and priority (figure 2.3).

In the provincial capitals and in El Alto, service distribution is measured by linear kilometer, with less coverage being provided in peripheral than in downtown areas. In medium-sized and small municipalities, only the main streets are swept. On average it is calculated that coverage in downtown streets stands at 86 percent, but reaches only 60 percent in the periphery. In large towns, the modus operandi is similar to that in the provincial capitals, although actual functions may vary in terms of the resources allocated, the persons managing funds, and the local context. On average, it is calculated that coverage in downtown areas is 67 percent, with a mere 30 percent on peripheral streets. In medium-sized and small municipalities (less than 10,000 inhabitants), the service usually is performed only on the main streets (those around the main plaza), again depending on town size. On average, it is estimated that coverage in the downtown areas of such localities ranges from 55 percent to 57 percent.

**Figure 2.3 Coverage of street-sweeping services in provincial capitals and large, medium-sized, and small towns (%)**




*Source:* Elaborated from Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2011).

## Garbage Collection and Transport

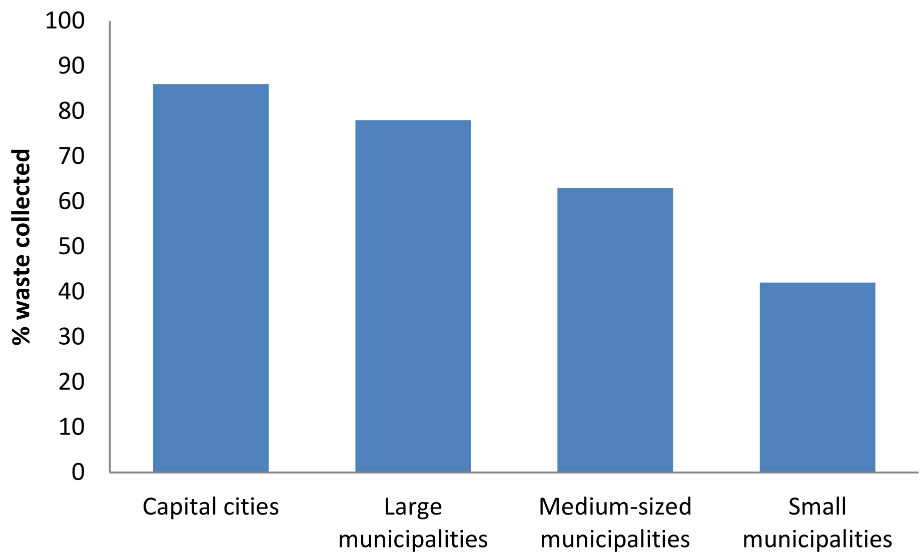
**"It is estimated that 80 percent of the waste collected comes from individual homes; 7.6 percent from public areas; 6.4 percent from marketplaces; 0.8 percent from health establishments; and 5.3 percent from slaughterhouses and**

Solid waste collection and transport services vary dramatically between the main cities, large towns, and small urban centers (figure 2.4). The percentage of individual homes at which garbage is collected fluctuates between less than half of the population in smaller towns and up to 80 percent in provincial capitals. As estimated by the DGGIRS, in provincial capitals and large towns, garbage collection covers both the downtown area and peripheral neighborhoods. In these urban centers, coverage reaches more than 80 percent in downtown areas. In medium-sized and small towns, coverage includes downtown, but only on occasion the periphery. On average, garbage collection in medium-sized municipalities varies between 41 percent and 80 percent; it is between 26 percent and 67 percent in smaller towns.

On its web page the National Statistics Institute publishes historical data on solid waste collection and transport in the provincial capitals and El Alto. On average, it is estimated that 80 percent of the waste collected comes from individual homes; 7.6 percent from public areas; 6.4 percent from marketplaces; 0.8 percent from health establishments; and 5.3 percent from slaughterhouses and industries. The

DGGIRS notes in 2011 that 68 percent of the 1,745,280 tons of urban solid waste produced nationwide each year is collected.

**Figure 2.4 Waste collection coverage in provincial capitals and large, medium-sized, and small towns (%)**




*Source:* Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2011).

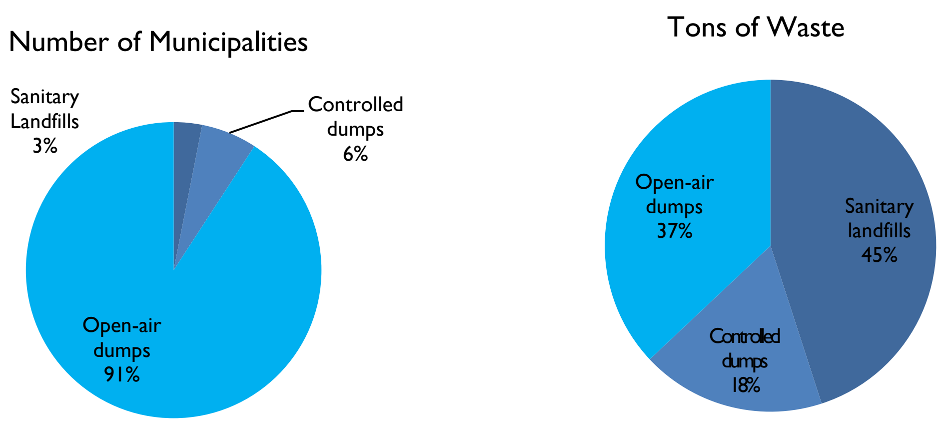
## Final Solid Waste Disposal

Final disposal is considered the most delicate stage in urban solid waste management because of its potential for environmental pollution. In Bolivia, the problem of final disposal is pressing, given that for the most part it takes place at open-air garbage dumps (figure 2.5). In many provincial capitals and larger towns, waste disposal sites are in the final phase (last one to three years) of their useful lives, as is the case in El Alto and Cochabamba. In places they are located near population centers, thus aggravating the problem.

Of the 183 municipalities analyzed by the DGGIRS, 9 dispose of their waste in sanitary landfills, 20 in controlled dumps, and 154 in open-air dumps. Municipalities with sanitary landfills are as follows: La Paz, Santa Cruz de la Sierra, Oruro, Tarija, El Alto, Sacaba, Villa Abecia, and Tarabuco.

Of the 327 municipalities in Bolivia, 90 percent dispose of solid waste in open-air dumps, 7 percent in controlled dumps, and only 3 percent in sanitary landfills. Of the total amount of solid waste generated nationwide, approximately 49 percent is disposed of in sanitary landfills, 23 percent in controlled dumps, and 28 percent in open dumps (as estimated in the Diagnostic of Solid Waste management in Bolivia). Measured by population, only 38 percent of their waste is disposed of using sanitary landfill technology. The infrastructure at final waste disposal sites built to prevent and control environmental pollution usually consists of landfill cell bottom sealing, capture and treatment systems for lixiviates and gases, and groundwater monitoring wells.

**Figure 2.5 Final disposal in sanitary landfills, controlled dumps, and open-air dumps (of the 183 municipalities studied by the DGGIRS)**



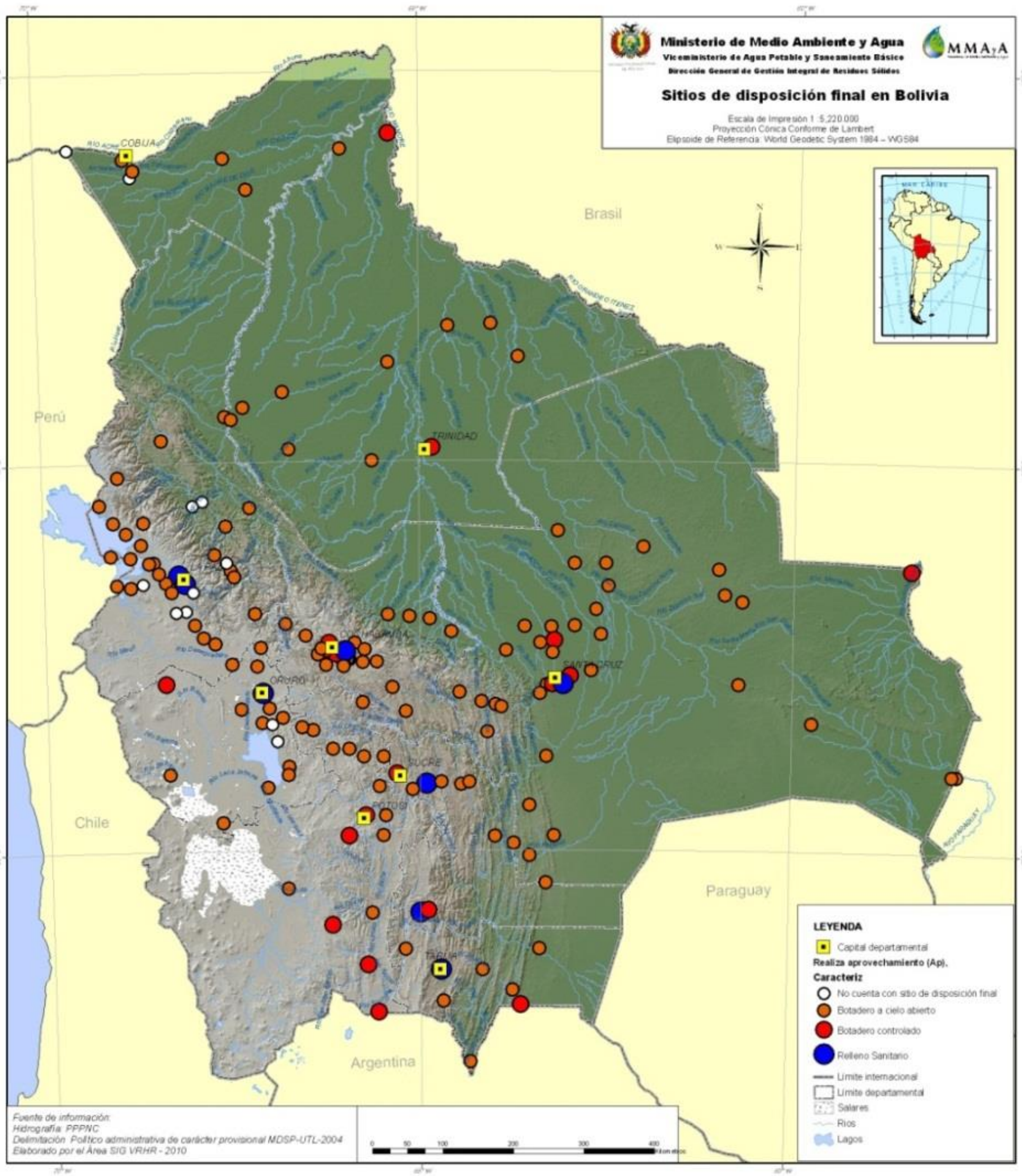

*Source:* Diagnostic of Solid Waste Management in Bolivia (DGGIRS 2011).

### *Open-Air Dumps*

Open-air dumps are found in human-made pits or natural depressions in which solid waste is deposited with no pollution prevention or control measures, and the waste is burned fairly frequently. The most significant pollution impact is on water sources, including those used for human consumption and irrigation. The problem is made worse because often the waste is deposited on riverbanks. Likewise, groundwater and soils are affected due to lack of bottom sealing systems in dumps and the consequent infiltration of leachates. Because the waste is not covered, and particles are emitted when burned, air quality also is affected.

Of the total number of open-air dumps in the municipalities analyzed, 30 percent of the sites were found to be near rivers, 5 percent near fields on which crops are grown, and 25 percent at a distance of less than 1 kilometer from a population center. Figure 2.6 indicates the location of open-air dumps (orange), controlled dumps (red), and sanitary landfills (blue). Another very common aspect is the presence of farm animals such as pigs, cows, or goats that come to feed in the garbage dumps, thus placing the population's food safety at risk.

### Figure 2.6 Map of Bolivia showing location of garbage dumps and sanitary landfills




Source: Author.

### *Recycling*

In Bolivia, as elaborated by the DGIRRS, 4.6 percent of the total production of waste is recycled or composted. Recycling is an activity pursued in large measure by the informal sector, and governmental pilot projects for recycling, composting, or vermicomposting take place only in 15 municipalities.

People in the informal sector work both at garbage dumps and in urban centers. At sanitary landfills, only in Alpacoma (La Paz) and Normandia (Santa Cruz) are solid waste segregators not allowed. At the remaining final disposal sites, garbage segregation takes place informally. In Sucre and Potosí, the activity is remunerated by municipal sanitation companies, under service provision contracts. This motivates the segregators to gather as much recyclable material as possible for sale. The income generated is used to pay wages for the work undertaken. In other municipalities, such as El Alto, Cochabamba, Sacaba, Quillacollo, Tiquipaya, San Matías, and Caravani, work by solid waste segregators is also allowed and coordinated with solid waste management companies or entities.

**"In Bolivia 4.6 percent of the total production of waste is recycled (3.7 percent) or composted."**

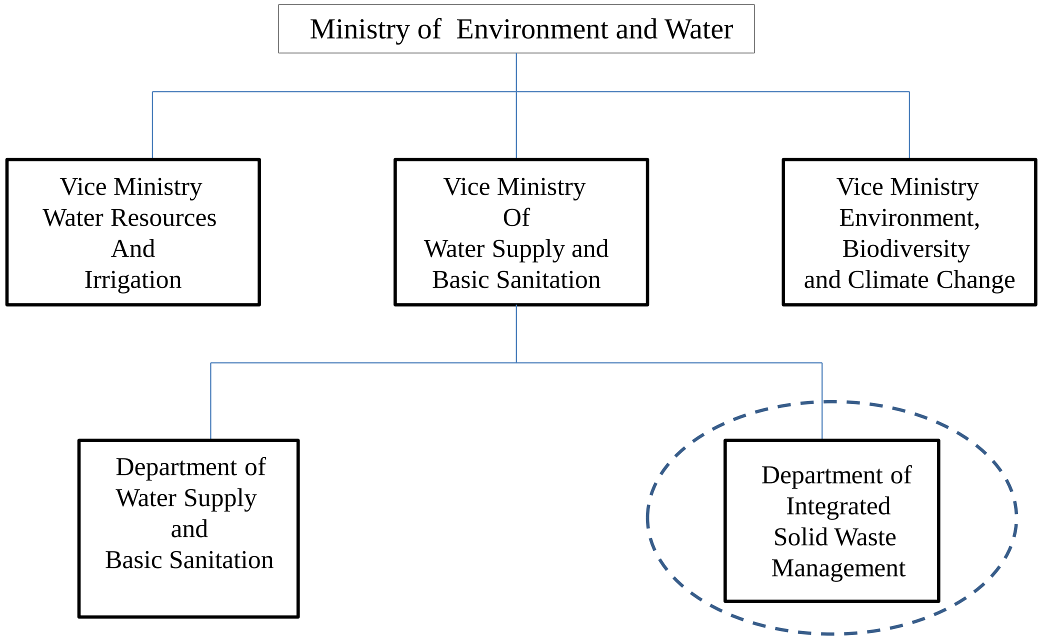
## 2.2 Strengthening the Sector

Solid waste management takes place under regulations that are part of Environmental Law No. 1333 (1995) and form the foundation of the legal framework for the sector in Bolivia. In 2009, through Supreme Decree No. 29894, the General Directorate for Integrated Solid Waste Management (DGGIRS) was created under the Vice Ministry of Drinking Water and Basic Sanitation at the Ministry of Environment and Water (figure 2.7) to monitor and undertake financial supervision of solid waste management projects and programs. DGGIRS responsibilities include planning, coordinating project oversight and implementation, promotion of standards and regulatory provisions, and strengthening the information system.

The establishment of the DGGIRS was a decisive moment for the sector. The situation evolved from the municipalities struggling on their own to the involvement of the central government. Specifically, with the creation of the DGGIRS, national solid waste policies began to be formulated, and support for municipalities intensified.

**National planning.** During 2011 the DGGIRS carried out a National Diagnostic of Solid Waste Management. The data contained in this chapter were extracted from that source because they are comprehensive and regularly updated. The study took place in all nine provinces and 183 of Bolivia's 327 municipalities. The DGGIRS has also developed the Plurinational Program for Integrated Solid Waste Management, which sets forth programmatic lines, goals, projects, and amounts necessary for investments in solid waste for the period 2011–2015. The amount needed to improve the standard of services and solid waste infrastructure is estimated at Bs. 435 million.

**Figure 2.7 Ministry of Environment and Water organizational chart**




*Source:* Adapted from the Ministry of Environment and Water organizational chart.[6]

**Legal reform.** Currently the DGGIRS is completing a draft Bill for Comprehensive Solid Waste Management. It is expected that the Solid Waste Management Law will become the legal foundation for comprehensive solid waste management. Among other things, the law will probably define the creation of provincial agencies[7] (departmental agencies for regulatory services for solid waste management) with responsibilities for regulation and the establishment of quality and control indicators.

**Technical support.** Finally, a DGGIRS guide to the presentation of preinvestment projects for solid waste management is being prepared, which is expected to assist municipalities with issues related to solid waste management and handling. Standards and manuals under preparation or already published aim to disseminate information on the sector, including operational guides for the construction of small sanitary landfills, closure of dumpsites, and recycling; a manual for calculating rates and fees; a guide for environmental education; a guide for the preparation and evaluation of projects; and several documents containing information on training.

All together, these documents constitute a solid foundation for planning and establishing a legal framework for the sector in the future. However, there are several challenges that must still be dealt with in order to implement the plans, and to better manage the solid waste sector. The enforcement of solid waste management laws is a difficult and ongoing process everywhere in the world. Specifically, the crucial challenges facing successful implementation are:

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[6] As established by Supreme Decree No. 29894, "Estructura organizativa del Poder Ejecutivo del Estado Plurinacional," 2009.
[7] Section IV of the Enabling Regulations for Solid Waste Management Service Operators (latest update 05/31/2012).

- Ensuring financing is available for research;
- Operation and maintenance of the service;
- Regulation of service quality and enforcement of legal aspects;
- Application of organizational and operational models to ensure efficient services and contractual models for the private sector.

These issues are relevant and important in the Bolivian context, as the country moves toward implementation.

## 2.3 Key Implementation Issues: Financing, Regulation, Management and Contractual Models

The implementation of a comprehensive solid waste management system tends to face greater challenges in those areas that are also the most important to a successful system.

The first challenge the municipalities face will be to obtain financing. Finding resources is always subject to delays, due to constraints in the availability of resources or the lack of incentive mechanisms. National resources are usually insufficient to meet the competing demands of different sectors. Private investments are scarce due to the lack of incentives, economic risks, and political decision making. As will be seen later, Bolivia is very dependent on external financing, but this is not a source of funding that is sustainable in the long run. On the other hand, recurrent costs are an ongoing difficulty for the sector. Low tax collection rates imply that in most municipalities the service is strongly subsidized. The lack of resources for the municipalities' current expenses is a critical problem for the proper operation of the service.

Another challenge facing the sector concerns regulation of the service, based on preestablished criteria and standards, to the extent needed to reach national goals, for example the closing down of illegal garbage dumps. Regulation is important as it leads to a demand for investment, ensures compliance with environmental protection standards, and promotes service quality and sustainability.

Finally, it is fundamental to select adequate management and contractual models for each municipality. The model and contract to be chosen will depend upon the size of the municipality, the amount of waste generated, and the presence of a developed private sector. A good model could take advantage of economies of scale, provide more efficient public management, and consider the possibility of including private companies in order to meet the different needs of municipalities and the private sector market.

### *2.3.1 Financing Models for Urban Solid Waste Management*

This section analyses the various sources and models that may be used to finance solid waste management. Possible sources of investment and resources are considered that may be made available to cover the costs of administrating, operating, and maintaining the service in the municipalities. On the one hand, investments in Bolivia have in large measure depended on loans and grants awarded by external organizations; on the other, government or municipal funds to cover recurrent costs are scarce due to low tax collection and the inadequate design of rates to be charged.

## Investments

In Bolivia, solid waste management has been part of the basic sanitation sector for several years. However, it has not been afforded the political priority it deserves, with the consequence that it is not allocated a significant budget. Investments in solid waste during the 1987–1997 period[8] totaled around $50 million, of which 83.9 percent (around $42 million) was financed by the donor community and municipal governments, and 16.1 percent ($8 million) by sanitation service operators (table 2.2 and figure 2.8). According to data from the Ministry of Finance,[9] from 2001 to 2007, approximately $268 million was invested in basic sanitation, of which 0.9 percent went to the solid waste sector.

Since the creation of the DGGIRS, interinstitutional financing agreements have been signed with donor organizations, both for institutional strengthening of the DGGIRS and implementation of local projects in the municipalities. The total amount of cooperation for the period 2009–2011 was Bs. 15.5 million (approximately $2.2 million) (DGGIRS 2010). In the year 2010, some municipal governments and their sanitation companies negotiated their own funds for the renewal of the vehicle fleet. This was the case, for example, in Tarija, where with support from municipal and provincial governments, financing in the order of Bs. 20 million was granted. Other similar experiences, using municipal resources, took place in La Paz, Quillacollo, Uyuni, and Bermejo (DGGIRS 2010).

**Table 2.2 Economic participation in the solid waste subsector by source of financing, 1997–2011**

| | Source of financing (US$) | | |
|---|---|---|---|
| Period | International donors | Municipal government | Private companies |
| 1987–1997[a] | 34,248,000 | 7,729,000 | 8,081,300 |
| 2001–2007[b] | 1,920,000 | 1,470,000 | 2,420,000 |
| 2008[c] | 80,000 | | |
| 2009–2011[d] | 2,201,055 | 2,857,000 | 12,000,000[e] |
| Total subsector investment | 58,259,055 | 12,056,000 | 22,501,300 |

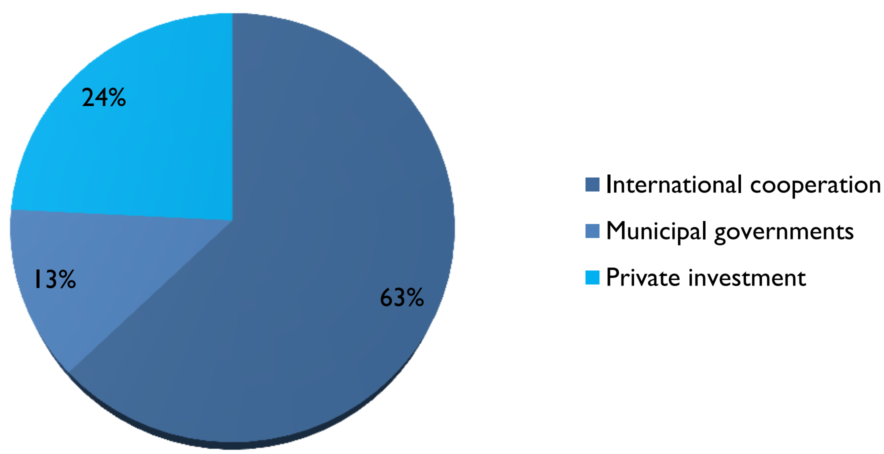
a. National Basic Sanitation Plan 2001–2010, p. 38.
b. National Basic Sanitation Plan 2008–2015, p. 35.
c. Estimate by consultant team based on data from PCDSMA.
d. Diagnostic of Solid Waste Management – Ministry of Environment and Water, 2011, p. 9.
e. Estimate by consultant team considering the investment in machinery by companies holding concessions in El Alto, La Paz, and Santa Cruz.

Most of the investments in the large and medium-sized cities were made in the decade 1987–1997. After 1997, most investments made with national financing (municipal or private companies) were used for maintenance of facilities, replacement of machinery, or small increases in coverage. Almost all the machinery purchased in the 1990s, as well as the landfills built at the time, have completed their useful life cycle, and the time has come for a new "investment boom" in the sector. The Plurinational Program for Integrated Solid Waste Management estimates that Bs. 435 million (approximately $63 million) are needed to improve current solid waste services and infrastructure. However, with a new and economically weak Directorate General for Solid Waste, and especially without a specific investment

[8] National Basic Sanitation Plan 2001–2010.
[9] As cited in the National Basic Sanitation Plan 2008–2015.

program, it will be necessary to develop financing strategies in order to deal with the wave of investments that are expected.

**Figure 2.8 Economic participation in solid waste subsector by source of financing (%)**




Source: Author.

Currently, sources of financing for investments in solid waste are the donor community and central government transfers to the municipalities. As can be seen in table 2.3, investments made by the donor community stem mainly from the Inter-American Development Bank, World Bank, Swisscontact, Catalan Agency for Development Cooperation, and Andean Development Corporation.

For its part, central government transfers include Joint Tax Participation in Specific Resources, the Special National Dialogue Account (HIPC II, 10 percent for public health projects), mining royalties (Law No. 3787, Supreme Decree No. 29577, 15 percent to municipal governments, 85 percent to provincial governments), and the Direct Hydrocarbons Tax (of which 100 percent is used for investment projects). However, the funds available from these sources are still insufficient, because they are earmarked for several sectors competing for the same resources, without a clear overall allocation by sector.

**Table 2.3 Institutes that support the solid waste subsector with economic resources**

| Entity | Project |
|---|---|
| Swisscontact (Swiss Foundation for Technical Development Cooperation) | 500,000 euros |
| Catalan Agency for Development Cooperation and Catalan Waste Agency | 70,000 euros |
| Andean Development Corporation | not available |
| Inter-American Development Bank | $20 million |
| World Bank | $3.5 million |

Source: Author.

### Recurrent Costs: Administration, Operation, and Maintenance

Expenses for administration, operation, and maintenance of services are considered to be recurrent costs. In the solid waste management sector these are as important, if not more so, than investments, considering that many of the investments made are wasted due to poor operational practices (for example, an engineered sanitary landfill can be converted into an open dump through bad operation). Sources of funding may come from fees charged to service beneficiaries, or from municipal and provincial resources.

### Fees

According to the solid waste management regulations contained in Environmental Law No. 1333, the sustainability of sanitary services must be generated through income from the collection of mandatory taxes paid by service users.

However, only some 54 municipalities in the country have implemented these fees, and even so the income derived has not been enough to cover operative costs. Most of these municipalities are provincial capitals or large towns. In 85 percent of the municipalities the service continues to be free of charge, meaning it is subsidized in its entirety by the local governments.

In the medium-sized municipalities that manage to charge fees, the amount collected does not exceed 60 percent of the resources necessary for the administration, operation, and maintenance of solid waste management services. Only the sanitation companies in Santa Cruz and Oruro have reported levels of income from fee collection that allow them to cover almost all their expenses for service provision.

In Bolivia there are three payment modalities for urban sanitation services:

- With the electricity consumption invoice. The sanitation service fee is applied based on the category of electrical energy consumption, area of residence, and frequency of collection. The company providing the service pays a monthly commission for the collection made by the electricity company, calculated as a percentage of the total income collected.
- With the drinking water consumption invoice.
- Direct payment to the Mayor's Office via door-to-door collection.

The quality of the service will reflect existing economic constraints. This is why in many places there is no adequate final disposal and the waste is simply thrown out into the open or, exceptionally, a tractor is used to bury it. In almost all cities, the frequency of street sweeping in peripheral areas is limited, there are not enough garbage bins, and there is a lack of dissemination and education campaigns. Another factor that is not well understood among urban sanitation service providers is how to go about replacing their equipment and machinery, and paying for the expansion of the business. In theory, these should be paid for by user fees, but in practice the companies themselves expect the municipal governments to pay for these expenses. For this reason, much of the equipment is in poor shape and obsolete.

### Municipal Government Resources

Urban sanitation services are subsidized by central government resources transferred mainly from national Joint Tax Participation funds and the Direct Hydrocarbons Tax.[10] It has not been possible to establish the amounts or percentages of those resources used for solid waste management, as there exists no rule for their use, nor is a fixed percentage set in national standards or in municipal solid waste regulations.

### Provincial Government Resources

There exists a precedent for the use of provincial resources for the replacement of machinery in favor of the City of Tarija Municipal Sanitation Company,[11] in the form of a concurrent project between the Tarija Mayor's Office and the former Prefecture of Tarija. Presumably resources from the Direct Hydrocarbons Tax were used, as these allow for the transfer of resources to the decentralized entities under a purchasing agreement reached in 2007.

### *2.3.2 Regulation*

The regulation of the solid waste management sector is fundamental to ensure adequate implementation of management programs. The legal framework for environmental regulations already exists. This section shows how the regulation of the sector and compliance with national goals evolved over time.

The regulatory system for sanitation services in Bolivia have been evolving since the 1990s, as indicated in box 2.1.

While the legal framework establishes that AAPS is in charge of oversight, social control, and regulation of basic sanitation, to date no action has been taken regarding the provision of solid waste services. In April 2012, AAPS acknowledged that its responsibilities now included regulation and provision of solid waste services in addition to the attributions of the former Basic Sanitation Superintendency (drinking water and sanitary sewerage systems), but it lacked the economic resources, procedures, and expert professionals capable of formulating adequate solid waste regulations. In the short term, it is not expected these services will be regulated, unless the new Solid Waste Management Law (currently being drafted) determines the procedure for allocating resources for this activity.

Finally, the draft bill currently being prepared[12] includes the creation of provincial regulatory agencies for solid waste handling services, whose attributions are similar to those of AAPS. However, beyond proposing their creation, it is not clear in the Solid Waste Management Law what resources will be used to create these provincial agencies, nor what entity is to act as regulator until they are established. In brief, there is a regulatory loophole that requires a solution.

[10] Municipal Supervision and Regulation System, La Paz municipal government.

[11] Diagnostic of Solid Waste Management in Tarija, 2010, section 3.2.6: "Vehicle Fleet Used for Garbage Collection and Transport."

[12] Section IV of the Regulation on Solid Waste Handling Service Operators.

**Box 2.1 Evolution of the regulatory framework in Bolivia**

**Law No. 1600, 1994: regulate, control, and supervise.** The concept of "service regulation" was introduced to Bolivia with the promulgation of Law No. 1600 in 1994, whose aim was to "regulate, control and supervise those activities in the telecommunications, electricity, hydrocarbons, transport, water and other sectors which by law are incorporated to the system and which are submitted to regulation in accordance with the respective legal and sectoral standards." The new Constitution established the levels of government and the types of competencies applied to solid waste management:

- Exclusive competence of the central government: basic service policies.
- Exclusive competence of the autonomous municipal government: urban sanitation, solid waste management, and treatment in the framework of State policy.
- Concurrent competencies of the central government and autonomous territorial units: drinking water projects and solid waste treatment.

**Service Provision and Use of Drinking Water and Sanitary Sewage Law, 2000.** By this law, basic sanitation sector competencies were restructured, and the Basic Sanitation Superintendency established as the entity responsible for regulating drinking water and sewerage services.

**Shift in focus and new system, 2009.** In the framework of the new Constitution, in April 2009 Supreme Decree No. 071 was promulgated, dissolving the sectoral regulation system and replacing it with the Authority for Oversight and Social Control of Drinking Water and Basic Sanitation (Autoridad de Fiscalización y Control Social en Agua Potable y Saneamiento Básico, AAPS), which took over the attributions of the former Basic Sanitation Superintendency. Its competences covered control and industrial regulation in the exploitation of water sources, and the treatment and final disposal of wastewater. This process was an important milestone, as it provided tools for a change in emphasis from service regulation to oversight and social control, thus formalizing the involvement of social organizations in hierarchical, administrative, and operational definitions concerning the provision of drinking water and sanitation services.

Source: Author.

