OPS/CEPIS/PUB/02.99
Original: Spanish

Regional Project

Integrated Systems for the Treatment and Recycling of Waste Water in Latin America: Reality and Potential

IDRC–PAHO/HEP/CEPIS Agreement
2000-2002

Guidelines for the Formulation of Projects on Integrated Systems for Wastewater Treatment and Recycling

Prepared by the Project Technical Committee:
Eng. Julio Moscoso Cavallini, Principal Researcher
Eng. Luis Egocheaga Young, Associated Researcher
Eng. Roberto Ugás Carro, Researcher in Agricultural Issues
Dr. Eloísa Tréllez Solís, Researcher in Social Issues

IDRC
CANADA

International Development Research Centre of Canada

Pan American Center for Sanitary Engineering and Environmental Sciences
Division of Health and Environment
Pan American Health Organization
Pan American Sanitary Bureau, Regional Office of the World Health Organization

Lima, 2002

PAHO/CEPIS is a specialized agency of the Pan American Health Organization (PAHO/WHO).

Los Pinos 259, Lima, Peru
P.O. Box 4337, Lima 100, Peru
Telephone: (511) 437 1077
Fax: (511) 437 8289
cepis@cepis.ops-oms.org
http://www.cepis.ops-oms.org

CONTENTS

GUIDELINES FOR THE FORMULATION OF PROJECTS ON INTEGRATED SYSTEMS FOR WASTEWATER TREATMENT AND RECYCLING

1. BACKGROUND AND JUSTIFICATION

Latin America is one of the regions with greater population density in urban areas, encompassing more than 360 million inhabitants (74% of its total population). The coverage of domestic wastewater treatment is only 14% and more than 500,000 ha of crops are irrigated with raw wastewater, which implies high risk of enteric disease dissemination.

Taking into account this context, the International Development Research Centre of Canada (IDRC) and the Pan American Health Organization (PAHO/WHO) signed an agreement for the execution of the project **Integrated Systems for the Treatment and Recycling of Waste Water in Latin America: Reality and Potential,** to be carried out by the Pan American Center for Sanitary Engineering and Environmental Sciences (PAHO/CEPIS) during 2000 and 2002. The project was aimed at analyzing wastewater management experiences in Latin America, recommending strategies for the design and implementation of such systems, and identifying new opportunities.

The Project has been executed in three stages of data collection and analysis in various cities of the Region. The topic to be studied was whether or not these cities treat their domestic wastewater and apply them into irrigation. In the first stage, called **General Studies**, broad technical and economic aspects of 18 cases were addressed. Then, 11 out of the 18 cases were selected to carry out the second stage, **Complementary Studies**, which included the evaluation of their environmental, social, cultural, and legal aspects, as well as the preparation of the preliminary proposal for the integration of wastewater treatment and use in agriculture. During the last stage, **Feasibility Studies**, seven out of the 11 cases were selected and the socialization and development of the proposal with the main local actors was promoted. Table 1 shows four cases of wastewater management: cities where

Table 1. Relationship of case studies for the four management situations

	With treatment	Without treatment
With reuse	Antofagasta (Chile) Cochabamba (Bolivia) Juárez (Mexico) La Vega (Rep. Dominicana) Mendoza (Argentina) Tacna (Peru) Texcoco (Mexico) Villa El Salvador (Peru)	Mezquital (Mexico) San Agustín (Peru) San Martín (Argentina) Santiago (Chile)
Without reuse	Fortaleza (Brazil) Maracaibo (Venezuela) Portoviejo (Ecuador) Puntarenas (Costa Rica)	Ibagué (Colombia) Jinotepe (Nicaragua) Luque (Paraguay) Sololá (Guatemala)

wastewater are treated and used for agricultural irrigation; cities where wastewater are treated, but are not used; cities where wastewater are neither treated nor used for irrigation.

These systematized experiences have made it possible to propose a model for integrating domestic wastewater treatment and use for irrigation, identifying the aspects that determine the design, implementation, and management of integrated systems. The product of this exercise will be reflected in the directives and guidelines to be prepared by the Project.

2. OBJECTIVES

2.1 General objective

These Guidelines are intended to provide a practical methodology to address the aspects that determine the viability and sustainability of integrated systems for domestic wastewater treatment and use.

2.2 Specific objectives

- To propose a logical sequence to address the evaluation of the problem and the formulation of an adequate proposal.
- To describe a practical methodology to develop the technical, environmental, social, and economic aspects that determine the feasibility and sustainability of the proposal.
- To suggest the terms of reference that should be considered in the feasibility studies.

3. DEVELOPMENT PROCESS OF THE PROJECT

The preparation of the case studies sponsored by the Regional Project followed three stages according to the conventional patterns to formulate pre-investment studies. However, the coordination work and technical visits to the localities showed that the sequence used for the development of those studies was not the most adequate. Therefore, the following sequence was discussed and approved by the Technical Committee of the Project to address the feasibility studies:

- Conceptualization of the integrated system model
- Location of the study within the context of the basin
- Identification of the study social context
- Identification of the wastewater legal context
- Evaluation of the existing treatment and reuse practices
- Environmental diagnosis of the study area
- Identification of the actors involved in the project
- Evaluation of water and soil resources in the basin

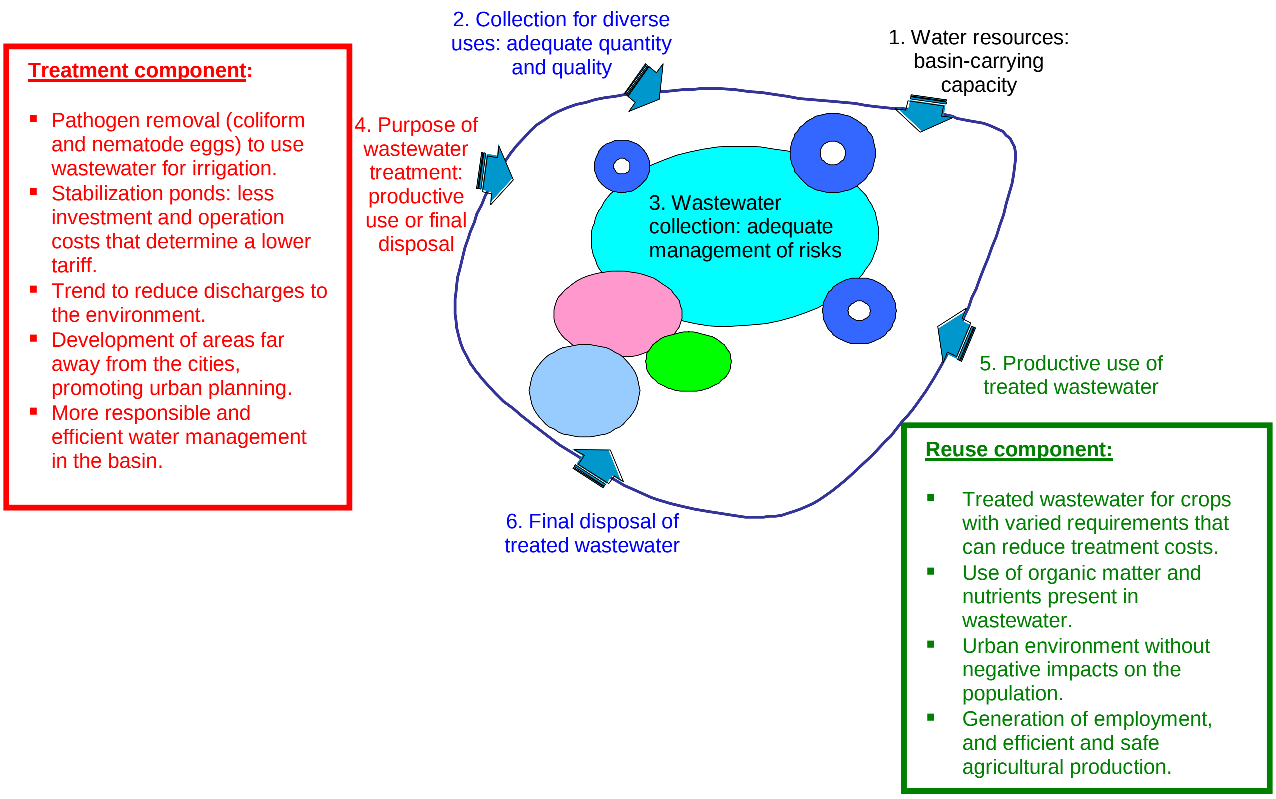
- Definition of the integrated system proposal
- Socialization of the proposal with the actors involved
- Preparation of the agricultural plan
- Design of the treatment system
- Definition of the project implementation plan
- Formulation of the project management proposal
- Definition of the project financing strategy
- Economic and financial evaluation of the project

This sequence does not necessarily correspond to the structure of the document to be prepared for the presentation of the study, since the order of the official document should follow the national standard for the formulation of pre-investment studies established in each country. Accordingly, it should be clear that the sequence is presented as a recommendation to develop the study.

