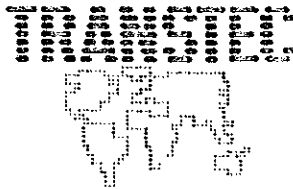


ANNEX 3

Report of study by contract



UNICO

SYNTHESIS OF THE INFORMATION AVAILABLE
ON THE MINING POLLUTION PROBLEMS OF THE
PILCOMAYO RIVER BASSIN GENERATED IN THE
DEPARTMENT OF POTOSI - BOLIVIA

REPORT

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January, 1998

BOLIVIA

SYNTHESIS OF THE INFORMATION AVAILABLE ON THE MINING
POLLUTION PROBLEMS OF THE PILCOMAYO RIVER BASSIN GENERATED
IN THE DEPARTMENT OF POTOSI - BOLIVIA

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The opinions expressed in this document are those of the Consultants and not necessarily those of UNICO, nor the Government of Bolivia

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Synthesis of the information available on the mining pollution problems of the Pilcomayo River Basin generated in the Department of Potosí - Bolivia.

INTRODUCTION

Within the framework of the evaluation study of the impacts generated by the mining sector of the department of Potosí, entrusted to UNICO International Corporation by the Japanese International Cooperation Agency (JICA), the Belgian Consultant Company TRANSTEC signed a contract in January 1998 to prepare a report on the systematization of the documentation available in Bolivia and referring to the socio-economic aspects of pollution problem of the Pilcomayo River Basin (PRB).

This report has been written according to the terms of reference presented in annex 1.

Its principal objective is to make use of the information available at present in Bolivia, so as to offer an objective and most complete view of the pollution problem caused by the mining activity and its impact in social and economic terms.

Starting from generally accepted hypotheses and from data of the context, the mission identified the most important bibliographic sources and evaluated the existing documents in terms of methodology and contents. The report concludes with the presentation of suggestions and proposes measures that will strengthen the current institutional initiatives designed to improve the understanding of the problem and to mitigate its impacts.

The team responsible for the mission, is grateful for the efficient collaboration of Dr. Bernardo Paz, Rene Coro (map making) and for the support of all other persons who have contributed to this report.

Brussels, January 30, 1998.

Pascal Rossignol, Consultant
Alain Schollaert, Consultant

I. BACKGROUND

I. 1. Origin of the pollution of the Pilcomayo River

The Pilcomayo River is polluted in biological, chemical and physical terms. This situation is due to the past and current human activities as well as, although to a lesser extent, to geological natural processes. The existence of real possibilities to face the human sources of pollution has justified the interest that national and international institutions have acquired in the causes and has encouraged them to try to identify solutions which may mitigate the problem.

Several human activities are at the root of the pollution problem of this river basin.

- **Towns and cities:** these agglomerations produce certain quantities of fumes as well as solid and liquid waste materials which affect the water quality of rivers. However, this factor is not very true in the Department of Potosí since it does not have big urban areas. Potosí only has 120.000 inhabitants and this is the only important city.
- **Agriculture:** chemical products are used in farming and cattle raising for the protection and development of crops and stockbreeding. These products are sometimes toxic and they cannot always degrade before being carried away to the rivers. Moreover, farming activities and the extraction of wood used as an energetic source affect soils and vegetation communities stability; this loss of ecological stability intensifies at the same time the natural processes of soil and water erosion as well as of sedimentation.

Due to the fact that regional ecosystems are globally overused by poor farmers and that the use of agrochemical products is limited by cultural and economical factors, it can be considered that soil erosion and sedimentation constitute the pollution source originated by this sector.

- **Industries:** these produce a significant quantity of chemical and physical elements. The Department of Potosí is characterized by a very limited industrialization and it is focused on mining. Mining activities have caused chronic and sometimes acute pollution within several sub-basins of the Pilcomayo River Basin. The dumping of residual water that comes from the mining mills, the accumulation of mineral tailings in precarious conditions and the loss of water from active and abandoned mines constitute the mass of the pollution sources generated by this sector.

The dumping of chemical elements caused by present and past mining activities, and soil erosion caused by farmers and wood cutters constitute, without any doubt, the main causes of pollution in the Pilcomayo River Basin.

Chemical pollution has been the object of many studies, while physical pollution has been practically ignored even though it has incidence over:

- potential water uses, such as watering and electricity generation.
- the intensity of the most common natural disasters in the region (droughts and floods).

I.2 Incidence of the main pollution sources

Tens of mineral concentration plants which are presently operating or which are inactive, and hundreds of abandoned and operative mines, located in the territory of Potosí are at the root of the current pollution processes of the Pilcomayo River Basin.

Nevertheless, the existence of other pollution problems generated within and outside the territory of Potosí should not be ignored. Those problems are worsened through an inappropriate management of the basin by farmers, stockbreeders, coal merchants and wood collectors. In fact, the lack of planning for the use of natural resources and the management systems adopted without sustainability criteria are causing a process of regional deforestation and serious disturbances of the water cycle.

The pollution of the Pilcomayo River due to past and present activities of the mining sector generates a series of negative impacts that can be classified as follows:

Social Impacts:

- Poverty caused by the difficulty or the impossibility to maintain traditional productive activities.
- Migration caused by poverty, lack of good quality water, particularly during winter and spring, and the risk to catch sicknesses, which could eventually be serious.
- Migration and poverty are damaging the structures of the traditional social organizations.

Economic Impacts:

- Decrease and instability of the fishing, agriculture and cattle raising production.
- Reduction of the economic and political importance of the farming sector in the Pilcomayo region's economy.

Environmental Impacts:

- The accumulation of, sometimes toxic, chemical elements into rivers, soils and food chains.
- Increase of the ecosystem's sensitivity in the face of disturbing factors (human or natural).

At present there have been no significant changes in the methods of extraction and treatment of minerals. Some actions were undertaken by mining companies, particularly medium and large scale operations; they are mostly focused on the construction of tailing dams which dramatically reduce the dumping of solid elements into the rivers.

Nevertheless, there are two problems which have not been treated adequately: the dumping of dissolved elements and the management of solid wastes considering the medium and, most of all, the long term.

I.3 Extent of the survey

The pollution of the Pilcomayo river constitutes a topic of great interest and preoccupation for some sectors of the Bolivian society as well as for Argentina and Paraguay. These countries share the Pilcomayo River Basin territory with Bolivia. The most interested sectors are national and departmental governments, farmers, groups of environmental conservation, projects of rural development, organizations that support the mining sector and finally, the mining companies and cooperatives themselves.

It is known that many small and large institutions, specialized in environmental, social and/or economic issues, have worked or are working on the evaluation of Pilcomayo river's health and of mining activities' impacts.

Sadly, the information and data obtained are not always used in an optimal way, since they are spread across the country and have generally not been evaluated in a systematic way. In a political and economic context which is already delicate, this lack of systematic evaluation discourages the achievement of investments oriented to treat the causes of the PRB pollution.

This work pretends to partially fill this gap with the identification, qualification and analysis of the documents available in Bolivian institutions. Likewise, beginning from this analysis, concrete proposals are presented for actions adapted to the regional socioeconomic and political setting.

To promote the continuation of this initiative and allow a better understanding of the choices made in terms of documents selected, the criteria used to assess all the documentation found are presented in Chapter III.

II. General information and data referring to the affected area (only in Bolivia) and to the impacts of the Pilcomayo River Basin's pollution

II.1 Social aspects

According to official estimates of the INE (National Statistics Institute) the Bolivian population for 1998 will reach a total of 7.949.933 inhabitants spread in nine departments.

The same institution estimates that the departments of Potosí, Chuquisaca and Tarija correspond to more than the 99 percent of the area covered by the Pilcomayo River Basin in Bolivia. They have, respectively, a population of 755.895, 562.917 and 379.704 inhabitants. Even though parts of these departments correspond to other river basins, the majority of the population and industries of this region are settled in the PRB.

The difficult social situation, particularly in Potosí, traduces itself by:

- An annual population growth rate, respectively of 1.1, 2.4, 3.2 percent for Potosí, Chuquisaca and Tarija, which corresponds to the period of 1990-1995, while it was situated around 2.4 % at the national level.

- A children mortality rate, for the five-year period of 1990-1995, which is very high for Potosí (111.5 per thousand births). In Tarija (60 per thousand) and Chuquisaca (83.9 per thousand), this rate lies closer to the national average (75.1 per thousand).
- A life expectancy of 53 years in Potosí, 57.7 years in Chuquisaca and 63.12 years in Tarija, while the average at the national level is of 59.33 years.

In this context, the pollution of many sub-basins of the PRB constitutes a further difficulty for the population, essentially poor to very poor farmers, settled in the river banks. The few alternatives of employment and income generation are influenced by the decrease of and/or the irregular quality of the water resources. In fact, in this arid to semi-arid environment, water resource is of vital importance, for human daily activities as well as for the traditional productive activities (cattle raising, agriculture and, in certain regions, fishing).

There is no doubt that for the peasant communities living downstream, close to mining operations, the water, soil and/or food chain pollution has worsened the deficient nutrition and hygiene which characterizes Southern Bolivia's rural life and the emigration process. All this contributes to the accelerated growth of some cities and to the unplanned colonization of other rural areas of the country.

Nevertheless, the complexity of the predominant social situation, marked by poverty and marginality makes it difficult to determinate exactly the degrees of incidence of the different factors that together are at the root of the regional socioeconomic crisis.

II.2 Economic Aspects

The two principal economic sectors related to the PRB's pollution problems are agriculture and mining.

Rural sector

The peasant sector is constituted by thousands of poor families who mainly depend for their survival, on activities of low profitability and high risk.

The low and excessively irregular prices paid for the traditional products of this region (potatoes, maize, wheat, barley, meat, wool, fish, etc.) do not permit to secure a sustainable growth process of these activities. As a consequence, there is a very low level of reinvestment in these production systems, which contributes to the gradual reduction of the productive capacity of the ecosystems.

According to the INE (1996), the participation of the departments of Potosí, Chuquisaca and Tarija was, respectively, of 5.36%, 7.99% and 5.81 % of the gross national product obtained by agriculture in 1993. The agricultural gross product of these three departments was, for 1993, of some 45, 67 and 48 million dollars, respectively.

The incidence of pollution in the sub-basins of the PRB over the traditional productive activities is difficult to estimate in a precise way.

In fact, the shortage or absence of monitoring systems of the climate, of soils quality and river flows, as well as of many other related parameters, makes it impossible to determine the specific incidence of each causal factor. Among these, we can quote droughts and floods, soil degradation caused by inadequate production systems, use of genetically degraded seeds and animals, etc...

Mining Sector

The mining sector is subdivided in the small mining private companies, the medium mining private companies, the public company (COMIBOL) and the cooperative mining companies. In 1992, these sub-sectors occupied, respectively, 12138, 3540, 5082 and 51890 people (Roberto Soza, 1993).

In 1980, the sector generated a global gross profit of 756 million dollars (SGAB, 1993). Since then, the Bolivian mining production has declined, mainly due to the fall of metal prices. The INE estimates that this sector generated a gross product of 139 million US\$ in 1986 and of 216 million US\$ in 1996.

According to the INE (1996), in 1993, the participation of the departments of Potosí, Chuquisaca and Tarija was, respectively, of some 29, 3 and 1 % of the GNP, obtained through the production of metallic and non-metallic minerals (US\$ 204 millions).

In 1996, the most exported minerals were the following:

- Zinc with 31.6 % of the total exported, for a total of 29 million US\$
- Gold with 25% of the total exported, for a total of 23 million US\$
- Tin with 17.5% of the total exported, for a total of 16 million US\$
- Silver with 13.4 % of the total exported, for a total of 12 million US\$

II.3. Physical Aspects

Bolivia is located in the central part of the South American continent between 57° 26' and 69° 38' of occidental longitude of the Greenwich meridian and between the parallels 9° 38' y 22° 53' of southern latitude. Its territorial extension is 1.098.581 square kilometers.