### *2.3.3 Management Models*

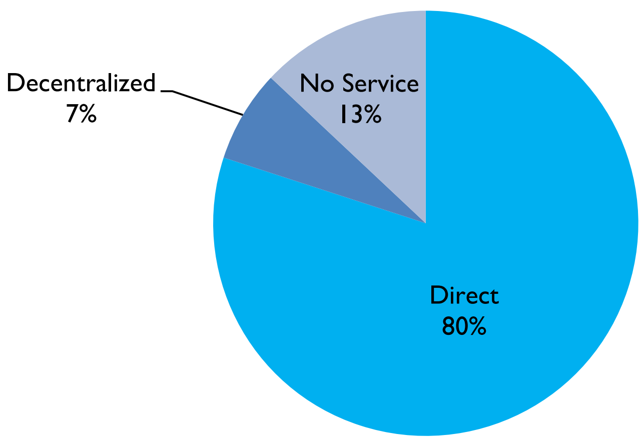
According to the Bolivian legal framework, solid waste management is a municipal competence in the entire territorial unit,[13] to be implemented through a solid waste service provision model. Therefore, the municipal autonomous government is the only entity responsible for the planning, design, implementation, and sustainability of urban sanitation services in its jurisdiction. To cover the entire territory, the municipal government may come to a variety of institutional arrangements. Which ones actually materialize will depend on the economic capacity of each municipality and the priorities set by a particular administration.

Sanitation service provisions are developed in various modalities: direct management by the municipality (80 percent of cases); by a decentralized public entity (7 percent); or no service at all (13 percent). In

[13] See the enabling regulations for solid waste management of Environmental Law No. 1333, Municipalities Law 2028, the Framework for Autonomies and Decentralization (Law No. 031), and the draft Bill for Solid Waste Comprehensive Management.

some cases public management is joined with the private sector for the provision of a service. In Bolivia concession procedures take place in 1 percent of the municipalities and other types of public-private arrangements in 9 percent (figure 2.9).

**Figure 2.9 Urban solid waste management models in the municipalities**




Source: Author.

A natural evolution of solid waste service models is under way, due to several factors, for example urban population growth. In general, in Bolivia, several models are in use at municipal level. In terms of management model – which entity is in charge of the administration of solid waste management – there are several alternatives, including (a) a solid waste unit set up and run directly by the municipality (direct management); (b) a unit deconcentrated to the municipality (deconcentrated management); or (c) a decentralized unit with its own equity and legal status, which is not attached to the Mayor's Office (decentralized management). At the same time, the service may be outsourced or granted in concession, although responsibility still rests with the municipality (direct management by concession or direct outsourcing). Among the most interesting models are the deconcentrated, decentralized, and direct by the municipality with outsourcing for service provision (for instance through a service contract, see box 2.2).

**Box 2.2 Examples of models for solid waste management in Bolivia**

**Deconcentrated**

The deconcentrated model is being used in medium-sized towns with populations of approximately 100,000, such as Quillacollo. Deconcentrated units are dependent on the municipal government, but are more mature in how they manage solid waste than the direct model. Solid waste collection and transport takes place in special compacter trucks. However, final disposal still takes place without control, and nothing is done to recycle usable waste.

**Decentralized**

The decentralized model is found in cities with more than 100,000 inhabitants, such as Oruro, Potosí, Sacaba, and Sucre. Decentralized entities have administrative autonomy as concerns management, as well as their own equity. Still, they are not autarchic and depend on transfers from municipal governments (with the exception of the Potosí Municipal Sanitation Company). Solid waste service provision takes place using own staff and machinery. Many of their employees have been with these companies a long time and the equipment is largely specialized, although rather old. Final disposal takes place in controlled garbage dumps, a source of much opposition from civil society. All use heavy machinery to bury solid waste.

**Direct with service contract**

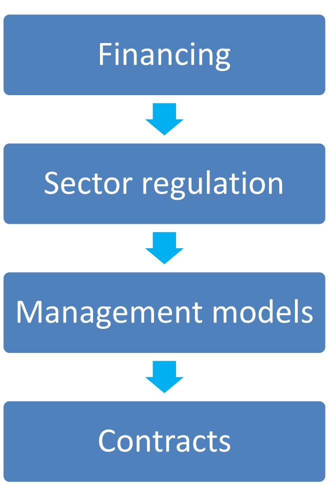
A direct service contract was found to be in use in San Buenaventura, a small town of some 5,000 inhabitants. In this model the administration of solid waste management is undertaken by a municipal government unit. The service is outsourced to a private company, a microenterprise, or an individual. The service operator (or operators) is contracted by the pertinent municipal government unit (the administrative or financial office), while a different unit oversees the quality and efficiency of the service (the environmental office or the technical office). An important aspect of this type is that economic resources can be budgeted from any source by the municipal government, while the private operator is concerned only about fulfilling the terms of their contract. The municipal government could outsource service components to one or more companies, while undertaking no operational tasks whatsoever.

Source: Author.

### 2.3.4 *Contractual Models*

Several types of contracts exist for solid waste management that can be used for the various activities (street sweeping, garbage collection, transport, treatment, final disposal). The choice usually depends on political reasons, the capacity of each municipality to provide the service, the presence of the private sector in the area, the size of the municipality, and the tonnage of solid waste being handled (in general, it is more profitable for a private company to operate in larger municipalities, where the amount of waste produced allows for taking advantage of economies of scale). Each of the groups engaged in contractual arrangements in the solid waste subsector are described in annex B.

## 2.4 Options for the Future




Upon analyzing the Bolivian context, some options can be considered for improving the future management of solid waste in the country. The alternatives proposed herein focus on key aspects of urban solid waste management, such as financing, sector regulation, management models, and contracts. Each of the following sections lists a few activities that could be implemented in the light of a comprehensive solid waste management system.

### 2.4.1 *Financing*

As noted earlier, one of the main difficulties is the scarcity of resources. This is the case due to lack of investment, but there is also the difficulty of paying for recurrent costs and ensuring the service is sustainable.

There are several alternatives that might be applied in order to increase the availability of resources for the solid waste sector.

### Investments: Increased Funding

Due to lack of investment in the sector, it is necessary to identify sources of funding and improve mechanisms and incentives for financing. One of the priorities for improving solid waste management is to increase funds to municipalities that are earmarked for the sector. Options include the following:

- **Increase bank resources.** This option would reduce external resources such as loans or grants, and strengthen financing for solid waste management from development funds or commercial banks, which have experience in making loans to municipal governments using their own resources. To facilitate this, it is necessary that the solid waste sector is established as a usual sector for investment by funders with capacity and experience in the development and management of solid waste projects. An example of a development fund is the National Fund for Regional Development, which has experience in making loans to municipalities and has the possibility of using its own resources to finance investments.

- **Develop a solid waste management sectoral program over the medium term.** The sectoral development program would be charged with the task of organizing the different sources of financing for solid waste management, taking into account all types of municipalities and investment, including external financing, and including the amount needed in each specific investment area. It would need to ensure that all municipalities, including the smallest ones, have access to resources. Such a plan must be structured to exist over the long term, or at least the medium term.

- **Increase specific national transfers earmarked for solid waste management.** Investment resources for the municipalities can be increased through transfers from specific sources in the central government to the municipalities.

- **Increase private sector investments through corporate social responsibility programs.** A legal framework can be created, including the necessary incentives, to facilitate the presence of the private sector as an investor in social responsibility projects. For example, a company that invests in accordance with its corporate social responsibility plan is the Bolivian Cement Corporation. An example is its recycling project in Viacha, which has contributed to raised awareness among the population of the importance of recycling.

- **Increase investments in services by the private sector, particularly by national companies.** It is advisable to create legal frameworks and encourage investments in order to facilitate the presence of the private sector as an investor in solid waste management projects. Such an option is more viable in larger cities and could be implemented whenever appropriate from an environmental, economic, and social standpoint. In addition, this alternative must be supported by strong contractual arrangements and a technical team able to carry out oversight activities in the municipality.

### Investments: Incentives and Financing Mechanisms

For the purpose of increasing sources of investment, it is necessary to ensure there are incentives and financing mechanisms in place to favor and facilitate investments. Options include the following:

- **Joint financing formulas.** In some countries there exists a preestablished formula by which to provide national and local financing to be used as incentives for investment and a means to provide the necessary support for small or poor municipalities. The joint financing model must establish percentages for central, provincial, and municipal government investments, as well as private investors (if applicable). It must also indicate the type of investment (loans, grants), based on municipality size and type. In such a scheme, all municipalities must have access to credit.

- **Minimum investment law.** This alternative is a requirement in the national framework for municipalities to make a minimum investment in solid waste. The intention is to ensure that the amount budgeted for the sector is not spent by the municipal government on other needs.

- **Incentives for national strategic priorities.** Among the financing mechanisms, it is important to channel investment toward the strategic priorities established at national level. This means financing will be provided by prioritizing those project modalities considered most viable, for example those that take advantage of economies of scale; regionalize final disposal sites (formation of associations of municipalities); and include waste segregators in recycling projects (this has been done in Brazil, for example, where such projects are prioritized for financing). Management models will be selected that include public-private participation or are the most appropriate for a particular municipality.

- **Diminished risk for the private sector.** In order to facilitate private sector participation in solid waste management projects it is important to ensure timely payment by municipalities, by means of guarantees or income collection-raising formulas. Another alternative may be the implementation of pilot projects in order to verify the viability of the models.

## Recurrent Costs

It is also fundamental to ensure the availability of funds to cover administrative, operational, and maintenance costs in the municipalities. Experience certainly shows that the lack of resources may cancel the benefits produced by an investment (for example, poor operation of a sanitary landfill or the lack of maintenance of trucks and equipment, leading to early depreciation of these assets). The sources that may be used by the municipalities to cover recurrent costs are service fees, central government transfers, or taxes on tourism. Alternatives identified to obtain such resources are described in the following sections.

### *Recurrent Costs: Increase in Service Fees*

An increase in service fees is a very touchy issue in a country such as Bolivia. Therefore, it is crucial to implement such a rise only gradually, and to take into account the initial subsidy of the service, which is inevitable. It is necessary to integrate mechanisms that ensure the system is sustainable, including consideration of the following factors:

- **Calculation structure.** The first phase in raising the price of the solid waste collection and disposal service is to determine how much is needed for the system to maintain itself. This would involve the drafting of rules and a guide to calculate the rates and fees structure concerning service and investment costs.

- **Distribution criteria.** It will be necessary that some sectors of the population subsidize others. These criteria must be part of the rates and fees structure and be set according to the capacity to pay of each individual. Some factors to take into account when determining these rates are (a) user type (companies and industries, domestic users, etc.), for example the increase in price for the service may start by charging companies and industry more before moving to the population at large; (b) income levels among the population, which may involve the wealthier sectors subsidizing the poorer population groups; and (c) type and level of service offered in each municipality.

- **Tax collection law.** Such a law is needed to ensure a fundraising mechanism is in place, and to indicate the minimum amount that needs to be collected by the municipalities. This would serve as an incentive to collect taxes and bolster the sustainability of municipal governments.

- **Environmental education programs.** These are intended to raise awareness among the population concerning the importance of the solid waste management sector and the need to pay a fee for the service.

- **Training in tax collection among the municipalities.** If the system is to be sustainable, it is necessary for tax collection to be carried out in an efficient manner. Staff at the Mayor's Office must be trained to select the best revenue and collection models allowed by law. For example, depending on the situation, the service fee could be charged together with the electricity bill, the water bill, or separately.

***Recurrent Costs: Adding Other Resources***

Normally, the solid waste sector requires that other sources of income become involved, in addition to tax collection efforts, in order to ensure it can pay for recurrent costs. In Bolivia today, the municipalities subsidize these costs using tax income or transfers, but the amounts involved are usually inadequate. With ever more modern investments, costs will only tend to go up. Therefore it is necessary to identify other sources of income. Some options to be considered are as follows:

- **Allocate resources for operation and maintenance of solid waste management services in central government transfers.** One possibility would be to write this allocation into the law. Another is to set up a trust fund with resources to be used exclusively for solid waste management service operation and maintenance. This would ensure the resources allocated to the sector are indeed used on solid waste management and are not treated as current expenditures by the municipalities.

- **Environmental cross-subsidy.** As has already been noted, in the case of solid waste management investments, corporate social responsibility mechanisms such as an environmental cross-subsidy could be used to cover recurrent costs on waste management. From an economic-environmental perspective, it is possible to subsidize urban sanitation services by charging an environmental tax for certain commercial or tourism activities. These would be applied by municipal governments and the revenue therefrom could be used later in solid waste management in the same city or town in which they were charged. One example applicable to Bolivia would be to charge a tax for placing advertising billboards along highways, roads, and streets.

- **Tourism tax.** Likewise, it would be possible to include the cost of waste management in tickets issued to tourists, meaning they would be paying for the garbage they produce. This alternative too could include a trust fund to ensure the resources are used on solid waste management.

### *2.4.2 Regulation*

Together with already existing environmental laws, the solid waste management regulatory framework should be designed to comply with the national goals set forth in the solid waste management law, while regulating the service and ensuring it complies with quality standards. Currently, neither type of regulation is apparent in Bolivia.

### Regulation for Compliance with National Solid Waste Management Goals

Regulation on the declared national goals identified in the Solid Waste Management Law must establish which entity will be charged with regulating the closing down of garbage dumps or other goals that have been set. Currently, this has not been clearly defined nor are there economic resources available or legal instruments in place for such an entity to play its role. Some actions to be taken include:

- **Determine the actor.** It is fundamental to determine who is responsible for regulating national goals and targets. In other Latin American countries the regulation of national goals is usually done by the equivalent of the Ministry of Environment and Water, and this may be a viable alternative in Bolivia as well, through the DGGIRS.

- **Legal capacity and adequate staffing.** Once the legal entity charged with regulation is established, it will be necessary to ensure it has the legal capacity, the necessary staff, and the budget required for exercising its functions, among which are oversight and imposing penalties for failure to comply.

- **Regulation criteria.** A good definition of regulation criteria will facilitate the work of the legal entity.

### Regulation of Services

Particularly in the case of the legal entity charged with regulating national goals, it will be essential to determine who will be responsible for regulating the sanitation service and what its exact role will be. The steps to be implemented are:

- **Define the actor.** In order to achieve national goals it is necessary to clearly define the entity charged with regulating the service. In the framework of the new Constitution and Supreme Decree No. 29894, and according to Law No. 2066 (which places the solid waste sector under basic sanitation), the regulatory agency should be AAPS. In this case it will be necessary to allocate the budget necessary for it to carry out its functions. Further, the Solid Waste Management Law foresees the creation of provincial regulatory agencies for solid waste management services, albeit without indicating timelines or where the necessary investments would come from to establish these bodies.

- **Legal capacity and adequate staffing.** Once the regulatory entity charged with regulating the path to reaching national goals is established, it will be necessary to ensure it can function appropriately. This can be done through training and the appointment of competent persons in the various positions.

- **Regulation criteria.** A clear definition of criteria for the regulation needed will make it easier for the regulating entity to execute its task. Therefore, the DGGIRS should set the main indicators for regulation and follow-up to national urban sanitation services, as part of its Solid Waste Sector Development Policy (chapter 3.6 of the Plurinational Program for Integrated Solid Waste Management) and its Strategic Objective No. 1 (chapter 3.7).

### 2.4.3 Management Models

This section illustrates some options for strengthening solid waste management by means of more efficient or viable management models:

- **Municipal model with decentralized companies.** One option for improving solid waste management is to create competent decentralized public companies. This is a promising alternative, as it allows for invoicing the fees directly to the public company and improves service efficiency. For the small and medium-sized municipalities, this alternative could be implemented through, for example, the creation of companies responsible for water, sewerage, and sanitation. This option tends to be the most viable and facilitates the collection of fees. In addition, these operations can begin to function quite soon, given the existence of EPSAS, the State-owned company for water distribution and sanitation services. On the other hand, it will be necessary to define the decentralized companies from a legal standpoint. Currently, it is not clear whether a decentralized municipal entity is allowed to receive transfers from municipal governments, although they provide a basic service as an extension of municipal competencies and are not necessarily self-sustainable.

- **Intermunicipal models.** Regionalized solid waste management has many advantages, in terms of sheer viability (using economies of scale) and the efficiency of the service (given there is a specific body in charge of management). The two modalities identified in Bolivian intermunicipal models were (a) metropolitan companies, designed for urban areas with a population of over half a million, and implying the creation of an operating body with financial autonomy, normally with a directory of users in the municipalities within the metropolitan area; and (b) associations of municipalities, which can access the economic resources they receive from member municipalities and are legally enabled to obtain central government transfers from other sources. It will be necessary to provide incentives to encourage the creation of these models, and to provide financing for joint proposals, technical assistance, and strengthening of the associated organizations.

- **Outsourcing.** The outsourcing of all or some services in solid waste management may offer solutions to many of the problems facing municipalities. It is necessary to evaluate the best alternatives for each municipality, depending on size, technical capacity, and the presence of a private sector or microenterprises in the area. In order to stimulate private participation it is recommended to create legal instruments, guides, and incentives for the various schemes, attuned to the scale of the enterprise: (a) for small municipalities, alternatives include public franchises, whereby private microenterprises (such as cooperatives or solid waste segregators) engage in operation and recycling, and private franchises, or professionalization contracts for training at municipal public company level; (b) for medium-sized municipalities, public-private participation schemes can be implemented without making investments, as long as the private sector is involved; (c) for large municipalities and provincial capitals, public-private participation with investments made by the public partner can be considered, with nationwide legal and financial measures to stimulate and encourage private investment and reduce the risks for the private partner.

- **Garbage handling model for recyclers.** Recycling models that include solid waste segregators can be successful. These can be put in place by formalizing activities such as recycling or garbage collection. Involvement of waste segregators in solid waste management can be encouraged by designing guides to introduce possible models; including it as an alternative in the legal framework; and establishing it as a strategic financing priority.

### 2.4.4 *Contractual Models*

Different contractual models may be adapted and used for solid waste management. Possible DGGIRS initiatives for disseminating the most suitable model in any given situation include formulation of guides for the various types of solid waste management contracts, setting up pilot programs, and the adaptation of other types of contracts for the solid waste management sector. Solid waste management contractual options include leasing, franchising, turnkey, and design-build-operate.

- **Leasing.** A leasing contract is of interest to a user who wishes to acquire an asset, verifies its price, and enters into agreements with the owner or importer. Once the information is obtained the user may go to the bank, which acquires the asset from the manufacturer and then hands it back to the user for use and exploitation. It is possible to use such financing schemes for waste collection and transport vehicles for their estimated depreciation period.

- **Franchising.** There are two main types of franchise contracts: (a) public franchise, by which a private enterprise or microenterprise is granted the right to provide (for example) street sweeping and garbage collection services in a particular area of a city, which could be of interest for larger municipalities due to the high profitability of the service and the need to supervise the contracted company; and (b) private franchise, by which a private company supports the public management of solid waste by transferring know-how and providing training and assistance, a model that could be of interest to any municipality, especially those that carry out solid waste management services through decentralized companies.

- **Turnkey.** Conceptually, this is the contract whereby a bidder offers a full service, including design, construction, facilities, start-up, equipment, training, and intellectual and technological transfer. This type of contract is suitable when building a final disposal site and can be used in any type or size of municipality.

- **Design-build-operate.** This contractual type involves an agreement with a single construction company for the building of a facility (for example a landfill). This type of contract does not include investment on the part of the private company, and can be tailored to the needs of the municipality. Thus the operation phase may last a year or more (usually three to five years), and at the end of this period the municipality can take over the operation and contract a different company, or can continue working with the same company. Specifically, a design-build-operate contract may notably shorten the processes, given that there is only one company in charge and there are few delays in the design, construction, and operation phases. While it is necessary to prepare a feasibility study before the bidding process begins, no detailed engineering study is necessary. It is important to take into account that for this type of contract a strong oversight team is needed (municipal or external).

## 2.5 Conclusions

The solid waste sector in Bolivia faces major challenges in the coming years. Population growth patterns and the subsequent increase in consumption as a result of economic development will be reflected in a significant increase in the production of solid waste. Although coverage in terms of garbage collection, street sweeping, and transport is good in provincial capitals and in large municipalities, weaknesses are evident in medium-sized and smaller towns, particularly those located in outlying areas. Conditions for final disposal are inadequate in most municipalities, and only half the waste produced in the country is transported to landfills.

***"Conditions for final disposal are inadequate in most municipalities, and only half the waste produced in the country is transported to landfills."***

In view of the challenges that lie ahead, the Ministry of Environment and Water has taken several positive steps over the past few years. The most significant of these has been the creation of the DGGIRS as a specific unit for the solid waste management sector. For its part, the Directorate has worked hard to strengthen the sector, including through national planning initiatives (the Diagnostic of Solid Waste Management, the Plurinational Program for Integrated Solid Waste Management); tightening the legal framework (drafting of the Solid Waste Management Law); and putting in place technical assistance (the guide for preparing solid waste projects and other guides, manuals, and workbooks).

It is therefore important to move forward to the implementation phase of the measures prepared by the DGGIRS. To that end, the main challenges identified are the scarcity of resources and the difficulty in obtaining financing; the regulation of the sector regarding compliance with national aims and service provision; and the selection of management models and contracts suitable to the types of municipalities existing in Bolivia.

In the latter part of this chapter, a number of options were described that could be implemented by the government to deal with these challenges. Alternatives to increase resources include increases in national, external, and private investments in the sector by means of different financing mechanisms, development of a cost calculation mechanism, and introduction of a service fee collection law to cover recurrent costs. In order to regulate the sector it is important to clearly define the actors (for implementation of national goals and service regulation) and grant them the economic and legal instruments they need. Management models could be geared toward the regionalization of the service (for instance the establishment of associations of municipalities) and the creation of decentralized solid waste units. The contractual models to be used may vary, depending on the size and type of municipality, as well as the degree of participation from the private sector.

# Chapter 3. Reuse of Wastewater to Mitigate Water Scarcity: Case Studies in Cochabamba and Tarija

## 3.1 Current Situation Regarding the Reuse of Wastewater for Irrigation

This chapter describes the results of the third in a package of studies and technical assistance activities of the program "Environmental Management in Bolivia: Innovations and Opportunities." It consists of an evaluation of the potential for reusing wastewater to irrigate agricultural land in Bolivia, based on a technical and economic analysis carried out in the provinces of Cochabamba and Tarija. The main goal of this evaluation is to place the reuse of wastewater in Bolivia in a broader context and generate lessons from what has been achieved thus far. The analysis undertaken in these case studies is intended as a preliminary stage in the development of wastewater reuse projects using a wastewater stabilization reservoir technology that could be successfully applied in Bolivia. However, it is necessary to think ahead to later stages, which will include an evaluation of the social impact that wastewater stabilization reservoirs will have on communities in the areas of influence of wastewater reuse projects.

This study is very pertinent for Bolivia, given the scarcity of water available for irrigation and the high level of unsatisfied demand, to such a degree that farmers have been using wastewater with only inadequate treatment, and often with no treatment whatsoever. The problem is aggravated by the inexistence of nationwide wastewater reuse policies and programs. However, as one of its priorities, the current government plans to advance policies and actions that aim to improve this situation. It is understood that not doing so will only intensify the problem, as farmers continue to increase their use of untreated wastewater, with all that implies for public health.

According to the 2008–2015 National Basic Sanitation Plan, in 2007 nationwide drinking water and sewerage services were available to 74.5 percent and 47.7 percent of the population, respectively. In urban areas, these percentages climb to 87.5 percent and 53.7 percent. The research for this document indicates that one of the main challenges faced by the sector is the reduction of water resource pollution, caused among other things by the discharge of inadequately treated wastewater. In this regard, the National Basic Sanitation Plan estimates that 70 percent of the wastewater collected is not treated at all, with the remaining 30 percent receiving inadequate treatment, due to difficulties with the efficacy of wastewater treatment plants.

Rapid urbanization and industrial growth in some areas of the country have led to a sharp increase in the demand for water for use in homes and for industrial purposes, and have been factors in the increase in water pollution. On occasion these sectors use up the entire supply of water, to the detriment of irrigation for agricultural uses. In such a scenario, the reuse of wastewater becomes a need and serves to compensate for the fact that very few water sources are entirely uncontaminated.

There are places in which the volume of wastewater produced by urban growth is such that it would not only satisfy the existing demand for irrigation, but in fact generate an increase in agricultural activity, based on informal reuse practices as a response to a surplus of wastewater resources. This reality is illustrated by a recent study undertaken by the Ministry of Environment and Water with support from the German Agency for International Cooperation (GIZ), which identified 105 urban centers at which the use of wastewater for irrigation is common practice. It is estimated that nationwide at least 5,000 hectares of cropland are currently being irrigated with wastewater (GIZ 2012).

In the National Basic Sanitation Plan the government of Bolivia establishes, among specific objectives regarding the sustainability of drinking water and sanitation services, that there is a need to develop policies and wastewater reuse programs to deal with problems related to water resource scarcity. The objectives, goals, and strategies for the sector set forth in the National Basic Sanitation Plan were officially reviewed and updated in April 2011 and promulgated in the 2011–2015 Sectoral Development Plan for Basic Sanitation. Included therein is the goal proposed by the National Wastewater Treatment Program to implement six pilot projects for the reuse of wastewater for agricultural and production purposes.

This chapter is part of the research carried out on the subject. It describes two case studies in which the wastewater stabilization reservoir technology is used. This method makes it possible to use and optimize unrestricted amounts of water for irrigation by storing it during the rainy season, when it is not required. The study consists of five sections: (a) brief description of wastewater management for reuse and the most commonly used techniques; (b) presentation and results of the case study carried out in Cochabamba; (c) presentation and results of the case study carried out in Tarija; (d) user fees required to cover the costs of the technology proposed; and (e) conclusions and recommendations.

## 3.2 Reuse and Technology of Wastewater Stabilization Reservoirs

The treatment and reuse of domestic wastewater for crop irrigation is an increasingly common practice in many countries, due to the lack of freshwater for use. In Israel, 67 percent of domestic wastewater is reused for irrigation, 25 percent in India, and 24 percent in South Africa (Friedler 2001; Gómez et al. 2010).

The use of domestic wastewater for irrigation allows for achieving yields similar to or greater than those obtained with the use of natural water and avoids or reduces the use of fertilizers, as wastewater is high in nutrients, particularly nitrogen and phosphorus. However, unless appropriate treatment techniques are used, risks to the health of farmers growing the crops as well as to consumers of the harvest are high. Therefore, domestic wastewater reuse methods must follow strict treatment and control measures that allow for enjoying the advantages this practice involves, while minimizing risks to farmers and consumers.

There are four basic domestic wastewater reuse modalities in agriculture, as follows:

- **Direct reuse.** Domestic wastewater is applied directly to crops. This is not advisable, given the enormous implicit risks to health, but farmers often do it anyway.
- **Indirect reuse.** Water for irrigation is taken from waters and rivers that receive domestic wastewater. The risk associated with this type of reuse depends very much on the flow and volume of the receiving water body and its capacity for self-purification. It is therefore necessary to evaluate the water source, taking into consideration that the more diluted the domestic wastewater, the fewer nutrients will be applied to the harvest.
- **Direct reuse after treatment.** This is currently a very common practice, as the degree of water treatment can be tailored to the level needed by the crop to be irrigated. This reuse model has two basic disadvantages: (a) the level of treatment needed for unrestricted irrigation (meaning that it can be applied to vegetables and other crops that are consumed without cooking) may be very demanding, costly, and difficult to operate and manage, especially in developing countries; and (b) during the rainy season, when the treated wastewater is not

needed for irrigation, untreated wastewater is discharged into the receiving water body. This leads to the loss of a resource that could be stored and used as needed during the dry season.

- **Reuse with wastewater stabilization reservoirs.** This type of reuse requires prior treatment, albeit not as advanced as in the case of direct reuse after treatment, considering that the domestic wastewater treated during the rainy season is stored in wastewater stabilization reservoirs, where it receives additional treatment prior to later application during the dry season. This allows time for improving water quality and accumulating the amount required for unrestricted irrigation because of the long period of retention in the reservoirs, during which microbiological and photochemical treatment processes take place, as well as the sedimentation necessary to obtain the required levels of BOD5,[14] fecal coliforms, and helminths.

Wastewater stabilization reservoirs are lagoons 4 to 15 meters deep that serve two functions: (a) to store partially treated wastewater for long periods of time, for the purpose of discharging it during a specific part of the year, under optimal conditions and using tight controls; and (b) to improve the quality of water stored during the months it remains in the reservoir. Therefore, the use of wastewater stabilization reservoir technology as a post-treatment system in tropical regions where rainfall is concentrated during a well-defined season in the year allows for maximizing the area of irrigation and simplifying the prior treatment necessary. Box 3.1 describes why this methodology has particular potential for Bolivia.

Given the advantages demonstrated in the use of wastewater stabilization reservoirs, the prevailing climatic conditions, and the scarcity of water for irrigation in many places in Bolivia, it is considered that this method has the highest potential for successful large-scale application in Bolivia. Therefore, the critical aspects of the application of this water treatment technology were assessed in depth in the two case studies in Cochabamba and Tarija. In these two regions a high potential was found for the reuse of water in the agricultural sector, due to the scarcity of water for irrigation in these zones and the high level of unsatisfied demand in the agricultural sector. In both places the effluent from existing wastewater treatment plants is being or will be used (Alba Rancho in Cochabamba and Santa Ana in Tarija, the latter currently under construction). The effluent from the treatment plants stored in the stabilization reservoir thus receives additional treatment. The water from the wastewater stabilization reservoir can be used for unrestricted irrigation, and the increased storage capacity would allow for a greater availability of water during the dry period. This would facilitate the watering of areas currently under cultivation, and would also contribute to the expansion of the area under cultivation. Box 3.2 describes the methodology used for assessing the technological feasibility and design of wastewater stabilization reservoirs.

[14] BOD5 is the biochemical oxygen demand of wastewater during decomposition over a five-day period, and is a measure of the organic content of wastewater.

**Box 3.1 Why does this study focus on stabilization reservoirs?**

It is recommended that wastewater stabilization reservoirs be applied on a wider basis, as it is the method with the greatest potential in Bolivia. The main reasons for this recommendation are as follows:

- There is no constraint on land availability for the construction of a stabilization reservoir, which make it the most cost-effective method. Among the different options, the cost of building a stabilization reservoir is the lowest, and the benefits to be obtained in terms of the quality of water for use in unrestricted irrigation are the same as those achieved using other conventional water treatment technologies. Prior treatment of wastewater for the stabilization reservoir is not as rigorous as for other technologies; operative costs are lower because it does not need electrical energy for operation, unlike more rigorous treatment methods; and the operation is simpler than that required by other wastewater treatment technologies, and therefore the need for training of staff is reduced.
- WHO recognizes that wastewater treatment in stabilization reservoirs may be an effective way to obtain the microbiological quality standards that are essential to the use of wastewater for irrigation.
- The weather in some areas in Bolivia is another favorable factor for applying this technology, as the intense sunlight and tropical heat helps remove organic matter, so during the months the water is trapped in the stabilization reservoir the quality of water improves.
- Storage of water during the rainy season gives this technology the additional advantage of resource optimization, as it is stored when not needed in the rainy season and used as necessary during the dry months. This allows irrigation of a greater area of land than conventional treatment technologies that do not store water during the rainy season but rather discharge it into a receiving water body.
- The wastewater stabilization reservoir is a proven technology, as it has been used in some countries since the 1970s, and its advantages have been demonstrated. In Israel it is applied throughout the country. In Latin America a few wastewater stabilization reservoirs are in the process of being implemented. Examples are Colombia, where a wastewater stabilization reservoir has been designed at engineering detail level in the town of Maicao, in the state of Guajira; Chile, where two wastewater stabilization reservoirs were projected for Santiago de Poniente, but never went into operation because the treatment plant was overloaded; and Bolivia, where prefeasibility studies are under way in Viacha and Achacachi.
- However, adoption of the technology alone is not sufficient to ensure successful use. It is necessary that the design be drafted by experts on the subject who understand the conditions prevailing at a particular site and that implementation is accompanied by policies that ensure institutional, financial, technical, and social sustainability.