3.1 Conceptualization of the integrated system model

The integrated system model for domestic wastewater treatment and use incorporates sanitary, environmental, agricultural, social, institutional, legal, and economic aspects. Therefore, the institution or consultancy firm should set up a multidisciplinary team to prepare the studies including these issues.

Figure 1. Treatment and reuse components and its location in the water cycle



The technical team of the project will conceptualize the integrated system model (see Figure 1). In general terms, it will propose the treatment of domestic wastewater to use it productively. This implies prioritizing pathogen removal to protect public health instead of the removal of organic matter and nutrients that are important for agriculture. It will also propose the implementation of stabilization ponds as the most appropriate technology to achieve this objective and the use of treated effluents in agricultural, aquaculture, and forest activities to reduce treatment costs.

3.2 Location of the study within the context of the basin

Figure 1 shows the location of the project in the basin water cycle. It includes the following components: sources, water demand, urban wastewater management and treatment, the current or potential use for irrigation, and its final disposal.

The model proposes the incorporation of the integrated system into the efficient water management of the basin. Thus, the use of treated wastewater for irrigation will reduce and even eliminate discharges to water bodies that always generate negative environmental impacts.

3.3 Identification of the study social context

The social situation of the project is disregarded in most technical and economic studies, even when the area of study is inhabited. This occurs because the proposal is managed as if the actors involved were separated and their decisions were not shared. Nonetheless, the area of study is often related to human groups who carry out different urban and agricultural activities. Accordingly, different aspects should be considered when preparing the study, such as land tenure, affordability to cover water treatment or use costs, and farmers communal or private organization.

3.4 Identification of the wastewater legal context

Although most countries lack specific legislation on domestic wastewater, it is necessary to identify any legal instrument that could prohibit, limit or promote integrated systems of domestic wastewater treatment and use. Obviously, every proposal should be subjected to the country's regulatory framework, although it may not be the most encouraging for the project.

Some legal aspects that should be reviewed include the regulatory and legal framework for environmental management (territorial), wastewater quality parameters for its final disposal or productive use, technical standards for domestic wastewater treatment and agricultural use, and the rights to use treated waters.

3.5 Evaluation of the existing treatment and reuse practices

Depending on the particular situation of each case ─with treatment and reuse (With T-With R), with treatment and without reuse (With T-Without R), without treatment and with reuse (Without T-With R) or without treatment nor reuse (Without T-Without R)─ it will be necessary to know the characteristics of the operative treatment and use systems.

The policy of the water company (or municipality) in relation to urban wastewater management should also be considered. If one or more domestic wastewater treatment plants exist, it is convenient to know its location, design, technology, effluent sanitary quality, and operation and maintenance situation.

If wastewater is used to irrigate agricultural areas, it is important to evaluate the farmers' experience in managing wastewater for different crops, its productive efficiency, costs, commercialization channels, and product marketing.

3.6 Environmental diagnosis of the study area

If no treatment is implemented, the study should identify, describe, and assess the environmental and health impacts generated by domestic wastewater final disposal. If treatment plants do exist, it will be necessary to evaluate its treatment coverage and efficiency to alleviate the impact of untreated waters. Risks of contingencies posed by overloads and losses of the dam capacity and stability in the treatment plants should also be observed.

When agricultural fields are irrigated with wastewater, it is necessary to know the quality of the water used and the contamination risks posed by the products, especially if no preliminary treatment is applied.

This information will make it possible to define adequate measures for managing negative environmental impacts and prepare the environmental management plan. The investment and operational costs required to implement such plan should also be estimated.

3.7 Identification of the actors involved in the project

The identification of direct and indirect actors, interest groups, their capability, and the people affected is essential for the feasibility of the project. Their level of knowledge regarding domestic wastewater treatment and use should be also identified to evaluate their acceptance level of the integrated model.

3.8 Evaluation of water and soil resources in the basin

To locate the project in the most appropriate site, it is necessary to define the basin agricultural potential based on knowledge of its water resources and soil physiography and capacity.

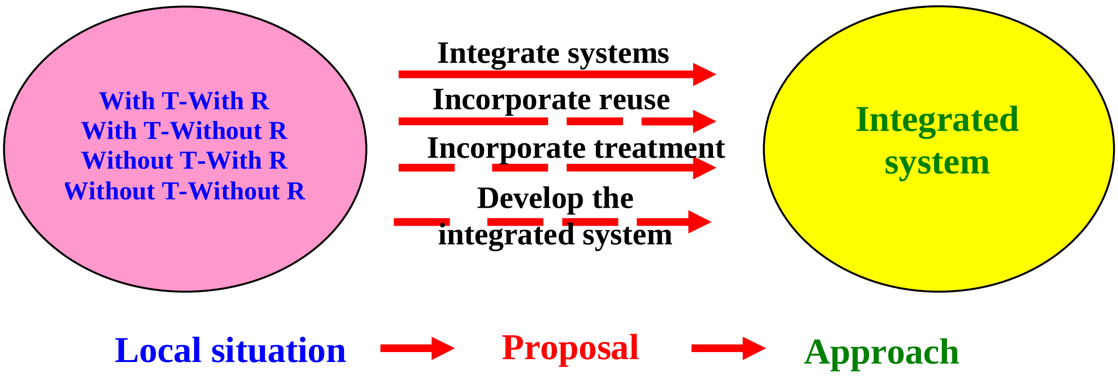
The evaluation of water sources (rain, surface, ground and waste waters) and its sanitary and agronomic quality will also be important for the study. Reliable information on water demand for livestock and municipal use will allow to know the effective availability of water for irrigation. Finally, the water balance and seasonal variation of the sources should be defined.

The formulation of the proposal implies to know the current and potential extension of the lands likely to be irrigated. This area should also include the treatment system. Since stabilization ponds and the agricultural area to be irrigated require available and inexpensive lands, it should be located in the outskirts of the city. Thus, the integrated system will generate minimum negative impacts on the population and the environment, and the collection system will promote urban development duly planned.

3.9 Definition of the integrated system proposal

The integrated system focuses mainly on the productive use of treated wastewater. Consequently, the study will be oriented towards defining the feasibility of the integrated proposal, which involves the exploration of real and potential options on the part of the interested parties. The proposal will be intended to either improve the existing systems or propose options to develop the missing component, according to the real situation of each case. Therefore, the proposal should define the components to be implemented, improved, or expanded in the study case. Figure 2 illustrates how the proposal could vary in accordance with the situation of the case.

Figure 2. Project development scheme



3.10 Socialization of the proposal with the actors involved

The previously collected information will allow to know the actors' needs, interests, and relationships to define the management mechanisms for the proposed integrated system. To this end, it is essential to know beforehand the actors' perception of the project. The socialization of the project is strongly advised before the implementation of the technical and economic studies.

3.11 Preparation of the agricultural plan

The formulation of the agricultural plan, including crop selection and rotation, and seeding plans (areas, agricultural schedule, and production) is the first step of the technical proposal. The irrigation method to be implemented should also be defined during this stage to establish water quantity and quality requirements.

The technical, administrative, and technical support requirements of the agricultural plan and its production costs will depend on the agronomic management of the selected crops. The definition of the marketing for the products, prices, seasonality, and terms and policies for sale are also important, as well as the estimation of the investment required and expected earnings.

3.12 Design of the treatment system

Defining the treatment system after the agricultural plan may be unusual to many consultants, since the design has been traditionally focused on sanitation. The integrated system model proposes the adjustment of the treatment to the quality and quantity requirements for agricultural use (crop quantity and type). This explains why the agricultural plan should be defined first.

The treatment level will be determined by wastewater characteristics and quality requirements of the crops selected for the agricultural plan. The evaluation of the technological options for the agricultural plan will allow to select the most appropriate technology for the treatment. It is important to bear in mind that the integrated model proposes domestic wastewater treatment for productive use. This implies prioritizing pathogen removal to protect public health, instead of the removal of organic matter and nutrients, which are important for the type of agriculture to be developed.

A description of the proposed treatment phases should be included in the evaluation of the location and design of the treatment plant according to the options of the agricultural plan. The design of the plant will define in detail the physical characteristics of the infrastructure (ponds) and water collection and distribution systems.

The final stage of the estimations will establish the requirements for machinery, equipment, labor force, and supplies. The investment, operation and maintenance costs, and administrative expenses of the treatment system will be determined according to the plant implementation plan.

3.13 Definition of the project implementation plan

The general implementation plan of the project will include the timetable for agreements and commitments, funding management, the plans for agriculture, implementation of the plant, environmental management, and start off of the project. The general implementation plan is a requirement for the economic and financial evaluation of the project.

3.14 Formulation of the project management proposal

Wastewater treatment and use are two activities that have traditionally been carried out separately and independently. Therefore, there is usually limited concertation of interests and alliances among operators and farmers. The proposed model requires the definition of mechanisms for the integrated management of both activities (treatment and use). Hence, it will be necessary to define the organization and management procedures of the treatment and agricultural units to be implemented in the project.

A training and technical assistance program in wastewater management is advised to ensure the proper management of the project.

