THE CHANGING WATER QUALITY FROM THE STORAGE RESERVOIR TO THE IRRIGATED FIELD, TUNUYÁN SYSTEM, ARGENTINA

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INTRODUCTION

Water quality problems have increased through time due to the growth and concentration of populations and industrial centers. Often, these problems have been viewed as inevitable consequences of community development and, sometimes, have even been accepted as evidence of affluence and progress. Only after recognizing that serious health impacts could result from uncontrolled wastewater discharges did we finally initiate systematic water pollution control activities. Although health is still an important consideration today, it has been recognized that the impacts of water pollution are far more complex than on health alone. In fact, most pollution control programs are now based on reasons only remotely, if at all, related to health.

The word pollution implies undesirable quality, but it may be interpreted in various ways by different individuals. This may be attributed partly to emotional reactions but often involves substantive differences about our goals in using water resources and quality characteristics desired or needed to meet those goals. The presence of constituents that may be viewed as pollution by someone seeking a municipal supply could be acceptable or desirable to someone else who wishes to use the resource for swimming or fishing. From this statement it can be seen that water quality cannot be evaluated meaningfully without considering specific uses to which it will be put. Based on that fact, it is possible to define pollution as "the presence of materials in water that interfere unreasonably with one or more beneficial uses of it" (Lamb, 1985).

Water quality is, by definition, the set of physical, chemical and biological characteristics in the natural condition or after they are modified by man. This definition points to the fact that the study of water quality encompasses mainly the characteristics of natural waters, the changes caused by man's intervention, the effects of those changes, and pollution quality control methods (Cubillos, 1988).

The effect of a water constituent depends on its concentration. If it is sufficiently dilute, it would exert no adverse impact on water uses. In fact, many water constituents that could be objectionable at high concentrations may actually be beneficial, or even necessary, for some uses. As the concentration of a constituent increases, water quality may be adversely affected for some beneficial uses and, ultimately, may become unsuitable for virtually all desirable uses.

Although any water constituent, if sufficiently high in concentration, could interfere with the use of the resource, it could be misleading to refer to it as a pollutant. Often, a chemical or other constituent does not pollute water in the sense outlined before, because its concentration is below that which would cause objectionable quality or because the change in quality does not interfere with a reasonable use for that watercourse.

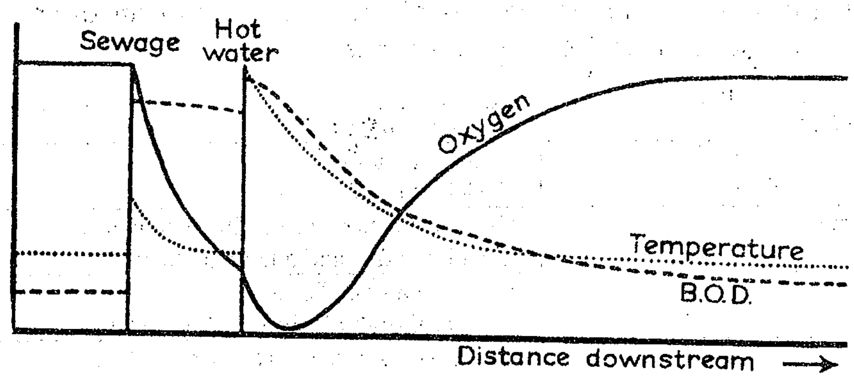
A rational approach for some authors is to consider every water constituent as suspect until its concentration is demonstrated to be below a level that creates an unreasonable quality problem by impacting beneficial uses that should be protected. Accordingly, it is preferable to refer to water constituents as "potential pollutants", as having the potential for causing water quality problems, but not necessarily always doing so (Lamb, 1985).