The departments of Potosí, Chuquisaca and Tarija cover, respectively, areas of 118.218, 51.524 and 37.623 square kilometers. The region formed by these departments limits, to the West with Chile and the Department of Oruro, to the South with Argentina, to the East with Paraguay and to the North with the departments of Cochabamba and Santa Cruz.

The La Plata River Basin, that in Bolivia includes the Bermejo and Pilcomayo river basins, covers 9% of the Bolivian territory.

The Pilcomayo River Basin covers an area of some 272.000 square kilometers; this means 8.4% of the surface of the basin of La Plata (OEA, BID and PNUD, 1977).

Following CER-DET and QPID, 1997, some 99.110 square kilometers, this means 36.7 % of the Pilcomayo Basin, correspond to Bolivia, distributed between the departments of Potosí (42.987 square kilometers, Chuquisaca (30.818 square kilometers), Tarija (24.591 square kilometers) and Oruro (714 square kilometers).

This basin is subdivided in six main sub-basins: superior, middle and inferior Pilcomayo, Tumusla River, San Juan del Oro River and Pilaya River.

The Pilcomayo river rises in the Province of Avaroa (Department of Oruro) and, in Bolivia, ends in the Province of Esmeralda (Department of Tarija). Its length is of 670 kilometres and it flows into the Paraná river.

According to data of the hydrological station of Villamontes (Department of Tarija), the river can get as deep as 6.6m and has a width of 150 m. Its annual average flow is estimated at 203 cubic meters per second.

The weather that characterizes the basin is variable. In its highest part (altitude up to 4.500 meters) corresponding to the most extended area, a cold arid to semi-arid climate predominates. Downstream, the climate is mild and sub-humid. Close to the border of Paraguay and Argentina (minimum altitude of 250 m), the climate is torrid and arid to semi-arid.

In the high part of the basin, there are important mineral deposits where the most common metals are: lead, tin, zinc, silver, antimony, copper and bismuth.

II.4. Political, institutional and legal aspects

The past and current national policies discouraged the investment in sustainable environmental systems in mining. No economic instruments were designed to promote the sustainable management of natural resources on the part of the mining sector.

On the other hand, some years ago, a promotion of the territorial ordering and the planning in the land uses began to take place. Despite these facts, there is still a gap between the theory and the practical application of these instruments.

During the present decade, Bolivia advanced considerably in terms of equipping itself with legal instruments designed to regulate the use of its natural resources. However, there are also serious problems regarding the effective application of these instruments. It is understood that the economic conditions of the sectors interested in the usage of the natural resources makes it very difficult to respect these instruments (Environmental Law, Mining Code and Forestry Law).

Moreover, we should mention the existence of problems affecting the institutions that plan and execute rural development and environmental conservation programs and projects; in fact, politicization, competition, corruption, instability and lack of resources, are some relatively common aspects which limit the efficiency of their interventions.

III. METHODOLOGY

III.1. Information sources

The present work aims at the research and analysis of all the written documents referring to the pollution of the PRB caused by mining activities, available or accessible at the adjacent information centers of the cities of Potosí, Sucre and La Paz.

Initially, a list of all the known bibliographic references was elaborated, list which referred to the pollution and/or to the management of the Pilcomayo River Basin. These references were used in order to identify and/or locate the identified documents in a dozen of institution known for their affinity with the issue (LIDEMA, MEDMIN, WORLD BANK, SERGEOMIN, ISALP, PNUD, FOCHMADE, FOPOMADE, PAC/C, UATF, SOPE, UMRPSFXCH).

Furthermore, contacts with specialists in the field were taken in order to identify additional reports.

Finally, a list of the institutions and people with prior experience in research-work about water pollution and/or watershed management problems was made.

III.2. Preliminary evaluation criteria

With the objective of selecting the most relevant documents towards the realization of the work, all of the documents were subjected to a first content evaluation; the evaluation criteria applied were the following:

1. Institution potential

Size, experience and resource availability of the funding institution

2. Amount of the investment in human and financial terms.

- Duration of the survey
- Number of the professional disciplines represented

3. Correspondence between "PRB pollution problems and solutions" and the issues treated in the document

- Relative importance accorded to the issue of PRB pollution in relation to the global document

4. Clarity of the methodology used

- Efficiency of the methodology in terms of reaching the defined goals
- Quality of its presentation

5. Existence of solution proposals

Existence of concrete proposals in terms of potential solutions and evaluation of their viability (quality of the explanations and arguments).

6. Existence of information about the pollution impacts

Existence of data and/or information related to the social, economical, and/or environmental impacts of the pollution (besides the simple verification of the presence of polluting elements in the water).

The first five defined criteria were evaluated in a homogeneous way, considering a relatively equivalent importance of each. Considering the objectives of the present work, particularly related to the need of better knowing the social and economic impacts, a double-relative importance was given to the sixth criteria.

Even though it did not correspond to any specific criteria, in a general way, the already mentioned evaluation criteria were applied considering how serious the given information was. Furthermore, the given information and data were valued even more when they were analyzed from a holistic point of view.

In this respect, it is also necessary to mention that there is an evident lack of information and data about certain variables that, however, have drastic effects on the most commonly used pollution evaluation parameters. This situation lies at the root of a chronic lack of confidence of the interpretations made by the investigators over, for example, the socioeconomic impacts of water pollution. This situation seriously limits the investigators capacity in terms of determining the specific impacts of pollution over the social and economic life of the affected towns and people. In front of this situation, it was important to value more the documents that were elaborated by experts representing different fields and with valuable professional backgrounds.

This assessment was made only to select the documents that were considered as the most useful according to the goals to be reached. It does not mean, obviously, that the documents that were not selected might not be useful for other objectives.

III.3. Detailed evaluation criteria

Once selected, the documents were analyzed and assessed in a more complete and precise way, applying the following criteria:

1. Globality of the approach

Attention paid to different variables influencing the dynamics of the surveyed environments: for instance, rain characteristics and river flows of a sub-basin, water quality, nutrition and life hygienic of eventually polluted people, etc.

2. Size of the study

- Duration: short (less than a month), medium (between 1 and 6 months) and long period (over 6 months).
- Geographic extension: only one sub-basin, several sub-basins, the entire PRB in Potosí or larger.

3. Quality and clarity of the methodology used in the work

- Confusing presentation.
- Clear presentation, doubtful application.
- Clear presentation and application.

4. Objective and scientific assessment of the pollution impacts.

Existence of information and data referring to previous situations and to social, economic and environmental changes caused by pollution.

5. Clarity and relevance of conclusions and recommendations

- Existence of conclusions and recommendations related to the methodological aspects of the realized work
- Existence of conclusions and recommendations related to the problem of mining pollution
- Usefulness and relevance of the conclusions and recommendations presented.

6. Clarity and facility of the reading

Existence of a correct presentation structure (introduction, presentation of the problem, work methodology, realized activities, conclusions and recommendations) index, paging

7. Existence of historical references and their usefulness

- In the description of the problems, existence of data and historical information
- Usefulness of the historical data and information thanks to the presentation of the sources (who got them, how, when, where, etc.)

8. Existence of bibliographic references

Adequate presentation of bibliographic references with name, author, editor, edition, date, title, etc.)

III.4 Map elaboration

A map has been elaborated with the aim to inform about certain important aspects of the pollution problem of the PRB.

Based on the processed information, the map present the approximate geographical position of the main pollution sources from the mining sector and the pollution levels of the main rivers of the six sub-basins forming the PRB in Bolivia.

Sources, contradictions and/or lack of information have also been indicated and summarized in table 1 of the conclusions.

It was also intended to present the social, environmental and economic impacts of pollution caused by mining activities.

IV. EVALUATION OF THE INFORMATION

IV.1. Preliminary analysis and document selection

A total of 27 documents were analyzed applying the criteria exposed in the lower chapter. These documents have been grouped in four categories according to the theme presented:

- A. Evaluation of mining pollution in Bolivia or of the Pilcomayo River Basin
- B. Pilcomayo river basin or sub-basin diagnosis
- C. Proposition of solutions and projects
- D. Other documents of interest

Whenever the document refers, at once, to an assessment of pollution and to solutions, it was inserted in the "solutions" group.

In annex 2, a complete list of the identified documentation is presented.

In annex 3, the same list is divided into three parts: the first one corresponds to the documents assessed in a detailed manner; the second one refers to the documents about which a short comment is presented. Finally, the third part points out the documents that the mission could not revise, considering the probability that analyzing them could add interesting elements of information to complete the present work. In this latter case, comments and references actually available are also presented; including title, author, investors, date and where it can be found).

In annex 4, a list of institutions and expert is also presented to complete the main references.

Through the application of the prior selection criteria, it is considered that the selected documents content the most relevant information available in this moment for the people and institutions interested in the mining pollution problems of the Pilcomayo River.

Hereafter are presented the 11 documents that were elected for a detailed content evaluation (the numbers of the documents correspond to the ones of the list of Annex 2).

A. Evaluation of mining pollution in Bolivia or of the Pilcomayo River Basin.

2. Pilcomayo River

- * Studies about the lead concentration and other toxic metals in muscles, inner organs, bones, and entire bodies of the silver fish (*Prochilodus platensis*).
- * Studies about the concentration of lead and Zinc Protoporphirine in the Guaranian's blood.
- * Determination of lead in the silver fish, entire fish, and different parts, and blood tests of the Guaranians of the Itika Guasu area.

Russel Groves, Melanie Quevillon y Roxana Castro
CER-DET y QPID - 1997

5. Informe sobre los daños causados a los agricultores por la contaminación del Río Pilcomayo - 1997
and "Informe técnico mensual de consultoría Cuenca Pilcomayo" - 1996
Epifanio Pacheco C.
Prefectura del Departamento de Chuquisaca
6. Evaluación del grado de contaminación en aguas y suelos de las principales cuencas menores del Departamento de Potosí
U.A.T.F. - FONAMA - 1996
8. Análisis del impacto socio-económico de la contaminación del río de La Ribera-Pilcomayo
Jaime Hinojoza D. and Samuel Rosales R.
MEDMIN - 1995
13. Informe de misión sobre la contaminación de aguas por la explotación minera en las regiones de Uncía y Otavi - Departamento de Potosí, Bolivia
PAC - European Commission - 1991
15. Impacto ambiental de la actividad minera de Comibol en Bolivia
Duran de la Fuente H. and Sergio Castro F.
World Bank - 1989

B. Pilcomayo river basin or sub-basin diagnosis (data and information over other aspects of the basin)

19. Balance hídrico superficial de la Cuenca del Pilcomayo
Ricardo Arellano Albornóz
PHICAB - 1988

20. Cuenca de La Plata: Aprovechamiento Múltiple de la Cuenca del Río Pilcomayo
OEA
Governments of Bolivia, Argentina and Paraguay – OEA - PNUD - 1977

C. Proposition of solutions and projects

23. Estudio de factibilidad para la construcción de un dique de colas en Potosí – Bolivia
Golder Associates
MEDMIN - 1996
25. Evaluación ambiental de los sectores minero e industrial
SGAB, SENMA and MMM
Government of Sweden and World Bank - 1993

D. Other documents of interest

28. Review of the Porco mine tailings dam burst and associated mine waste problems, Pilcomayo Basin, Bolivia
Macklin M.G., Preston D. and Sedgwick (Universidad de Leeds, School of Geography) and Payne A.I. (Marine Resource Assessment Group Ltd) - 1996

IV.2. Detailed analysis of the elected documents

DOCUMENTO N° 2

Pilcomayo River

- Studies about the lead concentration and other toxic metals in muscles, inner organs, bones, and entire bodies of the silver fish (*Prochilodus platensis*)
- Studies about the concentration of lead and Zinc Protoporphyrine in the guaranian's blood.
- Determination of lead in the silver fish, entire fish, and different parts, and blood tests of the guaranians of the Itika Guasu.