3.15 Definition of the project financing strategy

The low coverage of wastewater treatment in most cities occurs because its cost has not been included in the tariffs owing to the limited knowledge of the population about its importance, to the users' low affordability, and to poor collection mechanisms of the water and sanitation companies. As a result, it will be necessary to evaluate the real affordability and make an economic valuation of the significant environmental impacts caused by wastewater final disposal on natural environments or agricultural fields. The funding and borrowing capability as well as the operation of the institution responsible for the management of the integrated system should also be studied.

The analysis of funding options from different sources will make it possible to select the most suitable strategy for the proposed system (structure and credit line).

3.16 Economic and financial evaluation of the project

The estimation of fixed investments and capital required by the proposal, as well as the schedule of financial statements (balances, earnings, losses, and cash flows) and calculation of profitability indicators (net present value, internal rates of return, and benefit-cost ratio) are required to conclude the study.

The above information is the basis to carry out the economic and financial evaluation and the sensitivity analysis of the project (investment, costs, and prices) that will allow to select and justify the best treatment and use option for the project.

4. METHODOLOGY TO DETERMINE THE PROJECT FEASIBILITY

The integrated system proposal focuses on the productive use of treated wastewater. Consequently and depending on the particular situation of every case, the greatest effort of the team responsible for the study will be oriented towards defining its feasibility, which involves the exploration of real and potential options.

The analysis of the project strengths and weaknesses will allow the establishment of strategies to handle its technical, environmental, social, economic, legal, and institutional aspects. The analysis of the case studies promoted by the Regional Project on Reuse has made it possible to identify 35 factors that determine the feasibility and sustainability of integrated systems. These factors have been grouped into four general aspects and nine specific aspects (see table 2).

Table 2. Factors that determine the feasibility of integrated systems

General aspects	Specific aspects	Determining factors
Technical	Water and soil resources	Land availability
		Soil capacity for agriculture
		Wastewater demand for irrigation (water and nutrients)
	Agricultural activity	Markets and commercialization channels
		Experience in productive activities
		Agronomic management techniques using wastewater
		Productive efficiency (productivity and costs)
	Wastewater treatment	Wastewater management policy of the water company
		Sanitary, environmental, and agronomic quality requirements of the effluent
		Technology selection
		Location and design of the treatment system
		Sustainability of the plant operation and maintenance (technical capability and tariffs)
Environmental	Legal context	Regulatory and legal framework for environmental planning
		Quality parameters for domestic wastewater disposal and use
		Technical standards for domestic wastewater treatment
		Technical standards for agricultural use of domestic wastewater
		Rights to use treated wastewater
	Management	Assessment of significant environmental impacts
		Surveillance of wastewater quality and agricultural products
		Management of sludge and wastewater surplus
		Risk management of hazards and contingencies
Social	Cultural	Identification and characteristics of the actors (direct, indirect, groups of interest, competitive and affected groups)
		Knowledge of the actors about wastewater treatment and use
		Acceptance level of the integrated model by the actors
	Institutional	Land tenure
		Actors' needs, interests, and relationships
		Communal or private organization of farmers
		Management mechanisms of the integrated system
Economic	Capabilities	Investment, borrowing, and operation capability of the integrated system
		Users' affordability and collection mechanisms
		Strategy funding for integrated systems (structure and funding sources)
	Indicators	Economic valuation of environmental impacts
		Economic profitability
		Financial profitability
		Sensitivity analysis (range of costs and prices)

4.1 Technical aspects

Among the technical aspects related to integrated systems of treatment and use, there are three groups of factors that determine its viability and sustainability: water and soil resources, agricultural resources, and wastewater treatment.

4.1.1 Water and soil resources

This group of resources includes water and soil as necessary resources for the installation of integrated systems:

- *Land availability*

  The concept of integrated system implies locating the treatment and reuse plants in the same place. Accordingly, it is essential to know the current and potential extension of the land likely to be irrigated. This area should also include the treatment system. Land availability is not only related to its physical existence but also to the acceptance on the part of the owner(s) to install the two components of the integrated system. This topic will be addressed under the item on social issues.

  Land availability can be verified with the property registers and official land records, which are available in local governments. A relevant aspect is the legal ownership of the land and its real availability to the project.

  In most countries of the Region, uncultivated lands, which are probably the most adequate and rapidly available, are owned by communities or similar organizations that usually cannot demonstrate their property rights, hindering the effective land availability for the project.

  Finally, it is necessary to evaluate the regulation that determine the current or potential use of the land. Restrictive use could make it difficult to install one of the integrated system components, usually the treatment plant.

- *Soil capacity for agriculture*

  Among other criteria, soils are classified according to its potential and limitations to sustain crop production, which is known as the soil capacity. In the integrated project, the following aspects should be evaluated to determine the soil capacity for agriculture:

  a. *Soil fertility*. Soil fertility evaluation includes its texture, effective depth, organic matter content, cation exchange capacity, carbonate content, salinity or electrical conductivity, and the concentration of major elements (nitrogen, phosphorus, and potassium). Soil fertility depends on its previous uses, whether agricultural, industrial, or the like, and on the presence of potentially polluting activities. Soil fertility can be evaluated through the analysis of soil characteristics or indirect measures such as bioassays.

  b. *Natural limitations for agriculture*. In areas where the presence of aluminum or sodium has caused toxicity, or with poor drainage and problems of salinity, it is important to evaluate if the efforts to improve such conditions can affect the system profitability. Other factors, like the risk of erosion on very steep slopes or floods in riparian areas should also be analyzed to determine the cost of the interventions required and its impact on the system profitability.

  c. *Soil response to wastewater*. To evaluate the soil response to wastewater used for irrigation, it is necessary to analyze its texture and organic matter content, infiltration rate, retention, and water table, among others. This can be essential to decide the irrigation system or the crops that will be included in the agricultural plan, depending on their water needs and productive efficiency. This response can be evaluated by means of soil analysis, hydraulic conductivity tests, and bioassays.

- *Wastewater demand for irrigation*

Some of the aspects that should be considered in this factor are:

a. *Water need*: The agricultural component of the integrated system defines the need of wastewater. Water demand is probably not met owing to lack of water resources, the season, or distribution of water supply throughout the year. Wastewater can be added to the availability of water for irrigation. In areas with rain-fed agriculture, for example, wastewater enables cultivation the entire year if it rains only during certain times and if wastewater volume is significant. In other cases, however, when soils are saturated, water storage during rainy seasons may also be required.

Water needs can be estimated through the water balance of the study area and the preparation of the agricultural plan. The water balance points out the differences between water supply and demand during a specific period, usually one agricultural year. Water supply is composed of natural sources (rain, surface water, groundwater) and, within the context of integrated systems, of wastewater. Water demand is defined by crop water needs, including biological demand, evaporation, and filtration.

To calculate the monthly water balance it is necessary to determine the difference between monthly supply and demand of water, which yields a water deficit or surplus that allows the evaluation of management options, such as irrigation system improvements and the installation of reservoirs.

Table 3. Water balance form

Component	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SUPPLY (+):												
River flow												
Precipitation												
Wastewater												
DEMAND (-):												
Crop biological requirement												
Crop evapotranspiration												
Evaporation												
Infiltration												
BALANCE (+ or--)												

b. *Need of organic matter and nutrients*: Wastewater is frequently appreciated owing to its contribution of nutrients. This can be analyzed through its content of organic matter and major and minor nutrients that are essential to the plant. Organic matter is important to improve the physical, chemical, and biological quality of the soil. In Latin America, the concentration of organic matter in agricultural soils is usually low and manure is frequently added to soil, though it is becoming increasingly scarce, expensive, and inadequate. Therefore, the contribution of organic matter through wastewater can favor the acceptance of integrated systems by farmers. The study of the dynamics of wastewater organic matter in soil, however, is still incipient and further research by institutions such as universities is needed.

   The provision of nutrients to crops can save the use of chemical fertilizers, which represents the main cost in fertilization.

4.1.2 Agricultural activity

The several situations that have been analyzed during the project have shown that agricultural production integrated with domestic wastewater treatment should also meet obvious requirements ─such as productive efficiency and adequate commercialization channels─ and should be adjusted to specific conditions determined by wastewater use. The main factors that determine the feasibility of integrated systems and its sustainability for agriculture are:

- *Markets and commercialization channels*

  Integrated systems should have an adequate relationship with the market and meet the demands in a sustainable manner in quantity and quality. Obviously, an integrated system project should not be aimed at ensuring water for irrigation only, but it also should promote changes in agriculture. Therefore, it is important to identify the crops with greater demand in the market. Farmers and investors should understand that changes in the existing productive systems are usually necessary or advisable to integrate them into wastewater treatment efficiently.