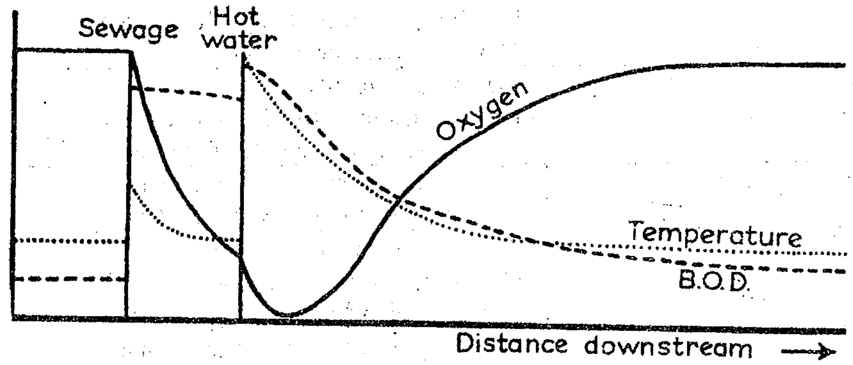
The general list of potential water pollutants include:

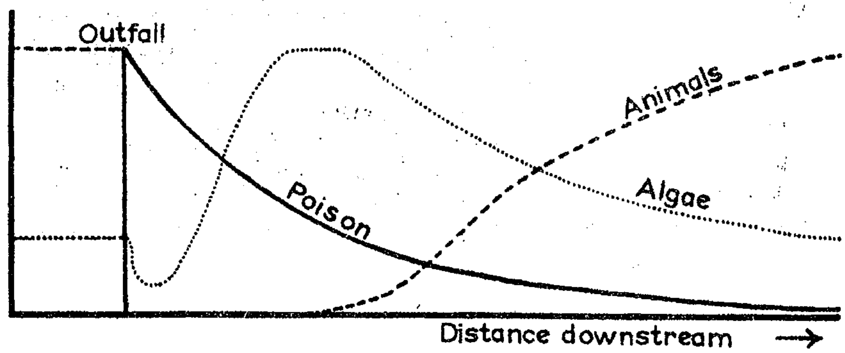
- Infectious and toxic agents
- Oxygen-demanding substances
- Persistent organic chemicals
- Plant nutrients
- Minerals and chemicals causing specific problems
- Suspended matter
- Radioactive substances
- Heat

Behavior of water quality parameters

The next figures show the behavior of selected chemical, physical and biological water quality parameters as the water flows downstream from an effluent discharge point (e.g. sewage or outfall). These curves show what the behavior of a particular water pollutant might be.


Sewage
Hot water
Oxygen
Temperature
B.O.D.
Distance downstream


Sewage
Hot water
Oxygen
Temperature
B.O.D.
Distance downstream


Outfall
Animals
Algae
Poison
Distance downstream

The following table includes a detailed list of some of the most important water pollutants as well as the main problems they may arise:

Chemical	Potential problems
Arsenic	- Toxicity to humans - Toxicity to aquatic life
Chlorine	- Organic reactions form trihalomethanes - Toxicity to fish and other aquatic life
Calcium	- Causes "hardness"of water - May result in scale formation in pipes
Iron	- Causes stains in laundry and on fixtures - May kill fish by clogging their gills
Ammonia	- May accelerate eutrophication in lakes - May improve productivity of the water - May be toxic to aquatic life
Nitrates	- May be toxic to babies - May accelerate eutrophication in lakes - May improve productivity of the water
Dissolved Oxygen	- Low concentrations harmful to fish - Low concentrations may cause odor
Phenolics	- Tastes and odors in drinking water - Can cause tainting of fish flesh - May be toxic to aquatic life
Sulfides	- Objectionable odors in and near water - May be toxic to aquatic life - May corrode concrete through acid formation - Oxidation to sulfate exerts an oxygen demand
Sulfites	- React with dissolved oxygen and exert oxygen demand
Sulfates	- Increase water corrosiveness to metals - Decompose anaerobically to form sulfides - Salty taste and laxative effects

Important agricultural parameters

When water is mainly used for agriculture, the principal causes or sources of pollution and the most common parameters to be determined are:

PROBLEM	MAJOR CAUSES/SOURCES	COMMON MEASUREMENT VARIABLES
Elevated temperature	Irrigation withdrawal, drainage, Reservoir warming	Temperature
Salinity	Drainage, Reservoir evaporation	Specific Conductance, Dissolved Solids
Nitrates	Inorganic fertilizers, Feedlots	Nitrates
Sanitary quality	Feedlots, Slaughterhouse wastes, Livestock grazing	Faecal coliforms, Faecal Straeptococci, E. coli, others
Decomposable organic wastes	Feedlots, Slaughterhouse wastes, Dairy operations, Food processing, Pulp and paper mills	DO, BOD, COD, Ammonia, Suspended solids
Erosion/Sedimentation	Intensive cultivation, lumber production, Livestock grazing	Suspended sediments, Bed sediment accumulation
Nutrient enrichment	Fertilizers, Feedlots, Food processing, Pulp and paper mills	Nitrates, Nitrites, Ammonia, Total phosphorus, Orthophosphorus, Algae, Chlorophyll
Toxic trace sediments	Irrigation drainage	Selenium, Arsenic, Molibdenum, Boron, Lithium
Pesticides	Applied herbicides and insecticides	Atrazine, Alachlor, Chlordane, DDT. Malathion, Parathion, many others