Russel Groves, Melanie Quevillon y Roxana Castro
CER-DET and QPID - 1997

A. Autors

CER-DET and QPID have done this study.

The responsible team consists of two members of the QPDI and one specialist from the Toxicology Bolivian Institute, whose professions are not reported.

B. Funding sources

FIA, FOBOMADE and Prefectura of the Department of Tarija.

C. Objectives

Respectively, the general objectives of the studies that are part of the global report are:

- Continuation of a preliminary investigation of three years about water and fish quality in the area called Itika Guasu, quantifying the amount of heavy metals in fish.
- Continuation of an investigation about the contamination of the Pilcomayo river begun in 1995, through the concentrations of lead in the blood of the inhabitants and fishes in the Itika Guasu region.
- Assess the lead concentrations in the blood of the population of the Itika Guasu region and in the Silver fish.

D. Methodology

Study 1

- Location of the area to be studied according to the pre-studied areas in the above-mentioned investigation.
- Investigation of the pollution sources based on secondary information sources.
- Description of the main characteristics of the silver fish.
- Collection of 39 samples (entire silver fish). Analysis of entire fishes and specific parts at the Zenon Environmental Laboratory of Burlington (Ontario - Canada).
- Evaluation of arsenic, cadmium, chrome, copper, nickel, and lead contents
- Analysis of the data referring to the entire fish based on the Statistic program Statview, and the data referring to parts of the fish based on the application of parametric statistic.
- Presentation and discussion of the results.

Study 2

- The two first stages, as well as the last two, are the same ones as the ones used in study 1.
- After the identification of the pollution sources, collection of 101 blood samples from 48 women and 53 men.
- Analysis of the samples at the Dynacare laboratory (London - Canada).
- Evaluation of the lead and protoporphyrine of zinc (ZPP) content.

Study 3

- Selection of the sampling locations based on geographical conditions.
- Collection of 60 blood samples from a total number of 10 guaranian communities.
- Collection of 159 samples of silver fish.
- Description of the Pilcomayo River.
- Description of the silver fish (sábalo).
- Analysis of the samples at the Laboratory of the Toxicology Bolivian Institute.

- Presentation and discussion of the analytic results.

E. Results

Related to the issue of mining pollution of the PRB, globally, the main products of this work are:

- A better knowledge of the lead concentration levels in human blood and in the silver fish, in a sector of the PRB located between the Pilaya River and Villamontes.
- The possibility, in the future, of evaluating the tendency in terms of this area's pollution by a few heavy metals, using several prior studies of the same team, and of Payne, A.I. (document 40)
- The following statements:
 - lead pollution levels are not significantly threatening the studied zone, except for the silver fish bones. In spite of the obtained results, it is recommended that the thrown of heavy metals should be reduced.
 - The evaluation of the impact of lead pollution is difficult due to the unspecificity of the affections related to its absorption by human beings.

F. Global evaluation

Integrity of the focus

The evaluation parameters considered by the study (population and fish pollution levels) are influenced by a series of variables; an important one, in the second case, is the fish behaviour. This and other variables, such as the thrown of domestic wastes, agriculture, fishing and the natural sources of pollution were also taken into account.

Other facts such as the food habits, migration, etc., also affect the health of the human population; a survey which gives us a better understanding of some of these variables was carried out.

However, to relate the different pollution levels in fish with human interventions, this kind of investigation should be integrated to other ones referring to the management of mineral wastes and of water resources in general, rain characteristics, temperature, etc.

Extent of the study

Although covering a reduced area (some communities located between Villamontes and the Pilaya River), this study constitutes a good example of what should be done to know the situation better. Effectively most investigations are very short in time, while this one was begun in 1995. Furthermore, the continuation of this monitoring activity is recommended by the investigators.

Quality and clarity of the methodology

The three studies have applied the same methodology of investigation which seems to be adequate to reach the defined objectives.

However, the following problem was observed: the chapter referring to the methodology of the work study 1, corresponds to the presentation of the context and the results more than to an explanation of the used method.

Objective and scientific evaluation of pollution

The presented work, for instance, in terms of blood tests of humans and fish, shows a will of scientific seriousness. The interpretation and discussion of the results are characterized by a good objectivity level. However, the problems associated with the determination of the relationships between causes and effects are not considered (see Conclusions and Recommendations)

Clarity and consistency of conclusions and recommendations

The recommendations and conclusions are clear and coherent. The need to continue a systematic investigation is recognized. They restate the need to continue monitoring the concentration of heavy metals in human and fish.

Some actions oriented to the improvement of the proposed methodology are presented; e.g. extending the analysis of other basic food of the Guaranian population, and the sampling of children under 16 year.

Quality of document presentation

Some problems in the translation from English to Spanish are observed. Even though, the document is understandable thanks to a good structure.

However, it is observed, that in study n°3, the selection criteria of sampling locations are presented after the sample collecting phase.

Historical references and their utility

Besides some references to prior studies, no historical information or data are mentioned.

Bibliographic references

The bibliographic lists are complete and useful.

Other comments

Globally, the work is of good quality and offers a clear idea of the situation in terms of pollution by lead, zinc and some other heavy metals.

DOCUMENT 5

**Informe sobre los daños causados a los agricultores por la contaminación del Río Pilcomayo
and "Informe técnico mensual de consultoría Cuenca Pilcomayo" - 1996
Epifanio Pacheco C.
Prefectura del Departamento de Chuquisaca - 1997**

A. Authors

Besides the name of the consultant who has elaborated the report, nothing else is indicated. The annex II of the document presents a field work which was done by an agronomist, about whom only the name is given.

B. Funding sources

Prefectura of the Department of Chuquisaca.

C. Objectives

The general objective of the work is the quantification of the damages caused by pollution to agriculturists in the department of Chuquisaca on the Pilcomayo River banks.

Its specific objectives are:

- Determination of the effects of the use of polluted water in the horticulture, fruit production, and livestock production in general.
- Quantification of the affected areas.
- Determination of other environmental impacts caused by pollution.
- Settlement of an information database in order to help to the planning of proposals in terms of mitigating pollution.

D. Methodology

The study was done between May and September 1997.

No explanation was found about the global methodology of the work, but one was found about the field work. The field work has very similar objectives but is a little more centred in the social aspects (human health, migration) than the global study.

The report concerning the field work, presented in the annex of the report signed by the author of the document provides little explanation of the methodology used. However, it has been observed that the methodology used is precisely the one presented in document 8.

E. Results

Because of the motives presented above and below, it is considered that the results of this work are not useful, even if some analytic data and social information do exist. There is a lack of seriousness in the interpretation that discredits the rest of the document.

F. Global evaluation

Integrality of the focus

Theoretically, the study is integrated since it touches social and economical impacts of water pollution. Deplorably, different aspects of the reality are treated very superficially and are not coherently related.

Extent of the study

The studied zone corresponds to the Pilcomayo River banks on the political border between the Department of Potosí and the provinces of Yamparacé and Oropeza of the department of Chuquisaca. The study covers 10 villages.

Quality and clarity of the methodology

As it was already pointed out, the methodological steps are identical to those followed in document 8.

The main part of the work and the methodology referring to the field work in Annex II (after the presentation, in the first annex, of the correspondence exchanged between The Prefect of the Department of Chuquisaca and other political authorities), complicates the understanding of the methodological process of this study.

Objective and scientific evaluation of pollution

The subjectivity of the authors is demonstrated all along this document. There is no confidence in the interpretations presented. This situation is observed, e.g. in the case of the analysis of temporal migration. The report coming from the field work indicates that approximately 82.12% of the economically active population travels temporally in periods free of agricultural activities. Nothing supports this. No mention is made of other possible causes for emigration (prices, climatic problems, etc.). The author states that the fundamental cause for this is the Pilcomayo River pollution.

As another example of this lack of objectivity, we can mention chart 18 of page 32 that estimates the losses in terms of gross income coming from horticulture, fruit production, and fishing. The corresponding period to which those data are related is not specified, but data are given about the area's gross income before (20.370.950 millions of Bolivianos) and after pollution (11.925.170 millions of Bolivianos). Nothing indicates which products it is referring to, nor what the climatic or commercial conditions were like; however, it is stated that a diminution of the 41.46% is due to pollution!

Clarity and consistency of conclusions and recommendations

Among the three recommendations presented by the author, the following recommendation is found: "The project of the tailing dam (document 23) is not an integrated alternative, the best would be to move the mills to a dryer valley".

This is to say that the recommendations presented are not useful.

Quality of document presentation

In spite of having copied the presentation structure of document 8 and due to a large number of difficulties with written expressions, the work is very confusing and difficult to read.

Historical references and their utility

No relevant historical reference was found.

Bibliographic references

Five bibliographic references were found; four of them belong to the author and the fifth to document 8.

Other comments

This work constitutes a reference of what should not be done (see above). The report recognizes the lack of serious studies about the pollution impact in the Department of Chuquisaca. Lamentably, this work does not improve the situation.

It is also important to mention that the analysis of this document allows to ratify the existence of a lack of coherent methodology oriented to the evaluation of socio-economic impacts of the PRB. Likewise, it is not always easy to find professionals with the required profile.

DOCUMENT 6

Evaluación del grado de contaminación en aguas y suelos de las principales cuencas menores del Departamento de Potosí

U.A.T.F.

FONAMA - 1996

A. Authors

Facultad de Ingeniería Geológica de la Universidad Autónoma "Tomás Frías" - Potosí (UATF)

B. Funding sources

Fondo Nacional para el Medio Ambiente – MDSMA

C. Objectives

- Evaluation of the environmental problems generated by mining, particularly in terms of its impacts on soils and water.
- Formulation of project profiles oriented to the mitigation of pollution impacts.

D. Methodology

The survey began in July 1995 and ended in December 1996. However, until the beginning of 1998, the final report, presented to FONAMA, had not been yet approved, nor published.

In order to reach the mentioned objectives, the following steps were followed:

- Research for information related to the study issue and preparation of maps to realize the field work.
- Field visit oriented to plan the field work and initial sampling in order to identify conflicting zones.
- Election of the sub-basins to be studied. Detailed ground sampling of mining solid wastes, water and sediments in all of the sub-basins to be studied. Inventory of the corresponding pollution sources.

E. Results

The main products of the survey are:

- Data and information about the pollution level of the sub-basins of the PRB situated in the Department of Potosí (upper Pilcomayo, Tumusla and San Juan del Oro).
- Identification of the main pollution sources of this sub-basins.
- Proposals of mitigation steps by sub-basins.
- 14 profiles of projects oriented to mitigate the mining pollution impacts in waters.

The analytic results offer a quite detailed idea about the situation of the sub-basins being considered, in terms of ground and water pollution.

However, due to unexplained interpretation methods, that seem incoherent, the mentioned interpretations do not allow to have an idea of the environmental impacts of pollution.

Moreover, the environmental conditions during the monitory time are not described, in terms of rain characteristics, river flows and other parameters that dramatically influence water pollution levels.

Although analytic results corresponding to sediments are presented, they do not inform about the possible amount of these selfsame materials, nor about possible evaluation methods of these amounts. Lack of information to this respect is generalized in the available documentation and constitutes a serious problem.

F. Global evaluation

Integrity of the focus

The study is focused upon the assessment of water and soil pollution. Social and economical aspects have been confederate, but superficially. The technical character of the surveys is associated with the presentation of mostly technical solutions.

Extent of the study

The surveyed zone corresponds to three sub-basins of the PRB (upper Pilcomayo, Tumusla and San Juan del Oro).

Quality and clarity of the methodology

The used methodology enabled to reach the foreseen results but not to avoid incongruities at the moment of the interpretation of the analytical results.