Table 4. Form to record the production, prices, and sales of the main products cultivated in the area of the project

Crop	Market variables	Year									
		1	2	3	4	5	6	7	8	9	10
1	Volume (MT)										
	Price (US$/ MT)										
	Earnings (US$)										
2	Volume (MT)										
	Price (US$/ MT)										
	Earnings (US$)										
3	Volume (MT)										
	Price (US$/ MT)										
	Earnings (US$)										
4	Volume (MT)										
	Price (US$/ MT)										
	Earnings (US$)										
5	Volume (MT)										
	Price (US$/ MT)										
	Earnings (US$)										

The existence of adequate commercialization channels is related to the integration of agricultural activities into processes that increase added value to the product, as agro-industrial processes or adequate post-harvest management techniques that diminish deterioration. In this regard, it is important to note that post-harvest losses in most Latin American countries are frequently greater than those caused by pests, diseases, and weeds.

Finally, it is important to analyze if these integrated systems ─which create a strong relationship between urban and rural inhabitants to recycle limited resources─ should be encouraged by the governments or other authorities.

- *Experience in productive activities*

Integrated systems should foster improvement of production techniques and training of farmers as an essential requirement to reach competitiveness and efficiency in agriculture, as well as sustainability. Training should focus on efficient use of water, improved irrigation systems, crop fertilization plans that consider the provision of wastewater nutrients, integrated pest and disease management, and the selection of crops according to market demands. Training needs should be properly analyzed, since they involve costs and commitments on the part of the beneficiaries and executors of the project.

- *Agronomic management techniques using wastewater*

Wastewater use in agriculture requires an adjustment of the agricultural plan that involves crop selection, use of water, and fertilization plans:

a. *Crop selection*: It refers to the selection or combination of crops best fitted to the conditions of the area to ensure the integrated system sustainability in terms of profitability. The selection depends on the soil capacity, climate, land availability, level of investment, and producers' organization and their involvement in agro-industry or livestock activities. Within the context of integrated systems, water sanitary quality depends on the type of crop. Forest and fruit orchards are usually irrigated with wastewater, however, as long as the water meets more stringent requirements for agriculture, short stalk vegetables are becoming more frequent.

b. *Water use*: Integrated systems usually incorporate gradual improvements in treated wastewater management, reducing losses and making water use more efficient. This includes the improvement of collection channels, storage infrastructure (reservoirs, dams, etc.), and irrigation systems.

   In addition, previous improvement of the productive infrastructure should be made frequently, such as improvement of the drainage system, control of erosion in slopes through terraces or other structures, forestation for slope protection, etc.

   Irrigation systems can be divided into two large groups: gravity and pressurized. Gravity irrigation conveys water to the fields where it is distributed along furrows or by flood. Water efficiency use in gravity irrigation is quite low owing to high evaporation or infiltration losses. Modern irrigation techniques use pipes or hoses very near to the plant, which diminishes losses and allows greater productivity. Modern irrigation requires pressurized equipment and more human and material resources. It includes sprinkler, microsprinkler, and drip irrigation —ordered according to its water use efficiency. It is important to take into account, however, that particles present in treated wastewater may affect the operation of some systems. Therefore, technology should be selected carefully. It is also important to bear in mind that when applying sprinkler or microsprinkler irrigation, particles or organisms could remain on the crop foliage affecting the quality of the final product if water does not meet sanitary quality requirements. Nonetheless, this could be prevented using furrow or drip irrigation.

Table 5. Irrigation systems applied in the area of study

Irrigation systems	Irrigated area (ha)	Applied rate (m^3/ha/year)	Water use efficiency (%)
Flood			
Furrows			
Sprinkler			
Microsprinkler			
Drip			
Others			

c. *Fertilization plans*: Nutrients necessary to crops are usually provided through organic matter sources (dung, compost, and green fertilizers) and synthetic fertilizers. Besides promoting soil life, organic matter usually has lower concentration of all nutrients (major and minor) required by plants, while synthetic fertilizers usually have high concentrations of some nutrients (mainly nitrogen, phosphorus, and potassium). A growing problem in modern conventional agriculture is the dependence on synthetic products. Organic matter contained in wastewater is certainly a source of nutrients, which should be considered when preparing fertilization plans. Although further studies should be carried out to verify this contribution and its effective availability for the plant, the importance of organic matter and nutrient provision is recognized. Besides, this can be reflected on the more rapid and vigorous plant growth.

   In many places where treated wastewater is used, however, fertilization doses are usually similar to those used in places where surface water is used for irrigation. The use of wastewater for irrigation is actually a way of fertilization that contributes to soil and productivity improvement, and saves costs reducing the use of agrochemicals.

Table 6. Management characteristics of the main crops in the project area

Agronomic management details
Crop name
System: monoculture or polyculture
Common water supply technique: rain-fed or irrigation
Water consumption per campaign (m^3/ha)
Technological level: low, average, or high
Mechanization level: low, average, or high
Are animal traction and machinery used together?
Type of seed: traditional, improved, or hybrid
Availability of organic fertilization: limited, average, or abundant
Volume used (MT/ha/year)
Chemical fertilization rate NPK (kg/ha/year)
Is soil fertilized with minor nutrients?
Is wastewater nutrient contribution recognized?
Has this contribution been quantified?
Number of agrochemicals applied per campaign
Products usually applied (the three most significant)
Are restricted periods respected?
Experiences of biological control of pests and diseases: seldom, average, or abundant
Mention the two main experiences of biological control of pests and diseases
Productivity (kg/ha): average
National average
Maximum in the region
Potential maximum
Labor requirement: wages (man-days/ha/campaign)

A balance of nutrients similar to the methodology used for water balance is required to define fertilization plans. Nutrient supply and demand depend on every campaign and type of crop. Supply depends on the contents of nutrients and organic matter in soil, its mineralization rate, and wastewater nutrients. Demand depends on the average use of nutrients by the crop and the rate of fertilizer use.

- *Productive efficiency*

  The use of wastewater in integrated systems is aimed at achieving the greatest productivity in real (yield per unit of area and quality of the product) and economical terms (profitability). Therefore, those systems that maximize water use efficiency and take advantage of wastewater nutrients will be in a better position. Agricultural systems are increasingly evaluated according to their ecological sustainability. This means that the level of substitution of agrochemicals for less polluting and less expensive technologies will be a very valuable factor in the future. In this regard, treated wastewater can make a significant contribution to the system profitability. However, high productivity not only depends on water management and nutrients but also on well-designed techniques that are included in an agricultural process in compliance with good agricultural practices.

4.1.3 Wastewater treatment

As explained above, the integrated system model is aimed at the treatment of wastewater to irrigate agricultural and forest fields. Accordingly, the treatment system will depend on the requirements of the agricultural plan.

- *Wastewater management policy of the water company*

  The policy of most water and sanitation companies in Latin America only considers the sewerage service as a means to dispose of domestic effluents without previous treatment. A smaller group of companies ─usually from big cities─ has made improvements by introducing wastewater treatment into their policies to reduce environmental impacts caused by sewage disposal. This has been supported by traditional technologies applied in developed countries and a regulation that only penalizes the disposal of organic matter and toxic elements. Management of health risks posed by pathogen dissemination is still incipient in the Region.

  In this context, when preparing an integrated project for wastewater treatment and use, it is essential to evaluate beforehand the policy of the water and sanitation company. The city's master plan is the first document to know the plans of the company. Information will be completed along work meetings with the executive board of the company.

  The situation of most of the cases studied in the Project might not be too encouraging regarding the proposal of integrated systems. Therefore, the first efforts should focus on informing the company's executive board about the advantages of the integrated system model.

- *Sanitary, environmental, and agronomic quality requirements of the effluent*

The initial definition of water quality considered the likelihood of using it for human consumption in the first place and then for other uses such as irrigation. At present, this concept also includes the environmental dimension of managing the pollutants present in water, which may cause a negative impact on the flora and fauna of natural water bodies. This definition has led that national legislations on wastewater management consider water quality according to its contents of total solids, organic matter, and some toxic elements (environmental quality). Only few legislations include parameters related to public health (sanitary quality), as pathogenic parasites, bacteria, and viruses. Agronomic quality is mentioned only in legislations related to the use of natural waters for agricultural irrigation (general law of water), but no legislation specifies the agricultural quality required to use domestic wastewater.

The implementation of integrated systems for domestic wastewater treatment and use should consider water quality in its three dimensions: sanitary, agronomic, and environmental. Sanitary quality depends on the level of parasite concentration, represented by the number of helminth eggs and fecal coliforms as indicator of the levels of bacteria and virus that cause enteric diseases to human beings. Agronomic quality is related to the concentration of nutrients (nitrogen, phosphorus, potassium, and oligoelements), salinity, and excessive levels of boron, heavy metals, and other elements that are toxic for agriculture. Finally, although environmental quality should consider all the aforementioned parameters, in practical terms it is focused on concentration of solids, organic matter, nutrients, and toxic elements that can generate negative impacts on water bodies.

The quality of the plant effluents in the integrated system shall meet the sanitary and agronomic requirements of the selected agricultural crops, aquaculture, and forest activities. Obviously, the water quality that a forest can tolerate is lower than the quality required for lettuce production. In this regard, effluents should be treated according to the sanitary requirements of the crops to be irrigated in the integrated system. The complete removal of parasites is expected to protect the health of the workers at the treatment plant and the health of the farmers who irrigate the land.