Source: Author.

Wastewater stabilization reservoir technology began to be used in Israel in the 1970s, and has become widespread around the country, given its adequate control of risk to public health and occupational safety. The use of the technology is not yet very common around the world, although in some parts of Latin America its implementation is being proposed.

**Box 3.2 Methodology for assessing technological feasibility and design of wastewater stabilization reservoirs**

The feasibility assessment and design of a wastewater stabilization reservoir needs to include the following general steps:

- The volume and quality of the domestic wastewater flow available (treated or untreated) is determined based on the population, wastewater management facilities, and their design period.
- Irrigation requirements for crops in the area and the net hydric balance necessary to satisfy demand need to be calculated, taking into account such factors as the amount of water needed for the crops growing in a particular area, natural water losses, type of soil, type of harvest, height above sea level, proximity to population centers, and climatic conditions, including maximum and minimum air and water temperatures, solar radiation and cloud cover, potential evaporation and transpiration, and monthly rainfall.
- If no wastewater pretreatment plant exists, one must be designed. If there already is one in place, it is necessary to calculate the quantity and quality of treated domestic wastewater to be stored in the stabilization reservoir.
- Net demand for irrigation must be established for each month of the year, based on what can be grown during different times of the year.
- The size of the stabilization reservoir is determined by the supply of existing treated wastewater and the net monthly demand for irrigation on a month-by-month basis.
- The area to be irrigated and cropped is calculated based on the amount of water available (domestic wastewater minus losses due to evaporation and precipitation in the vicinity of the stabilization reservoir).
- The stabilization reservoir is designed based on the topography, geology, and possible gradients for the slope, and a soil study should be carried out and data gathered on permeability at the proposed reservoir site in order to estimate infiltration.
- The quality of the discharge must be calculated.
- A social assessment of the acceptability of the technology by the local population, and a well-designed communication campaign, is essential for putting in place a wastewater reuse scheme.

Source: Author.

## 3.3 Case Study 1: Evaluation of the Stabilization Reservoir in Cochabamba as a Recommended Solution for Wastewater Reuse

### *3.3.1 Current Situation in the Wastewater Treatment Plant Area*

A wastewater treatment plant was built at Alba Rancho, Cochabamba, in 1986. It consists of simple preliminary treatment (thick grating, pumping, thin grating, and flow measurement), and four modules, each placed parallel to two primary facultative ponds, also parallel to each other, and a secondary facultative pond after these. The way in which the plant currently operates shows that the ponds are overloaded practically all year round, the efficiency level of removing BOD is on average 76 percent, and the removal of coliforms is insignificant.

The area of influence of the Alba Rancho wastewater treatment plant is used primarily for milk production and the growing of crops and grasses related to cattle-raising, such as alfalfa, corn, maize feed, fodder oats, and ryegrass. The effluent is used for irrigation by cattle-ranchers and farmers alike, although the quality is not good enough to be recommendable for the aforementioned animal feed species, given that they show evidence of high levels of different types of pollution, with a consequent risk to the health of farmers and society at large. High levels of fecal coliforms, such as those found in the effluent, may cause disease among cows, and thus infections can be transmitted through the milk, leading to gastrointestinal problems (Orozco 2011). The high levels of chemical oxygen demand (COD) indicates a possible loss of nitrogen along the way, thus lowering the amounts of nutrients in the water that finally reaches the parcels of land on which crops are grown. The quality of the effluent used does not meet minimum requirements for irrigation by Bolivian standards, nor those recommended by WHO.

The water available for irrigating the zone is less than that required by farmers. In the last few years, the Cochabamba valley has faced frequent drought, thus further aggravating the situation regarding availability of water. The deficit occurs despite the fact that there are other sources for additional irrigation besides the wastewater treatment plant, such as (a) untreated wastewater taken by farmers from holes they make in the pipelines conducting wastewater to the wastewater treatment plant; (b) the Rocha River, which takes in water discharged by upstream industries and communities; (c) wells; and (d) the dam at La Angostura. It is estimated that the supply of wastewater for irrigation is 7.4 cubic meters per second, while demand is higher at 9 cubic meters per second. The Association of Irrigation Users has organized the delivery of water according to the available supply.

### *3.3.2 Recommended Solution*

The solution proposed in this study consists of building a stabilization reservoir able to store and improve the quality of water emerging from the Alba Rancho wastewater treatment plant. This would provide the quality necessary for unrestricted irrigation, while conserving the nutrients found in wastewater and ensuring the needed amount of water required all year long, not only to irrigate the area currently under crops in the zone, but also to expand the irrigable area.

The study proposes the construction of a stabilization reservoir at the current site of the Quenamari lagoon, which is strategically located near and downstream from the Alba Rancho plant. The proposed solution would make it possible to collect all of the water produced at Alba Rancho, with additional treatment being provided at the stabilization reservoir in order to obtain the quality of water needed for unrestricted irrigation of crops resistant to a salinity of 1,000 milligrams per liter of dissolved solids. In addition, the water from the effluent would have a greater amount of nutrients than currently available, thus improving crop productivity and saving money on fertilizers. It is important to highlight that implementation of the proposed project would require solving existing property conflicts over the land in the Quenamari area.

Two alternatives were drawn up and studied for the design of the stabilization reservoir: the first considers using the current wastewater available at Alba Rancho, and the second considers the projected domestic wastewater to be obtained by 2020, based on population increase estimates. For a standard hectare combining different proportions of crops typically grown in the area, such as alfalfa, corn, maize feed, fodder oats, and ryegrass, it was calculated that with the first option it would be possible to irrigate approximately 2,131 hectares, and with the second option 4,478 hectares. A field visit undertaken by the consultants conducting this study found that the latter figure was far higher than the area actually fit for farming in the treatment plant area of influence; therefore, the first alternative was selected.

The first alternative, which would allow the irrigation of 2,131 hectares, would bring important benefits to the area: (a) it would improve the quality and the supply of water in the area currently irrigated in the zone (about 1,382 hectares); (b) it would provide water of sufficient quality and quantity to irrigate 449 hectares that are currently being used for annual crops and that depend entirely on rainwater; and (c) it would enable expansion of the irrigable area to an additional 300 potential hectares that are currently not being used for any purpose.

### 3.3.3 Cost of Adopting the Proposed Solution

The investment requirement for the recommended solution consists of the stabilization reservoir, a pumping station, and a drainage system for the Quenamari lagoon. The total cost is estimated at $6.68 million. The projected lifetime of each of the components varies, ranging from 10 years for the pumping station and drainage system to 50 years for the stabilization reservoir. A rough estimate of the annual costs of operation and maintenance is $200,000, of which half is accounted for by the consumption of electricity.

In a 20-year period the present value of total costs (investment and operation) is about $7.8 million.[15]

### 3.3.4 Economic Evaluation

The benefits generated by the project consist of incremental benefits obtained in the agricultural sector, plus indirect benefits generated in the overall economy. Net benefits of the project are estimated as the difference between incremental benefits and incremental costs. The incremental situation resulted from the difference between two scenarios: with and without the recommended project.

[15] The investment cost of the stabilization reservoir is $6 million, which is equal to an annual cost of $722,000, when using a lifetime of 50 years and a 12 percent discount rate. Investment cost of the drainage system and pumping equipment is $680,000 for a 10-year lifetime, which equals $121,000 per year, This brings the investment cost up to $843,000 per year. When operation and maintenance cost of $200,000 per year is added, the resulting total cost is about $1 million per year. Over 20 years this value is $7.8 million.

The benefits to be obtained in the agricultural sector were calculated for three different categories of beneficiaries: (a) farmers that currently cultivate the land that is being irrigated (1,382 hectares), who would see benefits reflected in higher productivity as more and better quality of water will be provided; (b) farmers that currently cultivate seasonal crops on rain-fed land (449 hectares), with benefits reflected in higher crop yields; and (c) farmers who have land that is not being used for any purpose yet has high potential for agricultural use, who would obtain benefits according to the productivity achieved when the land is cultivated.

Additional benefits for the economy were estimated as the multiplier impact of the increase in agricultural production on the economy at large. This impact was weighed using input-output matrices and the associated technical coefficients prepared by the National Statistics Institute. With regard to cost allocation, three scenarios were taken into account: (a) the State pays the investment as well as operation and maintenance costs, and farmers do not participate in financing the project; (b) the State pays the investment and farmers cover operation and maintenance costs by means of a fee; and (c) the State provides no subsidy and farmers pay for investment and operation and maintenance costs, again through fees.

### 3.3.5 *Impact on the Agricultural Sector*

The economic evaluation of the impact that the proposed solution would have on the agricultural sector was calculated for three "standard hectares," which combine in varying proportions the five crops typically grown in the area (alfalfa, corn, maize feed, fodder oats, and ryegrass) (table 3.1). For each of these crops the costs and revenues are calculated for two scenarios: *without* and *with* the recommended project. The *without* project scenario is based on current production and costs. The *with* project scenario includes the gains in productivity, and the corresponding costs increase.

**Table 3.1 Crop combinations studied**

| | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|
| Alfalfa | 20% | 40% | 50% |
| Corn | 20% | 10% | 5% |
| Maize feed | 20% | 40% | 40% |
| Fodder oats | 20% | 0% | 0% |
| Ryegrass | 20% | 10% | 5% |

Source: Author.

The incremental benefit is calculated over a 20-year period for each of these combinations of crops. The results are as follows:

For farmers currently cultivating irrigated land, the benefits include the higher productivity obtained as a consequence of increased water supply, improvement of water quality, and a higher content of nutrients. The current irrigated area of 1,382 hectares would experience an increase in production depending on the crop, varying from 25 percent for fodder oats up to 100 percent for alfalfa after the second year. Production would increase for two reasons. First, each hectare would receive the full amount of water it needs to produce at optimal level. It is estimated that currently farmers are getting only about 50 percent of the water they need. With the stabilization reservoir they would have enough water. Second, the nutrients that come with the effluent pumped from the reservoir would amount to 85 percent of what is required by maize feed and 50 percent of that needed by alfalfa. The difference would have to be covered by application of fertilizer or urea. Those benefits would be partially offset, as production costs would also go up, in percentages that vary from 16 percent to 44 percent, depending on the crop.[16] The increase in cost is due to the higher requirement for inputs that come along with the production increase (for example labor and seeds), which is partially compensated by a drop in the fertilizer needed. Present value of net benefits over a 20-year period for the entire area varies from $4 million to $7 million depending on the combination of crops.

For farmers currently cultivating rain-fed or unirrigated land, the benefits would be reflected in higher productivity from irrigation. In this scenario, 449 hectares would pass from annual corn, fodder oats, and ryegrass production to yearly crops, including alfalfa. Present value of net benefits over a 20-year period for the entire area varies from $2.7 million to $4 million, depending on the combination of crops.

For farmers that will cultivate area currently idle, the transformation of currently unused land into farmland would provide another $2.3 million to $3.0 million.

Total net benefit to be obtained by these three categories of farmers would be between about $9 million and $14 million, depending on the combination of crops decided upon (table 3.2).

**Table 3.2 Net benefits for categories of farmers, by combination of crops**

| | Present value, incremental benefit (20 years) US$ million | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| 1. Farmland currently under irrigation | 4.187 | 6.357 | 7.021 |
| 2. Rain-fed (unirrigated) farmland | 2.755 | 3.840 | 4.099 |
| 3. Land currently not farmed | 2.302 | 2.976 | 3.045 |
| Total | 9.243 | 13.173 | 14.165 |

*Note:* Figures apply to the total area receiving benefit from the proposed project.

Source: Author.

### 3.3.6 *Additional Benefits for the Economy*

In order to measure the impact that the increase in agricultural production would have on other economic sectors, an input-output matrix and technical coefficients prepared by the National Statistics Institute were used.[17] The input-output matrix is a simple way of showing the transactions that take place in the economy, indicating the production structure and use made of the supply of goods and services over a selected time period. The matrix characterizes the demand placed on and the supply

[16] The amount of nutrients per hectare to be obtained from the stabilization reservoir effluent is estimated at 34 kilograms of nitrogen and 32 kilograms of potassium. The requirement for these nutrients is 40 kilograms per hectare for corn and maize feed and 60 kilograms of potassium for alfalfa. With the water available from the pond, 85 percent of nutrients required by corn and maize feed will be obtained, as well as 50 percent of fodder oats.

[17] National Statistics Bureau, Bolivia, Input-Output Matrix, 2006. Matrix of Baseline Technical Coefficients, 1990.

offered by each productive sector in relation to the other sectors. In addition to describing transactions between different sectors in the real economy, it allows analysis of the effects that the variation in the final demand for any sector has upon the other sectors.

Table 3.3 shows a summary of technical coefficients in Bolivia for two economic groups: the nonindustrial agricultural sector and the remaining sectors. This information indicates that if all sectors of an economy grow by a particular monetary unit, the agricultural sector would grow an additional 0.12 and the remaining sectors an additional 0.77, for a total additional effect of 0.89 ("forward effect"). On the other hand, if the agricultural sector increases by a particular monetary unit, it would need from itself an additional 0.12, and from the other economic sectors 0.06, for an additional total of 0.18 ("backward effect").

Given that the aim here is to measure the effect that the agricultural sector will generate on the whole economy, calculations are carried out using the coefficients, which measure the "backward effect."

**Table 3.3 Direct and indirect requirement matrix**

| | Nonindustrial agricultural products | Other sectors | Total forward effect |
|---|---|---|---|
| Nonindustrial agricultural products | 0.12 | 0.77 | 0.89 |
| Other sectors | 0.06 | | |
| Total backward effect | 0.18 | | |

Source: Author.

The results show additional benefits close to $12 million for alternative 1 and close to $4 million for alternatives 2 and 3 (table 3.4).

**Table 3.4 Multiplier benefit in the economy**

| | Present value of multiplier benefit to the economy (20 years) US$ million | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Generated by increase in production of all hectares | 2.659 | 3.841 | 4.198 |

Source: Author.

The net benefit to be obtained with the recommended project would correspond to 1 percent of total annual production of the nonindustrial agricultural sector in the department of Cochabamba.

### 3.3.7 *Results of the Economic Evaluation*

The results of the economic evaluation show total net benefits between $4.0 million and $10.5 million, depending on the combination of crops. The internal rate of return is at least 129 percent and may be as high as 216 percent (table 3.5).

**Table 3.5 Total benefits to be obtained with the proposed budget**

| | Net present value 20 years | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Agricultural sector | | | |
| *Farmer profits* | | | |
| Net present value 20 years (US$ million) | 9.243 | 13.173 | 14.165 |
| Internal rate of return | 372% | 384% | 354% |
| *State* | | | |
| Cost of investment / operation & maintenance (stabilization pond) | (7.811) | (7.811) | (7.811) |
| *Other benefits to society* | | | |
| Impact of increase in agricultural production on the economy | 2.659 | 3.841 | 4.198 |
| *Total benefits* | | | |
| Net present value 20 years (US$ million) | 4.092 | 9.203 | 10.553 |
| Internal rate of return | 129% | 216% | 214% |

Source: Author.

The results are expressed in constant 2011 prices and therefore the rate of return is shown in real terms and does not account for inflation, making it even more attractive.

### 3.3.8 *Distributive Analysis*

The project would have differing impacts on stakeholders, including the government, the Association of Irrigation Users, the entity in charge of operating the stabilization reservoir, the farmers, and other sectors of the economy. For some of these stakeholders the impact would be positive, while for others it would not. This section identifies some of the "winners" and "losers," and the magnitude of the gains and losses. The analysis is made using as reference the crop combination defined in alternative 2.

**Government.** The government would benefit from higher tax revenue on added value tax (13 percent) associated with construction-related activities and the operation of the stabilization reservoir. Yet, this benefit may be entirely or partially erased by the subsidies it may end up paying in order to finance the investment and costs of operation. The difference between tax revenue and subsidies would be the fiscal impact. The magnitude of the subsidy would depend on the policy decision on the irrigation fees to be charged to farmers. The results of the distributive analysis show the following, according to irrigation charges: (a) if government pays the entire cost of building and operating the stabilization reservoir, the losses would be $6.9 million; (b) if government pays for investment costs, but farmers pay for operation and maintenance costs through an irrigation fee, the net loss for the government would be $5.4 million; and (c) if farmers pay for the whole cost, namely investment and operating costs, the government would have a net profit of $0.9 million. The subsidy granted by the government would be transferred to the entity in charge of operating the Alba Rancho wastewater treatment and stabilization reservoir, which probably would be the Cochabamba Municipal Drinking Water Service.

**Farmers.** The analysis is carried out for four groups, as follows: (a) farmers who currently irrigate their land with insufficient, low-quality water, who would benefit from productivity increases; (b) farmers who currently depend on rainfall for their crops and would benefit from an increase in crop production; (c) farmers who will transform idle land into cultivated land; and (d) the remaining farmers, whose production would increase due to the indirect impact generated by the incremental demand on the benefiting land. For the distributive analysis it is assumed that the first two groups of farmers would directly benefit from increased production made possible by more and better water for irrigation. The new farmers in the third group are not competitors of existing farmers, but rather would complement production and help satisfy the demand for dairy cattle and the associated crops they consume. The impacts are estimated with and without subsidy for the irrigation fees, with the following results: (a) with a full subsidy of investment costs and operation and maintenance, their profits would be $13 million; (b) when fees are charged for operation and maintenance, profits would be $11 million; and (c) if fees were used to cover all expenses, profits would drop to $5 million. The fourth group of farmers would see their production increase due to the indirect effect generated by higher demand from the first group. Their profits would be $2.5 million.

**Association of Irrigation Users** (or entity charged with operating the reservoir). The assumption is that the net impact for the entity in charge will be zero, as it will receive either from the government or from the users the revenues necessary to cover costs. However, if this is not the case, and the irrigation fees are higher than the costs, it would obtain a profit; or if fees were lower and not compensated with transfer from the government, it would have a net loss.

**Suppliers.** Other sectors would increase production due to the indirect effect generated by growth in the agricultural sector. Profits would be $1.3 million.

**Total benefits.** The total benefits to be obtained by society are estimated at $10 million (see annex C).

### *3.3.9 Sensitivity and Risk Analysis*

Sensitivity and risk analyses allow measuring the impact on the results when there are changes in the assumption of selected variables. The sensitivity analysis measures the impact when a variable changes, while all others remain constant. For its part, the risk analysis estimates the expected profit when variables change simultaneously. In this analysis the impact was measured for changes in the following variables: (a) crop productivity or changes in the price of agricultural products; (b) changes in costs of agricultural inputs; and (c) changes of investment and operating costs of the recommended project.

The results of the sensitivity and risk analyses confirm the robustness of the proposed project, as the probability of having positive returns is close to 100 percent.

## 3.4 Case Study 2: Evaluation of the Recommended Solution for Reuse of Effluents in Tarija

### 3.4.1 Current Situation in the Wastewater Treatment Plant Area

Agriculture is the driving economic force in the Tarija Central Valley, especially the production of grapes, which is used for direct consumption or as an input for both wine and singani industries (RIMISP 2012). In the last five years, tourism has become important for the economy as well. In addition to grapevines, traditional products such as maize, potatoes, and fruit are grown, alongside some nontraditional crops such as vegetables, berries, and flowers for both the domestic and international markets. The area also has a dairy industry based on Holstein cattle, and milk products are manufactured at several plants. Finally, there are chicken farms with significant production capacity. Existing agriculture has been favored by the construction of the San Jacinto dam, which provides water for irrigation. However, this source is not sufficient to cover the existing and potential demand, and currently there are many hectares of land that cannot be used due to lack of water.

Grape production has increased in importance in the Tarija Central Valley due to its favorable climate and altitude conditions. The vineyards are located at an altitude of 1,500 to 2,000 meters above sea level, and are among the highest in the world.

The vineyard register prepared by FAUTAPO (2010)[18] estimates that 2,115 hectares in Bolivia are dedicated to grape production, of which most are in the southern valleys. Tarija alone has 1,756 hectares or 83 percent of the total, and it is estimated it contributes 93 percent to the country's total grape production. The difference in productivity between the provinces is due in part to climatic conditions and in part to how the crop is handled. In recent years improvements have been made to grape varieties in Tarija, vine conduction systems, pruning methods, and pest and disease control.

Further, FAUTAPO estimates that 57 percent of grape production is sent to wineries, 17 percent is transported to the cities for consumption as fresh fruit, 12 percent is sold to retailers, and 14 percent is unaccounted for. FAUTAPO estimates that viticulture represents 1.6 percent of the province's GDP. In the Tarija Central Valley it is the most important crop. There is a substantial demand for grapes that cannot be met, in part because there are large tracts of land that go unused for lack of water.

In its search for a solution to the problem posed by insufficient water for irrigation, the province's Secretariat of the Environment has been working on the design and construction of a wastewater treatment plant at Santa Ana. In addition to reducing pollution, this would allow for unrestricted irrigation of crops on nearby land. The plant is currently undergoing a bidding process. Construction of the wastewater treatment plant is *not* conditional upon adoption of the complementary solution regarding stabilization reservoirs being described in this document.

As currently conceived, the Santa Ana wastewater treatment plant consists of three modules, each capable of processing 200 liters per second, for a total capacity of 600 liters per second. Each module consists of a desander, an upflow anaerobic sludge blanket digester, a biofilter, and a clarifier, installed in series, as well as a sludge drying bed. The three modules are to be built gradually, and it is expected the

[18] FAUTAPO is a foundation supporting education for development in Bolivia.

entire system will be in full operation by the year 2030. The reason for this gradual approach is related to the population receiving the service and the volume of wastewater to be collected. With the current design it is expected that when the three modules are in operation and the volume reaches the plant's maximum capacity, there will be sufficient treated domestic wastewater in terms of both quantity and quality for unrestricted irrigation of 1,130 hectares. Each module built will produce enough treated wastewater to irrigate 377 hectares.

Given that the construction of the Santa Ana plant as described in the foregoing is an ongoing process, for the purpose of evaluating the incremental benefits associated with the construction of a stabilization reservoir, the future situation with the Santa Ana treatment plant, built and operating according to the current design, is considered to be a "situation *without* the project."

### *3.4.2 Recommended Solution*

The solution proposed for Tarija in the current study consists of the construction of a stabilization reservoir downstream from each of the three modules in the Santa Ana wastewater treatment plant. The reservoir will allow for storing the water treated in the plant during the rainy season, and will therefore increase the area to be irrigated. In addition, the recommended solution would simplify the line of treatment, as it would allow the elimination of biofilters in each module (Orozco 2012).

The stabilization reservoir would allow irrigating 1,200 hectares using the effluent from a single module of 200 liters per second at the Santa Ana wastewater treatment plant. Without the stabilization reservoir, that same module would only produce enough water to irrigate 377 hectares. Therefore, the stabilization reservoir increases the irrigable area by 823 hectares per module, for a total increase of 2,470 hectares for the entire plant (table 3.6).

**Table 3.6 Irrigable hectares, with and without the project**

| | Irrigable hectares | | |
|---|---|---|---|
| | Without wastewater stabilization reservoir | With wastewater stabilization reservoir | Increase |
| Hectares that can be irrigated with wastewater treatment plant at Santa Ana | | | |
| For each 200 liters per second module | 377 | 1.200 | 823 |
| For the three modules (600 liters per second) | 1,140 | 3,600 | 2,470 |

Source: Author.

The stabilization reservoir calculated for in this study is adequate to optimize the functioning and area under irrigation associated with a single 200 liters per second module. Therefore, the estimated incremental economic benefit includes an 823-hectare increase in the amount of land to come under irrigation. In either situation ("with project" or "without project"), the quality of the effluent would allow for unrestricted irrigation of the crops grown in the valley.

### *3.4.3 Stabilization Reservoir Costs*

The incremental investment cost associated with the adoption of the solution proposed herein is determined by the cost of building the stabilization reservoir and the savings associated with the elimination of the biofilter; both costs total $3.85 million. The increase in annual operation and maintenance costs derived from building the stabilization reservoir is calculated at $118,500. The present value of investment and operating cost in a 20-year period is $3.8 million.[19]

Given that the useful life of the different components that make up the investment vary, the costs of each is annualized and the operation and maintenance expenses are then added in order to get a figure for the total annual cost. Thereupon this annual cost is calculated in terms of present value for a 20-year period. The resulting cost, as mentioned, is $3.8 million.

### *3.4.4 Economic Evaluation*

The economic impact is measured as the net benefit to be obtained with the additional 823 hectares to be used for agricultural purposes. The evaluation uses three types of "standard hectares," which combine three different crops typically grown in the area ( grapes, alfalfa, and maize) (table 3.7). For these three alternatives, land preparation costs were included.

**Table 3.7 Standard hectares with different proportions of three typical crops**

| | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|
| Grapes | 60% | 70% | 80% |
| Grain maize | 20% | 10% | 10% |
| Alfalfa | 20% | 20% | 10% |
| Total | 100% | 100% | 100% |

Source: Author.

### *3.4.5 Benefits to Farmers*

The costs and benefits to farmers are projected for each of these alternatives over a 20-year period. The benefits are estimated based on the productivity of each crop, according to characteristics in the zone and associated costs. The net present value of the benefits shows profits of approximately $9 million for the whole area of 823 hectares (table 3.8). The internal rate of return is close to 25 percent for all three alternatives.

**Table 3.8 Net present value of benefits for cropping alternatives**

| | Net present value, incremental benefit (20 years) | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Net present value (US$ million) | 8.251 | 9.078 | 9.066 |
| Internal rate of return | 28% | 27% | 25% |

*Note:* Figures apply to total number of hectares under cultivation.

Source: Author.

[19] The stabilization reservoir investment cost of $5 million annualized over 50 years at a discount rate of 12 percent is $602,000; the savings achieved by not having to install biofilters ($1.15 million), annualized over 10 years at the same discount rate, is $204,000. This means the total annualized investment cost is $398,000. Operation and maintenance costs are $118,000. Total annual cost is therefore estimated at $516,000. This cost annualized over 20 years represents a present value of $3.8 million.

### 3.4.6 *Additional Impact on the Economy*

Using the input-output matrix, additional benefit generated by growth in the agricultural sector is estimated with results of about $4 million (table 3.9).

**Table 3.9 Multiplier effect of the increase in agricultural production on other sectors of the economy**

| | Present value multiplication in the economy (20 years) | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Generated by increase of production on all hectares (US$ million) | 4.135 | 4.574 | 4.826 |

Source: Author.

Total net benefits correspond to about to 7 percent of the whole annual production of the nonindustrial agricultural sector in the province of Tarija.

### 3.4.7 *Economic Evaluation Results*

Total benefits to be obtained with the recommended project vary from $8 million to $10 million, depending on the combination of crops, and the internal rate of return would be between 25 percent and 28 percent (table 3.10).

**Table 3.10 Total project benefits**

| | Net present value 20 years | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Agricultural sector | | | |
| *Profits to farmers* | | | |
| Net present value 20 years (US$ million) | 8.251 | 9.078 | 9.066 |
| Internal rate of return | 28% | 27% | 25% |
| *State* | | | |
| Cost of investment / operation & maintenance (stabilization pond) | (3.862) | (3.862) | (3.862) |
| *Other benefits to society* | | | |
| Impact of increase in agricultural production on the economy | 4.135 | 4.574 | 4.826 |
| *Total benefits* | | | |
| Net present value 20 years (US$ million) | 8.524 | 9.789 | 10.030 |
| Internal rate of return | 27% | 26% | 25% |

Source: Author.

The results of the sensitivity and risk analyses confirm the robustness of the proposed project with high probabilities of having positive returns.

### *3.4.8 Distributive Analysis*

The project would have an effect on several stakeholders: the government, the Association of Irrigation Users (or entity in charge of operating the stabilization reservoir), the farmers, and other sectors of the economy. For some of these stakeholders the impact will be positive, while for others it will not. This section identifies some of the "winners" and "losers," and the magnitude of gains and losses. The analysis uses the crop combination defined in alternative 2, as the alternative with intermediate results.

**Government.** As was presented for Cochabamba, the results in Tarija show that the government would benefit from the higher tax revenue on added value taxes (13 percent) associated with construction-related activities and the operation of the stabilization reservoir. However, this benefit may be entirely or partially erased by the subsidies it may end up paying in order to finance the investment and costs of operation. The difference between tax revenue and subsidies corresponds to fiscal impact. The magnitude of the subsidy depends on the policy decision on the irrigation fees to be charged to farmers. The results of the distributive analysis are shown for three situations: (a) if government pays the entire cost of building, operating, and maintaining the stabilization reservoir, the net loss would be $3.4 million; (b) if government pays for investment costs but farmers pay operating costs through irrigation fees, the net loss would be $2.5 million; and (c) if government does not give any subsidy and farmers pay for all the costs (investment and operating costs), the government would get a profit of $444,000. In case of subsidy, the government would transfer it to the entity in charge of operating the Santa Ana wastewater treatment and stabilization reservoir, which could be the executive unit of the Tarija water treatment plant or the Tarija Drinking Water and Sewerage System Cooperative.

**Farmers.** The analysis is carried out for two groups: (a) farmers whose land would be irrigated; and (b) the remaining farmers, whose farms will increase production as a result of the indirect impact generated by the incremental demand on the irrigated land. For the first groups it is assumed that the new farmers are not competitors of existing ones, but rather will complement production and help satisfy the demand for grapes and wine. The analysis for this first group was made with and without a subsidy for the irrigation fees, and the results show that (a) with a total subsidy of investment costs and operation and maintenance, their profits would be $9 million; (b) when fees are charged for operation and maintenance, profits would be $8 million; and (c) if fees were used to cover all expenses, profits would still be attractive at $5 million. The second group of farmers would see their production increase due to the indirect effect generated by higher demand from the first group, with profits in the order of $3 million.

**Suppliers.** Other sectors benefiting from growth in agriculture in the area would have profits of $1.5 million, due to higher demand by farmers.

**Total benefit to the economy.** The total benefits to be generated for society would be approximately $10 million (Annex C).

### *3.4.9 Fees Required to Cover the Cost of Building the Stabilization Reservoir*

If the government decides to recover the cost of running the stabilization reservoir by charging farmers a fee for every cubic meter of wastewater treated, the amount charged would be approximately $0.015 (1.5 cents) to cover the cost of operation and maintenance. If the government decides that in addition it wishes to recover the cost of building the reservoir, it would raise the fee to 6 cents in the case of Cochabamba and 9 cents in the case of Tarija (table 3.11).

**Table 3.11 Fee to be charged to cover costs of stabilization pond**

| | Fee per cubic meter of stabilization pond effluent (US$) | |
|---|---|---|
| | Covers operation & maintenance only | Covers operation & maintenance and investment |
| Cochabamba | 0.015 | 0.06 |
| Tarija | 0.016 | 0.09 |

Source: Author.

It is important to point out that this fee reflects only the cost of the stabilization reservoir studied in this report. Previous water treatment costs required for the reservoir do not form part of this evaluation.

## 3.5 Conclusions and Recommendations

The results of the two case studies undertaken regarding the technical and economic viability of installing the wastewater reuse systems planned for the cities of Cochabamba and Tarija by using stabilization reservoir technology illustrate the significant potential for safe reuse of treated wastewater in Bolivia as a solution to the problems caused by water scarcity in parts of the country, and show how it can be driving force behind their economic development.

The case studies also demonstrate how through the use of appropriate technology, such as stabilization reservoirs, it is possible to achieve the quality necessary for safe and unlimited irrigation, to optimize the use of water by maximizing the arable land surface under irrigation (on occasion even tripling the number of hectares irrigated with the use of other technologies), and to simultaneously simplify the operation and maintenance work needed to ensure the long-term sustainability of the irrigation service. It is revealing that according to the data found in a recent GIZ-sponsored study carried out by the Ministry of Environment and Water, with the solutions proposed herein for Cochabamba and Tarija, irrigation using good-quality water can be ensured for a surface equivalent to 67 percent of the total number of hectares currently under irrigation in the country and that use wastewater on an irregular basis.