Objective and scientific evaluation of pollution

Considerations of the social and economic impacts are limited to excessively general observations; e.g., about soil samples, it is indicated that "the production is from good to regular" without specifying what these adjectives correspond to, nor what sort of production they refer to. No references are made about previous situations.

In environmental terms, the pollution levels observed are the output of serious analysis. Lamentably, their interpretations seem to have been affected by excessive levels of subjectivity.

Clarity and consistency of conclusions and recommendations

The conclusions presented for each sub-basin should be questioned due to the observed incongruities. As an example, we can point out the Tumusla sub-basin's case, for which it is mentioned excessive concentrations of cadmium, boron, antimony, and mercury in water samples. Moreover, excessive concentration of at least one toxic element (mercury, cadmium, arsenic, antimony, lead, etc.) has been detected in soil samples.

However, in the conclusions, it is indicated that, in terms of water pollution, pollution level is low to medium in upper waters, and that the lower part of the sub-basin presents good quality water. Likewise, globally, the sub-basin is barely contaminated.

As another result of this work, it can be considered that the presented project's profiles correspond to recommendations. However, those profiles are extremely general, poorly formulated, homogeneous among the sub-basins and not very useful in the actual economic and political context, mainly because of their elevated costs.

Furthermore, the proposed solutions are, mainly, of a technical type.

Quality of document presentation

The work is very voluminous, but well structured. Deplorably, reading is sometimes difficult, due to a deficient redaction.

Historical references and their utility

The document does not provide information, nor data about previous situations. However, it partially informs about the evolution of the mining sector in the region.

Bibliographic references

No bibliographic references were found.

Other comments

Lack of consistent information and data about socio-economic and environmental aspects, as well as incongruities characterize this version of the final report.

The latter case in point is referred to the amount of sediments. The progressive downward transportation of solids from the upper towards the low parts of the basins is a serious problem that is not even mentioned in this study.

In respect to the lack of professionalism and seriousness of many such surveys realized in this region, it is worth informing with more details about some other problems observed in this document.

Among the several questionable interpretations observed, we can mention the two following:

- At page 126, it is pointed that, in two samples collected in the rainy season, cadmium concentration in water reached 200 times the permissible limit in the first case and more than 100 times in the second one. In the meantime, the results obtained from samples collected during the dry season demonstrate a low level of this element. The surprising explanation is that the variation registered is due to the dilution caused by the river flow growth during the rainy season.

- At page 131, regarding soil sample S-209, it is pointed that "the concentration of cadmium is high and overcomes in 52 times the permissible limit", however, in the same phrase, it is indicated that "the production is good, there are no pollution problems".
- At page 169, regarding soil sample S-175, it is indicated that "there is a high concentration of lead, arsenic, and antimony. The production is from regular to good. Land quality is good and they care for the effects of pollution".
- On the other hand, despite the great diversity of situations, all of the project profiles presented propose practically identical goals and the same budgets (US\$ 48498)!

Therefore, it is fully justified that FONAMA has asked for a review of the work. However, it is deplorable that the investment realized can not be translated into a useful product for interested sectors, even a year after the work has been concluded.

It seemed useful to insist on those problems to inform over the dramatic situation of the country in terms of accessing good studies about the pollution of the PRB. It should be clear, at this time, that in this context, it is very difficult to determine the relationship between pollution causes and socio-economic problems.

DOCUMENT 8

Análisis del impacto socio-económico de la contaminación del río de La Ribera-Pilcomayo
Lic. Jaime Hinojoza D. and Lic. Samuel Rosales R.
MEDMIN - 1995

A. Authors

The authors are two thesis workers about whom nothing is said.

B. Funding sources

MEDMIN – COSUDE and ETESA

C. Objectives

Their objectives are:

- Identification and analysis of the social and economic impact of the Pilcomayo - La Ribera River banks pollution (understood as the river that goes down from Potosí, through Tarapaya, until its confluence with the upper Pilcomayo sub-basin).
- Determination of how some villages situated on the Pilcomayo River banks feel the impact of the contamination.
- To know the solutions proposed and/or applied by those villages.
- To know the position of villages facing the possibility of the construction of a tailing dam on the Pilcomayo-La Ribera River.
- To estimate the potential socio-economic effects of the construction of the proposed dam, taking into account the number of people that would benefit from it.

D. Methodology

The methodology of this work can be summarized as follows:

- Spatial and temporal delimitation of the investigation area.
- Determination of the size of the sample.
- Collection of data from primary sources throughout meetings with villages and individual interviews.
- Collection of data from secondary source such as reports of personalities and local or national institutions (IGM, INE, Departmental Sanitary Unit).
- Direct field observations.
- Interpretation and presentation of the obtained information.

E. Results

Besides the observations on the methodology, the study informs about the following issues:

- Environmental, social and economic characteristics of the villages (grouped in five according to a proximity criteria). A positive element is that this information takes into account aspects related to animal and crop management systems.

- Possible causes of the emigration process.
- For each village, a short report of local people's opinions related to the river pollution is presented; this information is mainly referring to health, agricultural production and natural environment.

The most commonly detected effects are:

- Health problems such as cracking and bleeding of parts of the body which have been in contact with the river's water; intestinal and stomach diseases.
- Crop production problems: slow and irregular development of plants, death of plant before flowers, low productivity, low work efficiency, and agricultural ground degradation.
- Animal production problems: intestinal diseases, low level of reproduction and productivity and, in case of contact with water, degradation of animal nails.
- Environmental problems: disappearing of vegetation on the river banks, and aquatic life forms.

The main recommendations made, without indicating if it refers to authors' or villagers' ones, are the following:

- Execution of soil rehabilitation programs.
- Analysis of animal and vegetal products.
- Co-operation programs against poverty through agricultural production projects.
- Monitoring of water quality, as well as of river flow.
- Monitoring of the community member's health.
- Construction of irrigation systems fed with non-contaminated water.

The report also indicates that a gradual diminution of water pollution is associated with greater distances from the town of Potosí. However, the impacts appear to depend on the intensity of water and soil uses. These uses are more important in the lower and warmer areas that are located at a longer distance from the city.

Finally, not much is said about the tailing dam, except that some villages situated close to Potosí, are asking for urgent solutions expressing that they do not want to suffer from the damages and injuries that La Palca foundry plant has caused them in the past.

F. Global evaluation

Integrality of the focus

The investigation contemplates several fundamental aspects of the reality prevailing in rural areas. Even though superficially, social, economic and environmental problems are contemplated.

Extent of the study

The investigation, realized between June and September 1995, intends to cover a period of 5 years (from 1990 to 1995) and the territory of 23 villages (897 families) located in the departments of Potosí and Chuquicasa.

Quality and clarity of the methodology

The presentation of the methodology is slightly confusing; however, its application yields good results.

The report informs that some difficulties related to the methodology have been encountered. It is reported that some difficulties appeared through the contacts with the villages, which are attributed to the cultural differences between the Andean peasants and the investigators who live in the city. This would be related with different conceptualisations of time. Moreover, in some cases, villagers showed low availability and confidence.

Objective and scientific evaluation of pollution

The intention of reporting the perceptions of peasant communities is a valuable effort. It does not guarantee, obviously, the scientific character of the obtained information. The interpretations do not let overpass any subjectivity by the authors.

Clarity and consistency of conclusions and recommendations

Conclusions and recommendations referring to the global work are not presented (except about the methodology).

The conclusions correspond to the results of the investigations realized in each community.

The recommendations are only partially based on villagers worries and requests. Even those specific conclusions are superficial.

Quality of document presentation

The presentation is good and the reading easy.

Historical references and their utility

Having considered a period of 5 years, in some way, the report provides information about the situation's evolution.

Bibliographical references

In spite of having mentioned the review of external reports, a list of the corresponding references is not presented anywhere.

Other comments

It could have been interesting to realize the investigation, at least partially, during a time of less emigration. Generally, it is considered that the most active peasant population migrates during the winter due to the lack of job opportunities.

Likewise, it could have been interesting to specify which of the affected animal and vegetal species are the most sensitive.

DOCUMENT 13

**Informe de misión sobre la contaminación de aguas por la explotación
minera en las regiones de Uncla y Otavi -- Departamento de Potosí, Bolivia
PAC
EC Commission - 1991**

A. Authors

These are independent experts hired by the Belgian consulting firm TRANSTEC.

B. Funding sources

European Commission

C. Objectives

- Identify in a precise way the causes, sources and nature of pollution affecting areas of intervention of the Programa de Autodesarrollo Campesino (see detail below).
- Recommend actions oriented towards the improvement of mineral treatment systems and of river health and towards the education of public authorities and development organisms.

D. Methodology

No chapter referring to the methodology is presented. However, it can be observed that the investigation considers the following steps:

- Visit to selected areas according to the existence of actions programmed by PAC (Linares and Nor Chichas provinces), and collection of algae, soil and water samples.
- Assessment and interpretation of the existing information; particularly topographic and geological maps from IGM and UATF.
- Analysis of the samples in Bolivian and Belgian laboratories.
- Redaction of the final report.

E. Results

In respect to pollution affecting the PRB, the main products of this investigation are:

- Analytical data referring to algae from the Toropalca river and to garden bean vetch (*Vicia faba*) from the La Lava, Toropalca and Puna sub-basins. Those results indicate pollution in the La Lava and Toropalca sub-basins.
- Analytical data referring to water from the Toropalca, Andacaba (called Cumurana in the report), La Lava and Puna rivers. The results indicate :
 - the excellent quality of the Puna River water.
 - the pollution by sodium cyanide, zinc, antimony and manganese of the Toropalca River.
 - the extreme pollution by zinc, nickel, iron and manganese of the small Andacaba River.
 - the pollution by zinc and manganese of the La Lava River.

- the risk of accidental pollution in the Toropalca River

The main recommendations are:

- The implementation of a monitoring system of water and crop quality in risky areas.
- The strengthening of the laboratory of UATF, in terms of equipment and human resources. This action has been realized; however this does not solve the problems associated with analytical investigations in a definitive way.
- Protection of abandoned mines against drainage.
- Construction of tailing dams and implementation of specific sites where to deposit solid wastes, protecting them against rain and wind; this has been realized by some medium-size enterprises.
- Promotion of less toxic chemicals in the processing systems; the document does not specify which kind of products should be used.
- Establishment of legal mechanisms that would serve as reference in case of social conflicts; new regulations have, since then, be promulgated.

F. Global evaluation

Integrity of the focus

The survey considers some aspects related with agriculture, but it does it in a superficial way.

On the other hand, the proposed solutions demonstrate a more integrated approach.

Extent of the study

With respect to the PRB, this short survey (some two weeks) covers three sub-basins (Puna, La Lava and Toropalca).

Quality and clarity of the methodology

The methodology applied helped reaching the objectives of the study. However, it does not solve the limitations caused by the extreme shortness of the investigation.

Objective and scientific evaluation of pollution

The data and interpretations presented demonstrate an adequate level of objectivity.

Clarity and consistency of conclusions and recommendations

As already indicated, the recommendations and the conclusions are clear, coherent and interesting. Some recommendations have been applied recently.

Quality of document presentation

The document is relatively easy to read. Nevertheless, it must be indicated that no version has been found with a good reproduction level of the analytical results obtained from the Laboratory of the UMSS.

Historical references and their utility

There is no comments referring to historical aspects related to pollution caused by mining activities.

Bibliographical references

No bibliographical references were found.

Other comments

An important point is the one referring to the pollution produced by abandoned sites of production. It is said that they constitute a significant source of pollutants. Furthermore, the report states that the costs of treating contaminated waters is excessively high and that pollution should be tackled at the source. Ultimately, the authors suggest that the required technological changes would not be viable without a clear political decision on the part of the national authorities.

DOCUMENT 15

Impacto ambiental de la actividad minera de Comibol en Bolivia
Duran de la Fuente H. and Sergio Castro F.
World Bank - 1989

A. Authors

Nothing is said about the authors except their names.