In short, the project should include a description of raw wastewater and effluents of the treatment plant, considering the following parameters:

- Average flow (24 hours in three weekdays)
- Average temperature (24 hours in three weekdays)
- average pH (24 hours in three weekdays)
- Total and volatile suspended solids
- Biochemical oxygen demand (5 days)
- Fecal coliforms

- Nematode eggs (helminths)
- Total nitrogen
- Ammoniacal nitrogen
- Total phosphorus
- Potassium
- Salinity (or conductivity)
- Toxic elements (if evidence of its disposal to the system is available).

The reliability of the aforementioned data should be closely related to the extension of the sampling time and the laboratory's reputation.

- *Technology selection*

The selection of technology depends on the objective of domestic wastewater treatment for final disposal. In developed countries, wastewater disposal on water bodies has demanded the removal of the elements that cause negative impacts on such environments, mainly eutrophication. Therefore, the treatment technology has to be highly efficient in pathogen and organic matter removal. Domestic wastewater in Latin American countries, however, has high concentrations of enteric pathogen germs. Thus, when disposed of into water bodies ─which are then used for human consumption─ pose a high risk of transmission of communicable diseases, like diarrhea, typhoid, and cholera.

Stabilization ponds are the most appropriate technology for pathogen removal and the use of its effluents in forest activities and industrial crops ─that have less stringent quality requirements─ may significantly reduce treatment costs. In addition, the use of treated wastewater for irrigation reduces and even eliminates discharges that somehow always generate negative environmental impacts.

Stabilization ponds are a low-cost technology since they only require 20% of the investment and 10% of the operation costs that other technologies require. This advantage is explained because:

- they remove pathogens efficiently without any disinfection process;
- they do not require equipment or energy, except solar radiation;
- sludge is not permanently processed or disposed of;
- its operation and maintenance activities are very simple; and
- they only require 20 to 50% of unskilled personnel compared to other technologies.

For these reasons, PAHO/CEPIS has been promoting this technology in the Region, supported by researches conducted over the past 23 years and mathematical models developed to incorporate pathogen removal into the design of integrated systems.

- *Location and design of the treatment system*

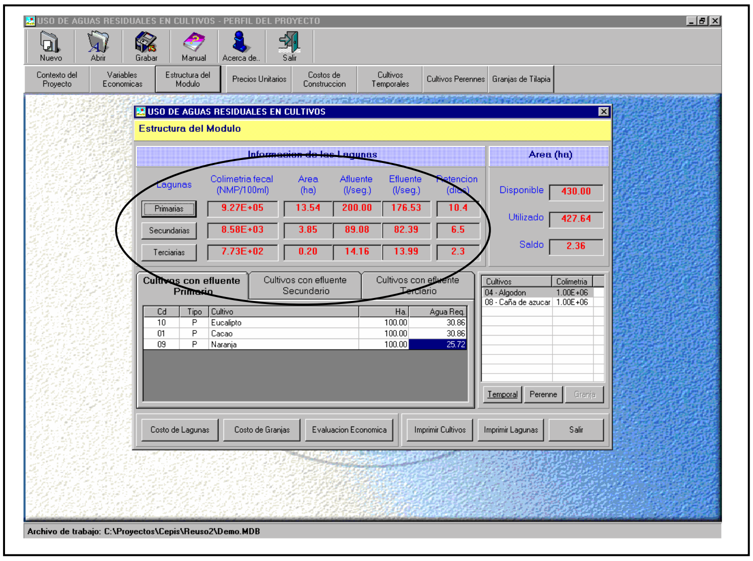
The integrated system concept proposes the location of the treatment plant in the same place where wastewater reuse will be applied. Therefore, it is important to know the real and potential extension of the area to be irrigated, which should also include the treatment system. To this end, the project shall be located in the outskirts of the city, where land availability is easier and costs are lower. Obviously, this condition will determine a more extensive wastewater collection system. The lower cost of the land offsets the higher cost of a longer collection system. In addition, this system can be converted into an open channel in the outer areas of the city, allowing an ecological environment with minimum negative impact on the population. Besides, arid areas are likely to be used as recreational areas for urban dwellers. Finally, the route of the wastewater collection system will also promote urban development, since new urban areas will be connected to the system.

Accordingly, designers should evaluate different locations, even when these areas are very far away from the cities. There are some cases, like San Bartolo in Lima, Peru, where wastewater has been conveyed along 30 km for its treatment and final use to irrigate 8,000 hectares of desert area. Hence, sites located far from urban areas are probably the most economic option for the project.

The design of the treatment plant will depend on wastewater characteristics, climatic conditions (temperature), and sanitary quality requirements of the activities selected in the agricultural plan. Thus, the concept of traditional design, based exclusively on applicable organic matter loads, has been expanded to incorporate the removal of parasites and pathogenic germs (represented by fecal coliforms) according to the different types of crops selected in the integrated project.

After 20 years of research on pathogen removal efficiency, PAHO/CEPIS has concluded that water retention time is more important that the number of units in a series of ponds. Accordingly, it is not necessary that two or three ponds be installed in series. It has also been verified that helminths can be removed through sedimentation when retention time surpasses 10 days. Finally, it recommends designing more than two batteries to handle sludge removal by drying the ponds every 5-10 years, preventing the interruption of an important part of the system.

PAHO/CEPIS, through its Regional Project on Reuse, has improved its model for the formulation of integrated systems for wastewater treatment and use (REÚSO 2.1). This tool was used by the case studies and is available for the users of the Region. The stabilization pond technology of the model is oriented towards "treatment for reuse," which involves adjusting the plant through stages to obtain effluents with appropriate levels of sanitary quality for different crops. The main screen of the software shows "Information on ponds" ─on the upper left side─ and has three buttons for each treatment stage (primary, secondary, and tertiary ponds), with data on fecal colimetry, used area, wastewater volume, and retention time according to the selected design. Wastewater volume entering the following stage is the volume assigned to each stage minus the volume withdrawn for the selected crops.



- *Sustainability of the plant operation and maintenance*

Technical visits to more than 220 domestic wastewater treatment plants in Latin America show that 80% of these systems operate in poor conditions and 10% have been abandoned. This situation is more common when units require energy and qualified personnel. One example are the aerated plants built in Northwest Brazil; nowadays no pond maintains its aeration system.

Although several reasons might explain the deficient operation of treatment plants, most companies adduce economic limitations to justify this situation.

Thus, the real economic and financial capability of water companies should be objectively assessed to decide what resources could be allocated to the operation and maintenance of wastewater treatment plants. Most companies still do not include treatment costs in their tariffs. The implementation of the integrated systems, however, will force them to add this cost. It has also been reported that in some cases, a cooperating agency has financed the construction of the plant but later on the local company or users have not been able to afford its high operation and maintenance costs. Consequently, it is necessary to select a technology with low investment and affordable operation and maintenance costs to ensure the sustainability of the system.

4.2 Environmental aspects

The experience of the cases supported by the Project shows that the two most important environmental aspects are environmental assessment and the preparation of the "base line" as an essential condition for adequate environmental management.

4.2.1 Legal context

Two aspects of the regulatory and legal environmental framework related to wastewater treatment and use are of concern. The first aspect deals with the regulation related to the objective of wastewater treatment. In most countries of the Region, domestic and industrial wastewaters are included under the same approach and treatment is oriented towards the removal of organic matter, nutrients, and other harmful components for outdoor environments. No country considers the adjustment of wastewater (domestic or industrial) according to sanitary and agricultural criteria for irrigation of crops or green areas.

The second aspect deals with the legal instruments (laws and regulations) and technical standards (for wastewater treatment and agricultural use) that define the limits within which the treatment and use of these waters are legally mandatory or advisable.

The analysis of the legal context should determine if the legislation favors or discourages the productive use of treated wastewater. The following factors are crucial from the environmental and legal standpoints:

- *Regulatory and legal framework for environmental management*

  The concept of "land management" (a management tool mainly based on soil capacity) has been included in the broader concept of "environmental management", which considers the environmental functions coexisting in a specific space as a criterion for land management.

  Unplanned urban growth is the main threat to green areas conservation (or expansion) in and around the cities. This lack of planning also affects lands that could be used for wastewater treatment plants. For this reason, it is important to identify the regulation and legal instruments that define the criteria and mechanisms for land management, especially those related to urban development and conservation or creation of green areas in the locality. Integrated systems require that areas allocated to treatment plants and crops be intangible to guarantee the fulfillment of specific environmental purposes (wastewater treatment and agricultural production).

- *Quality parameters for domestic wastewater disposal and use*

  Most countries of the Region have not yet adopted quality standards neither for wastewater disposal in water bodies nor for irrigation. When this regulation exists, it is oriented towards impact management but wastewater use in agriculture is neglected. Among quality control parameters for disposal, pathogens are partially addressed (in terms of fecal colimetry) or it is simply ignored (in terms of helminth eggs).