Some selected environmental effects of agriculture on water quality are listed below in order to depict the different sources of pollution from this activity:

Agricultural practices	Soil	Groundwater	Surface water
Land development, land consolidation programmes	Inadequate management leading to soil degradation	Other water management influencing groundwater table	Soil degradation, siltation, water pollution with soil particles
Irrigation, drainage	Excess salts, waterlogging	Loss of quality (more salts), drinking water supply affected	Run-off leaching or direct discharge leading to eutrophication
Tillage	Wind erosion, water erosion		Run-off leaching or direct discharge leading to eutrophication
Mechanization: large or heavy equipment	Soil compaction, soil erosion		Run-off leaching or direct discharge leading to eutrophication
Fertilizer use			Run-off leaching or direct discharge leading to eutrophication
Nitrogen		Nitrate leaching affecting water	Run-off leaching or direct discharge leading to eutrophication
Phosphate	Accumulation of heavy metals (Cd)		Run-off leaching or direct discharge leading to eutrophication
Manure, slurry	Excess: accumulation of phosphates, copper (pig slurry)	Nitrate, phosphate (by use of excess slurry)	Run-off leaching or direct discharge leading to eutrophication
Sewage sludge compost	Accumulation of heavy metals, contaminants		Run-off leaching or direct discharge leading to eutrophication
Applying pesticides	Accumulation of pesticides and degradation products	Leaching of mobile pesticide residues and degradation products	Run-off leaching or direct discharge leading to eutrophication
Input of additives, medicines	Possible effects		
Modern building (e.g. silos) and intensive livestock farming	See slurry	See slurry	See slurry

Source: Adapted from OECD, 1985

The quality of irrigation water is of particular importance in arid zones where temperature extremes and low relative humidity give rise to high evaporation rates, with the ensuing deposition of salts which tend to accumulate in the soil profile. The physical and mechanical properties of the soil, such as dispersion of particles, stability of aggregates, soil structure and permeability, are very sensitive to the type of exchangeable ions present in irrigation water. Thus, when effluent use is being planned, several factors related to soil properties must be taken into consideration (EPA, 1992).

Another aspect of agricultural concern is the effect on plant growth of dissolved solids (TDS) in irrigation water. Dissolved salts increase the osmotic potential of soil water and an increase in osmotic pressure of the soil solution also increases the amount of energy which plants must expend to take up water from the soil. As a result, respiration increases and plant growth and yields decline progressively as osmotic pressure increases. Although most plants respond to salinity as a function of the total osmotic potential of soil water, some plants are susceptible to specific ion toxicity.

Many of the ions which are harmless or even beneficial at relatively low concentrations may be toxic to plants at high concentrations, either through direct interference with metabolic processes or through indirect effects on other nutrients, which might be rendered inaccessible. Morishita has reported that irrigation with nitrogen-enriched pollution water can supply considerable excess of nutrient nitrogen to growing rice plants and can result in a significant loss of rice yields through lodging, failure to ripen and increased susceptibility to pests and diseases due to over-luxuriant growth. He further reported that non-polluted soil, having around 0.4 and 0.5 ppm cadmium, may produce about 0.08 ppm Cd in brown rice, while only a little increase up to 0.82, 1.25 or 2.1 ppm of soil Cd can produce heavily polluted brown rice with 1.0 ppm Cd.