B. Funding sources

The World Bank.

C. Objectives

No specific chapter is referring to the objectives of the survey. However, it is clear that the main one is to assess the environmental impacts of the mining activities of COMIBOL.

D. Methodology

No specific chapter is referring to the methodology applied; however, reading the document allows to identify the main methodological steps of the survey.

- Analysis of the economic context within which COMIBOL activities occur.
- Visits to operation sites of COMIBOL.
- Analysis of the environmental issues observed during the field visits and of the ecological, legal and professional context within which those issues take place.

E. Results

In respect to the issue of the PRB pollution, the main results of this survey are:

- A description of the activities of the visited sites (see below).
- Relatively detailed recommendations oriented to the control of pollution.
- The proposition of an action plan oriented to the mitigation of environmental impacts of those sites. The proposition is made of 18 activities that can be grouped in the following way:
 - Preparation and organization of the action plan
 - Design and construction of dams
 - Improvement of production systems in the sense of reducing the volumes of polluting cases emitted
 - Design and construction of sites where to deposit solid wastes adequately
 - Environmental monitoring in the production areas.

F. Global evaluation

Integrity of the focus

Some legal aspects are considered in the description of the context. The analysis of the impacts, as well as the suggestion of solutions seem to be based on a technical and less integrated approach.

Extent of the study

With respect to the PRB area, the survey realized between June and August 1989 covers some of the most important operations of COMIBOL:

- "Cerro Rico" mine and Velarde processing plant of Empresa Unificada of Potosí;
- Processing plants of Vetillas and Tatasi of the Empresa Minera Subsidiaria Quechisla;
- Foundry of La Palca of the Empresa Unificada de Potosí.

Quality and clarity of the methodology

The objectives defined were reached, but the methodology does not compensate totally the short duration of the study, particularly in terms of field work.

Objective and scientific evaluation of pollution

The information given over the environmental impacts is based on a very complete technical knowledge of the production systems of COMIBOL. This enables, even without specific analysis, to estimate the type and intensity of pollution processes generated by COMIBOL.

Clarity and consistency of conclusions and recommendations

The survey presents clear recommendations to face pollution processes caused by those operations of COMIBOL (see results).

Quality of document presentation

Even if the analyzed document is not the final version of the report, its reading is easy.

Historical references and their utility

Some historical references were found, but they are not developed.

Bibliographical references

No bibliographical references were found.

Other comments

It is suggested that pollution should be perceived as a symptom of the inefficiency in the management of the production system.

DOCUMENT 19

Balance hídrico superficial de la Cuenca del Pilcomayo
Ricardo Arellano Albornóz
PHICAB - 1988

A. Authors

Except his name, no information is given on the author who worked for PHICAB.

B. Funding sources

IHH, SENAMHI and ORSTOM.

C. Objectives

The main objective was to elaborate the water balance sheet of the PRB. More specifically, it is intended to improve the knowledge upon distribution, movement, quantity, variation and transport of water in the different places where it can be found.

D. Methodology

Even if there is no specific chapter referring to a methodology, it is possible to deduce that the investigation considers the following steps:

- Description of the Pilcomayo River and of the Pilcomayo River Basin, in terms of sub-basin limits, geographical unit limits, climatic limits and climatic classification;
- Description of the main characteristics of the basin, in terms of topography, geology, vegetation and soil uses, ecology and economic aspects;
- Survey of the parameters which intervene in the superficial water balance of the PRB;
- Data collection from the SENAMHI centers;
- Analysis of the consistency of data based on the method of double accumulation;
- Complementation of statistics referring to precipitation;
- Evaluation of precipitation based on the isoyet method;
- Presentation of the results for each sub-basin.

E. Results

With respect to the issue of pollution, the most relevant information are the following:

- The control of pluviometers is relatively discontinuous
- The density of the net of stations equipped to measure precipitation is not appropriate; it is insufficient (average of one station every 1.300 sq. km) and his spatial distribution is irregular.
- There is a lack of information about the basin and its sub-basins limits.
- Regarding temperatures and river flows, the situation is even worse (5 stations to monitor river flows and one station equipped to monitor temperature every 3.100 sq.).
- In the PRB, average precipitation and temperature vary from 300 to 1000 mm and from 6 to 24 Celsius grade, respectively.

A recommendation refers to the promotion of the progressive improvement and growth of the stations net to allow for the river flows and precipitation to be adequately monitored. It is also suggested that the projects related with the development of water resources should be clearly registered so as to encourage the planning of those resources use.

F. Global evaluation

Integrity of the focus

The investigation is focused on a specific aspect of the context that is of vital importance for the comprehension of pollution problems and to the planing of sustainable management systems of the PRB.

Extent of the study

The survey covers the entire PRB in Bolivia and bases itself on information collected during 15 years (from 1968 to 1982).

Quality and clarity of the methodology

No specific chapter refers to the methodology, but the reading of the report offers a clear idea of the steps followed.

Objective and scientific evaluation of pollution

This survey does not refer to water resources qualities and, therefore, does not inform about aspects related to the pollution issue.

Clarity and consistency of conclusions and recommendations

The conclusions correspond to a synthesis of the results obtained and are presented in an understandable way.

The recommendations are clear and have much to do with the issue of pollution monitoring of the PRB.

Quality of document presentation

The document is well structured and presents many maps that helps visualize the results of the different monitoring activities.

Historical references and their utility

Based on data referring to a period of 15 years, the investigation is particularly important to understand the spatial and temporal variability of climatic and hydrological parameters.

Bibliographical references

A very useful list of references related to the issue of superficial water balance is presented.

Other comments

To treat the issue of the PRB pollution in a consistent and professional way, it is absolutely necessary to understand that there is a tremendous lack of information and data. This fact makes the assessment of the impacts of specific causal factors difficult, if not impossible. In this sense, and even if this survey has been done at a preliminary level, this report is particularly valuable.

DOCUMENT 20

Cuenca de La Plata: Aprovechamiento Múltiple de la Cuenca del Río Pilcomayo
OEA
Gobiernos de Bolivia, Argentina and Paraguay – OEA - PNUD - 1977

A. Authors

The Inter-American Development Bank (IDB) acted as the executing agency of the United Nations Development Program (UNDP) and delegated the direct execution to the American States Organization (OEA).

B. Funding sources

The governments of Bolivia, Argentina and Paraguay, UNDP and OEA.

C. Objectives

The general objective of the work is: the integral regulation of the Pilcomayo river in order to reach a rational use of the water resources of the PRB (not only in Bolivia) inside a plan. This plan would look for the sustainable development of the region in socio-economic and environmental terms.

The specific objectives of this initiative, corresponding to the issue of the PRB pollution, are:

- Diagnosis of the social, economic and natural resources.
- Recommendations and formulations of a pre-project for the use of hydric resources and the ground conservation of the upper zones of the basin.
- Assessment of PRB region's potential in terms of underground water, wildlife and aquatic resources of commercial and nutritional value.
- Evaluation of the navigation possibilities.
- Formulation of criteria and proposition of measures oriented to the control of water quality and pollution.
- Contribution to the improvement of the social, economic and cultural conditions of the basin's population in terms of health and productivity.
- Training of personnel of the three countries in order to realize studies, formulate and execute similar projects.

D. Methodology

The study began in February 1975 and the field phase was concluded two years later.

Three volumes and six reports were elaborated.

No presentation of the methodology was found. However, from the reading of the documents, we can assume that to execute this project with respect to the issues directly or indirectly related with water pollution, the following actions were undertaken:

- Description of the global context of the project, in terms of natural and human resources, social and economic activities and characterization of the development projects presented in the reports (general volume);
- Descriptions of the climatology, hydrology, fluvial morphology and sedimentology. Information about the use of the water resources (with a short point referring to pollution from mining activities) and an evaluation of the superficial water resources (volume about water resources - the final version was not found-);
- Description of geology, vegetation, fishing resources, and information about other environmental issues (volume 3 - preliminary version);
- Elaboration of irrigation development projects reported in six specific reports.

E. Results

Nine volumes were elaborated. All important aspects of the regional context, not only in environmental terms, but in social and economic ones are considered.

In relation with the issue of mining contamination of the PRB, globally, the main products of this work are:

- Textual information, data and maps about the social, economic and environmental aspects.
- Recognition of the inter-relation among the different parts of the river (upper, medium, and lower sub-basins).
- Projects oriented to the natural resources uses of the basin.
- Advises about serious problems of pollution and sedimentation of the PRB affecting its potential in terms of social and economic development; likewise, about the growth of the impact of mining activities on soil and water resources of the basin. The document ratifies that pollution constitutes a serious problem due to the future requirement of water for socio-economic development.

In a more specific way, it is indicated that:

- The main problems of soil and water pollution of the PRB waters are due to the mills of Telamayo, Rosario, Santa Ana, Tatasi, Bierio Uno, and Salasala, which particularly affect the sub-basin of Cotagaíta.
- The Buen Retiro River is polluted with acid water emitted by mining operation sites
- Other pollution sources exist but without specifying names, nor locations. It is indicated that Sodium cyanide, lead and arsenic are among the most dangerous elements detected in the rivers.

F. Global evaluation

Integrity of the focus

The survey covers all the relevant aspects of the regional context. However, due to the extension covered, it is clear that many of those aspects are treated superficially.

Extent of the study

The survey covers the entire PRB in Bolivia, Argentina and Paraguay.

Quality and clarity of the methodology

No presentation of the methodology was found. However, it can be observed that the results are significant and correspond to the objectives. As it is the case for most of the surveys considered in the present work, no information is given about the resources used to reach the objectives. This makes it impossible to assess the efficiency of the methodology.

Objective and scientific evaluation of pollution

It is not possible to assess the scientific quality and the objectivity level of the information in terms of mining contamination. Besides mentioning a small analytical investigation done in Cotagaita by the corresponding public service, the study does not report about the references of any specific investigation.

Clarity and consistency of conclusions and recommendations

With respect to the water pollution issue, among the recommendations necessary to outline, the followings seem particularly relevant:

- The projects presented constitute a form of recommendation about how to develop the regional economy maintaining the potential in terms of natural resources; as far as we know, most of them, particularly those corresponding to the PRB in Bolivia, were not executed.
- The realization of a detailed assessment of the industrial wastes thrown into the rivers that flow into the Tumusla River.
- The installation of water treatment plants for all polluting operations.

Globally, besides some tailing dams such as those of Porco and Caballo Blanco (COMSUR), those proposals were not taken into account.

Quality of document presentation

The work is extremely voluminous, but well structured and formulated.

Historical references and their utility

This report constitutes a historical reference, but does not offer much information about the situation previous to the one found between 1975 and 1977. However, it is interesting to note that the survey reports that the pollution process caused by the mining sector operating in Potosi has a long history.

Bibliographical references

No bibliographical references were found.

Other comments

This work is a very valuable reference for anyone interested to know more about the PRB context and the situation prevailing some twenty years ago.

It is also necessary to observe that pollution problems are not new for the PRB's inhabitants. Moreover, it must also be recognized that knowledge of the problem has been improved in the course of the last two decades and that some initiatives have been implemented to face the pollution issue. However, at the same time, the magnitude and intensity of the problem has been growing rapidly due to the growth of the technological capacity characterizing some operations and to the accumulation wastes associated with centuries of mining activities.

DOCUMENT 23

Estudio de factibilidad para la construcción de un dique de colas en Potosí –
Bolivia
Golder Associates
MEDMIN - 1996

A. Authors

Golder Associates Ltd.

B. Funding sources

MEDMIN – COSUDE

C. Objectives

The objective of this work is the presentation of a project for the construction of a tailing dam that would collect the main part of the solid wastes produced by the mineral processing plants situated in or close to the city of Potosí.