  Despite the negative impact that unrestricted use of wastewater causes on public health, no country has incorporated WHO guidelines for domestic wastewater use in crop irrigation into its legal standards. To promote the management of health risks posed by wastewater use in agriculture, projects should at least consider these guidelines, which establish parameters to protect public health, even when legal standards to regulate the quality of discharges do not exist.

WHO Sanitary Guidelines (1989)

Reuse	Nematodes	Fecal coliforms
Restricted irrigation: Forestation, cereals, industrial crops, fruit trees, and fodder.	< 1 egg/liter	Without application
Unrestricted irrigation: crops that are eaten raw, fish culture, sport facilities, public parks.	< 1 egg/liter	< 1,000 / 100 ml

- *Technical standards for domestic wastewater treatment*

Since legislation obliges the removal of organic matter and nutrients from domestic or industrial wastewater, most technical standards for the design, construction, and operation of treatment plants focus on the control of physical (temperature, pH, total solids, suspended solids), chemical (metals, oils, polymers, anions, and cations), and biological (biochemical oxygen demand (DBO_5) and dissolved oxygen) parameters. Only recently some standards have included the detection of pathogenic bacteria (total and thermotolerant coliforms). So far, however, no technical standard considers the determination of nematode eggs, despite the high rate of parasite incidence in the population.

The project should consider the proposal of a technical standard for wastewater treatment, including the proper management of health risks through the removal of pathogenic bacteria and parasite cysts.

- *Technical standards for agricultural use of domestic wastewater*

There are no technical standards for agricultural use of domestic wastewater. As described earlier, the characteristics of these discharges notably differ from the water used in agricultural activities. The project should take into account these characteristics to recommend irrigation techniques, agrochemical use, and wastewater management that consider public health criteria (to protect farmers), particle contents (for irrigation systems), nutrients (for the application of agrochemicals), and pathogens (for irrigation management).

- *Rights to use treated wastewater*

  The right to access and eventual charge for wastewater, regardless of its treatment level, need a clear legal definition to manage wastewater adequately. None of the case studies clearly defines such rights and people responsible for the treatment do not supervise wastewater use or disposal outside their facilities, since their legislation does not consider mechanisms to collect wastewater treatment costs properly. An essential requirement to define the right to access and, consequently, the payment for wastewater use is the responsibility for the quality of the effluent. Just as legislation regulates other services, like drinking water supply, and assigns an entity the responsibility of the service and the collection of charges, it should also regulate wastewater treatment and charge its costs according to the quality of the effluent.

  Therefore, the project should consider the costs to obtain the wastewater quality required by farmers. Although a payment by the farmers for such required quality is acceptable, city's inhabitants should not be exempted from paying wastewater treatment costs.

4.2.2 Environmental management

Environmental management addresses the management of significant environmental impacts. It includes the identification and evaluation of such impacts, its economic valuation, the quality control of the involved processes, and the prevention and management of possible contingencies.

Some of the most important environmental aspects considered for the formulation of projects are:

- *Assessment of significant environmental impacts*

  Every activity (whether productive or not) generates environmental impacts that need to be classified in accordance with its effects (positive or negative), temporariness (provisory or permanent), and extension (local or regional). Significant environmental impacts are the major environmental strengths and weaknesses of the project and require special attention in its management since the project feasibility and sustainability rely on this.

  The assessment of significant environmental impact involves quantifying real (those generated by the project) and potential (those that the development of the project will generate) benefits or damages and proposing actions that either sustain or increase such benefits or reduce or eliminate the damages. The set of such actions ─which are organized within a time span─ is known as the "Environmental Management Plan."

A practical methodology to identify significant environmental impacts consists in determining its magnitude combining the three aforementioned dimensions (direction, temporariness, and extension) according to the following values:

Dimension	Description	Value
Direction (D)	Positive	(+)
	Negative	(–)
Temporariness (T)	Provisory	1
	Permanent	2
Extension (L)	Local	1
	Regional	2

These assessment criteria establish the magnitude (M) corresponding to each environmental impact. The impact magnitude formula to obtain the final score is:

$$M = D \times T \times L$$

Where:

M: Magnitude
D: Direction
T: Temporariness
L: Extension

The following table shows the impact magnitude:

Intensity	Magnitude (values)
High	±4
Moderate	±2
Low	±1

When the environmental impact is not significant and does not affect any existing area, a value of ±1 will be given and it will be considered low. If the impact causes a considerable effect on some component, a value of ±2 will be given and it will be considered moderate. If the impact can critically alter the environment, a value of ±4 will be given and it will be considered high. This latter impact category is significant and should be included in the Environmental Management Plan.

- *Surveillance of wastewater quality and agricultural products*

  Surveillance of the quality of wastewater treatment plant effluents and the products irrigated with these waters has received little or no interest from the authorities and those responsible for wastewater treatment and use. Quality control is essential for managing impacts (real or potential) on health associated with wastewater management.

  Quality control should focus on relevant health parameters: infectious agents present in wastewater and agricultural products (pathogen bacteria and parasites). The inflow of raw wastewater and the effluent of the plant are the critical points of the treatment component; those responsible for the treatment should monitor the quality of the effluent along the entire process. Quality control in this component of the integrated system is aimed at ensuring that the treated wastewater supplied meets the sanitary and agronomic quality requirements for the selected crops.

  Control of the irrigation system ─which includes the infrastructure and irrigation practices─, the products to be sold, and post-harvest practices are the critical points of the reuse component. This control is aimed at protecting the health of farmers and consumers regarding the products irrigated with treated wastewater.

- *Management of sludge and water surplus*

  Any wastewater treatment system produces sludge, whose volume and composition varies according to the wastewater source and treatment technology. If effluents others than domestic wastewater enter the collection system (for example, effluents from industrial, mining, or agricultural activities, or rain drainage), the treatment plant will have a determined retention time and removal efficiency of the compounds contained in the wastewater, which will depend on the applied technology. Compounds removed from wastewater are deposited in sludges, which should be adequately stabilized and disposed of. The proliferation of different wastewater treatment technologies, however, has generated increasing volumes of sludge that usually do not receive adequate treatment, causing serious environmental and health problems.

  The project should consider a sludge management program that includes the estimation of sludge volume, its stabilization in adequate environments, and its final disposal, either in agricultural lands or sanitary landfills.

  A surplus of wastewater is likely to occur when other sources outweigh the demand of agricultural soils, for example, during rainy seasons. In these cases, it is necessary to foresee options to handle the consequent surplus of treated wastewater, since it will not be used for irrigation. These options should consider the volume excess and the length of the situation. The storage in reservoirs of wastewater with final treatment before its use in irrigation is a good alternative and it may be used for fish culture.

- *Risk management of accidents and contingencies*

  Since large volumes of wastewater are considered for treatment and use, it is necessary to identify associated risks and prepare a risk management plan. The stability of the treatment plant infrastructure (especially of stabilization ponds), storage reservoirs, and collection and irrigation channels should also be considered, as well as any unforeseen overflow in the plant or irrigation system. The management of these accidents and contingencies should be explicitly dealt with in the Environmental Management Plan. In addition, it should be part of the training program of the staff in charge of the treatment system and agricultural activity.

4.3 Social aspects

The social components of integrated system projects analyze the social situation of the region where the experience is carried out. An articulated vision will be adopted covering cultural and institutional perspectives to propose management alternatives that consider the reality of the populations, regions, and existing organizations to orient strategies and actions towards the achievement of the expected results.

The proposal should be coherent with the purpose of improving the quality of life of the human groups involved. To this end, the starting point should be the knowledge of their characteristics, situation, and expectations regarding sustainable development.

The social components should be analyzed through a participatory investigation methodology that allows the analysis of factors using several experiences and multidisciplinary and multisectorial approaches. The analysis can be supported by information, studies, and documents stored in files or in national and regional bibliographies.

This participatory process of consultation to the various actors, strengthens the future acceptance of the proposal. Therefore, its design should consider the future incorporation of the interested sectors and groups.

It is advisable to use techniques as surveys, semi-structured individual interviews, workshops of participatory planning, consultation of focal groups, application of the SWOT methodology, etc.

4.3.1 Cultural aspects

- *Identification and characteristics of the actors*

  Actors include all human groups, organizations, and institutions that are either directly or indirectly related to the actions of the project, i.e., community organizations involved, national regulatory or executing institutions, regional or local institutions, and supporting and advisory institutions.

The objective is to identify and characterize the population and institutions of the study area ─mainly those directly involved─ and locate them within the local, regional, and national framework. Thus, the following data on local conditions and the social, cultural, economic, organizational, infrastructure, and service contexts will be used:

- Total population of the area involved in the project. Distribution of the population according to sex, age, and ethnic characteristics.
- Population dynamic mechanisms: growth of the population, fecundity rate, migrations, rate of birth, mortality, morbidity, life expectancy at birth (considering differences of sex, age, and ethnic groups).
- Characteristics of the families: nuclear, extensive, percentage of women who are head of household, etc.
- Earnings and economic activity: GDP per inhabitant/year; EAP according to sex and age.
- Education: percentage of literacy in adults by gender and ethnic group, percentage of regular education, elementary school, high school, and university education, according to gender and ethnic groups.
- Characteristics of the relationships and gender roles in the community. Gender equity.
- Main productive activities and responsibilities of these actors, according to their location in urban or rural areas, sex, and age.
- Basic community services of water and sanitation.
- Basic urban and rural infrastructure.
- Nutritional status of the population.
- Basic health services.
- Customs, traditions, and customary law.
- Forms of community participation.
- Forms of community organization in general.
- Presence of companies and productive or service partnerships.
- Presence of educational and research institutions.
- Non-commercial partnerships.
- National, regional and local entities and authorities.