The foregoing notwithstanding, in order to ensure the viability of the planned treated wastewater reuse scheme, it is necessary to overcome certain barriers that put its long-term sustainability at risk. Among these is the widespread discontent of the population living in the vicinity of the country's wastewater treatment plants, due to the foul smells that emanate as a result of inappropriate treatment technologies, inadequate maintenance and operation of the facilities, and poor urban planning. In the case of Tarija, this discontent translates into open opposition by broad-based sectors of the population to any type of initiative related to wastewater management.

# Chapter 4. Cooperative Gold Mining: Dynamics and Challenges in a Rapidly Growing Sector

## 4.1 Introduction

The main objective of this chapter is to investigate new trends in reducing environmental impacts in the artisanal, small-scale, and medium-scale (ASM)[20] gold mining sector in Bolivia and South America and how these experiences could lend themselves to the scale-up of programs to reduce contamination while increasing the productivity of the cooperative gold mining sector in Bolivia. This will be done by (a) analyzing the gold mining cooperative sector, its environmental impacts, and the legal framework under which it operates; (b) exploring international and national experience of introducing cleaner technology to ASM miners, particularly in the Andes; (c) analyzing the possibility of watershed management as a potential approach to work across sectors and engage multiple stakeholders; and (d) providing conclusions and recommendations.

This chapter's findings are based on a literature review and the results of two field visits carried out as part of this study: the first to some of the most important gold mining regions in the highlands of La Paz (Suches, Apolobamba, and Cotapata), and the second to the southern part of Potosí to visit traditional cooperative mining. The fieldwork included visits to different types of mines, field observations, interviews, and an open dialogue with the different mining cooperatives. The study is also based on a thorough review of alluvial gold mining experiences in the Andean region and an analysis of existing legislation and literature from Bolivia on cooperative mining. Finally, the study emphasized the collection of quantitative data on cooperative mining in Bolivia, as a comprehensive database does not exist (see annex D2 for further details on the methodology).

ASM gold mining is expanding rapidly in Bolivia (figure 4.1). From 2006 to 2011, 259 new gold mining cooperatives were registered by the Ministry of Mining and Metallurgy. This has almost doubled the number of gold mining cooperatives, and it is a tendency that seems likely to continue as long as gold prices remain high. In total, Bolivia has 1,327 registered mining cooperatives and they are generating up to 100,000 direct jobs.[21] Consequently, the cooperative mining sector is one of the major employers in rural Bolivia, complementing traditional agricultural activities, the main sector for rural employment in Bolivia.[22] The cooperative mining sector is producing new development opportunities and raising living standards in some of the poorest and most remote parts of the country.

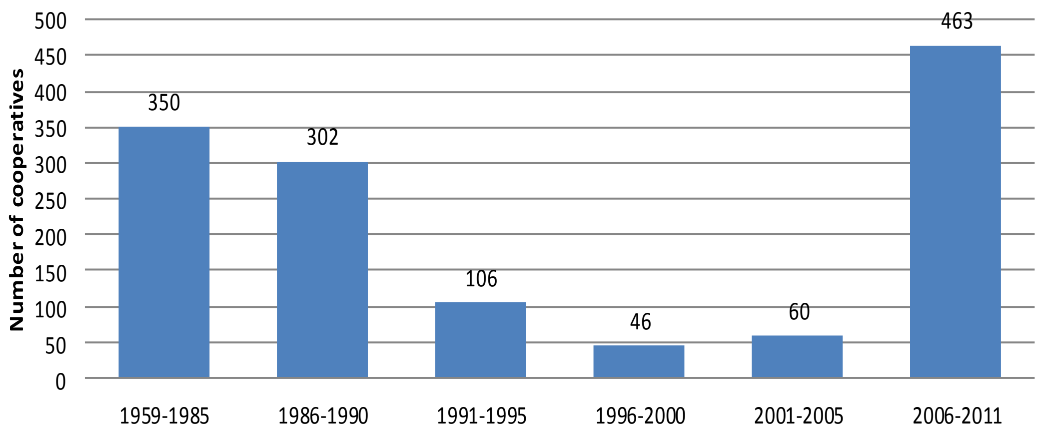
**"In total, Bolivia has 1,327 registered mining cooperatives and they are generating up to 100,000 direct jobs."**

[20] In this study artisanal mining refers to the use of rudimentary mining techniques with little or no mechanization; small-scale mining involves the use of some mechanical processes and can involve some heavy equipment; and medium-scale mining involves significant mine works and heavy equipment and involves an investment of at least $5 million (in contrast to the industry standard of not referring to any mining as medium-scale unless it involves at least $50 million of investment). The vast majority of gold mining cooperatives in Bolivia are artisanal or small-scale.

[21] Registered cooperatives by December 31, 2011. Based on information provided by the Ministry of Mining and Metallurgy and SERGEOTECMIN.

[22] The rural population makes up 35 percent of the demographic composition in Bolivia. Most rural people are dedicated to agriculture and stockbreeding with men often complementing incomes with work in other activities. The National Statistics Institute (2010) estimates that approximately 1,635,200 people are employed in rural Bolivia, which indicates that cooperative mining would employ approximately 6.1 percent of these people (full or part time). Though these are very rough calculations, as some miners migrate from the cities and many only dedicate a few months per year to mining, it demonstrates the importance of mining in many rural regions.

**Figure 4.1 Historical registration of mining cooperatives**




*Source:* Authors' elaboration based on information from SERGEOTECMIN and Ministry of Mining and Metallurgy, reported in Pinto and Terceros 2012.

Mining has always played a significant role in Bolivia's economy and continues to be a key source of income, composing 9.6 percent of GDP and 30.9 percent of total exports in 2011 (National Statistics Institute 2012; Central Bank of Bolivia 2012). This makes the mining sector the second largest source of exports in Bolivia after the hydrocarbon sector and illustrates that Bolivia continues to depend on primary commodity exports. Whereas traditional private investments in the mining sector have stagnated, government and cooperative investments have increased significantly.[23] Gold was the fourth most important mineral extracted in Bolivia in 2011. Whereas medium-scale and large-scale investments in the mining sector have stagnated in recent years, government and cooperative investments have increased significantly, as well as some smaller-scale private investments. San Cristobal, the last medium- or large-scale mine to move to exploitation, began construction in 2005. However, the number of legally registered cooperatives increased by 463 between 2006 and 2011, with a large surge in gold mining cooperatives. It is estimated that cooperatives produced approximately 70 percent of gold in 2011, up from the already substantial 40 percent in 2008. Similarly, COMIBOL, the State-owned enterprise, has reemerged as an important player and is now involved in operations at Huanuni, Corocoro, Vintno, and Colquiri, with further plans to be involved in the development of the large silver deposit at Malku Khota.

The increase in gold prices by more than 600 percent in a 10-year period has been the major trigger of the rapid growth of the gold mining cooperatives operating in processing both new and old deposits.[24] Nevertheless, according to official data from the Ministry of Mining and Metallurgy and the Central Bank of Bolivia,[25] gold extraction is today dominated by the cooperative mining sector whereas privately managed mines have reduced their productivity, which has resulted in a decline in the total extraction of gold in Bolivia since 2007. However, the official numbers are probably rough estimates, as cooperatives often do not declare actual production and much gold is traded informally with Brazil and Peru. Despite

[23] This observation is based on the increased/decreased gold production volume of cooperatives and private mining operations as well as the two government-led programs FOFIM and the Bolivian Gold Company.

[24] Gold prices have increased from $260/oz in March 2001 to $1,000/oz in September 2009 to $1,670/oz in August 2012, peaking at $1,800/oz in July 2011.

[25] Own calculations based on data from Ministry of Mining and Metallurgy 2011 and Central Bank of Bolivia.

the limited data available, it demonstrates a clear development trend toward an increased share of gold production being undertaken by the ASM cooperative sector in Bolivia.

Almost 50 percent of the gold mining cooperatives are relatively new, established within the last five to six years. This suggests that many cooperatives probably have limited technical, organizational, and financial resources. It is a situation that requires immediate attention in order to introduce more adequate processing techniques and to reduce adverse environmental impacts.

Broader use of cleaner technological processes by ASM miners depends largely on five conditions:

- Adequacy of the legal framework, including mining sector regulations;
- Adequate enforcement of the laws and regulations;
- Knowledge of alternative production methods and their implementation, including access to inputs, by cooperatives;
- Positive or at least not significantly negative cost-benefit of utilizing clean production technologies as perceived by the miners;
- Pressure by stakeholders, and legal ways of manifesting this pressure, including by local communities negatively impacted by environmental and social externalities of mining production.

Although the legal framework for managing environmental impacts in the mining sector is in place and there seems to be a willingness within many mining cooperatives to introduce cleaner technologies, several barriers persist that prevent feasible support, such as the high levels of informality of the sector, contradictory interests between different stakeholders, and the heterogeneous character and widespread dispersion of the cooperatives.[26] Moreover, cooperative gold mining is often characterized by a boom and bust cycle where profitability heavily depends on global gold prices. As a result, ASM operators are driven by the goal of maximum profit with minimum investment within a short timeframe.

In addition, there are weak incentives to meet legal obligations due to limited monitoring and enforcement of regulations, partly due to the large and growing number and dispersed nature of the cooperatives, which means that there is an implicit heavy reliance on voluntary self-monitoring. Moreover, there does not appear to be an adequate institutional mechanism for communities, cooperatives, and other stakeholders to respond to competing and conflictive interests in a specific area. As proposed in this chapter, the design and implementation of the National Watershed Plan could fill this institutional void by providing a multisectoral spatial framework for addressing competing interests at the watershed level.

During the last two decades several projects in South America have introduced cleaner technologies for artisanal and small-scale miners, with well-documented results. These experiences open the possibility of moving more quickly toward a more far-reaching platform of support for the extensive number of gold mining cooperatives in Bolivia.

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[26] The cooperatives' openness to improve their management and processing techniques is based on field visits and meetings with FENCOMIN. The fact that 89 percent of the environmental licenses have been issued between 2007 and 2011 also supports this conclusion, although without further research it cannot be ruled out that stronger monitoring and enforcement may have also been important in motivating cooperatives to get their licenses.

## 4.2 Dynamics of the Cooperative Sector Mining Operations

The Bolivian cooperative mining sector is very diverse, covering artisanal, small-scale, and medium-scale mining operations with investments by individual cooperatives ranging from less than $1,000 to over $5 million.[27] Its unique strength, in comparison to most other mining countries, is that most cooperative ASM mining activities are registered and recognized by the government, but the sector is also a heterogeneous group made up of wide variety of cooperatives not easy to target in a single program.[28] Even within gold mining, the multifaceted character is evident in the differences in size and productivity, culture and antiquity, and geographic region, and whether the operations are alluvial or hard rock mining. In general, the gold mining cooperatives are smaller in size than the traditional mining cooperatives[29] but vary from artisanal family-based operations to medium-scale operations with heavy equipment and up to 500 cooperative members and workers.

By the end of 2011, 1,327 mining cooperatives were registered in Bolivia. It is estimated that more than 75 percent are gold mining cooperatives, though one third had not reported what minerals they exploited (see figure D1.3 in annex D). According to Cuellar (2010), cooperative mining composes 83 percent of all employment in the mining sector. Direct employment estimates in the cooperative mining sector range from 66,000 to more than 100,000 jobs, which represent 5 to 6 percent of rural jobs.[30] Michard (2008) estimates that this number could be tripled by including indirect employment such as informal vendors, cooking services, teachers, and agricultural services. This makes the cooperative mining sector one of the most important employers in rural Bolivia, where 35 percent of the total population lives. Consequently the cooperative mining sector is a politically powerful actor that often has competing and conflicting interests with other stakeholders in the mining sector in general and in the specific locations where mining takes place.

All mining cooperatives tend to have a hierarchical structure and the concept of cooperatives should not be interpreted as egalitarian. The internal divisions within the cooperative can be divided between the direct members ("socios"), more permanent workers known as "voluntarios" (medium- and long-term workers), and day laborers (table 4.1). The specific arrangement differs from cooperative to cooperative but it is mainly the larger operations that have resources to contract workers and day laborers. The promotion of new technology should consider these differentiated roles and also take into consideration that the technology could improve the lives of some of the workers and day laborers, who are often working under very hazardous conditions.

Women's and men's differentiated roles and indirect impacts from mining are also important to consider in the cooperative structure. Women compose 6 percent of the direct employment in the Bolivian

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[27] The term "cooperative mining" will be used in this paper to cover artisanal, small-scale, and medium-scale mining operations but excludes private companies within this scale of mining.

[28] However, there are conflicts about mining boundaries and in some cases, such as the Cerro San Simón, legal user conflicts exist.

[29] Traditional mining cooperatives exploit the "traditional" minerals of Bolivia, particularly tin, silver, wolfram, copper, and zinc, often working in abandoned COMIBOL mining concessions or the tailings of other old (usually closed) mines. Most are located in the departments of Oruro, Potosí, and La Paz.

[30] No exact numbers exist but Cuellar (2010) estimates that 66,000 are directly employed in all cooperative mining, whereas the national cooperative mining association FENCOMIN estimates that more than 100,000 are directly employed by the mining cooperatives. Given the large increase in cooperatives since the Cuellar (2010) study, the FENCOMIN estimate is likely to be more accurate but might cover people working in the sector part time or seasonally.

mining sector (National Statistics Institute 2009) but do not have equal opportunities and face many indirect negative impacts. In cooperative gold mining, women tend to receive lower salaries, face discrimination, and fulfill more artisanal functions, such as simple alluvial panning (also known as *barranquilla* in Bolivia). In practice, women face tremendous difficulties in becoming official associates of cooperatives and they mainly achieve this through inheritance when widowed (Aranibar and Bernal 2005; Bocangel 2001). Therefore, programs for cleaner technology should also be targeted to reach women living in mining communities, or directly employed in the mining sector, by using a gender-sensitive approach, as has been done in Papua New Guinea (box 4.1).

**Table 4.1 Overview of cooperative organizational structure**

| Type of cooperative member or worker | Description of members' or workers' rights and responsibilities |
|---|---|
| Members (socios) | Legal partner of the cooperative and support with investments<br>Often different levels of members exist depending on length of service in the cooperative, financial support, etc.<br>Can be elected to the board/leader of the cooperative<br>Can be both active and passive in operations; if passive, a replacement (worker) is often required |
| Workers (voluntarios) | Long-term or permanent worker<br>In some cases, can become a member of the cooperative<br>Have a higher and more stable salary<br>Are often qualified workers coming from other mines<br>They experience low productivity or other problems |
| Day laborers (jornaleros y empleados) | Can fulfill most tasks in exploitation and processing<br>Receive a lower payment than permanent workers<br>Often perform the hardest and most hazardous work<br>In some cases payment is made by a specific task and not a fixed salary or they work in representation of a member |

*Sources:* Based on field interviews (2012); Aranibar and Bernal 2005; Michard 2008.

**Box 4.1 Gender-sensitive approach in Papua New Guinea**

Papua New Guinea is a culturally diverse, biodiversity-rich, and mountainous country located in the Pacific region. Like Bolivia, Papua New Guinea still depends on natural resource extraction and mining is a key foreign exchange earner. Global experiences show that the impacts and benefits of the mining sector are gender biased. Employment, decision making, and income are mainly captured by men.

The Women in Mining initiative, supported by the World Bank, aimed at mitigating negative environmental impacts of mining on women and enhancing the positive impacts. Specifically, the project supported the development of women's activities and strengthened their capacities and voice in mining-impacted communities.

The lessons learned can be summarized as follows: (a) investigate risks, environmental impacts, and benefits through a gender lens to promote gender-sensitive actions; (b) listen to women in a women-only setting, allowing the project to respond to women's needs rather than lecturing them, thereby empowering them to take a more proactive role in community decisions; and (c) inform women about risks and benefits and encourage them to participate in planning and negotiations, which in Papua New Guinea led to the earmarking of 10 percent of mining royalties for women's activities.

Though the project focused on impacts from large-scale mining, some of the methodologies are also relevant in the ASM context in Bolivia, where women also play a secondary role in cooperative mining. Environmental impacts and other externalities, such as additional workload, replacement of male community responsibilities, and increased social vulnerability as mining activities expand in communities, appear to coincide in both countries.

*Source:* Eftimie 2011.

Cooperative mining is also a significant source of environmental contamination and degradation in regions with high levels of mining operations. They often operate in fragile environments and at the upper reaches of strategic watersheds, as shown in chapter 5. Among the key environmental problems caused by gold mining are (a) contamination from mercury and other toxic chemicals; (b) degradation of landscapes and vegetation and soil erosion; (c) degradation of water catchments by destroying riverbanks, accelerating sedimentation and siltation processes; and (d) contamination from tailings and mud being dumped in rivers.[31] Despite an observed openness toward improving environmental management, most cooperatives are small rural enterprises with restricted financial resources and limited understanding of the environmental impacts caused by their mining operations.

In sum, gold mining cooperatives are a heterogeneous group creating important employment opportunities in rural Bolivia, but there is limited information on the types of processing techniques in use and the size of the operations, making it difficult to get even rough estimations of the environmental impacts. Whereas the mining cooperatives are complex in several ways, a number of projects have demonstrated that some technological improvements are fairly simple and inexpensive to implement, which will be investigated further in section 4.4.

[31] Globally, in many ASM gold mining areas cyanide pollution is also a major environmental problem, but currently in Bolivia gold miners are generally not using cyanide to refine gold.

## 4.3 Legal Framework and Mining Programs

Since the 1990s, many development programs have made efforts to strengthen the capacity and organization of mining cooperatives to reduce high levels of contamination.[32] These projects and programs have generated interesting experiences and have also supported the strengthening of the mining and environmental regulations.

Both the new Constitution and the 2006–2011 National Development Plan[33] of Bolivia recognize the importance of the cooperative mining sector. In the Constitution, articles 369 and 370 recognize mining cooperatives and emphasize that the State has the obligation to strengthen them so they can contribute more strongly to the socioeconomic development of the country, while also stressing a number of obligations that the cooperatives should fulfill. The National Development Plan stresses that small-scale and cooperative mining should be strengthened by improving working conditions, increasing productivity, and promoting environmentally adequate technology, all of which will allow for expansion and improvement of the operations.

The 1997 Mining Code (Law No. 1777) is still the sector's overall legal framework, although a new Mining Code is expected within the coming year.[34] This law supports financial and technological support to small-scale and cooperative mining and promotes incentives to protect the environment in operations. The code is complemented by the Environmental Law, which requires that companies exploiting minerals use adequate storage of tailings, use electricity and water efficiently, and, once the mining activity is concluded, restore affected areas. None of the legislation makes distinctions between artisanal, small-scale, and medium-scale mining apart from a paragraph stressing that cooperatives processing more than 300 tons of ore monthly should comply with higher environmental standards.

Cooperatives are required to meet their environmental obligations through a relatively complex process before an environmental license is issued by the Vice Ministry of Environment, Biodiversity, and Climate Change (see figure D1.2 in annex D). The process should ideally be led by the cooperative and later become institutionalized in its operations. During the process, the Ministry of Mining and Metallurgy and the municipality should also be involved. Though the national legislation and regulations are relatively sound from an environmental perspective, their practical implementation is more complex. The interministerial coordination and collaboration between different levels of government is difficult in practice. Many small cooperatives face difficulties complying with and understanding the technical requirements of the process. Larger cooperatives may obtain their license by hiring an environmental specialist but the paperwork is not always integrated in day-to-day operations. Finally, the responsible government authorities do not have sufficient resources to enforce the regulations and support the capacity building of the cooperatives, particularly considering the remote location of many mines and the rapid growth in the number of cooperatives.

During a series of field visits carried out as part of this study, cooperatives demonstrated a clear interest in improving existing practices and introducing cleaner technologies and processing techniques (see

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32 Donors engaged in the sector during the last decade include the Canadian International Development Agency, COSUDE, DANIDA, European Union, World Bank, and International Labour Organization.

33 The 2006–2011 National Development Plan continues to be the government's reference framework, as a new plan has not been approved yet.

34 Several drafts of the new Mining Code have been circulated and discussed with the different stakeholders but the slow progress toward a final law is another indication of the competing and conflicting interests within the sector.

annex D2 for further details on field methodology and field visits). This perception is supported by quantitative data from the Ministry of Environment and Water that show a significant increase in the number of environmental manifests, the legal environmental documentation required since 1997 (see figure D1.2 in annex D). Of the 346 environmental manifests registered from 2000 to 2011, 89 percent were received during the last four years. Some of the barriers to compliance stressed by the cooperatives were limited knowledge of new technology and complex, time-consuming administrative processes in La Paz.

## 4.4 International Experiences with Introducing Appropriate Cleaner Technology

Artisanal and small-scale mining is often characterized by using relatively simple, inefficient, and contaminating technologies in comparison to medium- and large-scale mining operations (Veiga, Maxson, and Hylander 2006; Tarras-Wahlberg et. al. 2000). However, many global and Latin American experiences have proven that adequate technology for ASM operations exists that can improve productivity, reduce operational costs, and limit contamination significantly at relatively low cost.

The establishment of a database of the capacity, size, and processing techniques of the cooperatives would be important in order to introduce adequate technology to the different types of operations. Particularly, it should be taken into consideration that the majority of gold mining cooperatives have less than five years of operational experience. Training modules and hands-on exchange of experiences with more advanced cooperatives could provide cooperatives with new capacities and inputs supporting demand-driven action plans. As demonstrated in box 4.2, this was done in Colombia with benefical results.

**Box 4.2 Colombia: Global Mercury Project II**

The Global Mercury Project II in Antioquia in Colombia organized an exchange of 18 Colombian miners to Ecuador. The miners were shown experiences with new technology such as retorts, small plants, and use of amalgamation drums. The exchange was used as a way of kick-starting the project in five municipalities in the autonomous region of Antioquia.

More than 20,000 peoples depend directly on mining in these municipalities. Use of mercury was high and inefficient, with an annual use of 60–100 tons of mercury and a mercury loss of 35–42 percent in the amalgamation process. The project goal was to reduce mercury use by 50 percent by using a number of different tools from awareness campaigns to health studies as well as capacity building and acquisition of more appropriate processing technology, including small beneficiation mills, capacitors for the heating of the amalgam, and retorts for the treatment of gold precipitates.

It is estimated that mercury use fell by 10.9 tons within a few years. Furthermore, the volume of minerals processed increased from 95 tons per day to 126 tons per day and gold recovery was increased due to the installation of 622 new machines for amalgamation.

*Source:* Pinto and Terceros 2012.

One area where ASM gold mining has demonstrated clear technological improvements has been related to the reduced use of mercury in processing. For example, retorts – the final process separating the gold from the mercury components of the gold amalgam – have been introduced in projects in Bolivia, Colombia, Ecuador, and Peru, and have generated positive impacts on production costs, decreasing mercury use and reducing health risk by eliminating direct exposure to mercury.[35] It appears that the use of retorts also is transferred among miners without the need for direct promotion from programs and projects, though it was observed in the field that the construction and use of some retorts was substandard.[36]

Despite these efforts, Veiga, Maxson, and Hylander (2006) estimate that countries such as Bolivia, Colombia, and Peru release between 10 and 30 tons of mercury every year. In Bolivia, the estimate was around 12 tons of mercury in 2010.[37] This is probably because mercury is available, inexpensive, and easy to use, and miners lack knowledge of the impacts, some of which only become manifest after several years of exposure or contact.[38] This indicates that mercury is still widely used, often inefficiently, and scaling up the pilot experiences would be crucial to ensure that the fairly simple and inexpensive alternatives are available for all cooperatives.

One of the first attempts to eliminate mercury use is the Oro Verde ("Green Gold") project in Colombia (box 4.3). While it has been quite successful, its reach is relatively limited and in a well-defined area. In Bolivia, MEDMIN and Cumbre de Sajama have implemented interesting projects for improving technology in ASM gold mining cooperatives, with one goal being the reduction of mercury use, although not its elimination. One noteworthy example is the Cotapata Mining Cooperative located in the Cotapata National Park near La Paz. This cooperative was the first one certified by Fairtrade/Fairmined in 2010 (ARM 2010). The processes observed here were more advanced than in other cooperatives and included crushing, grinding, and gravity-based concentration with jigs and concentration tables.[39] After this process, mercury is added in an amalgamation mill that separates the gold from the mercury through the distillation of the mercury (with retorts) and subsequent recovery of the mercury with an electrolytic reactivator for reuse. Such first-mover cooperatives cannot simply be copied by introducing new technology, as it also depends on the organizational and human capacity of the cooperative as well as the willingness to invest time and resources for improving the processing of the minerals. However, such cases can encourage and showcase more efficient and low-impact processing techniques to other cooperatives, as Oro Verde was one of the motivating projects for the Alliance for Responsible Mining (box 4.3).

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[35] Some projects are worth mentioning. Bolivia: Certification of the Cotapata Mining Cooperative implemented by Cumbre de Sajama, and the MEDMIN Program II. Colombia: Rio Suratà and La Llanada, Cumbitara, Global Mercury Project. Ecuador: Bella Rica, ARM.

[36] During the field visits, it was observed that the construction of retorts was not adequate, mercury was not reactivated, and in some cases retorts were used inside the homes of the miners.

[37] Global database, http://www.mercurywatch.org/.

[38] The expression "mad as a hatter" comes from the fact that in the 19th century hat makers used mercury in their production processes and after many years of such exposure became "mad." Of course, at the time the causal link was unknown.

[39] In nontechnical terms, the Cotapata Mining Cooperative has optimized the processing of the minerals by improving the mechanical processing and separation of the gold, which has reduced the use of mercury, improved the recycling of mercury, and achieved a higher recovery of gold. The cooperative has also introduced new social standards such as a minimum salary (which is the same for men and women), no child labor or even children living near the mine, and everyone has life and accident insurance.

**Box 4.3 Oro Verde (Green Gold): Pacific coast in Colombia**

Oro Verde is a community-driven program in the Choco bioregion in Colombia. The Afro-Colombian communities use ancestral techniques as well as environmentally and socially responsible methods. The overall project is based on 11 criteria, including no use of mercury and toxic chemicals, no use of heavy machinery, restoration of affected landscape and vegetation, and development should be based on the community criteria established by the Afro-descendent communities.

All in all, the program has worked with more than 194 separate family production units, with 112 family units currently participating. All mining is alluvial and generates 14.9 kilograms of gold per year with 85 percent purity. The project showcases how individual artisanal miners can continue their traditional practices and still promote responsible, certified mining. It also demonstrates sustainable ways to restore landscapes after mining activities are completed in fragile ecosystems with high biodiversity.

The project inspired the creation of the Alliance for Responsible Mining in 2004. Therefore, it differs from the certification in Cotapata, as it began with locally established norms and not based on international certification norms. One of the two producer organizations working in the Oro Verde program is certified by Fairtrade/Fairmined and the other by Ecological Gold Certification.

*Sources:* Alliance for Responsible Mining http://www.communitymining.org/ and Seed Awards (2009).

Contrary to the results of the pilot projects on reducing mercury use, previous attempts in Bolivia to establish financial and microcredit mechanisms have turned out to be more complicated, either because repayment rates have been low or because grant requirements, bureaucracy, and regulations have been too complex (Bocangel 2001). The most recent attempts by the government have been the creation of a new financial mechanism, the Financial Mining Fund (Fondo de Financiamiento para la Minería, FOFIM), in 2009, and the national-controlled Bolivian Gold Company (Empresa Boliviana de Oro, EBO) in 2010. Whereas FOFIM aims to support the mining cooperatives in all stages of the production chain, the objective of EBO is to buy gold from formal and informal producers, investigate the alluvial mining potential, and strengthen the commercialization chain. However, both institutions have made slow progress and faced more difficulties than anticipated during their first years.[40] Box 4.4 illustrates how Chile provides financial and technical assistance to smaller mining operations to improve their productivity and environmental performance. Even though most of the recipient operations are similar in size to or larger than the biggest cooperatives in Bolivia, a similar program in Bolivia could target the larger, more stable gold mining cooperatives.

[40] FOFIM had provided eight loans by September 2012. The total amount of loans is Bs. 98 million. However, one loan accounts for 85 percent of this total amount. This cannot be considered an extensive coverage for new small-scale mining cooperatives.

**Box 4.4 ENAMI, Chile: Training for and development of small- and medium-scale mining**

ENAMI is a State-owned company responsible for training for and development of small-scale mining in Chile. It aims to support small- and medium-sized mines to overcome traditional market failures. This is done through provision of technical assistance, training, access to technological advances, and knowledge of global markets. ENAMI has developed three overall strategic areas:

- Promotion of small- and medium-scale mining through financial mechanisms, preparation and evaluation of projects, training, and access to credit, including for exploration;
- Improvements in processing minerals and expansion of the production chain, thus adding value to the minerals;
- Provision of commercial services, allowing producers to buy equipment and commercialize their products in the global market while still minimizing their risk.

Though ENAMI generally works with operations larger than most Bolivian gold mining cooperatives, several of its services and products appear to be relevant for larger, more stable Bolivian cooperatives.

*Source:* http://www.enami.cl/.

Many projects have proven how cleaner, more appropriate technology improves productivity, reduces operational costs, and limits contamination of mercury. Documenting this win-win situation demonstrates to the cooperatives the positive impacts of the projects. Many projects in Bolivia, Colombia, Ecuador, and Peru have achieved impressive and well-documented results. However, few compare the up-front investment (often grants) with the benefits from increased productivity, reduced operational costs, and benefits of selling in certified markets. Therefore, it is still uncertain if cooperatives would be willing to invest in cleaner technology without a certain level of government or donor subsidies. The Rio Surata project in Colombia is a good example of a project demonstrating an interesting participatory monitoring and evaluation methodology promoting miners' direct participation in the monitoring programs and laboratories in nearby mines. It also shows strong technical results, but the sustainability or ability to scale up is not clear without further evidence, including an analysis of the benefits to nonmining impacted stakeholders (box 4.5).

A field with fewer experiences is the restoration of landscapes and the reduction of natural resource degradation from alluvial mining. In Bolivia, this is an important issue as, due to high gold prices, many cooperatives can relatively quickly accumulate enough funds to hire or buy heavy equipment with much higher impacts on local habitats, landscapes, and water resources. This call for a more integrated approach and engagement of multiple stakeholders to cope with these challenges (see chapter 5), which will be explored in the next section.

**Box 4.5 Colombia: Rio Surata project**

The city of Bucaramanga is supplied with potable water (1 million water users) from the Surata River, which was severely contaminated by mercury and cyanide. The objective of the Rio Surata project was to reduce this contamination from artisanal and small-scale gold mining upriver. The target group was 600 miners and their families in the Vetas and California regions.

Initially the project conducted an evaluation of the mineral processing methods and the environmental impacts. It also provided an extensive training and education program. In order to motivate the miners to change their existing mining and processing methods, new methodologies were introduced that increased the gold yield and at the same time reduced contamination (especially of mercury and cyanide). Laboratories were set up to monitor the processing in Vetas and California and were managed by both project partners and the mining associations.

The local laboratories allowed engagement of the miners in the monitoring of the results, which can be summarized as: (a) 67 percent reduction of the use of mercury; (b) 76 percent increase in recovery of gold; and (c) operational costs of alluvial material were reduced by 62 percent.

Though the project, which was implemented from 1997 to 2005, was probably not economically sustainable from an isolated mining perspective, a more integrated focus on all affected water users could justify the large investment.

*Sources:* IMC 2006; Hruschka 2003; Pinto and Terceros 2012.