D. Methodology

The principal methodological steps are:

- Identification of the most relevant factors to be considered for the design of the tailing dam
- Identification of sites potentially acceptable for the accumulation of this kind of wastes
- Determination of the geological conditions of the identified areas
- Search for soils with the required characteristics for the foundations of the dam
- Determination of the seismic and hydrological conditions
- Analysis of the characteristics of the tailings to be accumulated in the dam
- Analysis of the tailing collection mechanisms and of the recycled water distribution
- Proposition of a design for the dam
- Assessment of the capital, operation and closure costs and of the average cost per ton of accumulated material.

E. Results

This work offers a solid proposition for the construction of a system that, technically, offers an opportunity and conditions required to obtain an immediate and drastic reduction of the Pilcomayo-La Ribera River pollution by solid elements. It is generally considered that an average of a thousand tons of suspended solids are transported by this river every day.

Furthermore, it gives a clear idea of the costs associated with the construction (US\$ 2.3 millions), operation (US\$ 5.19 million) and closure (US\$ 1.52 millions) of the dam which will have a maximum capacity of some 3.1 million cubic metres. This would result in an average cost of US\$ 1.61 per ton.

F. Global evaluation

Integrity of the focus

The survey intends to demonstrate the viability of a technical solution to the problem of solid waste emissions concentrated in a quite reduced area (city of Potosí and surroundings). Presented in this way, the proposition does not seem to be based on an integrated approach.

This should be discussed with the promoters of the idea (MEDMIN-COSUDE).

Extent of the study

The survey realized between June and September 1995 pretends to design a technical measure that would substantially mitigate pollution of the PRB caused by mining.

Quality and clarity of the methodology

The methodology allowed for the objective to be attained.

Objective and scientific evaluation of pollution

The data and information given tend to demonstrate that the technical solution is the best one for the moment. It is stated that the main pollution problems arise from the solid elements transported in suspension in the water. This is sustained by arguments such as the one which stipulates that the chemical products used in the flotation process, exceptionally signify a problem in terms of toxicity of tailing water.

It would have been convenient to defend this statement which seems to be opposed to the conception many people have over those products.

It would also have been interesting to complete the cost-benefit analysis by informing in a relatively precise way about the effective potential benefits associated with the operation of the dam.

Clarity and consistency of conclusions and recommendations

The study constitutes a detailed recommendation oriented to solve one of the most serious problems caused by the mining sector at the PRB.

Quality of document presentation

The presentation is good and the reading easy.

Historical references and their utility

Some historical references are mentioned, but they are quite superficial

Bibliographical references

A useful list of references is presented and includes MEDMIN reports cited in Annex 2 and 3 of the present survey. Those mostly refer to technical information about the construction and management of this type of treatment system.

Other comments

The proposition is interesting. However, in the economic, social and political context prevailing in Bolivia, the viability of this project may be questioned. To organize the management of the dam could be quite more complex than what it appears to be at first sight.

Furthermore, the credit and/or donation that could allow the project to be implemented could be criticized due to the fact that this strategy could not be extended to the majority of the existing processing plants.

DOCUMENT 25

**Evaluación ambiental de los sectores minero e industrial
SES y Secretaría de Medio Ambiente y Ministerio de Minería y
Metalurgia
Government of Sweden and the World Bank - 1993**

A. Authors

This survey was realized by SES in coordination with SENMA.
The team of SES was formed by experts and engineers in industrial water, mining processes, health and industrial security, solid wastes, industrial economy, environmental regulations. A lawyer specialized in environmental issues was also part of the team.
On the part of SENMA, the team was formed by a lawyer, specialists in geology, water resources, construction, waste management, health and industrial security.

B. Funding sources

Government of Sweden and the World Bank.

C. Objectives

The main objective is the establishment of the foundations of a strategy that would mitigate the environmental problems caused by the industrial and mining sectors, based on an assessment of those sectors on a national scale.

More specifically, in respect to the issue of the PRB pollution, the objectives are to:

- Identify and assess the impacts of the main industrial sources of water pollution, in environmental and social terms.
- Recommend actions in the short term that would improve the environmental situation.
- Offer new and concrete ideas referring to the promotion of the design of a legal and institutional framework appropriate to face pollution consequences.
- Propose amendments to the legal instruments related with the natural environment.
- Suggest criteria for the identification of mitigation projects that would require a special treatment.

D. Methodology

Globally, this work was realized respecting the following methodological steps:

- Information and data collection over the industrial and mining sectors and the environmental conditions.
- Meetings with representative of both sectors.
- Identification and selection of the cooperation sites to visit considering criteria of representation of the different sub-sectors, geographical covering, and enterprises of different sizes.
- Data collection through visits to the elected enterprises, visual observations and sampling of liquid effluents and solid wastes.
- Systematization of the information and data obtained through the visit.

- Meetings with public authorities and private companies, oriented to consultation and discussion over legal and technical aspects.

E. Results

With respect to the issue of the PRB pollution, the main products of this work are:

- Description of the political, legal and environmental context within which the mining sector is developing.
- Information about environmental issues related with mining production.
- Information about the mineral processing systems of different plants and mineral extracted by different mines situated within the PRB.
- Short assessment of the social impacts of mining activities (this means that it was not referring to the social impacts of pollution), in terms of cultural settings and traditional organization structures of the Andean region.
- Information and data on the pollution caused by mining in the areas of Potosí and Quechisla. Among the information and data presented, we should mention the following:
 - Annually, the Pilcomayo-La Ribera River transports some 1200 tons of zinc, 30 of arsenic, 5 of cadmium, 70 of copper, 11 of antimony and 200 of lead as dissolved elements. At the sametime, a larger quantity of solid elements is transported in suspension. Moreover, it is recognized that large quantities of sediments are accumulated in the river beds.
 - In the Quechisla area, characterized by an arid climate, some fifty, mostly small, operations exist. Regarding this area, it is indicated that the environmental impact is significant and that it is possible that land of the Vetillas sub-basin were contaminated.
- Identification and recommendation of the most urgent actions and programs oriented to the mitigation of environmental problems caused by mining activities
- Assessment of the potential costs of mitigation actions based on the construction of tailing dams.

This report offers a clear and concrete description of the socio-economic context related to the environmental issue prevailing in 1992. It takes into account important factors such as the organization of the state, and the economic and environmental policies. It also insists over the critical situation found around the city of Potosí.

The solutions proposed are based upon an integrated vision of the national and regional contexts. They offer interesting ideas on the way environmental impacts could be mitigated. Among them, the following should be mentioned:

- The mining sector has to pay more attention to the environmental issue
- In terms of regulations, new instruments should be designed with precaution but the limited effectiveness of those regulations should also be recognized.
- In terms of public policies and sustainable technologies, those latter should be promoted through economic incentive mechanisms and information diffusion.
- Strengthening of the capacity of laboratories and of human resources in charge of environmental monitoring.
- Assessment of the economic viability of the production systems of small enterprises.

- The report does not emphasize technical solutions, but the promotion of an adequate context for the improvement of efficiency and sustainability in the use of natural resources. It means that, at first, improvements of the political and legal context should be preferred over technical ones.
- In terms of institutional aspects, it is recommended to specify the institutional responsibilities related to environmental issues within the public sector and to strengthen the institutional capacity within and outside the government.

F. Global evaluation

Integrity of the focus

Considerations for the most fundamental aspects of the context and the professional diversity of the team described above demonstrate a clear willingness to apply an integrated approach to the analyzed issues. Even if technical solutions are given relatively low priority, the suggested solutions are also integrated.

Extent of the study

The study covers the country and all the sub-sectors of the mining and industrial sectors.

Quality and clarity of the methodology

The methodology is well explained and its application is successful.

Objective and scientific evaluation of pollution

The analytical results presented, as their corresponding interpretations, show a high level of objectivity.

Clarity and consistency of conclusions and recommendations

As it has already been indicated, recommendations and conclusions are clear, coherent and very interesting.

Quality of document presentation

The document is well structured and is easy to read. In the accessed version of the report, some small problems of pagination are observed

Historical references and their utility

A historical perspective allows to learn some instructive aspects on the evolution of the mining sector and to better understand the environmental problem associated with it.

Bibliographical references

Bibliography is complete and useful. It has been used to identify a large part of the documents considered in the present survey.

DOCUMENT 28

Review of the Porco mine tailings dam burst and associated mine waste problems, Pilcomayo Basin, Bolivia

University of Leeds and Marine Marine Resource Assessment Group Ltd

Overseas Development Administration of the United Kingdom - 1996

A. Authors

This report was elaborated by Mark G Macklin, David Preston and Claire Sedgwick (University of Leeds - School of Geography) and by Ian Payne (Marine Resource Assessment Group Ltd).

B. Funding sources

Overseas Development Administration of the United Kingdom.

C. Objectives

The main objective of the report is 'to assess the extent of the environmental damage already done, the current risk and the likely future risks from seasonal changes in river flow rates' and 'to assess the effects on the fish population and possible consequent dangers to the human population'.

D. Methodology

No specific chapter is referring to the methodology applied. However, it is possible to observe that the report has been elaborated considering the following steps:

- Description of the background to the Porco incident.
- Visit to Porco mine and obtention of data and information through interviews and sample collections from sites situated in the Pilcomayo River Basin between Porco and Puerto Margarita.
- Interpretation of data and information.

E. Results

The main results are the following:

- Description of social and physical aspects of the Pilcomayo river basin (upper Pilcomayo and Pilaya sub-basins). For example, it is mentioned that the upper Pilcomayo sub-basin population is of 424.000 inhabitants (excluding the part of the population living in the Department of Tarija).
- Identification and evaluation of some impacts of the Pilcomayo river pollution. Amongst many valuable information, the following seems particularly important:
 - the degree of dependence on river water varies according to the site and the socio-economic situation of the people. The report states, for example, that many people living on its riversides have no alternative water source to the river and are unable to avoid drinking water at times of high silt load and possible maximum toxicity.

- the interpretation of the results corresponding to the water samples analyzed by the ODA mission stipulates that 'severe and widespread metal pollution has occurred in the Tumusla-Pilaya and Pilcomayo river basins arising from present and past mining activities.
- the extreme level of poverty and its associated low level of nutrition makes that many people are particularly vulnerable to water pollution, even with low levels of toxicity.
- the fishery for the sábalo of the Pilcomayo river is one of the largest suppliers of fish in the country with an average yield of 1.300 metric tons per year (Payne and Salas, 1993).
- the sábalo is an essential source of both food and income in the Guaraní region.
- some cultivated species (tomato) are more sensitive than others (potato, pumpkins, fruit trees).
- About the Porco incident, it is reported that the "black water" came in three waves, even by people living as far from Porco as Puerto Margarita. It is also said that people observe no particular mortality in fish or other animals associated with those waves. However, the report states that amongst the main risks with this kind of pollution are the bio-accumulation of heavy metals and the asphyxia of fishes caused by an excessive sediment load in the water. It is also said that the incident of Porco has demonstrated that wastes from the mining area in the headwaters of the basin does reach the lower parts of the river.
- Identification of some locally designed alternatives for partial decontamination, such as the use of the leaves of a local plant (in the Guaraní area) to speed the settlement of silt.
- In a report of a study conducted between June and August 1996 by QPID and CER-DET, it is mentioned that fishes were encountered with significant amounts of arsenic, copper, mercury, lead, tin and zinc.

The main recommendations are:

- The realization of an immediate assessment of the magnitude of the continuous discharge from small-scale mining and of the stability of large storage structures.
- The assessment of the risk associated with the regular consumption of fish and of river water caused by chronic mine waste pollution. Monitoring should include sediment, water, fish and socio-economic indicators.
- The provision of simple tube-wells for communities living on the riversides and that need to drink the river water.
- The improvement of the Pilcomayo river basin management through co-ordination at an international level and with the support of the international community and funding agencies.

F. Global evaluation

Integrality of the focus

Among the reports considered, this is probably one of the best in terms of the integrality of its approach.