- *Knowledge of the actors about wastewater treatment and use*

  To propose training actions that enable people and institutions to carry out the adequate management of the processes, it is necessary to know the level of knowledge of the various actors about wastewater treatment and use.

  Thus, it is necessary to make a survey considering the following five main groups:

- community;
- leaders;
- authorities;
- businessmen; and
- teachers.

The actors of the project are expected to know the following main issues:

- Characteristics of urban wastewater and types of treatment
- Treatment for the productive use of wastewater
- Wastewater management for agriculture, according to the type of crop
- Wastewater management for other productive purposes
- Consideration of environmental management and natural resources
- Agricultural techniques related to wastewater use
- Connections between treatment and use.

Since training needs may differ according to each type of actor, a differentiated survey should be carried out to know their level of knowledge to define future needs for dissemination, training, and technical assistance. Once the needs have been identified, a training plan should be established and executed throughout the project.

In recent years, participatory methodologies for promotion and training have reappeared in Latin American countries involving farmers in the process from its very beginning, using their experience to design integrated systems.

- *Acceptance level of the integrated model by the actors*

Actors' perceptions of what an integrated system of wastewater treatment and productive use is may vary on an individual basis. Perceptions related to potential risks may lead to acceptance, indifference, or rejection of the project proposals.

To achieve a good acceptance level, it is essential that actors know the risks, potential, and benefits of the proposal implementation. Clear information, showing all elements of the situation, turns perception into willingness, and willingness into acceptance. It is important to know the following aspects:

- The actors' perception of the integrated system (how they understand it, what they think, what attitudes they have regarding the integrated concept, etc.).
- Their willingness to be part of the experience (if they want to participate, refuse the issue, or show indifference).
- Their acceptance level (if they accept their inclusion in the proposal, propose alternatives, etc.).

4.3.2 Institutional aspects

- *Land tenure*

The system requires two types of land: one for treatment plants and the other for production. In all cases, to make the proposal feasible and sustainable it is necessary to know the following aspects:

- The type of property or tenure (state, private, community, in use, loan and restitution).
- The land physical and legal situation.
- The management policy.
- The existence of current and potential conflicts.
- Alternatives to solve conflicts.
- Alternatives to use other lands if such conflicts were not solved.

- *Actors' needs, interests, and relationships*

  Determining actors' needs, interests, and relationships is essential to introduce the proposal in their agendas. Actors should be classified in organized groups, including communities whenever their needs and interests are significant elements for the project.

  This classification is the basis to prepare the "map of actors," where the main groups and entities involved are defined, as well as their needs, interests, and relationships with other actors. This map should show existing and foreseeable alliances among them, as well as current and potential conflicts.

  This map of actors should include:

  - Their characterization: members, responsibilities, scope of their functions, type of organization.
  - Their needs: economic and social situation, main problems, and requirements.
  - Their interests: expectations of development, trends and goals, social influence.
  - Their relationships: joint efforts with other groups, coordination of actions, participatory approach, openness, and flexibility.
  - Their alliances: signed agreements, links with other groups, and merging of goals and commitments with third parties.
  - Their conflicts: different interests, unsatisfied demands, negative experiences, overlapping of roles.

  The preparation of this map will clarify the intersectoral and inter-institutional situation of the proposal and will provide key elements for the definition of strategies to reinforce alliances, minimize conflicts, and strengthen synergies among groups. This will build concertation lines and criteria that will lead to the signing of agreements.

- *Communal or private organization of farmers*

  It is important to know how farmers are organized in the project area because they are directly involved in wastewater productive reuse and, thus, will play a key role in the success of the integrated system proposal.

Therefore, it is essential to know:

- The existing partnerships of farmers.
- The type of existing partnerships: water users, producers, traders, etc.
- Mechanisms used by partnerships: selection of leaders, assignment of responsibilities, management of leadership, involvement of women in meetings and their participation as leaders, relationships among groups and institutions, etc.
- Background of the leaders and those involved in the administrative, financial, and management areas.
- Partnerships with third parties.

- *Management mechanisms of the integrated system*

The integrated system also requires an integrated management. The selection of the model and mechanisms for each case should be designed bearing in mind the implementation and sustainability of the proposal.

To this end, the management model should include:

- A leader entity to promote the system with participatory and coordination tools.
- A management area for the wastewater treatment component.
- A management area for the wastewater productive use component.
- Mechanisms to articulate, coordinate, regulate, plan, and converge the above mentioned components.
- Mechanisms to incorporate the general management components: the roles of authorities and cooperation and research entities.
- A global management strategy for the integrated system.
- An operation plan and a timetable for the strategy.
- A monitoring, follow-up, and assessment plan.
- A strategy to include changes in the operation plan, according to assessment results.

It is important to highlight the key elements of the management model and its mechanisms and strategies to analyze the technical, environmental, economic, and social factors of the project. The map of actors, for instance, is essential to design a strategy based on the knowledge of the interactions, alliances, and potential conflicts among actors.

4.4 Economic aspects

Two groups are included within the economic aspects:

4.4.1 Capabilities

Three factors that define the capabilities of the two main actors of the model (the water and sanitation company and the users of the wastewater treatment and use system) are considered within this group:

- *Investment, borrowing, and operation capability of the integrated system*

  To assume the responsibility for wastewater treatment, water and sanitation utilities should demonstrate financial stability to afford the works and guarantee their operation.

  Financial stability is supoported by the proportion of available resources (liquidity) with respect to their commitments (liabilities), the borrowing capacity assigned by the financial system according to its cash flow, and the prompt payment of debts.

  A brief analysis of the economic and financial indicators, including information collected on the financial statement of the local water and sanitation company will provide an overview of these capabilities.

- *Users' affordability and collection mechanisms*

  A fundamental component for the integrated system sustainability is the users' affordability, regarding both the treatment system (city's inhabitants) and the wastewater use component (farmers).

  The incorporation of wastewater treatment costs to the tariffs charged by water and sanitation companies for the provision of their services is a topic that has great social impact. In Latin America, few sanitation companies include treatment costs in their tariffs. It is mainly due to lack of knowledge of urban dwellers about their responsibility for the treatment of the wastewater they generate and to insufficient income to afford higher costs of living.

  The project should estimate the treatment costs and propose its distribution among urban users and irrigation beneficiaries. For the effective collection of the treatment cost, sanitation companies have efficient collection mechanisms that include the suspension of services (mainly drinking water supply) in case of pending debts. Similar collection mechanisms could be used in the case of treated wastewater.

- *Strategy for funding the integrated system*

  The ideal strategy for funding the integrated system requires the joint assessment of both treatment and agricultural use components. If the financial institution considers the objectives of public health and agricultural production separately, there is no way to guarantee that the assessment will be adequate and positive.

Table 7. Characteristics of funding sources

Credit line	1	2	3	4
Source of credit (lending agency)				
Amount (thousands of US$)				
Debt structure/capital (%)(1)				
Interest rate (%)				
Time limit for payment (years)				
Grace period (years)				
Risk rate (%)(2)				

(1) The debt/capital structure refers to the percentage of the total investment financed through the credit line.
(2) The risk rate is a value assigned to each activity (for example: agriculture, fishery, mining) and is usually defined by the banking sector of each country.

According to the investigations made by the project no credit line has been given to integrated systems. To be eligible, an integrated system proposal should subordinate one of the components. On the one hand, the treatment system is understood as a process where wastewater is adjusted for its use in irrigation and it is evaluated according to the selection criteria of agricultural projects. On the other hand, the agricultural activity is understood as a complementary component to the treatment system and represents an externality. In none of the cases the economic valuation of the earnings from the integration of both components is made.

Those responsible for integrated system projects should inform the lending agency and cooperating organizations about the need to carry out the most adequate assessment according to their specific characteristics.

4.4.2 Indicators

The most important economic and financial factors determining the viability of integrated systems are:

- *Economic valuation of environmental impacts*

Integrated systems represent positive environmental impacts of great magnitude. The correct valuation of these impacts can determine an important economic profitability that justifies the implementation of the project.

The main environmental impacts that offer economic benefits include the reduction of infectious diseases, the minimization or elimination of polluting discharges, the increase of water supply for irrigation, greater supply of food, generation of employment, and the preservation of areas for wastewater treatment and crops.

The main negative impacts include the loss of crop area (when installation or extension of the treatment system in areas of agricultural production is required) and the use of areas potentially adequate for urbanization (when the system is installed in the city).