## 4.5 An Integrated Perspective on Mining

For an integrated understanding of the different stakeholders and their use of natural resources, it is important to consider the competing interests and rights. Water tends to be the resource most vulnerable to mining contamination and a critical resource for many other user groups (agriculture, cattle-raising, and drinking water in larger cities). It is easily contaminated and, moreover, mining can often lead to significant degradation of riverbeds and nearby ecosystems. Integrated watershed management is currently being promoted in Bolivia and could be used for a multistakeholder approach across several sectors.

As expressed in the National Watershed Plan, "water basins are dynamic spatial units which organize different water users, respecting their culture and way of living from a territorial perspective."[41] The fifth component of the National Watershed Plan concerns water quality and contamination from the mining sector. A second phase of the plan is currently being developed, opening new opportunities to strengthen an integrated focus. It also intends to include miners in the planning of selected watersheds, such as the Poopó water basin in Oruro. The analysis in this study indicates that it is essential that this new phase of the National Watershed Plan opens up spaces for communities, mining cooperatives, farmers, and other stakeholders to interact, allowing an ongoing dialogue before disagreements turn into open conflicts.

Cooperative gold mining in Bolivia takes place in environmentally sensitive zones, protected areas, and often in the upper reaches of important watersheds, impacting populations further downstream.

[41] Watersheds are a living space in which different uses and users of water coexist and also include a specific cultural expression of the people who live there, including their lifestyles.

However, no comprehensive data exist on cooperative mining, the locations of cooperatives, production processes, and competing natural resource use by other stakeholders, which complicates territorial development planning. One reason is the limited interinstitutional coordination between different ministries and levels of government. As a result, no national or local planning of future mining concessions exists (this issue is investigated further in chapter 5). It may also be necessary to explicitly find alternatives or prohibit some types of productive processes in highly vulnerable regions and ecosystems, such as chute dredgers, that have proven in other countries (for example Peru) to have large environmental consequences that are difficult and in some cases impossible to remediate. For example, in Colombia all gold mining in the *páramos* (valuable and biodiversity-rich high Andean ecosystems) has been banned because these vulnerable ecosystems are crucial for the hydrologic balance in some of the most populated regions of the country.

A comprehensive overview is needed to prioritize resources and secure a more permanent presence of government agencies. One priority area could be the two national parks with intensive gold mining. In the high-altitude protected area of Apolobamba more than 206 mining cooperatives operate and mining concessions cover approximately 20 percent of the national park. The Cotapata National Park also experiences extensive mining activities, with 37 mining concessions covering 12 percent of the national park. Both protected areas are characterized by low population density but are located in the upper part of two major watersheds (Lake Titicaca and the Amazon River), and are very vulnerable ecosystems (see also chapter 5). Rather than only putting the emphasis on enforcement of environmental regulations, which has often proven to be conflictive, government agencies could also support cooperatives by introducing more efficient processing techniques.

An example where multiple interests should be considered is the surrounding mountains and glaciers near La Paz and El Alto. In this region, several small-scale mining operations are located above large dams, putting clean drinking water at risk for the two cities. Mining contamination in these areas should be supervised more closely than in other areas, and the granting of future mining concession near dams should be reconsidered in general. This would require information sharing across ministries but, currently, the granting of a mining concession is only an issue for the National Geology and Mining Technology Service (Servicio Nacional de Geología y Técnico de Minas, SERGEOTECMIN).

## 4.6 Conclusions

Most gold extraction in Bolivia is carried out by a large number of ASM mining cooperatives, many of which use labor-intensive and simple processing techniques. ASM mining is often characterized by the use of inefficient technologies and generates high environmental impacts (Tarras-Wahlberg et al. 2000). However, gold mining cooperatives also provide alternative income opportunities, complementing traditional agricultural activities in some of the poorest and most remote regions of Bolivia, and providing employment during times of the year when few other employment alternatives exist.

No data platform exists that provides a basic overview of the cooperative sector, including where miners operate, the size of their operations, processing techniques, or in some cases even what minerals they exploit. It would be relatively straightforward to establish such an information system for gold mining cooperatives as most are already registered, but it would require multiministerial collaboration, engagement of the mining federations, and a long-term commitment to sustain the database. This database would be crucial in order to propose and disseminate knowledge on appropriate technological improvements, in a tailored manner, considering the differentiated characteristics of the gold mining cooperatives.

In Bolivia, cooperatives seldom have studies estimating the gold deposits of their concessions and they are highly vulnerable to global price fluctuations. Therefore, their strategies as small-scale entrepreneurs are often driven by a short time horizon aiming to maximize their profit with a minimum of investment. Their willingness to invest in new and cleaner technology will be heavily influenced by this perspective. Hence, a comprehensive approach to their situation will often be necessary, whereby benefits and environmental impacts are analyzed in a broader context, one that will need to include all stakeholders.

Cooperative gold mining has received relatively limited attention in the last few years, but the rapid growth of the sector calls for immediate action to mitigate contamination and natural resource degradation. Though donor agencies and government institutions face difficulties providing such rapid responses, it is an important advantage that relatively simple and low-cost technologies already exist that can reduce the use of mercury and improve the recovery of gold. It is a potential win-win situation and it has proven possible to change the processing techniques of small-scale miners. Five key dimensions need to be addressed in order to scale up these pilot experiences in the gold mining regions of Bolivia:

- First, the cooperative sector is complex and mostly informal, and represents many conflicting and contradictory interests. Furthermore, gold mining processing techniques differ depending on the type of mining, geographic location, and the size of the operation. A one-size-fits-all approach would not work.

- Second, whereas progress in reducing mercury contamination has been demonstrated in cooperative ASM mining in Bolivia and other Andean countries, limited methodological progress has been observed regarding innovative processing techniques to protect and restore landscapes, natural vegetation, rivers, and river catchments. It will likely be necessary to include an approach integrating all stakeholders in these areas and it may be necessary to ban some productive processes.

- Third, previous attempts to establish financial and microcredit mechanisms for the cooperative mining sector have not succeeded, and recent attempts – programs by FOFIM and EBO – have progressed slower than expected. More analysis is needed of how credit mechanisms can address the problems of cooperatives and not siphon money away from more direct interventions such as technical assistance and improved monitoring.

- Fourth, though many cooperatives have expressed an interest in reducing environmental impacts, limited knowledge exists regarding their willingness to pay for these technological improvements.
- Fifth, there is currently no adequate institutional space for an ongoing interactive dialogue between miners, communities impacted by mining operations, and other stakeholders. The National Watershed Plan could potentially fill this void and promote an integrated development approach.

Despite these five challenges, cleaner and more efficient technology could be a win-win solution for most stakeholders and an acceptable approach for the government to engage more with the cooperative mining sector without triggering conflict, as has happened when relying exclusively on the enforcement of environmental regulations.

# Chapter 5. Mining and Water: The Benefits of Integrated Water Resource Management at the Watershed Level

## 5.1 Introduction

Integrated water resource management at the level of the watershed – an area of land delimitated by natural boundaries where all the water that is under it or falls onto it drains to a common place – is a priority of Bolivia. The 2006–2011 National Development Plan, which is a key instrument guiding the country's development and strategic investments, recognizes integrated water resource management at the level of the watershed as an indispensable condition for participatory sustainable development in Bolivia.

The government of Bolivia has been promoting integrated water resource management at watershed level since 2007. So far, considerable progress has been made in promoting cross-sectoral coordination in the planning of water resources for irrigation, drinking water, and sanitation. As regards water resources and mining, there still persists a sectoral vision of planning and management. The environmental impact assessments for mining activities often fail to measure impacts from a basin perspective. Impacts on the quality of water for downstream users, on the environmental services provided by ecosystems, and on agriculture, and issues of water stress and its impacts at basin level, are usually overlooked.

Bolivia is among the countries with the highest per capita water availability in the world (approximately 38,000 cubic meters per inhabitant in 2010). However, the distribution of this supply of water is not homogeneous, either in space or in time, and there are parts of the country that enjoy good availability, while others suffer from a water deficit. The mining sector uses 3 percent of Bolivia's water resources, but knowledge concerning the sector's demands for water and an understanding of its environmental impacts on the resource is limited.

In general, it is recognized that there is a need to act, and therefore political will exists to define a country strategy that promotes the sustainable use of water resources by the mining sector. For this reason, the government of Bolivia, nongovernmental actors, and other development partners have selected the issue of water and mining with a watershed perspective as an environmental policy priority for this program.

The work carried out, the results of which are summarized in this chapter, strives to identify the priority basins and sub-basins in terms of ongoing or future mining activities, using an integrated water resource management approach. Many studies have attempted to evaluate the impacts of mining activities on water resources, but unfortunately they fail to provide a countrywide overview of the most important basins in which the mining sector plays a predominant role. In trying to fill this knowledge gap, this study also contributed to the assembling of all available geographic databases relevant to an evaluation of the impacts caused by mining activity on water resources in a Mining-Environmental Information Platform. At the completion of the program, the Mining-Environmental Information Platform was transferred to the Ministry of Environment and Water and the Ministry of Mining and Metallurgy.

This study is directed mainly at experts in planning and environmental management at the Ministry of Environment and Water, the Ministry of Mining and Metallurgy, and the Bolivia Mining Corporation (COMIBOL), as well as to other Bolivian experts and specialists, in an effort to promote a better understanding of the impact of mining activities at the level of the watershed, and thus facilitate the definition of policies and setting of investment priorities.

## 5.2 Methodology and Main Results

### *5.2.1 Overall Approach*

As there is little information at the country level on the quality of water bodies, this study tried to estimate the possible magnitude of the impacts on water resources caused by mining activities. The analysis presented in this chapter helps to assess the magnitude of the possible pollution of water sources by mining activities and identify the areas that may be at risk of mining pollution. Specifically, the analysis helps answer the following question: What proportion of the runoff within each specific watershed originates from mining areas? All inputs in the analysis were converted to 90-meter resolution grids. "Mining areas" are defined in the analysis as the pixels partially to totally covered either by active mining operations or by environmental liabilities from the mining sector.[42] Next, the runoff is approximated by precipitation, for which the data are available.[43] Last, the proportion of the runoff potentially polluted by the mining sector, by virtue of having flowed from what is defined as "mining areas" in this study, is estimated for each river stream. The analysis provides insights about the share of runoff above any particular pixel in a watershed that has flown through the upstream "mining areas" in the watershed.

### *5.2.2 Methodology*

The unit of analysis used was the official fifth order hydrologic unit, of which there are a total of 1996 in Bolivia. The fifth order hydrologic unit (level 5 HU) is the smallest official breakdown level for watersheds in the country, and is used mainly for the physical planning of water resources (Ministry of Environment and Water 2010).

In order to determine the potential contribution made by "mining areas" to surface runoff in level 5 HU, the Human Water Quality Footprint methodology was employed (Mulligan 2009). This methodology allows for estimating the possible impact of upstream mining activities on downstream flow. It is worth noting that there exist other water users in the watersheds, such as agriculture, industry, and municipalities, and other sources of pollution, which can also have an impact on the quality of water resources. However, for the purposes of this study they were not taken into account. The analysis used the tools available in the ARCGIS 10 software and the Spatial Analyst extension, in particular the hydrology module.

The first step consisted in preparing the data for the development of the model. The digital elevation model at a resolution of 90 meters was hydrologically corrected by filling sink (depression) cells and

[42] The data for the period 2006–2010 were available on the location of the active mining operations and mining liabilities as points. Only for 2006, the data on the environmental liabilities was available in terms of the areas that they covered. Furthermore, environmental liabilities were classified in the 2006 data as "small, medium, and large." In the data for the other years, the environmental liabilities were classified into the same three categories but no estimates of the area they covered were available. In this analysis, a correlation was run between the 2006 data on the area of the environmental liabilities and their categorization as small, medium, and large. The resulting estimated coefficients were applied to the data on environmental liabilities for the other years in order to derive the approximate areas that they covered. The same transformation was applied to the data on the location of the active mining operations, classified only in terms of the category and not by size. Through this process, the "mining areas" were estimated in this study in terms of the number of cells, or pixels, that the active mining operations and liabilities covered within each drainage area.

[43] A more precise estimate would include evapotranspiration and infiltration rates in addition to the data on precipitation.

burning the river network. The next step was to create the flow direction grid map, which provides the down gradient flow direction for each cell. Using the flow accumulation tool on the flow direction grid map, the flow accumulation grid map was created to determine the number of upstream cells draining through each individual cell. A binary inferred drainage network map was then created by choosing all cells in the flow accumulation map that exceed the threshold flow accumulation value of 5,000.

The next step was to create a binary raster map of "mining areas" at a resolution of 90 meters. When the actual boundary of the area was available, a value of 1 was assigned to each cell covered (in its entirety or partially) by the environmental liability. When only the centroid of the site was available, the following values were assigned to the centroid cell based on the size category of the active mining operation or environmental liability: 1 for small, 5 for medium, and 100 for large.

Two additional flow accumulations maps were calculated. The first was based on the flow direction map, in which the annual average precipitation raster map (converted to a resolution of 90 meters) was used as the weight grid. This flow accumulation map represents the cumulative runoff from all areas in the watersheds. The second map was calculated based on the flow direction map, the binary raster map of "mining areas," and the annual average precipitation raster map. The last two maps were used as weight grids in the calculation. The resulting flow accumulation map represents the cumulated runoff from "mining areas" only. The cumulative runoff from "mining areas" was then divided by the cumulative runoff from all areas to obtain the percentage accumulation of runoff from "mining areas." This map represents an index of potential vulnerability to mining pollution.

The percentage accumulation map was then multiplied by the binary drainage network map to create a raster map of the drainage network showing the percentage of runoff from "mining areas."

For the analysis carried out under the framework of this study, the geographic data sets that are included in the Mining-Environmental Information Platform were used (see box 5.1 for a list of the various thematic layers of geographic information in the Mining-Environmental Information Platform).

**Box 5.1 The Mining-Environmental Information Platform for Bolivia**

During the initial phase of the study, the need was apparent for a geographic information system (GIS) for the spatial analysis that the team wanted to carry out on the impacts of the mining activities on water resources. After obtaining approval from the various institutions involved in the study, a decision was made to assemble all datasets of geographic information that were considered relevant for the study into a GIS platform, which was then called the Mining-Environmental Information Platform for Bolivia.

The platform includes datasets that are diverse in terms of scale, level of detail, format, year of reference, and other variables. At present, the Mining-Environmental Information Platform for Bolivia includes the following spatial layers of information:

- Digital elevation model with a 90-meter resolution obtained from the Bolivia Natural Resources Digital Information Center
- Map of the Bolivia hydrologic network provided by Ministry of Environment and Water
- Maps of 2010 Bolivia hydrologic units (first to fifth orders) provided by Ministry of Environment and Water
- Map of macrobasins of the 1991 Bolivia Surface Water Balance, obtained from the Bolivia Natural Resources Digital Information Center
- Precipitation map for the period 1950–2000 in raster format with a 1-km resolution, obtained from the AguaAndes portal.
- Water balance map for the period 1997–2008 obtained from the SWAT model (World Bank 2010).
- Map of dams from the 2010 National Dam Inventory provided by Ministry of Environment and Water
- Map of drinking water sources for towns with more than 10,000 inhabitants elaborated in 2005 and provided by Ministry of Environment and Water
- Map of 2010 population centers in Bolivia, 2010, produced by the National Statistics Institute and obtained from the Bolivia Natural Resources Digital Information Center
- 2001 poverty index map by municipality, provided by National Statistics Institute (updated to 327 municipalities)
- 2010 population density map obtained from the CIESIN portal
- Map of mining concessions in Bolivia for 2010 and 2011 provided by SERGEOTECMIN
- 2010 map of active mining operations (centroid) provided by SERGEOTECMIN
- 2006 map of mining liabilities provided by SERGEOTECMIN
- 2010 map of mining liabilities (centroid) provided by SERGEOTECMIN
- 2011 map of national protected areas provided by National Park Service (SERNAPA)
- 2008 map of departmental protected areas obtained from the International Conservancy portal
- 2008 map of municipal protected areas obtained from the International Conservancy portal
- 2008 maps of agricultural production by municipality provided by the Ministry of Productive Development and Rural Economy.

Making use of the initial information available on the Mining-Environmental Information Platform, a preliminary evaluation was made for the purpose of determining the priority macrobasins from the point of view of possible impacts on the population (including number of inhabitants, number of families, and number of localities), the agricultural areas, and the protected sites. Within the prioritized macrobasins, microregions were selected in which mining activity had the highest potential of causing an impact on the population (including numbers of inhabitants, number of families, and number of localities), production of priority crops (rice, quinoa, potatoes, maize, wheat, vegetables) and reservoirs (Perotto-Baldivieso, Ledezma, and Miranda 2011). This preliminary analysis, which did not take into account the potential pollution risk of mining areas or the scarcity of water resources, allowed to refine the methodology that was finally used in the study.

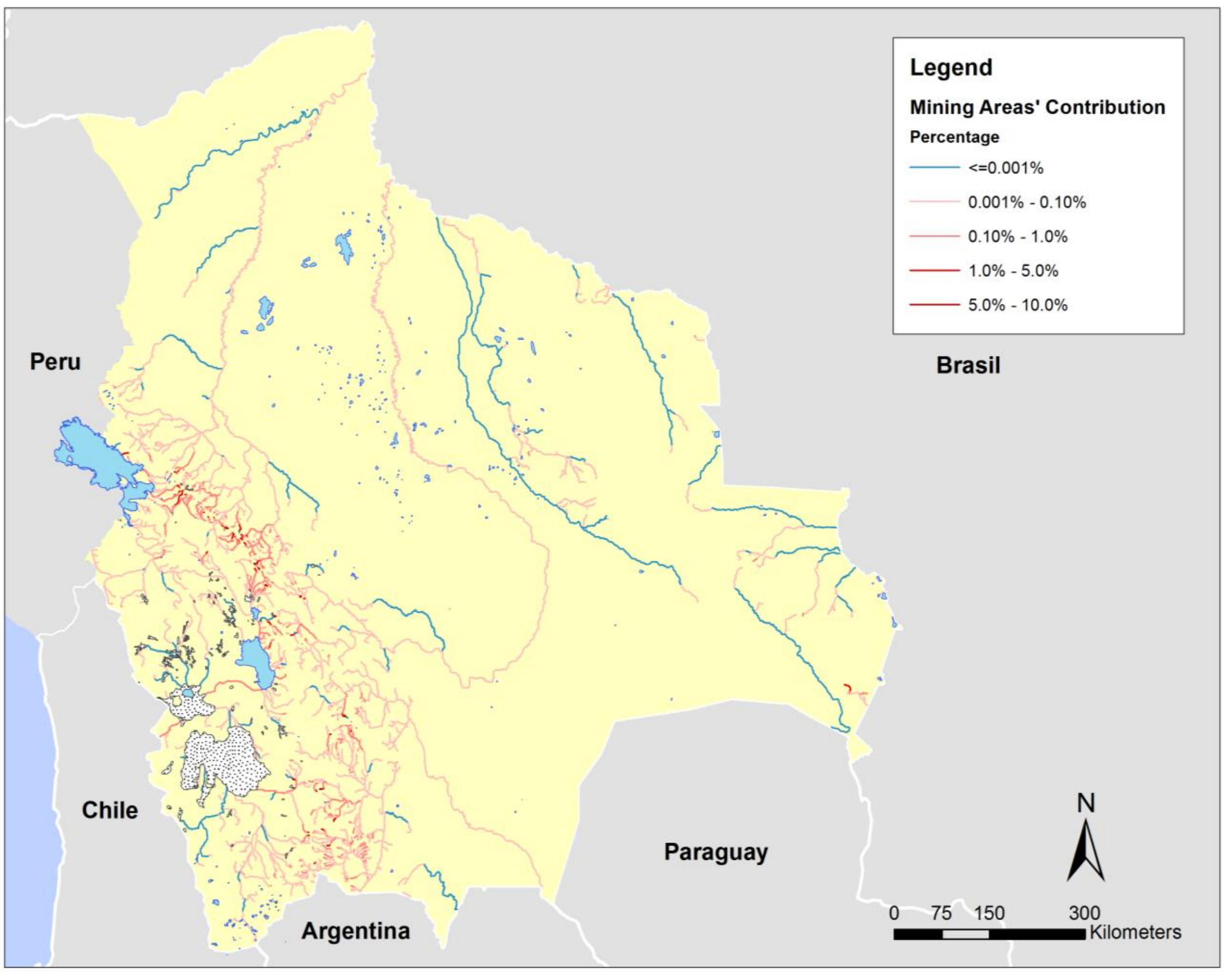
Source: Author.

### *5.2.3 Results: Analysis of Mining Concessions and Threats to Water Sources*

As can be seen in figure 5.1, the rivers most vulnerable to pollution caused by mining in Bolivia are in the basins of the Tumusla River (Blanco, Cotagaita, Fundación, Limata, and Tumusla Rivers), the San Juan del Oro River (Tupiza, Tatasi, Sococha, and San Juan de Oro Rivers), the Pilcomayo Alto River, the Caine River (Caine, Choyanta, and Toco Paya Rivers), the Grande River, the Desaguadero Bajo River (Desaguadero, Santa Fe, and Huanuni Rivers), Lake Poopó, Lake Titicaca, the La Paz-Boope River, the Beni River, and the Mamor River.

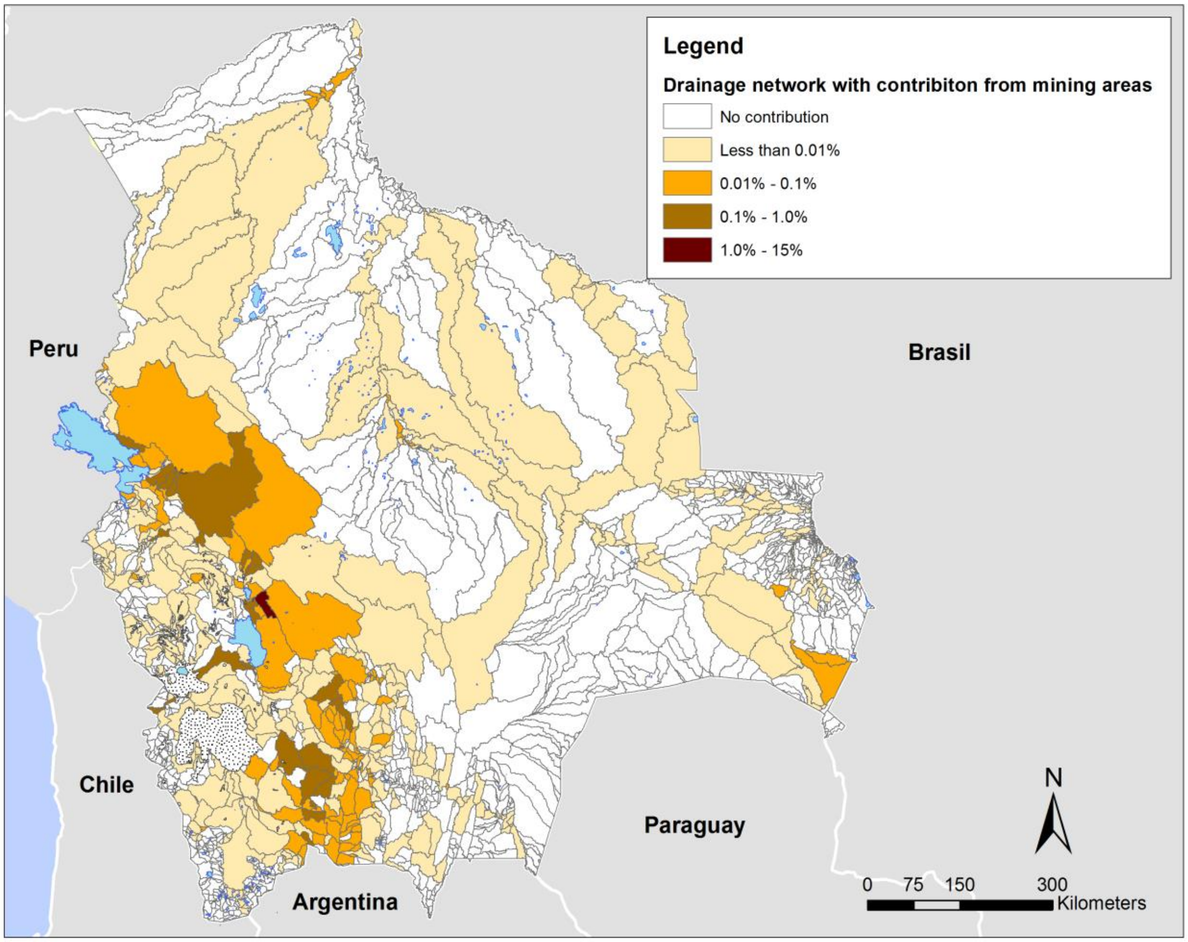
According to estimates, it was determined that approximately 17 percent of the level 5 HUs, which cover an area of 305,000 square kilometers (some 41 percent of the country's surface), receive contributions of water that has passed through zones with mining activities in them (figure 5.2). Approximately 63 percent of the population in one way or another uses water coming from areas in which there is mining.

**Figure 5.1 Drainage network and contribution to runoff originating in mining areas**




Source: Author.

**Figure 5.2 Average contribution to runoff originating in mining areas to the drainage network of the level 5 hydrologic unit**




Source: Author.

There is a risk that the water draining to the reservoirs is polluted. While it appears that most reservoirs are protected from pollution caused by mining activities, the analysis shows that approximately 6 percent of dams have drainage areas that are possibly exposed to pollution from heavy metals, as the water that reaches the reservoir has passed thorough mining areas. (For the analysis, it was considered as insignificant contribution if less than 0.001 percent of water that reached the reservoir had passed through mining areas). While the actual percentage is low, the surface involved covers around 14 percent of the area draining into all of the country's reservoirs.

The results suggest that four of the reservoirs used to supply drinking water might be compromised, given their location downstream from areas in which mining takes place: Hampaturi, Incachaca, Miluni, and Jatun Chaluma. Another six reservoirs that provide water for irrigation, namely Khara Khota, Yana Orgho, Amalla 1, Amalla 2, Las Carrera, and Chochilla (also used to produce electricity), may be exposed to pollution. The volume of these reservoirs is estimated at 33.6 million cubic meters. Depending on the technologies used in mining activities, these reservoirs could be exposed to contamination. Monitoring and detailed studies are needed to establish if pollution is indeed present and to what degree.

With regard to the possible impact of runoff from mining areas flowing into other sources of drinking water that do not depend on reservoirs created by dams, it was found that a large number of sources of drinking water (surface, subsurface, and groundwater) being used by population centers of over 10,000 persons could be exposed to pollution from mining, as the runoff within a radius of 200 meters from the source contains contributions of water coming from areas in which there are mining activities. Potentially affected towns and cities include Tupiza, Oruro, Villazón, La Paz-El Alto, Sucre, and Potosí. Water sources that may be compromised are shown in table 5.1. The water sources of irrigation systems surrounding these towns and cities are also expected to be potentially compromised, which in turn may put at risk the sustainability of the irrigation systems, as shown in box 5.2.

**Table 5.1 Drinking water sources vulnerable to pollution from mining activities**

| Type of source | Name | Town/city |
|---|---|---|
| Subsurface | Caracota | Tupiza |
| Groundwater | Riosep | Oruro |
| Groundwater | pp13 | Oruro |
| Groundwater | pp12 | Oruro |
| Groundwater | pp15 | Oruro |
| Groundwater | pp16 | Oruro |
| Groundwater | Changuito | Villazón |
| Groundwater | well 4 | Tupiza |
| Groundwater | well 2 | Tupiza |
| Groundwater | b14 | La Paz-El Alto |
| Groundwater | a14 | La Paz-El Alto |
| Groundwater | well 3 | Tupiza |
| Surface | Peras Mayu | Sucre |
| Surface | Ravelo | Sucre |
| Surface | Huayña Pasto | Oruro |
| Surface | Chojña Khota | La Paz-El Alto |
| Surface | Cayara-La Palca | Potosí |
| Surface | La Mina | Tupiza |
| Surface | Choqueyapu | La Paz |
| Surface | Chojlla Jipiña | La Paz-El Alto |
| Surface | Huayña Potosí | El Alto |

Source: Author.

**Box 5.2 Threat to sustainability of irrigation by pollution from mining areas**

A recent report on the sustainability of 20 irrigation systems in Bolivia built under the National Irrigation Program shows that an irrigation system in Zamora, located in the Altiplano of La Paz, built to irrigate 53 hectares and support 66 families, is almost abandoned as a result of the contamination of the water sources from mining activities upstream of the source. During the planning and design phase, two abandoned mines were identified upstream of the water source, but no measure was undertaken to prevent future contamination. However, with the increase in the price of the metals during the past years, these two mines have resumed activities. The use of chemical substances to extract minerals and the inadequate disposal of hazardous material has led to pollution of the only water source for irrigation.

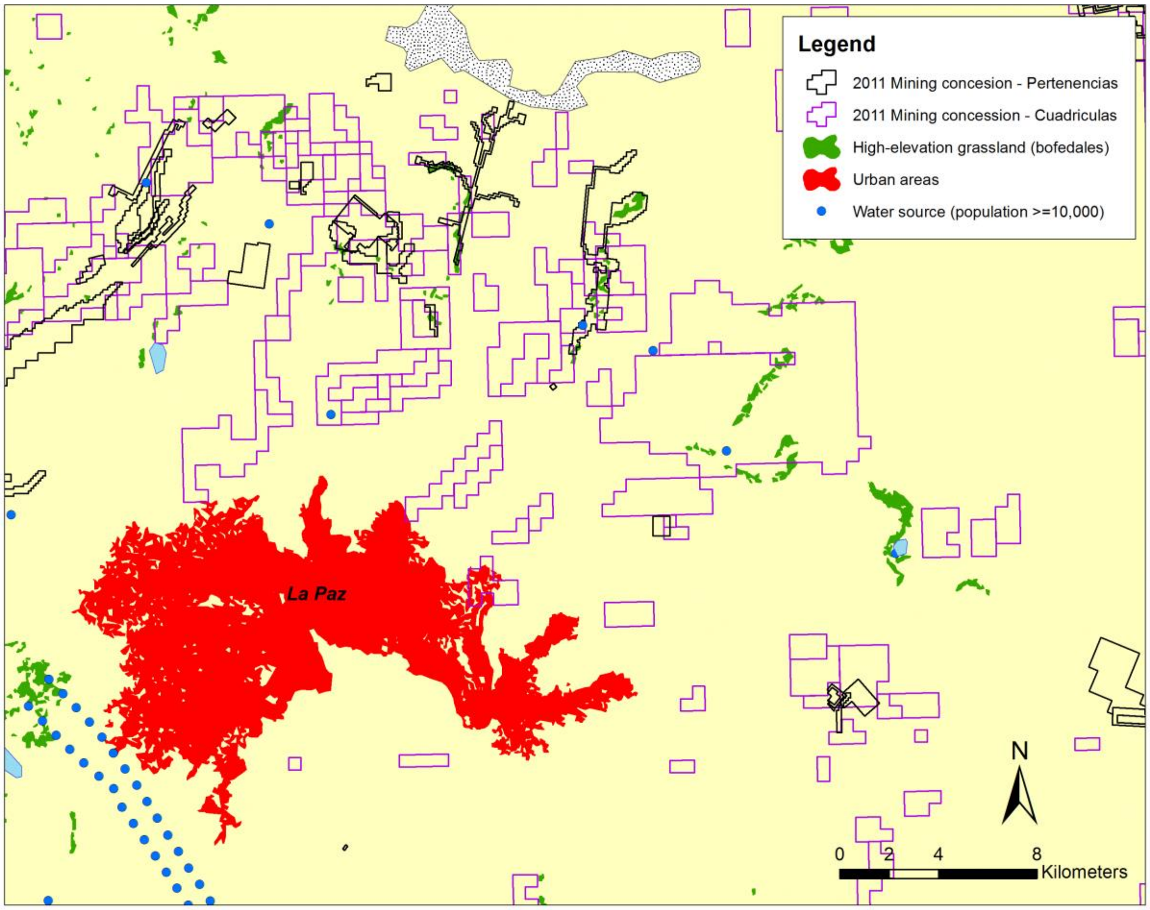
*Source:* Salazar, Saravia, and Rafael 2010.