Extent of the survey

The survey considers the Pilcomayo river basin from Porco (Department of Potosí) to Puerto Margarita (Department of Tarija).

Quality and clarity of the methodology

The methodology is considered to be efficient, having met the objective of the survey in a very short period of time.

Historical references and their utility

Although some references are mentioned, these are mostly limited to generalities.

Bibliographical references

Only two references are presented in annex.

Other comments

It is useful to contrast the observations made by this mission with the reports published by the COMSUR Company and by the Ministry of Sustainable Development and Environment (MDSMA).

The report of the latter indicates that 'as a result of the opportune intervention and actions realized by the national and departmental authorities, by COMSUR and by the peasant communities, it has been possible to control and mitigate the negative effects that could have been caused by the Porco Mine dam burst'.

Meanwhile, the ODA report indicates that 'the length of the Tunusla-Pilaya system affected by the Porco mine spill was considerably greater than suggested by MDSMA'.

Comparing both reports shows how serious is the problem of information management when treating the Pilcomayo's pollution issue.

The present report, particularly in terms of the information referring to the fisheries, has benefited from the reports of past missions organized by the ODA Misión Británica in collaboration with the Centro de Desarrollo de la Pesquería (Bailey 1973, Payne 1986, Payne and Fallows 1987, Payne and Harvey 1989 and Payne and Salas 1993).

This survey is the only one that mentions something on the following fact: the mine waste disposal problem in the headwaters of the river constitutes a time bomb threatening any future development of water resources within the river basin.

V. CONCLUSIONS ABOUT THE EXISTING DOCUMENTATION

From the analysis of the processed information, it is possible to give an outlook of the environmental and socio-economic problems caused by the mining sector in the Pilcomayo River Basin (PRB).

First of all, a map has been elaborated referring to the main pollution sources from the mining sector and the pollution levels of the main rivers of the six sub-basins forming the PRB in Bolivia. This map includes the information found in documents 3, 6, 8, 11, 13, 15, 16, 17, 18, 21, 24, 25, 28, 29 and 30.

The approximate geographical position of the pollution sources (mines and processing plants) is based on the information presented in document 6.

Document 19 constitutes the main source of information referring to the geographical situation of the rivers and sub-basin limits presented in this map.

It would have been possible to present on the map the specific source of the information but it has seemed to be more appropriate to detail this information on a specific chart because of the existence of some contradictions between documents.

Table 1.

Pollution levels of rivers pertaining to the PRB according to different information sources (part of the documents commented in the present report).

River name	Low Pollution Level	Medium Pollution Level	Heavy Pollution Level
Upper Pilcomayo			8, 24
La Ribera-Pilcomayo			6, 15, 23, 25, 28
La Lava			6, 11, 13, 21, 23, 25
Toropalca - Tumusla	29, 30	6, 13, 25	11, 28
Cotagaita		6, 17	15, 16
San Juan del Oro	17	6	15, 16
Pilaya	6, 30	3	24, 28
Vitichi		6	
Caiti		6	
Qhechisla		6	
Tupiza		6	
Tatasi		6	
Viluyo		6	
Blanco		6	
Tazna		6	

The figures in the table relate to the document numbers referred to throughout the present report.

In case of contradictory assessments over the pollution levels, as can be observed in Table 1, the rivers have been coloured mixing red and green. This occurs for the Cotagaita San Juan del Oro and Toropalca-Tumusla river basins.

The map also reports about the lack of information on the PRB's pollution levels in its lower part (questions marks on the map). But some information is available for the river downstream from Malmisa mine (this information comes from one of the Malmisa mine owners).

Documents such as number 1, 5 and 22 also contain data and information related to pollution levels of certain rivers. However, they have not been used for the elaboration of this map, for reasons that are exposed in the respective comments.

Concerning the graphical report of the impacts identified and/or assessed by some investigators, this has been considered as an impossible task. There are two basic reasons for this situation:

Firstly, the documents referring to pollution impacts (apart from the simple observation of increased concentrations of heavy metals in water draining mining operations), such as documents 1, 5, 6, 8, 10 and 22, suffer from serious deficiencies in terms of objectivity and/or scientific bases.

Secondly, it is considered that the lack of information system for monitoring the social, environmental and economic situations of villages supposedly affected by pollution, makes it difficult to assess the impacts of identified pollution causes in an objective and scientific mode. This does not mean that there are no impacts. But their analysis is not consistent so far ¹.

Apart from the information presented on this map and in general terms, it clearly appears from the analyzed documentation that:

- There are substantial differences between the levels of knowledge over the sub-basins forming the PRB. Effectively, the dynamics and state of some sub-basins in socio-economic, as well as in environmental terms, are still insufficiently understood or known (Lower Pilcomayo, Mataca, Malmisa, Pilaya), while some other sub-basins have been regularly surveyed (La Ribera-Pilcomayo and La Lava).
- Part of the available information and data suffers from deficiencies caused by different factors. The most common ones are:
 - Lack of a global framework of analysis and difficulty for the investigators to integrate different social, environmental and economic parameters and to take into account the relationships between these parameters (what is called an integrated approach).
 - Lack of consistent methodologies of investigation or insufficient information given about the methodology applied (see documents 5 and 22).
 - Spatial and/or temporal limitations of the surveys.

- Subjectivity of the collectors and/or of the interpreters of the data and information (compare documents 29/30 and 11/28).
- Limitations of the investigation team in terms of financial and/or professional capacity.
- Two main characteristics are reinforcing each other and are making it difficult to improve the global understanding of the problem:
 - The contexts in which pollution occurs, as well as its causes and impacts, are everything except static and homogeneous. They change over time and over space.
 - The information related to the pollution of the PRB has mostly been obtained during the last two decades, while the present pollution caused by mining activities is rooted five centuries ago.
- Some parameters, highly relevant to the assessment of the causes and impacts of pollution, are not or inadequately monitored (climate, soils, river flows, subterranean water resources, social practices, nutrition, human health, production costs and benefits in agriculture and mining sectors, etc.).
- The level of reliance of the information varies and must be assessed before the effective use of this information. ² However, the combination of the enclosed map with the chart above allows for an easy comparison and analysis of all the key data and information about any given part of the basin.

Based on this general assessment, the most relevant aspects about the context and impacts of the PRB pollution as well as the most attractive solutions are presented below.

V. 1. Existing information about the regional context

Generally the existing information is scarce and refers to small areas studied during short periods of time. Furthermore, those surveys are mainly selective and pay insufficient attention to the relationships between all the elements to be considered.

However, the following aspects are considered as particularly relevant:

Environmental context

- The pollution levels in terms of heavy metal concentrations observed between the Pilaya River and Villamontes, following document 2 and 3, are low or nil. This is questioned in document 28.
- Documents 6 and 13 report some analytical results concerning soils situated downstream from mining operations and indicate that the land is partially polluted by elements such as cadmium (Cd), zinc (Zn), lead (Pb) and boro (B).
- There is a clear consensus about the fact that almost all the rivers draining operating mining areas are chemically contaminated. Effectively, all documents are reporting excessive pollutant concentration close to the mining operation centres. Discussion can appear when the pollution levels are assessed at some distance from the pollution sources.

- Very few mining companies have adopted technologies or treatment systems oriented to mitigate their impacts on the environment (documents 25, 29 and 30). The large majority of mining operations are realized without any or with insufficient treatment of their liquid and solid wastes (documents 12 and 28).
- An interesting case is reported by document 13; it refers to the fact that indigenous people have expressed that pollution occurs through short events and is not permanent (Toropalca sub-basin).
- PHICAB in document 19 mentions deficiencies with respect to meteorological data collection and the lack of information about sub-basin limits.

Economic context

- The main pollution sources from the mining sector are quite well identified, in terms of operations which have ceased some few years ago or that are still active. In this respect, documents 6, 13, 15 and 25 add a lot of useful information. They report the principal characteristics of those operations (kind of technology, volume and type of mineral treated, geographical position, etc...).
- Very little or no information at all has been found in most documents about the pollution potential of abandoned sites and of sediments deposited in riverbeds. These aspects can however not be lost of sight in any operational approach in the future.

Social context

- Amongst the social aspects related to the pollution of the PRB, human health occupies a particularly important place. Its monitoring in Bolivian departments such as Potosí is generally irregular and faces insufficient human, technical and financial resources compared with the magnitude and extension of the problems.
- Principally referring to the Pilaya-Pilcomayo sub-basin, document 28 constitutes one of the very few documents offering interesting information and data confirming the variability of social contexts (degree of dependency on river water). It also reports about the extreme level of poverty and low level of nutrition which make people more sensitive to pollution effects. Furthermore, it informs about the socio-economic significance of the silver fish fishery (sábalo).

Legal and political context

- Bolivia has made substantial efforts approving legal instruments designed to conserve its environmental assets. However, three main problems are now faced:
 - Resources are lacking for the effective application of those instruments and there is no perspective concerning the national capacity to obtain sufficient financial resources so as to support the corresponding costs.
 - There are strong social and economic interests opposed to most of these regulations.

- The application of the new norms is causing and will cause a series of social and economic negative impacts. This is mainly due to the fact that a large part of national companies are already suffering from difficult economic conditions, caused by many factors such as high costs of electricity and transport. Those norms and regulations are progressively imposing the internalization of the environmental costs of production. The situation is obviously even worse for the poorest sectors of the population that will have to adapt themselves to those legal mechanisms.
- Document 25 offers some information about those contexts, confirming that substantial improvements could be made. Following this approach, it is particularly clear that the context created by economic policy and legal instruments should be considered in any analysis of this issue.

In general terms, as suggested by SES, the effectiveness of legal instruments is limited and the legal instruments should probably be designed with much more precaution, considering their social and economic impacts, as well as the costs of their application.

Normally, political measures such as particular fiscal, credit or pricing conditions have more possibility to be accepted and well received by the population because they are attractive economically and they concern both agriculture and mining sectors. This kind of policies should be considered to encourage the sustainable management of natural resources and compensate efforts made towards the internalization of environmental costs of production.

V. 2. Existing information about the pollution impacts caused by mining activities

Environmental impacts

It is clear that the main difficulty to assess environmental impacts in the PRB is the lack of information about the state of the ecosystems and about the corresponding ecological processes.

For example, is it very difficult to assess objectively the environmental and socio-economic impacts of a tailing dam burst, without having a clear knowledge of the situation prevailing before the event.

This is the reason why it is definitely necessary to establish a monitoring system in order to collect some reliable information about pollution levels in soils, water resources, sediments, etc.

The analysis of the documentation has largely confirmed this situation:

- Most information and data, commonly presented as part of the impact assessment, are only elements of diagnostics. In this sense, if such information and data are demonstrated to be reliable, it could eventually become a starting point for the implementation of monitoring systems.

- Some surveys, such as that reported in document 2, emphasize the difficulty of assessing pollution impacts. Another common difficulty is the lack of specificity of most symptoms which makes it difficult to determine the incidence or responsibility attributable to different potential causes.
- Almost all impact assessments realized until now are very punctual in time and space and are made without sufficient references about the situation prevailing before the occurrence of the fact which is supposed to be the cause of these impacts.
- Ultimately, supposing that adequate parameters could be identified to assess the pollution impacts, there would still be the difficulty of determining if the effects observed are the products resulting from the present or past emissions.

Social and economic impacts

If environmental impacts can not be assessed, how could we evaluate the social and economic impacts of pollution? It is obviously more difficult because these parameters are influenced by a large series of factors. For example:

- Emigration of rural people towards cities and other rural areas is the product of factors such as agroecosystems potentials, market prices of their traditional products, climatic conditions, state and private sector interventions (including development projects), economic policy, etc...
- Health conditions are also influenced by many different factors: water pollution by biological elements, consumption of alcohol and/or tobacco, inadequate food regime, excessive work intensity, lack of sleep, etc.