- *Economic profitability*

  Economic profitability is the (economic) balance between the benefits and social costs (economic and environmental) derived from the implementation of the project within a given context and time limit.

  Economic profitability is expressed through the current economic net present value (ENPV) and its complementary indicators, the economic internal rate of return (EIRR), and the benefit-cost ratio (BCR).

- *Financial profitability*

  Financial profitability is the capability of the project to assume the return of the loan granted for its implementation and operation under certain lending terms and conditions. It measures the capability of the economic balance (difference between the benefits and economic and environmental costs) to pay the credit line.

  Financial profitability is expressed through the financial net present value (FNPV) and its complementary indicators, the financial internal rate of return (FIRR) and the benefit-cost ratio (BCR).

  To estimate the financial profitability it is necessary to take into account the existence of funding under specific lending conditions, interest rate, and payment schedule. The definition of these values will provide an estimate of the financial profitability indicators of the project, such as the net present value, the internal rate of return, and the benefit-cost ratio.

  – The financial net present value (FNPV) is the summing of the own capital and the cash flow estimated for each of the 10 years of the evaluation period, reviewed to the year 0. The formula for the FNPV is:

    $$FNPV = (\sum VFRn) + EC$$

    Where:

    VFRn = Value of the financial flow revised to the year "n" (thousands of US$)
    EC = Equity capital (thousands of US$)
    N = each of the 10 years of the evaluation period

    The following formula will be used to update the financial flow:

    $$VFRn = VFn / (1 + DR/100)^{n}$$

Where:

VFn = Value of the n year flow
DR = Discount rate

The following equation should be used to estimate the discount rate (DR):

$$DR = [\ (1+ CDCS/100)\ (1+R/100)\ (1+INF/100) - 1\ ] \times 100$$

Where:

CDCS = Cost of the debt/capital structure (%)
R = Risk rate (%)
INF = Inflation rate (%)

The following formula is used to estimate the cost of the debt/capital structure (CDCS):

$$CDCS = [(INT/100 \times DCS/100) + (ACEC/100 \times (1-DSC/100)] \times 100$$

Where:

INT = Annual rate of the loan (%)
DCS = Debt/capital structure (%)
ACEC = Annual cost of the equity capital (%)

- Financial internal rate of return (FIRR):

  The financial internal rate of return is the discount rate necessary to drive the financial net present value to zero. The integrated formula in Excel makes this estimation very easy.

- Benefit-cost ratio (BCR)

  The benefit-cost ratio is estimated by dividing the total revenues to the year 0 by the total expenditures to the year 0 (NPV revenues/NPV expenditures).

Any further information deemed significant for the analysis can be included with a brief explanation.

- *Sensitivity analysis*

The assessment of changes in the economic and financial profitability indicators of the project, resulting from changes in the context, makes it possible to identify sensitive variables for the project. These simulations are useful to detect the project strengths and weaknesses regarding environmental changes and design strategies to alleviate its negative effects or strengthen the positive ones.

The product prices, demand, costs of inputs and other resources, and contingency risks are the most common variables to perform sensitivity analyses.

5. TERMS OF REFERENCE SUGGESTED FOR THE FEASIBILITY STUDIES OF THE PROJECT

Summary of the study

- *Justification*
- *Brief description of the study area*
- *Brief description of the treatment system and its current use*
- *Conclusions of the diagnosis of the study area (SWOT)*
- *Brief description of the integrated system proposal*
- *Indicators of economic and financial profitability.*

Background and justification

- *Wastewater situation at the local and national levels*
- *Studies carried out*
- *Justification of the project*
- *Objectives, results, and indicators of the project.*

General description of the basin and area of the project

- *Name and location of the city and basin*
- *Size and location of the area of the project*
- *Urban and rural population of the basin*
- *Water, sewerage, and wastewater treatment coverage*
- *Natural resources*
- *Economic activities*
- *Agricultural activity carried out in the basin and area of the project.*

Water and soil resources available in the area of the project

- *Climatic conditions*
- *Current and potential extension of lands for agricultural activity*
- *Soil physical characteristics and capacity*
- *Water resources*
- *Water balance: supply, demand, and seasonality*
- *Effective availability of water for agricultural irrigation*
- *Sanitary and agronomic quality of every water source.*

Legal framework

- *Regulatory and legal framework for environmental management (land tenure and type of use)*
- *Current quality standards for wastewater disposal and use*
- *Rights to use treated wastewater*
- *Current technical standards for domestic wastewater treatment*
- *Current technical standards for domestic wastewater agricultural use.*

Agricultural plan of the study area

- *Current agricultural activities (areas, productivity, and technological level)*
- *Integration between the agricultural activity and other activities*
- *Description of the existing area of reuse (experience and agronomic techniques to use this resource)*
- *Differences of productivity, quality, and costs for wastewater use*
- *Post-harvest and marketing of agricultural products*
- *Potential crops for agricultural development and management requirements (agricultural, post-harvest, and transformation)*
- *Marketing of current and potential agricultural products: supply, demand, and marketing channels*
- *Commonly used irrigation systems*
- *Proposals for the agricultural plan: crop selection or rotation and seeding plans (areas, agricultural schedule, production)*
- *Proposed irrigation system*
- *Water requirements in quantity and quality for the proposed agricultural plan*
- *Crop agronomic management*
- *Technical, managerial, and technical assistance requirements of the agricultural plan and production costs*
- *Proposed marketing techniques: prices, seasonality, modalities, sale policy*
- *Investment and expected revenues.*

Wastewater treatment

- *Description of the existing domestic wastewater treatment system*
- *Wastewater management policy of the water company*
- *Sustainability of the plant operation and maintenance (technical capability and tariffs)*
- *Domestic wastewater characterization and final disposal*
- *Treatment requirements for reuse: sanitary, environmental and agronomic quality and quantity of wastewater*
- *Evaluation of wastewater treatment technologies*
- *Technology selection and definition of the treatment efficiency*
- *Plant location and design according to the options of the agricultural plan*
- *Description of the stages of the proposed treatment*

- *Design of the plant: physical characteristics (general plans and details)*
- *Collection and distribution system*
- *Requirements for machinery, equipment, labor, and supplies*
- *Extension of the area required and budget allocated for construction works*
- *Execution plan of the plant*
- *Investment, operation and maintenance, and administrative costs.*

Evaluation and environmental management plan

- *Identification, description, and assessment of the significant environmental and health impacts*
- *Contingency risks of wastewater treatment systems (overflows, losses of the dam capacity and stability)*
- *Measures to treat negative environmental impacts*
- *Environmental management plan*
- *Investment and operational costs to implement the management plan.*

Management of the social aspects of the project

- *Identification and characteristics of the actors*
- *Actors' knowledge about wastewater treatment and use*
- *Acceptance level of the integrated model by the actors*
- *Terms of producers and consumers to accept the integrated system*
- *Tenure of lands used for the system (for treatment and reuse)*
- *Actors' needs, interests, and relationships*
- *Communal or private organization of the farmers*
- *Actions to strengthen the organization among producers*
- *Management model and mechanisms of the integrated system: organization and management of the treatment and agricultural components*
- *Monitoring and evaluation indicators of the sociocultural, legal, and institutional aspects*
- *Agreements among actors and schedule for meetings and activities*
- *Training plan and technical assistance.*

Implementation plan of the project

- *Schedule for meetings and activities*
- *Funding arrangements*
- *Plan of execution of the plant*
- *Agricultural development plan*
- *Environmental management plan*
- *Plan of training and technical assistance*
- *Implementation*
- *General implementation plan.*

Economic and financial evaluation

- *Analysis of users' affordability to pay the sewerage service, and collection mechanisms*
- *Economic valuation of significant environmental impacts*
- *Investment, borrowing, and operation capability of the institution responsible for the integrated system*
- *Analysis of options for funding: selection of funding sources*
- *Funding strategy to implement the integrated system (structure and lines of credit)*
- *Fixed investment and capital allocated to the project. Investment schedule*
- *Financial statements: profit and loss, cash flow, and break-even point*
- *Economic evaluation of the treatment and reuse options*
- *Financial evaluation*
- *Sensitivity analysis of the project (investment, costs, and prices)*
- *Selection and justification of the best treatment and use option.*

Conclusions and recommendations.

6. REFERENCES FOR THE FEASIBILITY STUDIES OF THE PROJECT

The Technical Committee has prepared the following materials to make the feasibility studies easier:

a. Terms of reference for the feasibility studies

It is the main reference document, since it establishes all the issues that should be developed in the feasibility study.

b. Methodoly to develop the various aspects of the feasibility studies

This document is aimed at facilitating the systematization and processing of all data included in the terms of reference. It briefly describes the procedure that executors should consider to develop the following issues:

- Agricultural plan of the study area
- Water demand and supply
- Wastewater treatment
- Evaluation and environmental management plan
- Strategy for the social feasibility of the project
- Economic and financial evaluation.

Visit the Project website for further information on the Integrated System Project:

http://www.cepis.ops-oms.org/bvsaar/and/project/proyecto.html