The threat to reservoir drainage areas and high-elevation puna grasslands or *bofedales* must be taken into account when mining concessions are granted.[44] These ecosystems are the only sources of water for some small communities in the highlands as well as the Andean camelids. There is a need to have an overall vision of the watershed, including knowledge of how the water flows, as mining activities may have a negative impact on the quality of water sources used for drinking or irrigation. Figure 5.3 shows the situation of the *bofedales* surrounding La Paz.

It is possible that the situation of the sources of water for drinking and irrigation may get worse in the future if the areas for which concessions have already been granted come to be exploited. A spatial analysis done of mining concessions awarded in 2011 reveals that concessions are being given in reservoir drainage areas. As can be seen in figure 5.4, a considerable number of reservoirs used for drinking water and irrigation have large parts of their drainage areas under mining concessions. By late 2011, concessions had been granted in the drainage areas of 40 reservoirs used for irrigation and six used to supply drinking water.

[44] Two types of mining concessions are currently used in Bolivia: *cuadricula* and *pertenencia*. The *cuadricula* is the current mining measure unit, which is an inverted pyramid with the inferior vertex pointing to the center of the earth with an exterior perimeter equal to 25 hectares. The *pertenencia* in turn is the measure unit of the mining concession applied under the old Mining Code. It is also an inverted pyramid with the inferior vertex pointing to the center of the earth with an exterior perimeter equal to 1 hectare.

**Figure 5.3 Situation of *bofedales* surrounding La Paz**

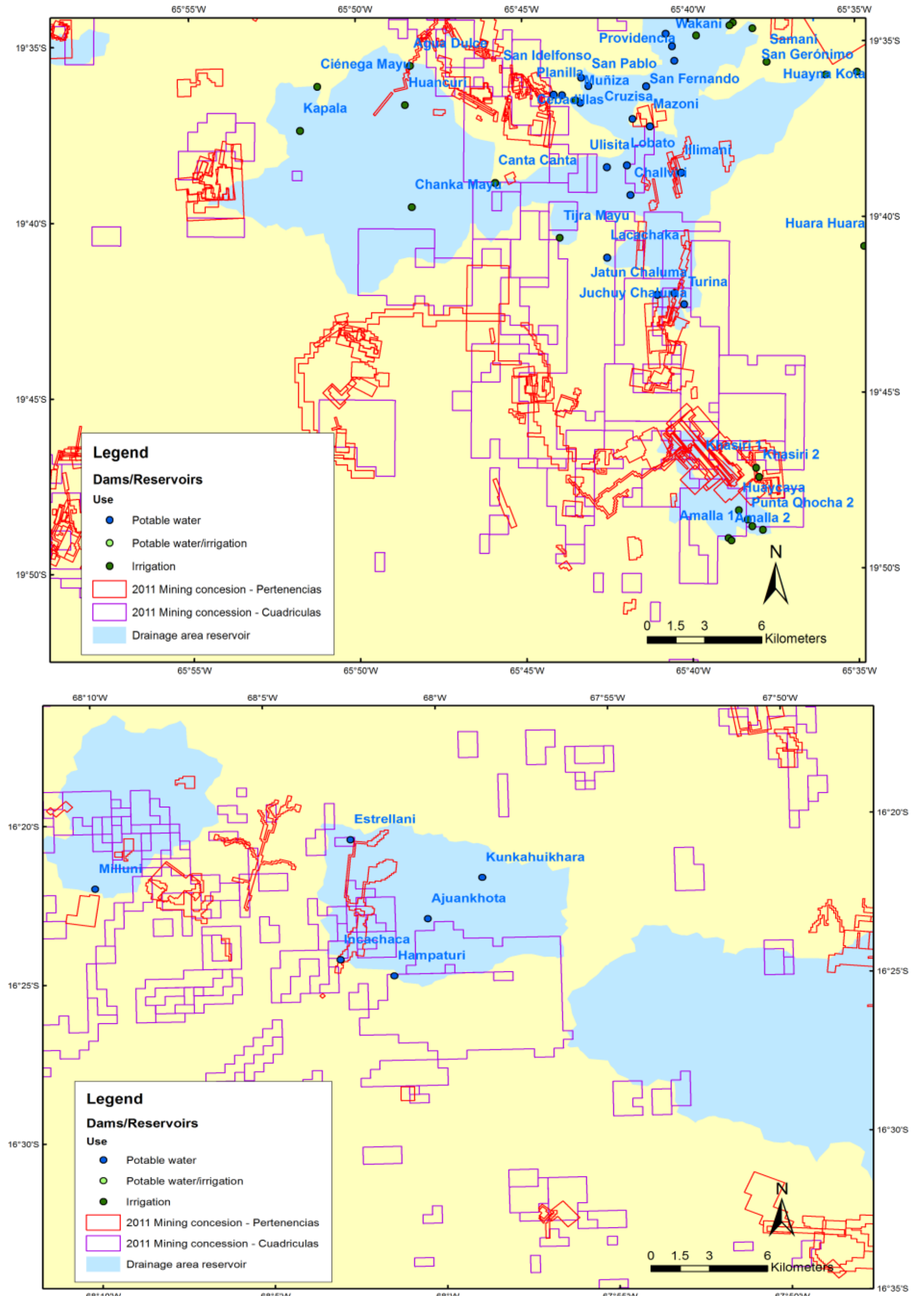



Source: Author.

Mining exclusion zones should be established in areas that drain into the reservoirs, particularly if the water they contain is intended for drinking and irrigation. Some Bolivian municipalities have declared terrain that drains into reservoirs to be protected areas, for the purpose of avoiding activities that cause pollution and ensure the good quality of water resources. The drainage area for hydroelectricity dams should also be free of mining activities, as these may lead to sedimentation and the eventual silting of the reservoir.

While there are many constraints associated with the limited availability of reliable monitoring information (both in terms of quality and quantity), the work carried out for this study constitutes a contribution to what information currently exists in Bolivia on the evaluation of impacts caused by mining activities on water resources. There is evidence that in some selected priority watersheds there are pollution-related problems, and the results are therefore considered reliable.

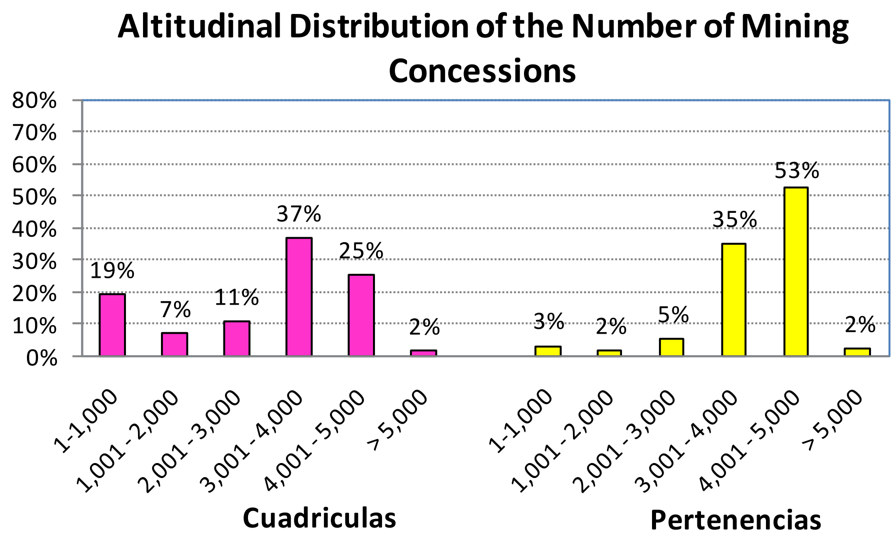
**Figure 5.4 Overlay of areas under mining concession at end of 2011 and drainage areas of reservoirs used for irrigation or drinking water**

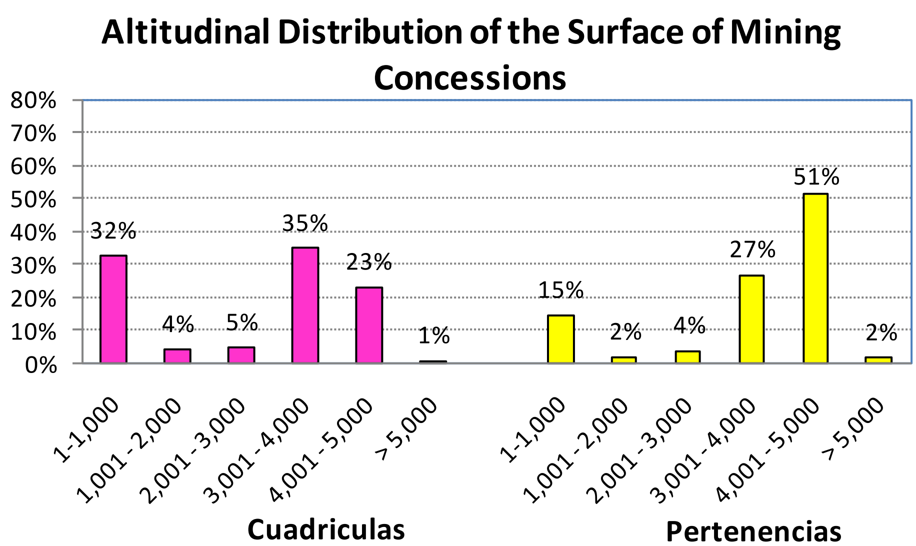



Source: Author.

Two out of every five mining concessions or claims granted at the end of 2011 are located in the headwaters of catchment basins. According to the analysis carried out, most of the surface under mining concessions using the *pertenencia* modality is found in these upper parts of the watershed. Approximately 41 percent of the mining concessions (under the *pertenencia* and *cuadricula* modalities), equivalent to 32 percent of the territory under concession, is at an altitude of more than 4,000 meters above sea level. As can be seen in figure 5.5, in the case of mining claims under the *pertenencia* modality, most of the number of actual claims and most of the surface under a mining claim is above 4,000 meters.

**Figure 5.5 Altitudinal distribution of mining concessions**




Source: Author.

By creating an overlay of mining concessions and protected areas, it can be seen that at the end of 2011, 267,400 hectares of the total territory granted in concession for mining purposes were located within protected areas – 14,500 hectares more than was the case in 2010. The evolution of mining concessions granted in protected areas nationwide is shown in table 5.2. The analysis also demonstrates there are two protected areas in which a particularly notable increase in land under mining concessions can be noted: the Cotapata National Park, which is intended to protect a Yunga cloud forest in the province of La Paz, and the Apolobamba Natural Integrated Management Area. The statistics indicate that the surface areas under mining claims in Cotapata and Apolobamba have increased by 45 percent and 20 percent, respectively, compared to 2010. By late 2011, 9.1 percent of Cotapata National Park and 16.5 percent of the Apolobamba Natural Integrated Management Area had been granted in concession.

**Table 5.2 Evolution of mining concessions in protected areas nationwide**

| | | Area under concession (ha) | |
|---|---|---|---|
| National protected areas under concession | Total area (ha) | 2010 | 2011 |
| National Reserve of Andine Fauna | 678,386 | 9,740 | 9,437 |
| National Reserve of Flora and Fauna | 247,589 | 0 | 0 |
| Biological Reserve | 106,828 | 0 | 0 |
| Natural Management Area | 5,799,886 | 210,736 | 222,836 |
| National Park and Area of Integrated Nature Management | 322,371 | 4,956 | 6,694 |
| National Park | 7,245,260 | 26,411 | 27,192 |
| Wildlife Refuge | 212 | 0 | 0 |
| Biosphere Reserve | 133,948 | 0 | 0 |
| National Park and Indigenous Territory | 1,291,110 | 987 | 987 |
| Biosphere Reserve and Idigenous Territory | 385,859 | 0 | 0 |
| National Reserve of Amazon Wildlife | 739,683 | 49 | 116 |
| *Total* | *16,951,132* | *252,879* | *267,262* |

Source: Author.

## 5.3 Watershed Prioritization

In order to prioritize level 5 HUs, an evaluation matrix was used. The matrix took into account the relative importance of these HUs with respect to population density, agricultural production, the poverty index, and land surface under protective regime. To each variable a value was assigned, as indicated in table 5.3. The final indicator of this importance dimension was a weighted average of the values assigned to each variable. In this case, a weight of 30 percent was assigned to population density and food security, and a weight of 20 percent was assigned to the poverty level and the portion of the HU under protection. The values assigned to each HU regarding its social and agricultural importance, and whether it is part of a protected area, are shown in figure 5.6.

**Table 5.3 Values assigned to the variables under the importance dimension**

| Assigned value | Population density ($km^2$/ha) | Population 2010 | Agricultural area (ha) | Percentage of protected area | Poverty index |
|---|---|---|---|---|---|
| 1 | < 1.0 | < 100 | < 10 | < 0.1% | < 60% |
| 2 | 1.0–5.0 | 100–1,000 | 10–100 | 0.1–1.0% | 60–70% |
| 3 | 5.0–15.0 | 1,000–10,000 | 100–1,000 | 1.0–10.0% | 70–80% |
| 4 | 15.0–75.0 | 10,000–100,000 | 1,000–10,000 | 10.0–50.0% | 80–90% |
| 5 | 75.0–180.0 | 100,000–1,000,000 | 10,000–100,000 | 50.0–99.5% | 90–98% |
| 6 | > 180.0 | > 1,000,000 | > 100,000 | > 99.5% | > 98% |

Source: Author.

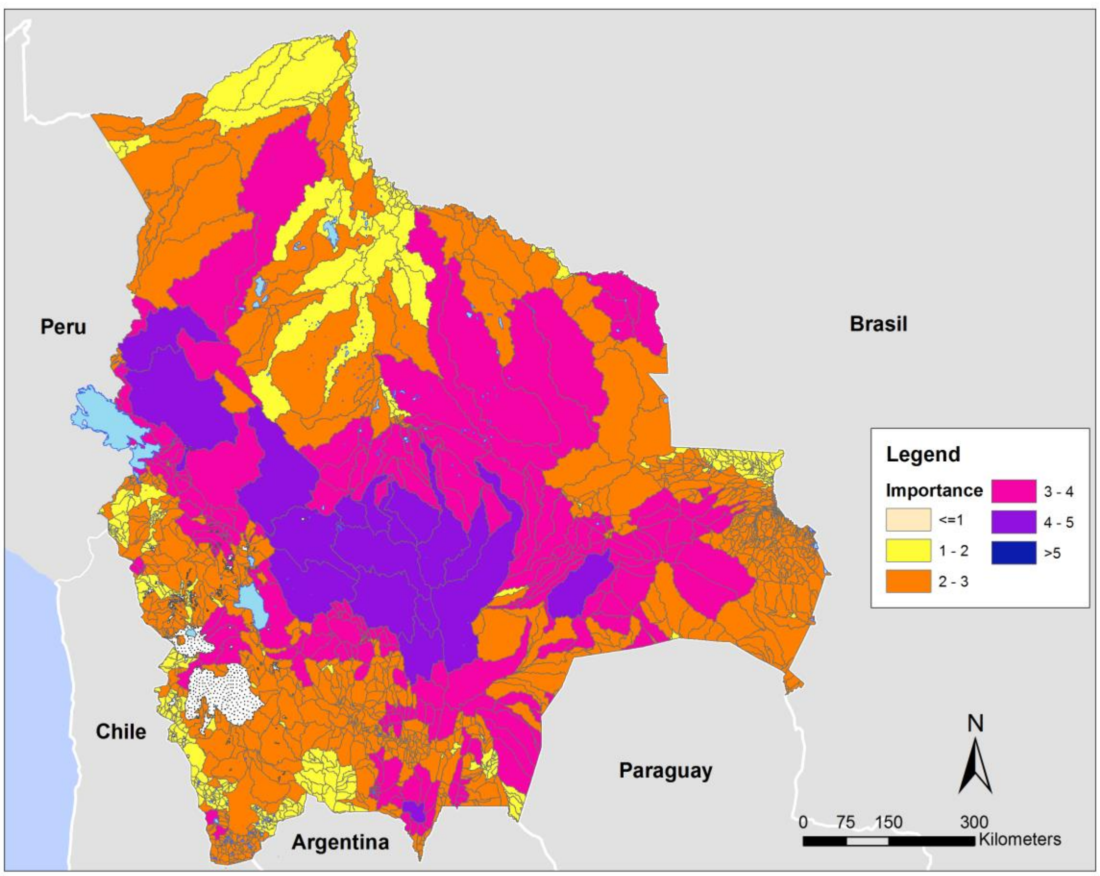
The other dimension of the matrix takes into account the situation regarding water and mining. It shows the availability of water resources, the percentage of land in the HU granted in concession, and the average runoff from mining areas in the HU's drainage network. As was the case earlier, to each variable a value was assigned, as indicated in table 5.4. The final indicator was a weighted average of the values assigned to each variable. In this case, a weight of 20 percent was assigned to the availability of water resources, a weight of 30 percent was assigned to the percentage of land under concession, and a weight of 50 percent went to the average runoff coming from mining areas. The values assigned to each HU regarding the dimension water/mining are shown in figure 5.7. In order to establish a nationwide prioritization among level 5 HUs from a mining perspective, the matrix shown in figure 5.8 was used. The results of the prioritization are displayed in figure 5.9.

**Table 5.4 Values assigned to the variables under the water/mining dimension**

| Value | Contribution by mining areas | Percentage under concession | Water availability ($m^3$/capita) |
|---|---|---|---|
| 1 | < 0.001% | < 0.1% | > 10,000 |
| 2 | 0.001–0.01% | 0.1–10% | 5,000–10,000 |
| 3 | 0.01–0.05% | 10–25% | 3,000–5,000 |
| 4 | 0.05–0.09% | 25–50% | 2,000–3,000 |
| 5 | 0.09–1.0% | 50–80% | 1,000–2,000 |
| 6 | > 1.0% | > 80% | < 1,000 |

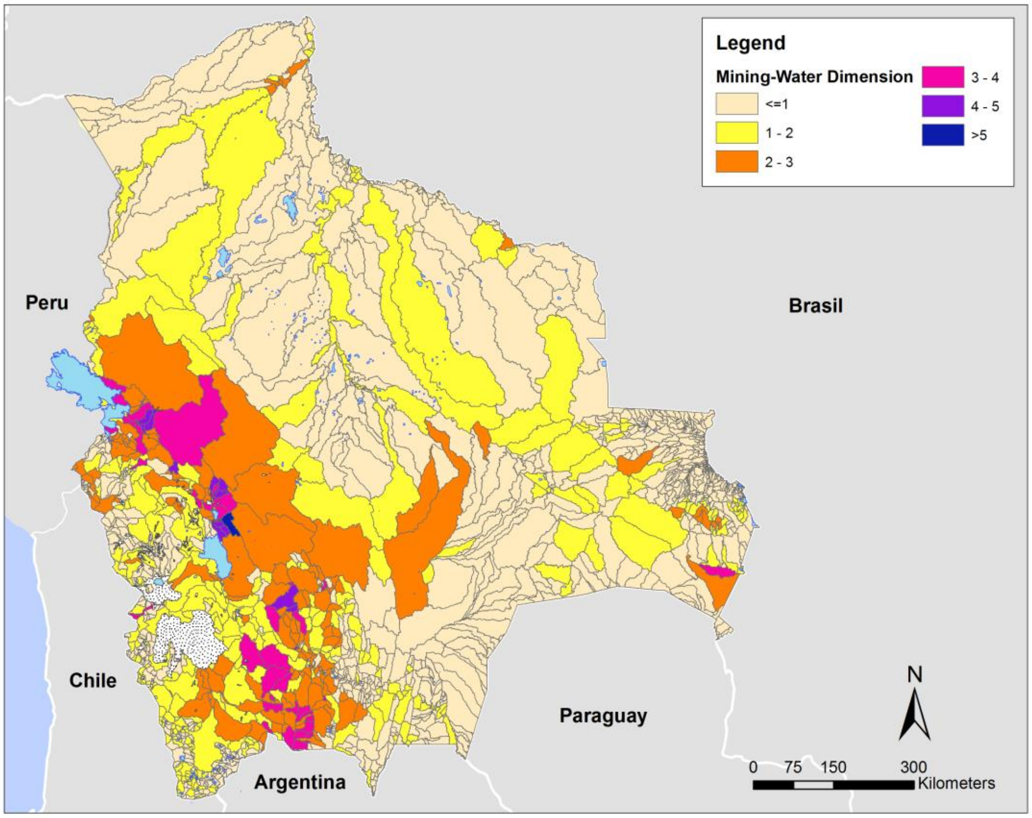
Source: Author.

**Figure 5.6 Values assigned to the importance dimension by level 5 HU**



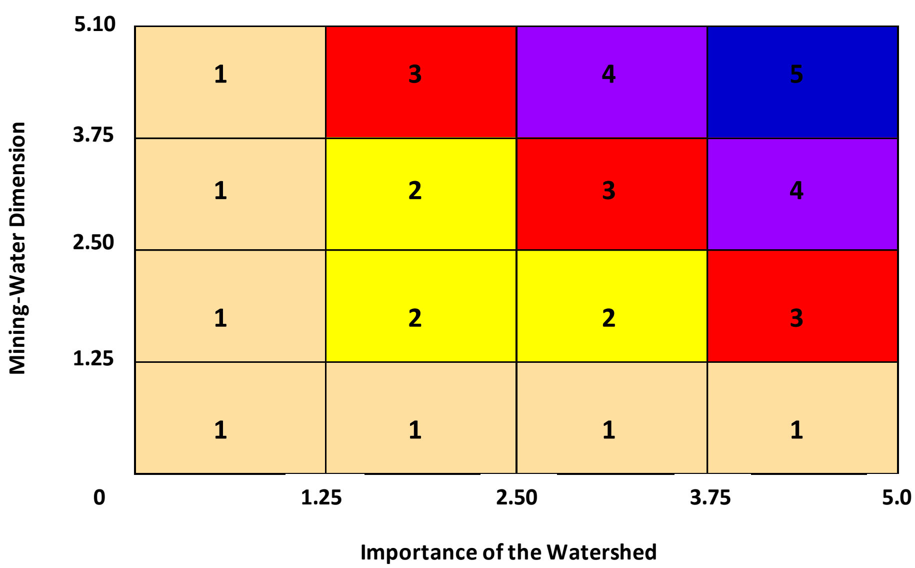

Source: Author.

### Figure 5.7 Value assigned to the water/mining dimension by level 5 HU




Source: Author.

### Figure 5.8 Prioritization matrix

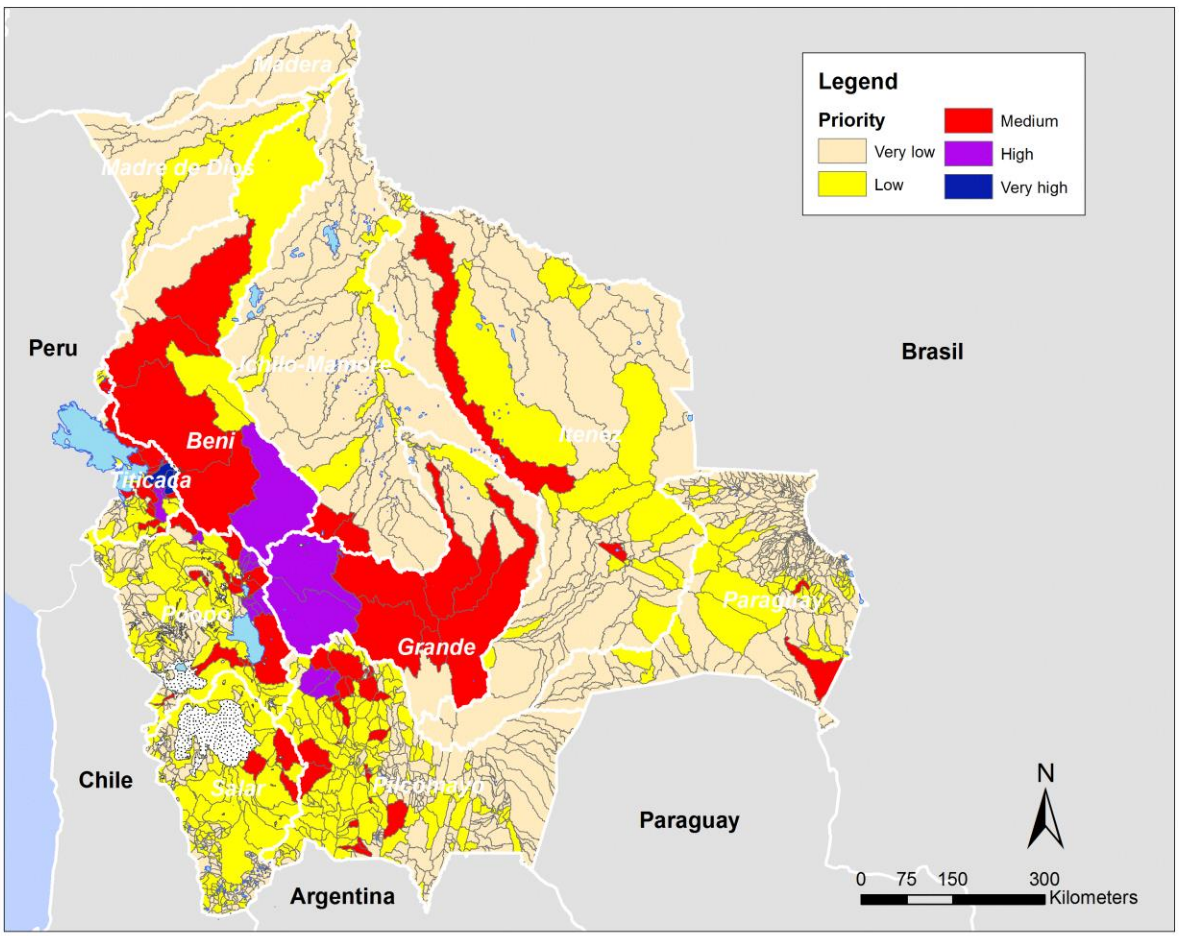



Source: Author.

As can be seen in figure 5.9, the priority level 5 HUs from a mining perspective and using a watershed perspective are located in the Lake Titicaca and Lake Poopó macrobasin, and at the headwaters of the macrobasins of the Beni, Pilcomayo, and Grande Rivers. It is in these HUs that close coordination between the Ministry of Mining and Metallurgy and the Ministry of Environment and Water needs to be promoted, for the purpose of planning sustainable use of water resources and developing specific programs.

Multiple types of analysis are possible with the use of the Mining-Environmental Information Platform, depending on the political question of interest. Box 5.3 shows an additional application of the tool.

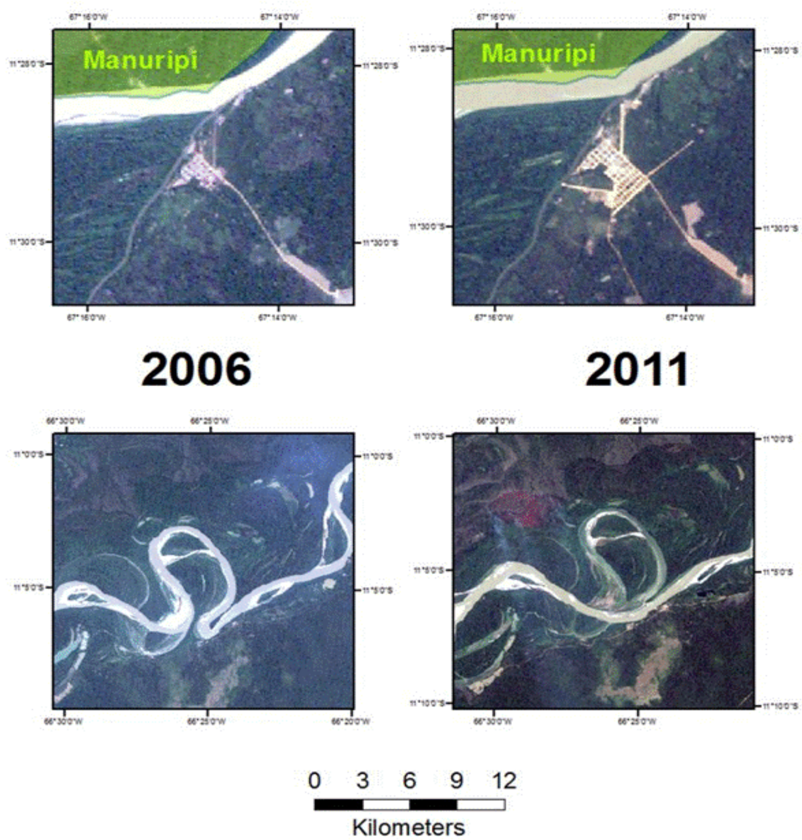
**Figure 5.9 Hierarchy of level 5 catchment basins in terms of mining activities**




Source: Author.

**Box 5.3 Monitoring impacts of mining activities in protected areas from space**

Imagery from earth observation satellites can be used to monitor environmental degradation of remote locations with a relatively low investment. Satellite imagery can be used to evaluate changes in land use, including the intrusion of economic activities in protected areas, rain forests, or high-elevation puna grassland (*bofedales*). As part of this study, freely available satellite images were acquired from the Landsat series of satellites (NASA/USGS) between 2006 and 2011. These images were analyzed using standardized analytical models and tools to evaluate changes in vegetation cover in protected areas associated with mining concessions. A preliminary analysis of vegetation cover change using the normalized difference vegetation index (NDVI) reveals numerous areas of change between the years 2006 and 2011. Satellite images of change detected through differencing of NDVI data are shown below. All images are from the Landsat 5 TM and downloaded from http://glovis.usgs.gov courtesy of the USGS. These true-color images highlight the ability to detect change using remotely sensed data: the top image shows human settlement expansion on the edge of a national park, the bottom image shows an example of a natural environmental change detected through remote sensing.




Landsat imagery can be incorporated into environmental management platforms to determine the location and scale of land cover change, as well as direct more intense investigation of environmental degradation through either higher-resolution satellite imagery or in situ investigation.

Source: Author.

## 5.4 Conclusions

This study reveals the necessity to coordinate national guidelines and policies for integrated watershed management, where plans prepared by each of the different sectors involved in the watershed are integrated and coordinated; and the necessity that mining activities have in place environmental management systems. Further, the study reveals the need to define the areas in which mining activities are prohibited, such as the drainage areas of reservoirs – not only due to possible impact on the quality of water used for drinking and irrigation, but also in order to avoid the sedimentation and siltation of dams. The study further reveals the need to restrict mining in protected areas, especially those that contain rain forests and wetlands. The use of these rapid diagnostic tools does not, however, replace the need for a strategic environmental and social assessment of the watershed or environmental impact assessments of mining projects. Finally, the study demonstrates how valuable it is to have on hand systematized spatial information.

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# Annex A

## Annex A1. Analytical Framework for Estimating the Burden of Diarrheal Disease

Fewtrell and Colford (2004) use results from Prüss et al. (2002), which provide a framework for estimating the burden of diarrheal disease from water, sanitation, and hygiene (table A1.1). Prüss et al. applied this framework to estimate the global burden of diarrheal disease, but it can also be applied to estimate the benefits and costs of improved water supply and sanitation.