Almost all documents address, in some way, the issue of the socio-economic impacts of pollution and this topic is central for documents 1 to 5, 8, 10, 22, 29 and 30.

However, reliable data and information are scarce, particularly concerning parameters such as land, crop and animal productivity, emigration, disease in humans, animals and plants. This situation has very serious consequences because it dramatically restrains the possibilities to identify solutions that correspond to the real needs of the region.

Based on regional experience it is considered that the inappropriate management of water and tailings by the mining sector, through its present and past activities during centuries, and the emission of millions of tons of wastes as toxic as cadmium, lead, arsenic and mercury, which are now spread across the PRB, constitute a very harmful and insidious cause of the present socio-economic regional crisis.

At the same time, unsustainable management of prairies and soils by the rural population are at the root of generalised soil erosion and river sedimentation processes.

These processes act in a complementary way with water and soil pollution, leading to dramatic social and economic consequences in the whole PRB. This aspect is certainly underestimated and almost inexistent in the documentation assessed.

Even in the absence of precise data, the regional experience allows for listing the main following consequences of these two factors (mining and soil erosion):

- Loss of land productivity and misery originated by the destruction and/or the pollution of the best land (alluvial areas) through inundation intensified by the brimming of river beds, and/or by the deposition of particles potentially harmful for plants and/or soil conditions.
- Loss of opportunities in terms of creating irrigation systems and hydroelectric dams caused by sedimentation and/or pollution.
- Increased pressure over marginal land, caused by the loss of alluvial plains.
- Disappearance of the cheaper source of natural protein (fish) in areas situated close to mining operations.
- Profound disturbance of the traditional Andean social organization.
- Chronic malnutrition and serious worsening of health conditions.
- Lack of employment opportunities and progressive emigration.
- Rapid destruction of infrastructure such as road and dams caused by sedimentation and inundation.
- Social conflicts.

V. 3. Existing information about the possible solutions

As it has been observed, there is a tendency in the available documents to favour technical solutions over political and legal ones.

Technical solutions

- Some technical solutions coincide with the impacts identified. This is the case with documents 6 and 8 which propose the realization of land rehabilitation programs. But this technical solution is made without previous assessment of other potential causes of land degradation, such as inadequate land use or inappropriate practices causing soil erosion, are considered. Another question referring to this proposal is that no idea is given about the costs and potential economic benefits associated with it.
- Interesting proposals, made in document 13, suggest that abandoned mines should be treated in such a manner that water would not be allowed to enter them. This proposal is obviously justified in technical terms. The question would be to determine who would be charged with the costs of such measures.
The author also suggests the promotion of the use of less toxic chemicals.
- The monitoring of water and agricultural products and river flows, interests many institutions, villagers and experts (6, 8, 13, 15 and 25).

- The construction or improvement of irrigation systems capturing and transporting good quality water (8 and 13), the monitoring of local people's health (8), the construction of tailing dams (15 and 23), the implementation of more efficient systems of production, which would release less wastes transforming them into benefits (15 and 25), the improvement of regional laboratories (13 and 25) and efforts oriented to the improvement of monitoring centres which would collect data about rain and river flows (19) are also suggested.

Political and legal solutions

The recommendations presented in document 25 are interesting and should be developed. They include the precautionary design and application of legal instruments accompanied by governmental policies oriented to the creation of economic incentive mechanisms favouring the adoption of sustainable technologies. It is suggested that important economic factors, such as water, energy and waste disposal prices, should be used to promote an efficient management of natural resources.

- 1 Present on a map impacts such as a 41 % diminution of gross benefits for "campesinos" in Chuquisaca, without specifying the years of production considered, the type and prices of products sold, the value of the national money and the climate having characterized the years of production considered, only would serve to create confusion.
- 2 A simple example can confirm the limited information and data confidence, even at the macro-level: PHICAB in document 19 states that the total area corresponding to the PRB in Bolivia is of 92.971 km². However, the EC-Request 4234-1995, mentioned by FOBOMADE in document 24, informs that this area would be of 80000 km². Finally, following QPID, FIA and CER-DET in document 4, the PRB area in Bolivia is supposed to cover 98.000 square kilometres.

VI. RECOMMENDATIONS

Based on the assessment above and on its conclusions, some recommendations are now presented. They intend to give concrete suggestions that could improve the understanding of the issues related to the PRB pollution problems, and to alleviate the critical situation faced by its inhabitants.

These propositions are mainly based on the knowledge obtained through the realisation and assessment of rural development projects in the region. This methodological approach consists for instance in integrating socio-economic factors in the environmental strategy, in order to improve its impact and its feasibility.

The three main fields of intervention recommended to that aim, are:

- Monitoring the Pilcomayo River Basin
- Implementing projects that address the very causes of the socio-economic problems resulting from the pollution produced by the mining sector;
- Creating a favourable context for the projects and activities that address the causes of pollution.

The proposed approach to these initiatives consists in:

- integrating some socio-economic factors in the preparation, implementation in monitoring of any study or physical investment in the sector. By doing so, it will be possible to better identify the priority needs, to optimise the impact of the projects and to enhance the sensitisation and motivation of all parties concerned;
- developing a participatory approach: an optimal participation of the different social and economic sectors and institutions concerned, will strongly improve the feasibility of any proposed action. This suggestion comes from the too frequent observation of the serious problems faced by interventions characterised by authoritative intervention and insufficient participation of local actors in planning, as well as in executing and monitoring development projects;
- integrating the recent institutional development of Bolivia into any proposed action: the "Ley de Participación Popular" provides some good opportunities for involving (and funding) local communities in some field action. The "municipio" and the "OTB" (Organización Territorial de Base) for instance, will be key players in the sector in the future;
- strengthening the process through quick-impact actions; whatever action is undertaken, be it at study or institutional level, this action should also pay attention to the identification and rapid implementation of some small field actions that will be of direct social and/or economic interest for the local population and for the local stakeholders;

VI.1. General methodological recommendations for any future project in the sector:

Any action in the sector could/should adopt some of the following modalities:

- Co-ordinated action between public and private institutions oriented to the organisation of the monitoring system implementation process.
- Evaluation of the resources available at the local ('municipios'), regional (department), national and international levels;
- Creation of a legally recognised instance which would be responsible for the monitoring of the project;
- Identification and selection of institutions able and motivated to assume the corresponding activities.

VI.2. Monitoring the Pilcomayo River Basin

The previous investigations could have paid more attention to the socio-economic crisis prevailing in the PRB area, because poverty is closely related with the environmental degradation process that is now affecting the most significant resource of the area: water. The uppermost importance of this resource in terms of social and economic development potential of the region indeed requires such particular attention.

Regrettably, the assessment of the available information demonstrates that those socio-economic aspects have only been treated superficially so far, and without the required human and financial resources.

However, it also shows that this issue must be considered as of the highest importance by people and institutions interested in improving the situation faced.

Any future project for monitoring the contamination of the Pilcomayo basin should therefore include:

- the incorporation of socio-economic criteria in the selection of areas to monitor: demography, migration, agriculture, social and economic structure of the mining business, economic potential of the area...;
- the design of an integrated monitoring methodology, that would register not only the physical impact of the contamination but also its social and economic impacts;
- the elaboration of an action plan covering at least a five-year period in order to assess the variation of the pollution over time but also the effect of the pollution on human settlement and activities;
- the monitoring and evaluation of the action, according to a protocol established beforehand, and associating all parties concerned including the population itself;
- sufficient guarantees in terms of financial support and personal stability. The role of the international co-operation agencies will be of crucial importance.
- sufficient independence from the established economic and political interests, that may have sometimes influenced the objectivity of such initiatives in the past. In this sense the institution in charge of the monitoring of the project should be financially and politically independent.
- the regular assessment of the capacities and performance of the participating laboratories;
- mechanisms allowing for the participation of local people and industries. Local people represented by their local authorities should be constantly informed of the information and data obtained, as well as of the corresponding interpretations. Even more, they should participate during the collection of data and be progressively prepared to collect it by themselves
- mechanisms to guarantee the progressive training and specialisation of the personal of the involved institution;
- a side-budget for the immediate implementation of any simple and effective physical action that would be assessed as potentially being of direct benefit for the local population .

VI.3. Implementing projects that address the very causes of the socio-economic problems resulting from the pollution produced by the mining sector

Any field project in the sector should also adopt some of the following modalities:

- inclusion of socio-economic factors in the objectives, activities, outputs and indicators of the project;
- invitation to the mining and other public and private interested sectors, presentation of the project, discussion and consensus over the strategic lines to be implemented.
- inclusion of socio-economic parameters in the selection of the mining operations to be improved - see above;
- a detailed assessment of the production systems of the selected operations;
- the inclusion of socio-economic criteria in the selection of the technical solutions adopted;

- the investigation at the national and international levels oriented to the selection of the most adapted and efficient technical solutions (document 21).
- the socio-economic evaluation of the costs and potential benefits of the selected solutions;
- the elaboration of a detailed, integrated strategy of action. This should be done in co-ordination with all sectors and in function of the available resources, the motivation levels of different actors (miners, municipios, villagers, etc...), as well as of the economic, political and social context of the moment.
- the consideration of the need for securing the sustainability of tailing dams and sites where solid wastes are accumulated over very large periods of time. The costs of maintaining the closed sites should be evaluated and incorporated in the costs of operation, long before the closure of the processing plant. Also long before the operation closes, the financial resources and the action plan required to maintain those sites in optimal conditions until risks disappear should be presented and approved by public and private representatives.
- a financial participation of the mining companies. No such projects should be fully subsidised. However, taking into account the economic problems of the country in general and of the mining sector in particular, such participation should not be imposed before having established a legal and institutional context in which miners would be encouraged to act in a sustainable way (see below).
- the installation of a monitoring system through all stages of the project.

VI.4. Developing structural measures to create a favourable context for the projects and activities addressing the causes of pollution

Such initiatives are mentioned here for the record mainly; however it may be useful to underline such needs during the implementation of any study or project. When considering structural solutions to environmental problems, it is generally referring to legal and political measures. As said earlier, it would be more advisable to focus on political initiatives.

To reach the goal of creating a differentiated context for those producers assuming measures to protect water and/or soils and for those who do not, the following methodological steps can be recommended:

- Organising workshops with the participation of representatives of all interested economic sectors and of the Ministry of Sustainable Development and Planning, with the objective to better identify the environmentally harmful national policies and practices; and assessing their environmental impact;
- Elaboration of propositions for reforming these harmful policies;
- Discussions and efforts towards consensus upon the proposed reforms;
- Co-ordination and negotiation of the propositions with policy makers, aiming at the application of the proposed reforms;

More generally and at an international level, in the global economy prevailing now, structural incentives could be designed through a better co-ordination between countries interested in promoting environmentally sustainable mining activities. Efforts could also be made towards the planning and organisation, at the international level, of commercial

systems aiming at the generation of economic benefits from the adoption of environmentally sound production systems. This would be a reproduction of what has for instance already been realised in the timber market for the wood produced in forests that are managed in a sustainable way. This obviously falls outside the scope of this study.

VI.5. Follow-up of additional information and studies

Considering the issues treated by documents 33, 34, 37, 38, 39 and 40 and by the institutions that have funded their elaboration, it is highly recommended to proceed to the analysis of these documents. Furthermore, document 41 is also part of the recommended lectures, even if the European Community Commission probably owns much more information referring to the PRB than this single survey.

REFERENCES

POLLUTION LEVEL

- HEAVY
- LIGHT
- IN DISCUSSION
- NIL OR UNDETERMINATED
- LACK OF INFORMATION

- * MINE
- TREATMENT PLANT
- △ MELTING PLANT
- ◐ LUXVIATION PLANT
- TOWN

— RIVER BASIN LIMITS

○ ? LACK OF INFORMATION

REPUBLICA DE BOLIVIA

PARAGUAY

ARGENTINA

50km