The interpretation of figures in table A1.1 is described briefly. The table shows that the risk of diarrheal illness in a situation of no improved water supply and no basic sanitation (scenario VI) is 60 percent higher ([11.0–6.9]/6.9) than in a situation with improved water supply and basic sanitation (scenario IV). The risk of diarrheal illness in a situation with improved water supply and basic sanitation (scenario IV) is 2.75 times higher (6.9/2.5) than in a situation with regulated water supply, full sanitation coverage, and partial treatment for sewage (scenario II). The risk of diarrheal illness in a situation of no improved water supply and no basic sanitation (scenario VI) is 4.4 times higher (11.0/2.5) than in a situation with regulated water supply, full sanitation coverage, and partial treatment for sewage (scenario II).[45]

**Table A1.1 Selected exposure scenarios**

| Scenario/ situation | Description | Pathogen load | Relative risk (RR) |
|---|---|---|---|
| VI | NO IMPROVED WATER SUPPLY AND NO BASIC SANITATION in a country that is not extensively covered by those services, and where water supply is not routinely controlled | Very high | 11.0 |
| Vb | IMPROVED WATER SUPPLY and no basic sanitation in a country that is not extensively covered by those services, and where water supply is not routinely controlled | Very high | 8.7 |
| Va | BASIC SANITATION but no improved water supply in a country that is not extensively covered by those services, and where water supply is not routinely controlled | High | 6.9 |
| IV | IMPROVED WATER SUPPLY AND BASIC SANITATION in a country that is not extensively covered by those services, and where water supply is not routinely controlled | High | 6.9 |
| IIIc | IV and improved access to drinking water (generally piped to household) | High | - |
| IIIb | IV and improved personal hygiene | High | 4.5 |
| IIIa | IV and drinking water disinfected at point of use | High | 3.8 |
| II | Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically found in developed countries | Medium to low | 2.5 |
| I | Ideal situation, corresponding to the absence of transmission of diarrheal disease through water, sanitation, and hygiene | Low | 1.0 |

*Source:* Based on Prüss et al. 2002.

[45] Scenario II corresponds to the situation typically found in developed countries.

According to the *Global Burden of Disease 2002* (WHO 2002), diarrheal incidence (cases per person per year) in most developing regions of the world is 3 to 5 times higher than in North America and high-income countries in Europe, and as much as 6 times higher in Sub-Saharan Africa. These figures are relatively consistent with table A1.1, suggesting that most developing countries are somewhere in the range of scenarios IV to VI. These figures represent averages, and there are larger variations that reflect the inequalities in water and sanitation coverage within each developing country, with some parts of the population being closer to scenario II.

Prüss et al. (2002) derived the relative risks of diarrheal illness from the international literature (table A1.2). The expected reductions in diarrheal illness from the provision of improved water supply, basic sanitation facilities, or both water supply and basic sanitation are from Esrey 1996 and supported by the results in Esrey et al. 1991. Prüss et al. identify the risk transition between scenarios IV and II as the more "data-scarce" transition between the scenarios in table A1.2. According to Prüss et al., there are no intervention studies that fully describe this transition. The authors therefore rely on a staged approach by applying results from the international literature that describe selected characteristics of the difference between scenarios IV and II, such as improved personal hygiene (scenario IIIb) and improved water quality (scenario IIIa). Among personal hygiene improvements, handwashing is often found to be the single most effective intervention to reduce disease transmission. Prüss et al. use the results from a review of studies of handwashing by Huttly et al. (1997) to indicate the reduction in diarrheal illness from scenarios IV to IIIb. For water quality improvements, Prüss et al. apply the results from a study by Quick et al. (1999), who found a 45 percent reduction in diarrheal illness from point of use water disinfection. The combined results of Huttly et al. and Quick et al. were then used to arrive at the expected reduction in diarrheal illness from scenarios IV to II.[46]

To assess the magnitude of diarrheal illness (between scenario II, typically found in developed countries, and scenario I) that is transmitted through water, sanitation, and hygiene, Prüss et al. deduct the share of diarrheal illness that is found to be foodborne in the United States, and a likely share that might be transmitted through aerosols.[47] This approach suggests that 60 percent of diarrheal illness in a scenario II situation is related to water, sanitation, and hygiene, and is therefore the expected reduction in diarrheal illness from scenarios II to I.

The percentage reductions in diarrheal illness shown in table A1.2 correspond to the relative risks presented in table A1.1. For instance, the difference in relative risk between scenarios IV and II is 6.9–2.5, which corresponds to about a 65 percent reduction [(6.9–2.5)/6.9] from scenarios IV to II.

Therefore, as in Fewtrell and Colford 2004, the attributable fraction (AF) or impact fraction of health effects (diarrheal disease) from water, sanitation, and hygiene is estimated using the following equation:

$$AF = \left(\sum p_i RR_i - 1\right)/\sum p_i RR_i,$$

where $p_i$ is a fraction of population under each scenario, and

$RR_i$ are relative risks of diarrheal disease for scenario I from table A1.1.

[46] The reduction in diarrheal illness from the combined results of Huttly et al. (1997) and Quick et al (1999) is calculated by $1-[(1-0.35)(1-0.45)] = 0.65$, as applied by Prüss et al.

[47] Mead et al. (1999) found that 35 percent of intestinal illness is foodborne in the United States.

Population distribution with regard to different situations for water supply and sanitation in Bolivia is presented in table A1.3.

**Table A1.2 Reductions in diarrheal illness used by Prüss et al.**

| Scenario progression | | Reduction in diarrheal illness | Source |
|---|---|---|---|
| From VI to Vb | Providing improved water supply | 20.8% | Esrey 1996 |
| From VI to Va | Providing basic sanitation facilities | 37.5% | Esrey 1996 |
| From VI to IV | Providing improved water supply and basic sanitation facilities | 37.5% | Esrey 1996 |
| From IV to IIIb | Improved personal hygiene | 35% | Huttly et al. 1997 |
| From IV to IIIa | Disinfection of drinking water at point of use | 45% | Quick et al. 1999 |
| From IV to II | Regulated water supply and full sanitation coverage, with partial treatment of sewage | 65% | Combined results from Huttly et al. 1997 and Quick et al. 1999 |
| From II to I | Absence of transmission of diarrheal disease through water, sanitation, and hygiene | 60% | Using results from Mead et al. 1999 |

Source: Author.

**Table A1.3 Population distribution for drinking water supply and sanitation**

| | Urban | Rural | La Paz | Oruro | Potosí | Chuquisaca | Cochabamba | Tarija | Santa Cruz | Beni | Pando |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No S, no W | 6 | 27 | 13 | 17 | 14 | 18 | 20 | 8 | 5 | 30 | 37 |
| No S, W | 34 | 65 | 36 | 49 | 58 | 43 | 24 | 33 | 30 | 5 | 0 |
| S, no W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| S, W | 21 | 34 | 23 | 19 | 18 | 19 | 31 | 29 | 35 | 40 | 42 |
| Piped water in household | 39 | 4 | 28 | 15 | 10 | 20 | 25 | 30 | 30 | 25 | 16 |
| Disinfection | 3.5 | 10.2 | 5.4 | 11.5 | 4.9 | 4.6 | 9.1 | 3.8 | 1.9 | 25.1 | 14 |

W: improved water supply, S: improved sanitation. Estimated based on DHS 2008.

Source: Author.

Using Fewtrell and Colford 2004 and data from table A1.2, the average AF in Bolivia for urban areas was estimated at 85 percent and for rural areas at 88 percent of the total diarrheal disease burden. The resulting attributable fractions are then multiplied by the disease burden – in terms of incidence, mortality, or disability-adjusted life years (DALYs) – to estimate the diarrheal disease burden that could be attributed to inadequate drinking water supply and sanitation:

Attributable disease burden of diarrhea (incidence, deaths, or DALYs)

= Attributable fraction x total disease burden of diarrhea (incidence, deaths, or DALYs).

## Annex A2. Baseline Data to Estimate Morbidity Costs

Baseline data for the cost estimates related to morbidity are presented in table A2.1. The percentage of diarrheal cases in the population older than 5 years who are treated at medical facilities is estimated from the percentage of treated cases among children (average in DHS surveys in the Latin America and Caribbean (LAC) region) and the ratio of treated cases among children under age 5 to treated cases among the population above age 5 from Ministry of Health 2002, i.e. 92 percent.

**Table A2.1 Baseline data for cost estimation**

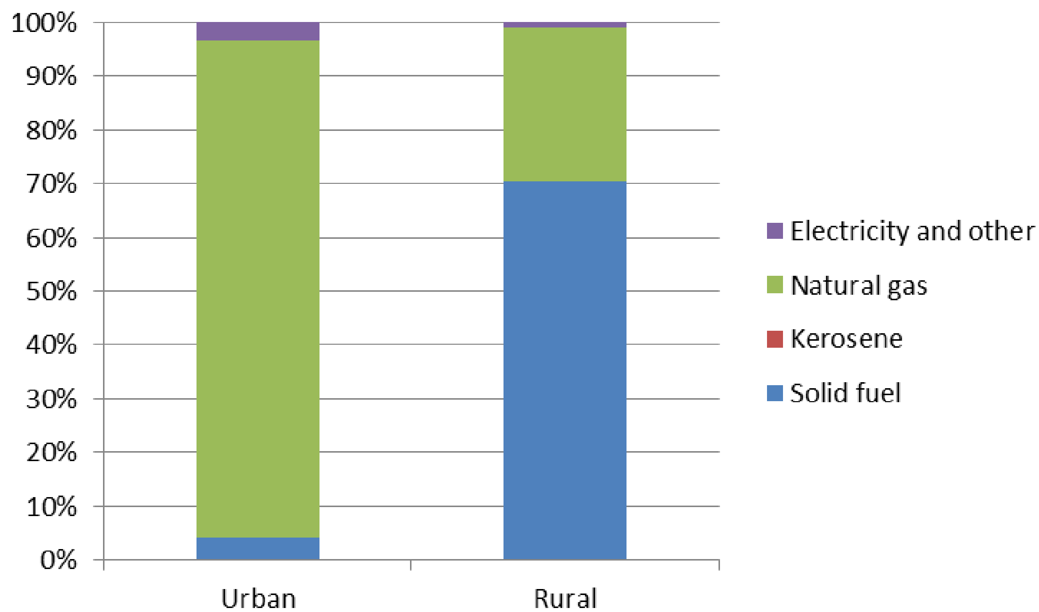
| | Baseline | Source |
|---|---|---|
| Percent of diarrheal cases treated at medical facilities (children < 5 years) | 41–55% | DHS 2008 |
| Percent of diarrheal cases treated with medicines | 32–43% | DHS 2008 |
| Percent of diarrheal cases treated with oral rehydration salts (ORS) (children < 5 years) | 41–47% | DHS 2008 |
| Percent of diarrheal cases treated at medical facilities (population > 5 years) and with medicines | 25–40% | Estimated from Ministry of Health 2009 and average LAC DHS surveys |
| Average cost of doctor visits (urban and rural) (Bs.) | 35–28 | Per consultations with pharmacies, medical service providers, and health authorities |
| Average cost of medicines for diarrheal treatment (Bs.) | 50–30 | |
| Average cost of ORS per diarrheal case in children (Bs.) | 5–6 | |
| Average duration of diarrheal illness in days (children and adults) | 3–4 | Assumption |
| Hours per day of caregiving per case of diarrhea in children | 2 | Assumption |
| Hours per day lost to illness per case of diarrhea in adults | 2 | Assumption |
| Value of time for adults (caregiving and ill adults): Bs./hour | 24 | Based on average wages in Bolivia |
| Hospitalization rate (% of all diarrheal cases): children under 5 years | 2% | Based on Ministry of Health data on hospitalization for intestinal disease |
| Average length of hospitalization (days) | 2 | Adjusted from Larsen 2004 |
| Time spent on visitation (hours per day) | 4 | Assumption |
| Average cost of hospitalization (Bs. per day) | 140 | Per consultations with hospitals |
| Percent of diarrheal cases attributable to water, sanitation, and hygiene | 85–88% | Author estimates |

Source: Author.

## Annex A3. Prevention and Treatment Costs

**Boiling of water.** DHS 2008 reports that about 3 percent of the urban population and 9 percent of the rural population boil drinking water, either all the time or sometimes. Figure A3.1 presents the fuel mix used by households in Bolivia for cooking in both urban and rural areas. Natural gas is the main fuel in urban areas and solid fuel is the main source in rural areas. Table A3.1 presents the estimated annual costs of boiling water for those households by type of household cooking energy used in Bolivia, totaling Bs. 9 million to 17 million per year or about 0.01 percent of GDP in 2009. It is about 10 times lower than in other Latin America countries due to the low share of people who practice disinfection and to subsidized natural gas prices. If UNICEF (2011) estimates of the share of the population that boils drinking water are applied, then averting behavior costs would be Bs. 23 million to 43 million. However, this estimate was not applied due to difficulties of primary data verification.

**Figure A3.1 Fuel mix for cooking in Bolivia**




*Source:* DHS 2008.

It is assumed that the average daily consumption of drinking water per person is 0.5 to 1.0 liters among households that boil water. The residential cost of natural gas and liquefied petroleum gas (LPG) is estimated based on data from the National Hydrocarbons Agency (table A3.2). The residential cost of fuelwood was estimated from consultant Juan José Miranda's discussions with local experts. The average stove efficiency is significantly higher for LPG and for natural gas than for fuelwood. Tables A3.3 to A3.5 presents results on water treatment methods from a UNICEF study of rural Bolivian communities (UNICEF 2011).

### Table A3.1 Estimated annual cost of boiling drinking water

| | Urban | | Rural | |
|---|---|---|---|---|
| | "Low" | "High" | "Low" | "High" |
| Households using natural gas and LPG | 1.5 | 3 | 1 | 1.5 |
| Households using other energy types (mainly fuelwood) | 0.5 | 1 | 6 | 11.5 |
| Total annual cost | 2 | 4 | 7 | 13 |

*Source:* Author estimates.

### Table A3.2 Baseline data for cost estimation

| | Urban | Rural | Notes |
|---|---|---|---|
| Percent of households that boil their drinking water | 3% | 9% | ssumption |
| Average daily consumption of drinking water | 0.5–1.0 | | Liters per person per day |
| Percent of households using natural gas and LPG | 92% | 30% | DHS 2008 |
| Percent of households using solid fuel | 7% | 70% | |
| Energy requirement for heating water (100% efficiency) | 4,200 | | Joules/ltr/1°C |
| Average fuelwood–natural gas stove efficiency for heating water | 25–50% | | Varies by type of stove |
| Average time to boil water (after water reaches boiling point) | 10 | | Minutes |
| Cost of LPG | 25 | | Bs./10 kg bottle |
| Cost of fuelwood | 1 | | Bs./kg |

*Source:* Author estimates.

### Table A3.3 Water treatment in Andean communities

| Method | % of use |
|---|---|
| Boiling water | 14% |
| Solar disinfection (SODIS method) | 6% |
| No treatment conducted | 74% |

*Source:* UNICEF 2011, p. 25.

**Table A3.4 Water treatment in Amazonian communities**

| Method | % of use |
|---|---|
| Filtering water through a cloth | 21% |
| Boiling water | 13% |
| Chlorinating water | 7% |
| Using ceramic filter | 5% |
| Letting water rest | 3% |
| Solar disinfection (SODIS method) | 2% |
| No treatment conducted | 55% |

*Source:* UNICEF 2011, p. 39.

**Table A3.5 Water treatment in Chaco communities**

| Method | % of use |
|---|---|
| Boiling water | 12% |
| No treatment conducted | 88% |

*Source:* UNICEF 2011, p. 54.

***Interview conducted in the zone of El Alto (La Paz, Bolivia) on March 13, 2011***

***Interviewee: A woman approximately 50 years old, working as a saleswoman in a shop***

**Water use and treatment**

- The main source of water is rainwater. The drinking water plant also uses rainwater (and treats it with lime).
- If drinking water from the public network is not available, well water is commonly used.
- When there is a public water supply system, or when there is no water (dry seasons, usually from May to September), water (as well as rainwater) can be purchased from a tanker truck. The cost of a "turril" (200-liter barrel) is Bs. 5.
- In distant zones, the use of turrils is quite common.
- Water is also boiled, but it is not a common practice. It is more common to draw water directly from a well, with no treatment.

- For households with wells, some buy limestone, which keeps the water clean. It is not known how long lime use in wells lasts.
- At a hardware store near the interviewee, the person in charge mentioned that a piece of limestone lasting one year in a well costs Bs. 30.

**Treatment of diarrhea**

- It is common to treat diarrhea with water in which rice and cinnamon have been boiled (home remedy).
- Another treatment using medications includes purchasing tablets at the pharmacy. One takes three tablets per day, for a total of two days. Each tablet costs Bs. 2. The name of the tablet is not known.
- Another hospital treatment is the use of oral rehydration packets. This treatment is for a total of three days. When these packets are available, they can be obtained at no cost. However, going to the hospital (30 minutes) and waiting to be treated discourage people from going to the hospital.
- The interviewee's perception is that there is more diarrhea in the dry season and that children drinking from baby bottles are more likely to get diarrhea because the nipples are contaminated.

***Interview conducted on the road to Lake Titicaca (La Paz, Bolivia), March 13, 2011***

***Interviewee: A man approximately 60 years old, working as a hotel taxi driver***

**Treatment of diarrhea**

- The man has a tank and drinking water in his home. However, when he has signs of diarrhea he takes Estreptocarbocaftiazol. Just one pill eliminates diarrhea.
- He does not purchase the medication because his daughter, a pharmacist, gives it to him.
- Other treatments for diarrhea include drinking anise or chamomile tea. For children, a common treatment is rice water.

**Water use and treatment**

- The man has a tank and drinking water in his home. He usually pays Bs. 20 to 25 per month for water service. His monthly consumption is about 15 to 20 cubic meters. He has a water meter.
- Gas tanks are commonly used for cooking. The cost of a gas tank is Bs. 22.50 and it lasts about 20 days.
- Firewood is commonly used in rural areas. This is usually found in the countryside so there is no cost (besides the time involved). In urban areas, firewood costs Bs. 10 to15 and lasts one day.

***Survey on water and diarrhea treatment (March 17, 2011)***

**Table A3.6 Diarrhea treatment**

| Diarrhea treatment | Unit price (Bs.) | Units per day | No. of days | Total cost (Bs.) |
|---|---|---|---|---|
| *Pharmacy/Drugstore A* | | | | |
| 1) Estreptocarbocaftiazol | 2 | 3 | 1 | 6 |
| 2) Oral rehydration packet | 2 | 1 | 1 | 2 |
| *Pharmacy/Drugstore B* | | | | |
| 1) Estreptocarbocaftiazol | 2 | 2 | 3 | 12 |
| 2) Oral rehydration packet | 2 | 1 | 3 | 6 |
| 3) Florastor (for mild treatment) | 10 | 2 | 3 | 60 |
| 4) Clotrimazol (for strong treatment) | 1 | 2 | 5 | 10 |
| *Pharmacy/Drugstore C* | | | | |
| 1) Estreptocarbocaftiazol | 2 | 4 | 2 | 16 |
| 2) Loperamide | 1 | 1 | 3 | 3 |

Source: Author.

## Water treatment

Drugstores/pharmacies and hardware stores (approximately 10) were asked about the sale of filters, chlorine, bleach, or lime for water treatment. However, none of these entities sells such products. Moreover, it was mentioned that few people use them. Therefore, it was decided to ask people (water users, approximately six people), and the only treatment they mentioned was water boiling.

It was mentioned that a "fardo" (bundle) of firewood costs Bs. 15 to 20 and lasts one to two days.

## Annex A4. Cost-Effectiveness Analysis

Several meta-analyses have recently been conducted on the international evidence of the effectiveness of interventions in the water, sanitation, and hygiene sector in reducing diarrheal illness and thus diarrheal mortality.[48] Household point of use drinking water treatment and handwashing with soap are generally found to be most effective in reducing diarrheal illness, followed by sanitation, especially in rural areas. Table A4.1 presents the results of the latest available meta-analyses. Table A4.2 presents the intervention effectiveness applied in the report.

**Table A4.1 Results of latest available meta-analyses**

| Intervention | Reduction of diarrheal cases | Range |
|---|---|---|
| Water supply improvement | 2% | 10–(–6)% |
| Point of use water supply | 21% | 37–2% |
| Source water supply | 5% | 10–0% |
| Water quality | 42% | 50–33% |
| Point of use water quality | 44% | 52–35% |
| Source water quality | 21% | 38–(–2)% |
| Storage device provided | 34% | 44–23% |
| Sanitation | 37% | 57–7% |
| Sewer connection | 31% | 62–(–26)% |
| Latrine provision | 34% | 58–(–1)% |
| Hygiene | 31% | 39–23% |
| Soap provision | 37% | 49–21% |
| Education | 27% | 37–16% |
| Multiple interventions | 38% | 54–17% |
| Water supply + sanitation/hygiene | 19% | 30–6% |
| Water quality + sanitation/hygiene | 57% | 67–45% |

*Source:* Adapted from Waddington et al. 2009.

The framework by Prüss et al. (2002) is used in this report to estimate the health effects and costs of interventions to reduce diarrheal illness in Bolivia. Two aspects of the framework have been modified to accommodate various combinations of the scenarios and not necessarily be limited to the sequence of pathogen load reductions used by Prüss et al. The relative risks are modified to reflect the more recent findings of relative risks in the meta-analysis study by Fewtrell and Colford (2004) presented in table A4.2, the meta-analysis study of handwashing by Curtis and Cairncross (2003), and the study by Waddington et al. (2009).

48 Diarrheal mortality is assumed to decline in proportion to the reduction in the incidence of diarrheal illness.

The first modification to the framework presented by Prüss et al. is to distinguish between households that disinfect their drinking water at point of use and those households that do not disinfect their drinking water.

**Table A4.2 Reductions in diarrheal illness applied in this report**

| Scenario progression | Intervention | Reduction in diarrheal Illness | Source |
|---|---|---|---|
| From VI to Vb | Providing improved water supply | 20.8–25% | Esrey 1996; Fewtrell et al. 2005 |
| From VI to Va | Providing basic sanitation facilities | 37–37.5% | Esrey 1996; Waddington et al. 2009 |
| From VI to IV | Providing improved water supply and basic sanitation facilities | 19–37.5% | Esrey 1996; Waddington et al. 2009 |
| From IV to IIIc | Improved access to drinking water (generally piped to household) with no source treatment | 5% | Waddington et al. 2009 |
| From IV to IIIb | Improved personal hygiene | 31–43% | Huttly et al. 1997; Curtis and Cairncross 2003; Waddington et al. 2009 |
| From IV to IIId | Improved access to drinking water (generally piped to household) with source treatment | 21% | Waddington et al. 2009 |
| Each scenario with D | Disinfection of drinking water at point of use | 30–50% | Waddington et al. 2009 |
| From II to I | Absence of transmission of diarrheal disease through water, sanitation, and hygiene | 60% | Using results from Mead et al. 1999 |

*Source:* Modified from Fewtrell and Colford, 2004.

The second modification is to distinguish between households with piped water supply that is treated at the source (water treatment plant) and those with piped water that is not treated at the source. Additional scenarios are added in table A4.3.

To allow for a comparison with Prüss et al. 2002, the relative risk for scenario VI without point of use disinfection is also 11.0. The relative risks in Vb and Va are derived by multiplying the relative risk in VI by the relevant relative risk ratios in table A4.3. As in Prüss et al., there is no difference between Va and IV. The difference between IV and IIId is a relative risk ratio of 0.95, reported in Waddington et al. 2009 for household water supply connection. The difference between IIId and IIIc is the relative risk ratio of 0.79 estimated fromtable A4.3. The relative risk for IIIc and IIId is assumed to be the same if drinking water is disinfected at point of use.

Scenario II, typically found in developed countries, is not included in table A4.3. Providing this level of service (including partial sewage treatment) to the entire urban and rural population in developing countries is likely to be very costly. The cost-effectiveness analysis in this report therefore focuses on improved water supply and basic sanitation to those segments of the population without these services. The definition of basic services is presented in table A4.4.

In order to use the data in table A4.3 to estimate the population shares in each of the scenarios, a set of allocation "rules" was applied. These rules are presented in table A4.5. Population distribution with regard to these rules is presented in table A4.6.

**Table A4.3 Relative risk of diarrheal illness associated with different scenarios of water supply and sanitation provision**

| | Intervention | RR |
|---|---|---|
| Scenario VI | No improved WS, no basic S, and no D | 11.0 |
| Scenario VI with D | D but no improved WS and no basic S | 7.1 |
| Scenario Vb | Improved WS but no basic S and no D | 8.7 |
| Scenario Vb with D | D and improved WS but no basic S | 5.7 |
| Scenario Va | Basic S but no improved W, and no D | 6.9 |
| Scenario Va with D | D and basic S but no improved WS | 4.5 |
| Scenario IV | Improved WS and basic S but no D | 6.9 |
| Scenario IV with D | Improved WS and basic S, and D | 4.5 |
| Scenario IIIc and no D | WS piped to household (no source treatment) and no D | 6.5 |
| Scenario IIIc with D | WS piped to household (no source treatment) and D | 4.6 |
| Scenario IIId and no D | WS piped to household (with source treatment) and no D | 5.5 |
| Scenario IIId with D | WS piped to household (with source treatment) and D | 3.8 |

WS: drinking water supply, S: sanitation, D: point of use drinking water disinfection.

*Sources:* Fewtrell et al. 2005; Waddington et al. 2009.

Author estimates.

**Table A4.4 Definition of basic water supply and sanitation services**

| Basic water supply services | Basic sanitation services |
|---|---|
| Unprotected well<br>Unprotected spring<br>Vendor-provided water<br>Bottled water<br>Water provided by tanker truck<br>Rivers, canals, ditches | No facilities<br>Service or bucket latrines (where excreta are manually removed)<br>Public latrines<br>Latrine with an open pit |

*Source:* WHO and UNICEF 2000.

Ministry of Environment and Water data (2009) were used to provide an estimate of the population share with treated piped water supply (30 percent). The analysis assumed that point of use disinfection is conducted by the same share of population in each scenario situation (3.5 percent in urban areas and

10.2 percent in rural areas). Earlier in this report, the number of diarrheal illness cases in Bolivia based on the Bolivia DHS 2008 survey was estimated at close to 13 million, or close to 1.1 to 1.6 cases per person (table A4.7).

**Table A4.5 Scenario allocation rules**

| Scenario/ situation | Allocation rule |
|---|---|
| VI | The lesser of population share without improved water supply and without basic sanitation |
| Vb | The difference between population share without basic sanitation and without improved water, if difference is > 0 |
| Va | The difference between population share without improved water supply and without basic sanitation, if difference is > 0 |
| IV | The lesser of population share with improved water supply and basic sanitation minus the population share with piped water |
| IIIc | Population share with piped water supply and no source treatment |
| IIId | Population share with piped water supply and source treatment |

Source: Author.

**Table A4.6 Population distribution with regard to drinking water supply and sanitation**

| | Urban | Rural |
|---|---|---|
| No S, no W | 6 | 27 |
| No S, W | 3 | 30 |
| S, no W | 0 | 0 |
| S, W | 52 | 42 |
| Piped water into household | 39 | 4 |
| Point of use disinfection | 3.5 | 10.2 |

W: improved water supply, S: basic sanitation. Estimated based on DHS 2008.

**Table A4.7 Estimated annual cases of diarrheal illness in Bolivia, 2008**

| | National | Urban | Rural |
|---|---|---|---|
| 2-week diarrheal prevalence (children < 5 years) | 26% | 23.6% | 29.1% |
| Total annual diarrheal cases | 13.3 | 7.8 | 5.6 |
| Diarrheal cases per person | 1.3 | 1.1 | 1.6 |

*Source:* Estimated using DHS 2008.

Estimated annual cases of diarrheal illness per person per year in Bolivia is estimated for scenarios IIId to VI from the relative risks in table A4.3,[49] the scenario population distribution in table A4.6, and the average diarrheal cases per person in table A4.7 (separately for urban and rural population). Table A4.8 shows that diarrheal cases per person average 0.4 in households that have piped water supply and basic

[49] Scenarios I and II, which correspond to a regulated water supply and full sanitation coverage with partial sewage treatment, correspond to a situation that typically occurs in developed countries and is nonexistent in Bolivia.

sanitation and practice drinking water disinfection, and 1.9 per year in households that lack improved water supply and basic sanitation and do not practice drinking water disinfection in urban areas. For the rural population (table A4.9), the range is 0.5 to 2.2.

**Table A4.8 Estimated annual cases of diarrheal illness per person in urban Bolivia**

| Scenario/ situation | Description | Without point of use disinfection | With point of use disinfection |
|---|---|---|---|
| VI | No improved water supply and no basic sanitation | 1.7 | 1.1 |
| Vb | Improved water supply and no basic sanitation | 1.3 | 0.8 |
| Va | Basic sanitation but no improved water supply | 1.0 | 0.6 |
| IV | Improved water supply and basic sanitation | 1.0 | 0.6 |
| IIId | IV and water supply piped to household (no source treatment) | 0.9 | 0.4 |
| IIIc | IV and water supply piped to household (source treatment) | 0.8 | 0.4 |

*Source:* Author estimates.

**Table A4.9 Estimated annual cases of diarrheal illness per person in rural Bolivia**

| Scenario/ situation | Description | Without point of use disinfection | With point of use disinfection |
|---|---|---|---|
| VI | No improved water supply and no basic sanitation | 2.2 | 1.3 |
| Vb | Improved water supply and no basic sanitation | 1.7 | 1.0 |
| Va | Basic sanitation but no improved water supply | 1.3 | 0.8 |
| IV | Improved water supply and basic sanitation | 1.3 | 0.8 |
| IIId | IV and water supply piped to household (no source treatment) | 1.2 | 0.5 |
| IIIc | IV and water supply piped to household (source treatment) | 1.0 | 0.5 |

*Source:* Author estimates.

The health effects of a particular intervention, k, in population group i are given by the following set of equations:

$$IR_{ik} = IR_i * \beta_k \quad (1)$$

$$IR_i = IR_{baseline} * (RR_i - 1) \quad (2)$$

$$H_{ik} = IR_{ik} * P_{ik} \quad (3)$$

where $H_{ik}$ is the health effect of the intervention (diarrheal morbidity reduction from diarrheal illness reduction); $\beta_k$ is the percentage reduction in estimated health effects of water, sanitation, and hygiene from the intervention; $IRi$ is an incidence rate of diarrheal illness in group $I$; $H_{ik}$ is the health effects of water, sanitation, and hygiene in intervention group $k$, with $RR_i$ in table A4.4; $P_{ik}$ is the intervention $k$ population in group $i$. IR baseline is estimated by applying the result of the scenario analysis in Bolivia, taking into account average cases of diarrhea per person in Bolivia.[50] In terms of specific interventions, $\beta = 0.3–0.5$ for water disinfection at point of use, $\beta = 0.05$ for piped water with no source treatment,

[50] 1.1 cases/person/year in urban areas and 1.6 cases/person/year in rural areas, as estimated in Strukova 2011.

$\beta = 0.21$ for piped water with water treatment at the source, $\beta = 0.37$ for improved toilet facilities, and $\beta = 0.23$ for improved water supply (table A4.3).

## Annex A5. Reduction of Diarrheal Incidence

**Table A5.1 Annual reduction of diarrheal incidence per person**

| Provision of improved or piped water supply | | | | |
|---|---|---|---|---|
| Scenarios | Urban/no disinfection | Urban with disinfection | Rural/no disinfection | Rural with disinfection |
| VI to Vb | 0.4 | 0.3 | 0.5 | 0.3 |
| VI to IIId | 0.8 | 0.5 | 1 | 0.8 |
| VI to IIIc | 0.9 | 0.5 | 1.2 | 0.8 |
| Provision of sanitation | | | | |
| VI to Va | 0.7 | 0.5 | 0.9 | 0.5 |
| Vb to IV | 0.3 | 0.2 | 0.4 | 0.2 |

*Source:* Author estimates.

Table A5.2 presents the target population for each scenario, estimated by applying data on interventions in urban and rural areas from tables 1.9 and 1.10.

**Table A5.2 Targeted population for each intervention scenario (number of people)**

| Scenarios | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| *Provision of improved or piped water supply* | | | | |
| *Urban* | | | | |
| VI to Vb | 70,549 | 82,302 | 96,096 | 98,120 |
| VI to IIId | 19,585 | 31,648 | 29,650 | 63,716 |
| VI to IIIc | 19,585 | 31,648 | 29,650 | 63,716 |
| *Rural* | | | | |
| VI to Vb | 0 | 5,764 | 0 | 0 |
| VI to IIId | 30,600 | 57,786 | 5,470 | 0 |
| VI to IIIc | 30,600 | 57,786 | 5,470 | 0 |
| *Provision of sanitation* | | | | |
| *Urban* | | | | |
| VI to Va | 8,432 | 19,289 | 29,695 | 74,861 |
| Vb to IV | 73,399 | 72,028 | 119,571 | 147,978 |
| *Rural* | | | | |
| VI to Va | 0 | 200 | 0 | 0 |
| Vb to IV | 33,120 | 53,942 | 22,917 | 0 |

*Source:* Author estimates.

## Annex A6. Malnutrition in Bolivia

Studies in different low-income countries with similar water supply, sanitation, and hygiene problems suggest that measures to reduce environmental damages are justified in a number of areas on cost-benefit grounds as well on grounds of benefiting the poor. For water supply and sanitation, improvements in facilities in rural areas yield benefits in excess of costs under most assumptions. In urban areas the focus should be on the monitoring of drinking water and on the rehabilitation of piped water supply and sewerage systems. The programs are justified on the grounds that the benefits are concentrated primarily among the poor. Hygiene programs have estimated benefits far in excess of costs and should receive the highest priority. The same applies for programs to encourage disinfection of drinking water. All interventions to improve water supply, sanitation, and hygiene also have the benefit of reducing the burden of malnutrition.

### Malnutrition and Water Supply, Sanitation, and Hygiene

Measuring the burden of disease and subsequent economic costs from environmental health risks is important in helping policy makers to better integrate environmental health into economic development, and specifically in their decisions related to resource allocation among various programs and activities to improve child health. Building on previous estimates, and due to the linkages among environmental health, malnutrition, and disease, WHO recently revised the burden-of-disease estimates, taking into account malnutrition-mediated health impacts associated with inadequate water and sanitation provisions, and improper hygiene practices (Fewtrell et al. 2007).

The new WHO estimates reveal that the environmental health burden in children under the age of 5 is substantially higher when all linkages through malnutrition, especially in those subregions where malnutrition and poor environmental conditions coexist, are incorporated. In a study of the linkage between the global disease burden and the environment (Prüss-Üstün and Corvalán 2006), it was estimated that 50 percent of malnutrition is attributable to the environment, essentially to water, sanitation, and hygiene (pooled expert opinion based on literature review).

Blössner and de Onis (2005) presented a methodology to quantify the burden of disease associated with malnutrition. To quantify the impact of malnutrition, it is necessary to factor in population data of weight for age (WA) in children and the disease burden (deaths, incidence, and DALYs) of infectious diseases and protein-energy malnutrition (PEM). For Bolivia, such information may be obtained from DHS 2008 and WHO deaths, incidence, and DALYs tables from WHO 2008.

The basic method applied to estimate the consequences of malnutrition in terms of health impact from infectious diseases in children under the age of 5 consists of the following steps (Blössner and de Onis 2005; Fishman et al. 2004):

- Estimation of the number of children with a WA below -2 standard deviations (SD) of the mean;
- Estimation of fractions of mortality due to diarrheal disease, malaria, measles, lower respiratory infections, other infectious diseases (besides HIV) and PEM that are attributable to malnutrition, based on relative risks from the literature;
- Calculation of the disease burden attributable to malnutrition by multiplying mortality, incidence, and DALY statistics with attributable fractions.

Fishman et al. (2004) present estimates of increased risk of cause-specific mortality and all-cause mortality in children under age 5 with mild, moderate, and severe underweight from a review of available studies. Severely underweight children (WA < -3 SD) are 5 times more likely to die from measles, 8 times more likely to die from acute lower respiratory infections (ALRI), nearly 10 times more likely to die from malaria, and 12 times more likely to die from diarrhea than non-underweight children (WA > -1 SD). Even mild underweight doubles the risk of death from major diseases in early childhood.

Child underweight also increases the risk of illness. Fishman et al. (2004) present estimates of increased risk in children under the age of 5 with moderate and severe underweight (WA < -2 SD). The largest increased risk of illness is for pneumonia/ALRI. No increased risk of measles is confirmed (tables A6.1 and A6.2).

**Table A6.1 Relative risk of mortality from mild, moderate, and severe underweight in children under age 5**

| Weight for age (WA) | < -3 SD | -2 to -3 SD | -1 to -2 SD | > -1 SD |
|---|---|---|---|---|
| Pneumonia/ALRI | 8.1 | 4.0 | 2.0 | 1.0 |
| Diarrhea | 12.5 | 5.4 | 2.3 | 1.0 |
| Measles | 5.2 | 3.0 | 1.7 | 1.0 |
| Malaria | 9.5 | 4.5 | 2.1 | 1.0 |
| All-cause | 8.7 | 4.2 | 2.1 | 1.0 |

*Source:* Fishman et al. 2004.

**Table A6.2 Relative risk of illness from moderate and severe underweight in children under age 5**

| Weight for age (WA) | < -2 SD | > -2 SD |
|---|---|---|
| Pneumonia/ALRI | 1.86 | 1.0 |
| Diarrhea | 1.23 | 1.0 |
| Measles | 1.00 | 1.0 |
| Malaria | 1.31 | 1.0 |

*Source:* Fishman et al. 2004.

The WA prevalence rates and the relative risks of cause-specific mortality can be used to estimate the population-attributable fractions (AF) of mortality from underweight in children under age 5:

$$AF = \left(\sum_{i=1}^{n} P_i RR_i - 1\right) / \sum_{i=1}^{n} P_i RR_i \qquad (1)$$

where $RR_i$ is the relative risk of mortality for each of the four WA categories (i) in table AII.2; and P is the percentage of children in each of the four categories (i). The results indicate that 20 to 25 percent of under-5 child mortality from pneumonia/ALRI, diarrhea, measles, malaria, and other causes of mortality is due to underweight in Bolivia.

In addition to these malnutrition-related mortalities, Fishman et al. (2004) include 100 percent of PEM mortality and a share of mortality from perinatal conditions (low birth weight associated with low maternal pre-pregnancy body mass index, BMI < 20 $kg/m^2$). About 9 percent of infants had low birth weight (< 2,500 g) in Bolivia in 2008 (DHS 2008).

The application of the relative risks of illness and WA malnutrition rates to (1) indicates that about 10 percent of pneumonia/ALRI mortality and 11 to 12 percent of diarrhea and malaria mortality in children under age 5 in Bolivia are from malnutrition (table A6.3).

**Table A6.3 Attributable fractions of under-5 child mortality and morbidity from underweight**

| | Mortality | Morbidity |
|---|---|---|
| Pneumonia/ALRI | 10% | 1.7% |
| Diarrhea | 12% | 0.5% |
| Malaria | 11% | 0% |
| Measles | N/A | N/A |
| Protein-energy malnutrition (PEM) | 100% | 100% |
| Other causes | 10% | N/A |

*Source:* Estimated in this report.

Table A6.4 presents the deaths and incidence of diseases among children under the age of 5 that could be associated with malnutrition. Since mortality, incidence, and DALYs from diarrheal and lower respiratory diseases in children were already counted as an impact of inadequate water supply, sanitation, and hygiene and indoor air pollution, only other diseases were included in the costs of malnutrition.

**Table A6.4 Annual mortality and morbidity among children under age 5 that could be associated with malnutrition**

| | Morbidity (cases) | Mortality (cases) |
|---|---|---|
| Diarrheal diseases | 86,730 | 292 |
| Malaria | 70 | 0 |
| Lower respiratory infections | 893,347 | 289 |
| Protein-energy malnutrition | 137,283 | 181 |
| Other[51] | | 307 |
| Total | 1,117,431 | 1,070 |

*Source:* Estimated using Blössner and de Onis 2005.

[51] Other diseases include "communicable, maternal, perinatal and nutritional conditions (group I)" after subtraction of the deaths/incidences listed for 0–4 year olds for HIV/AIDS (code 09), diarrheal diseases (code 10), measles (code 15), malaria (code 20), lower respiratory infections (code 39), perinatal conditions (code 49), and nutritional deficiencies (code 53) (Blössner and de Onis 2005).

# Annex B

## Annex B1. Contractual Modalities

**Minor Contract** (CM in Spanish): The procedure is simple; it is started through a solicitation of three proposals, and it is awarded to the best qualified. This type of contract is used mainly for punctual and short-term projects, and the maximum budget assigned is Bs. 20,000.

**National Support for Production and Employment Contract** (Apoyo Nacional a la Producción y Empleo, ANPE): Allows the free participation of an undefined number of bidders, supporting production and employment on a national level. The maximum contracting amount is the limiting factor for implementing solid waste management operations; but additional funds can be used for the elaboration of preliminary studies in the preinvestment stage or in a postinvestment stage for the implementation of a specific strategy (trainings, pilot composting plants, etc.). This type of contract is the most frequently used, probably due to the easy requirements and procedures for preinvestment and institutional strengthening activities.

**Public Bid** (Licitación Pública, LP): A way of contracting goods and services when the price is over Bs. 1,000,000. It allows the participation of an undefined number of applicants, and there exist two types of calls: National Call (amounts from Bs. 1,000,000 to Bs. 40,000,000) and International Public Call (for amounts over Bs. 40,000,000). This modality can be used for the various stages of implementation, from the prefeasibility to the operation of the service itself.

**Direct Contracting for Goods and Services** (Contratación Directa de Bienes y Servicios, CD): This modality allows direct contracting of goods and services without price limits, only and exclusively for public services: electric energy, water, and other similar services.

**Emergency Contracting** (Contratación por Emergencia, EM): It is used by public entities to contract goods and services, exclusively in response to disasters or emergencies on a national, departmental, or municipal level.

**Contracting by Exception:** Allows contracting for goods and services only in case of exceptions: when there exists only one provider for the contracting of goods, works, and general services, only if these cannot be substituted with similar goods or services of a generic brand; or when consulting services require a level of experience and specialization that can only be performed by one consultant or consulting firm.

**Contracting with Specific Objectives**

**Contracting with Applicant Financing:** The contracting entity establishes for the bidder to offer the provision of goods and construction of works with a partial or total financial proposal, in order to cover the investment on its own or through a third party. There are no examples applicable to the solid waste management sector, but it might be an interesting alternative when the public municipal budget does not allow the covering of some operations in the provision of service.

**Turnkey Contracts:** Conceptually, this is contracting through which an applicant offers a finished work, which includes the design, construction, and start-up of installations, equipment, training, or intellectual and technological transfer.[52] The Turnkey modality can be included in any of the Specific Contracting options, namely LP, ANPE, CD, since the concept is related to the form of project execution, independently from the contract type.

**Contracts Performed in Foreign Countries:** The contracts performed by the Government Representations of the Plurinational State of Bolivia in foreign countries should be established in the Specific Rules, on the basis of principles established in the current Basic Norms of the System for Administration of Goods and Services (NBSABS in Spanish), together with the acceptable practices of the country of residence. This contractual modality has not been yet applied in Bolivia for service provision in solid waste management.

**Leasing:** Contract by which the Owner gives a Tenant the right to use a good in exchange of the payment of leasing fees over a set time span, after which the tenant has the option of buying the good through the payment of a set price, give it back, or renew the contract. The leasing will cover the lack of funds budgeted for public instances, such as municipal governments and municipal solid waste management companies, when their resources are not sufficient to buy an asset (equipment or machinery).

### Contracting by a Financing Organism

Additionally, other modalities are in place, defined by the financing organism or norm, which relate to the characteristics observed in table B1.1.

**Table B1.1 Contracting by financing organism**

| CUCE[53] | Solicitor | Contractual model | Contract number | Object |
|---|---|---|---|---|
| -0041-00-139070-1-1 | Ministerio de Desarrollo Productivo y Economía Plural | OF | PP/002/2009 | Solicitud de expresiones de interes consultoria "Formulacion del programa municipal de gestión integral de residuos solidos y diseño de servicios de aseo urbano con proyecto a diseño final para los municipios de Copacabana, Tihuanacu, Achacachi y Tiquina" |
| 09-0041-00-141409-1-1 | Ministerio de Desarrollo Productivo y Economía Plural | OF | CI-003/2009 | Contratación de consultor individial "especialista en residuos solidos" |

Source: Author.

[52] It can have various denominations, such as lump sum, or design and build (DB) contract.

[53] Unique Code for State Contracting (Codigo Unico de Contrataciones Estadales).

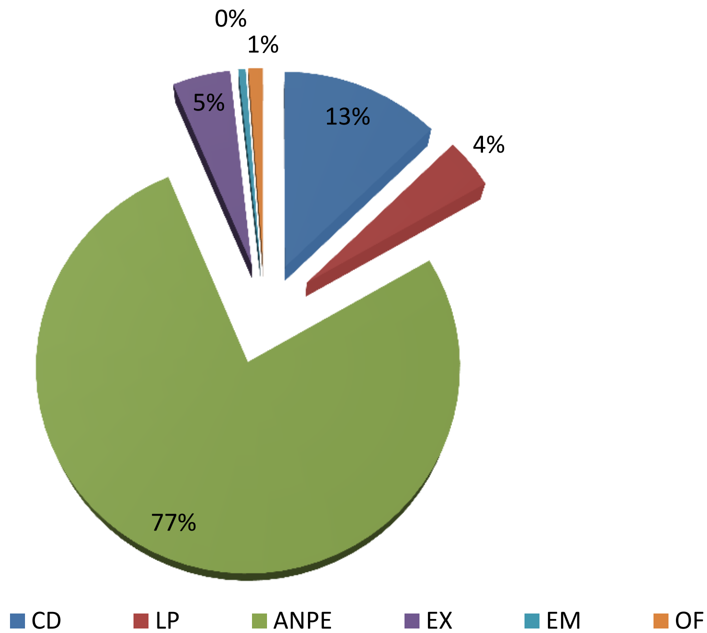
## Types of Contracts for Urban Solid Waste Management

Generally three forms of contracting can be identified or are being used in Bolivia for solid waste:

- Service contract for microenterprises
- Service contract for specialized enterprises
- Concession contract for specialized enterprises.

Figure B1.1 gives a breakdown of the types of contracts used in Bolivia in recent years.

**Figure B1.1 Contractual models executed in Bolivia, June 2009 to May 2012**




*Source:* Self-elaboration from www.sicoes.gob.bo data.

# Annex C

## Annex C1. Distributive Analysis

**Table C1.1 Distributive analysis of Cochabamba ('000 US$)**

| | Assumptions regarding rates | | |
|---|---|---|---|
| | Government subsidies 100% | Irrigation rate = O&M, government subsidies, investments | Irrigation rate covering the total costs |
| Fiscal impact | | | |
| Taxes | | | |
| Investment | 724 | 724 | 724 |
| Operation and maintenance | 174 | 174 | 174 |
| Total taxes | 899 | 899 | 899 |
| Subsidies and transfers | | | |
| Investment | 6,296 | 6,296 | - |
| Operation and maintenance | 1,515 | - | - |
| Total subsidies and transfers | 7,811 | 6,296 | - |
| Total fiscal impact | (6,912) | (5,397) | 899 |
| *Existing farmers* | | | |
| Incremental rate to be paid | - | (983) | (5,066) |
| Gaining existing land | 6,357 | 6,357 | 6,357 |
| Subtotal existing farmers | 6,357 | 5,374 | 1,291 |
| *Existing famers* | | | |
| Incremental rate to be paid | - | (320) | (1,647) |
| Gaining existing land | 3,840 | 3,840 | 3,840 |
| Subtotal existing famers | 3,840 | 3,520 | 2,192 |
| *New farmers* | | | |
| Incremental rate to be paid | - | (213) | (1,098) |
| Gains obtained service land | 2,976 | 2,976 | 2,976 |
| Subtotal new farmers | 2,976 | 2,763 | 1,878 |
| Total gain of benefited land | 13,173 | 11,658 | 5,362 |
| Other beneficiaries | | | |
| Other farmers | 2,563 | 2,563 | 2,563 |
| Providers in other sectors | 1,278 | 1,278 | 1,278 |
| Subtotal without government | 17,014 | 15,498 | 9,203 |
| Net benefit for society | 10,101 | 10,101 | 10,101 |

Source: Author.

**Table C1.2 Distributive analysis of Tarija ('000 US$)**

| | Assumptions regarding rates | | |
|---|---|---|---|
| | Government subsidies 100% | Irrigation rate = O&M, Government subsidies, investments | Irrigation rate covering the total costs |
| *Fiscal impact* | | | |
| Taxes | | | |
| Investment | 342 | 342 | 342 |
| Operation and maintenance | 102 | 102 | 102 |
| Total taxes | 444 | 444 | 444 |
| Subsidies | | | |
| Investment | 2,977 | 2,977 | - |
| Operation and maintenance | 885 | - | - |
| Total subsidies | 3,862 | 2,977 | - |
| Total fiscal impact | (3,418) | (2,533) | 444 |
| Agricultural land | | | |
| Payments for rates | - | (885) | (3,862) |
| Gain | 9,078 | 9,078 | 9,078 |
| Subtotal | 9,078 | 8,192 | 5,215 |
| Other beneficiaries | | | |
| Other farmers | 3,052 | 3,052 | 3,052 |
| Providers, other sectors | 1,522 | 1,522 | 1,522 |
| Total without government | 13,652 | 12,766 | 9,789 |
| Net benefit for society | 10,234 | 10,234 | 10,234 |

Source: Author.

# Annex D

## Annex D1. Overview of the cooperative mining sector in Bolivia

Data on cooperative mining are not easy accessible in Bolivia and no comprehensive database exists providing a basic overview of the cooperative mining sector. Therefore, it has been difficult to establish a clear overview of the sector due to the lack of availability of such basic information as the size of the cooperative mines, their processing techniques and levels of productivity, how many people are employed, or in some cases even what minerals they exploit. This annex provides some of the information that was possible to collect from different public sources and field visits.

The lack of transparent and easily accessible data is particularly a challenge for alluvial and hard rock gold mining, as most gold mining is commercialized informally. However, some sort of distinction of the different cooperatives is important to provide adequate technological solutions to the different forms of mining as well as their different levels of capacity, size, and processing techniques.

**Table D1.1 Gold mining cooperatives**

| Mining type | Technology and technical level | Size and financial resources | Environmental impact |
|---|---|---|---|
| Hard rock mining I (type: Cero Hermosa) | Manual and basic technology applied<br>Low-cost and often inadequate processing techniques<br>Very limited knowledge of environmental and health impacts<br>Second-hand equipment bought from other mines | Small size and limited productivity<br>Small cooperatives with basic organization<br>No workers employed<br>Complementing other income-generating activities | The small size makes the impact from each cooperative relatively small but can have a significant impact in regions with many cooperatives<br>Inappropriate use of mercury and other chemicals |
| Hard rock mining II (type: Rayo Rojo/Cotapata) | Mechanized operation with more advanced and mechanized processing techniques<br>Relatively well organized<br>Some knowledge of environmental impacts such as mercury use and tailings | Medium-sized operations<br>Workers and day laborers contracted | Tailings, mercury, and water contamination are among key environmental challenges |
| Alluvial mining I (type: Palca and some smaller mining areas in Guanay) | Often manual work in primitive tunnels in river catchment or using small pumps along the rivers<br>Exploration of alluvial deposits in river catchments and rivers beaches | Artisanal miners or small cooperatives often based on individual and family mining<br>Limited incomes complementing or substituting traditional agricultural activities<br>No workers | Rapid degradation of vulnerable ecosystems such as riverbeds<br>Contamination of important water resources |

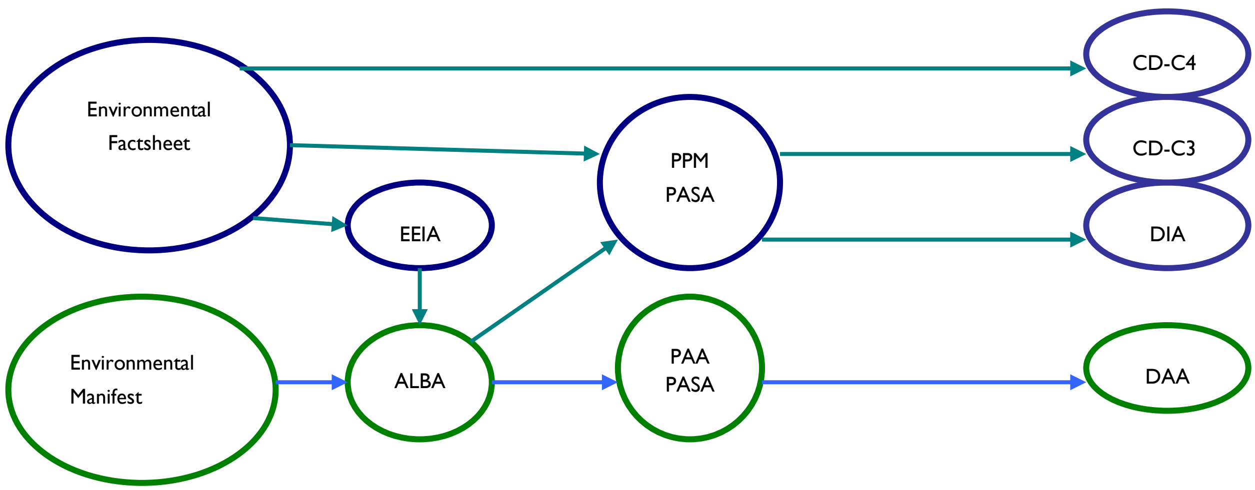
| | | | |
|---|---|---|---|
| Alluvial mining II (type: Suches and Larejaca | Use of heavy equipment (bulldozers, shovel loaders, dump trucks, etc.)<br>Use of sluice boxes, amalgation using drums or small cement mixers and retorts | Medium-sized operations<br>Using equipment that needs up-front investment<br>Have workers and day laborers | More adequate use of amalgamation process but could still be improved<br>Significant degradation of landscape and important river catchment<br>Remaining material, mud, and tailing dumped in rivers<br>Use of high quantities of water<br>Mercury contamination observed in some regions but not all |
| Alluvial mining III (type: Rio Madre de Dios) | Use of simple *balsas* (pontoons made out of floaters and wood)<br>Use of hoses and 4-cylinder diesel engines for the pumps<br>Use of amalgamation process and retorts | | Impacts on rivers and riverbeds<br>Contamination of the rivers<br>Impacts on local biodiversity |

*Sources:* Own elaboration based on field visits; Bocangel 2001; Carillos et al. 2011.

The development of mining cooperatives has faced two periods of rapid expansion. The first period was from 1985 to 1990, when national mines were closed and many workers formed cooperatives working COMIBOL's concessions. The second period is from 2005 to the present day, when a 600 percent increase in gold prices within a decade has resulted in an even faster expansion of cooperative mining than in the mid-1980s.

Obtaining an environmental license is a complex process with many technical requirements. Though an increasing interest has been observed from many cooperatives mines, the requirements are often difficult to comply with. Cooperatives with available financial resources often contract environmental engineers to elaborate the requested information but with limited institutionalization and ownership of the environmental license afterwards. The process is more or less equal for all cooperatives but four different categories exist, where only category I mines needs to get the DIA license. Despite these different categories, obtaining a license is a relatively complicated and expensive process for small cooperatives with limited incomes and located in remote regions of the country.

**Figure D1.1 Environmental licensing process**

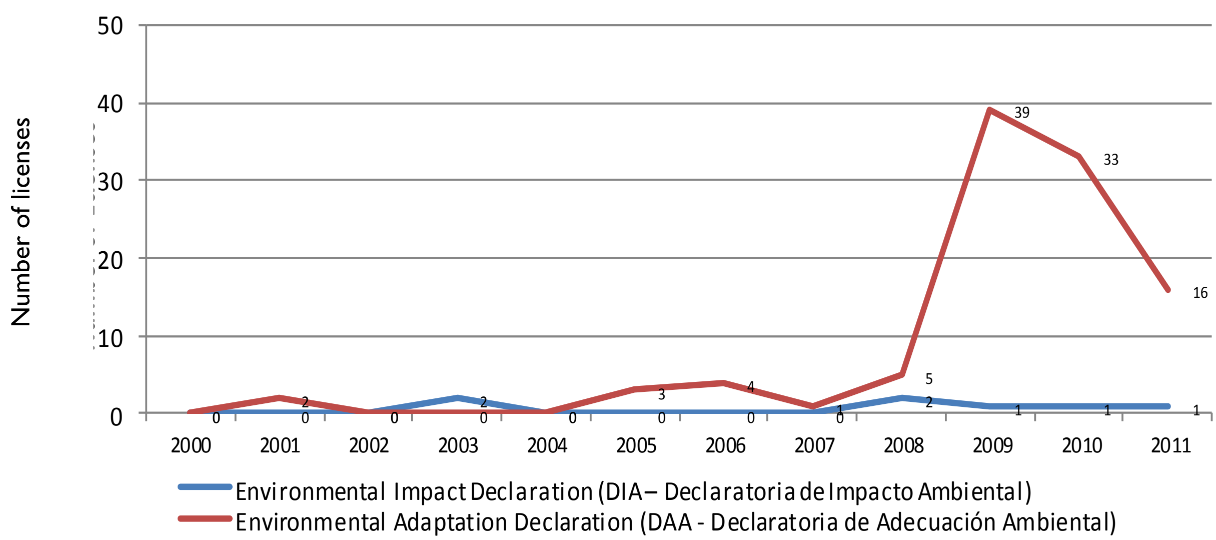



*Note:* The figure uses the following abbreviations in Spanish: EEIA (Environmental Impact Evaluation Study), ALBA (Environmental Baseline Audit), PPM-PASA (Program of Environmental Prevention, Mitigation and Monitoring), PAA-PASA (Plan for Adequate Environmental Planning and Monitoring), CD-C3 (Certification of Dispensation of Category 3), CD-C4 (Certification of Dispensation of Category 4), DIA (Environmental Impact Declaration), DAA (Environmental Adaptation Declaration, *Declaratoria de Adecuación Ambiental*).

Source: Pinto and Terceros 2012.

The qualitative interviews and the increasing numbers of cooperatives that have initiated the process toward obtaining environmental licenses indicate that many cooperative are interested in improving their environmental management. As most cooperatives need to get the DAA license, this is the one with a rapid development trend.

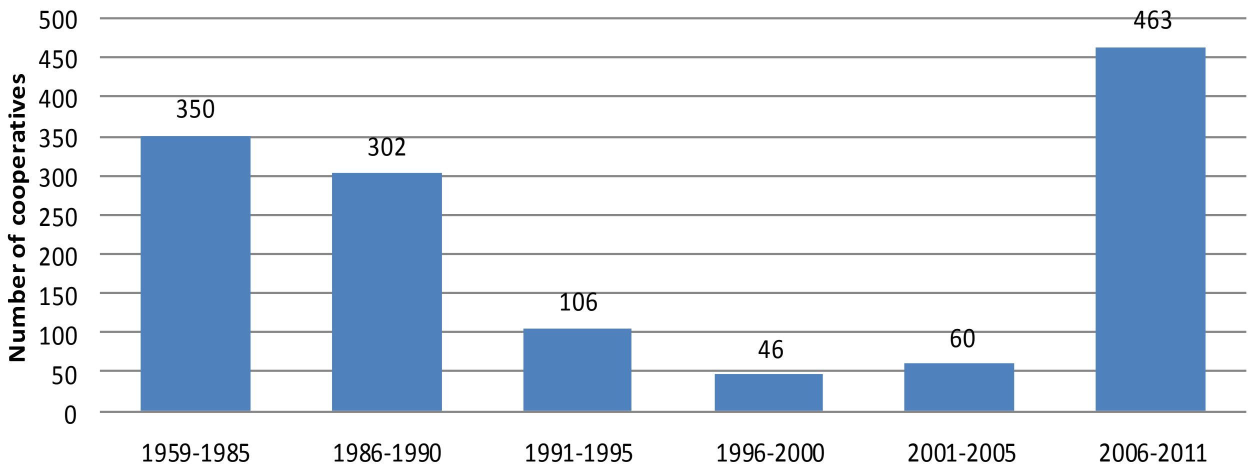
**Figure D1.2 Environmental licenses issued for mining cooperatives 2000–2011**




*Source:* Pinto and Terceros 2012, based on information from SERGEOTECMIN and Ministry of Mining and Metallurgy.

The cooperative mining sector can be divided into six categories. The database lacks details about size of the cooperative, processing techniques, and productivity, and approximately one third have not even registered what minerals they exploit. In consultations with the Ministry of Mining and Metallurgy, the study considers the nonspecified mines as gold mining cooperatives, as most are located in Larecaja province, department of La Paz.

**Figure D1.3 Historical registration of mining cooperatives**




*Source:* Authors' elaboration based on information from SERGEOTECMIN and Ministry of Mining and Metallurgy, reported in Pinto and Terceros 2012.

## Annex D2. Methodology

The study has been prepared in close collaboration with the Ministry of Mining and Metallurgy and Ministry of Environment and Water. Field visits have been coordinated with regional and national mining cooperatives through FENCOMIN. The research team highly appreciates the support provided by the authorities and the hospitality of mining cooperatives.

Field visits were made to two regions dominated by gold mining cooperatives (department of La Paz) and another visit to a traditional mining region in the southern part of Potosí.[54] In total, 12 cooperative were visited during the two field visits. The scope of these specific field visits was to provide the consultants with first-hand knowledge of the cooperative mining sector and allow a direct dialogue with mining cooperatives to understand their needs and hear their visions for the future. The site visits were selected to represent different types of cooperatives (size, technology, productivity, geological differences, etc.) but not to provide a complete overview of the sector in Bolivia. The objective of the field visits was to conduct a rapid assessment that could provide an adequate and up-to-date framework to identify relevant ASM experiences that had introduced new technology to ASM miners.

A thorough literature review complemented the field visits. It clearly demonstrated that the traditional mining sector is well documented but much less information exists on alluvial gold mining. Nevertheless, the review detected several interesting experiences in Bolivia on gold mining as well as the fact that there exist highly qualified professionals that could provide technical assistance to the cooperatives.

Another key effort was to collect data on the cooperative mining sector in Bolivia. No comprehensive database exists and the consultancy team spent considerable effort collecting the information that is presented in chapter 4 and the consultancy report (Pinto and Terceros 2012). This information included the total number of cooperatives, what minerals they exploit, the number of environmental licenses and manifest, and productivity. Finally, a rapid review of all relevant legislation, policies, and programs was made.

A review of experiences from the Andean region was made to find some relevant experiences that could be useful in a Bolivian context. The review identified many interesting experiences and a sample has been included in chapter 4. These experiences demonstrate that programs can be designed to target ASM miners with clear results and there is a willingness to improve environmental management. Finally, the team also included consultants' analysis of the social aspects of ASM mining and the possibilities of integrating ASM mining into the integrated watershed management plans promoted by the government in several regions. Close coordination was also established with the consultant developing a GIS database with quite comprehensive data on mining, hydrologic resources, and other productive sectors, which provides overviews of the most vulnerable watersheds and regions in Bolivia.

[54] The cooperative gold mines visited in the department of La Paz were Cerro Hermosa, Rayo Rojo, Cooperative Cotapata, and two cooperatives in the Suches subwatershed. The traditional mining cooperatives that were visited were Tasna, Animas, Siete Suyos, Chorolque, Tatasi, Tupiza, and Pampa Grande.

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