Important agricultural water quality parameters include a number of specific properties of water that are relevant in relation to crop yields and quality, maintenance of soil productivity and protection of the environment. These parameters include certain physical and chemical characteristics of water. The following table presents a list of some of the most important physical and chemical characteristics that are taken into account in the evaluation of agricultural water quality and the main wastewater quality parameters from an agricultural viewpoint:

Parameters used in the evaluation of agricultural water quality

Parameter	Symbol	Unit
Physical		
Total Dissolved Solids	TDS	mg/l
Electrical conductivity	EC	dS/m[1]
Temperature	T	°C
Colour/Turbidity		NTU/JTU[2]
Hardness		mg. equiv. $CaCO_3$/l
Sediments		g/l
Chemical		
Acidity/Basicity	pH	
Type and concentration of anions and cations:		
Calcium	Ca^{++}	me/l[3]
Magnesium	Mg^{++}	me/l
Sodium	Na^{+}	me/l
Carbonate	CO_3^{2-}	me/l
Bicarbonate	HCO_3^{-}	me/l
Chloride	Cl^{-}	me/l
Sulphate	SO_4^{2-}	me/l
Sodium Adsorption Ratio	SAR	
Boron	B	mg/l[4]
Trace metals		ppm
Heavy metals		ppm
Nitrate-Nitrogen	NO_3 - N	mg/l
Phosphate Phosphorus	PO_4 - P	mg/l
Potassium	K	mg/l

[1] dS/m = deciSiemen/metre in SI Units (equivalent to 1 mmhos/cm)
[2] NTU/JTU = Nephelometric Turbidity Units/Jackson Turbidity Units
[3] me/l = milliequivalent per litre
[4] mg/l = milligrams per litre = parts per million (ppm); also,
mg/l ~ 640 x EC in dS/m

Source: Kandiah (1990a)

PHYSICAL, CHEMICAL AND MICROBIOLOGICAL ANALYSIS

The water pollution parameters analyzed in this research, the analytical methods used as well as an explanation of their meaning are presented below.

Temperature: in the field and at the laboratory, with thermometer
pH:until October 1995, it was determined with indicative paper in the field and at the laboratory. As of December 1995, a pH meter was used in the laboratory.
Organoleptic characteristics description: color, smell and aspect.
Electrical Conductivity: conductivity meter.
Dissolved Oxygen: Winkler method.
Total, Fixed and Volatile Solids: dissecation in stove to 100 ± 2°C to constant weight. (AOAC Method, 1984).
Biochemical Oxygen Demand (BOD_5): according to the AOAC Method, 1984.
Total Nitrogen: Method of Kjeldahl (AOAC, 1984).
Chemical Oxygen Demand (COD): according to the method described in Berman, 1984.
Settleable Solids in 10 minutes and in 2 hours: Inhoff cone.
Nitrites, Nitrates and Phosphates: colorimetric determinations using Merck kits.
Aerobic Mesophile Bacteria (CFU/ml): inventory in plate (Swarthy, 1982)
Coliform Bacteria inventory: MPN/100 ml.(Swarthy, 1982)
Faecal Coliform bacteria inventory: MPN/100 ml (Swarthy, 1982)
Escherichia coli inventory: MPN/100 ml (Swarthy, 1982)

NOTE: as from October 1996, analyses of Chrome, Lead, Mercury and Arsenic were also included in some of the samples. Due to the cost of the analyses, they were repeated in samples taken during the months of March and April 1997.

Temperature

This parameter, in combination with the ambient temperature, may be used as an indication of pollution. In this way, possible pollutants can be detected if they have an influence in these values.

pH

It represents a measure of the acidity/alkalinity status of water. Is an indicator and it is rarely important for itself. The pH value is important for a quick assessment of the normal condition of the water body. Optimum pH values in irrigation water range between 6.5 and 8.4.

Total, Fixed and Volatile Solids

They are directly related to the solid material carried by water, to the flow and to water velocity. Fixed solids represent the inorganic fraction and volatile solids the organic fraction.

Settleable Solids

They represent the fraction of the solid material that can be divided by sedimentation. Measurement after 10 minutes gives an indication of the thicker inorganic matter (sand) and after 2 hours of the suspended organic matter.

Dissolved Oxygen

It shows the aerobic condition of the water body. Depending on its concentration, life development may or may not be possible. The minimum level required for life development is 4 mg/l (Kupchella, 1993).

Chemical Oxygen Demand (COD)

This parameter shows the organic matter in the water that can be degraded by chemical action.

Biochemical Oxygen Demand (BOD_5)

It shows the amount of oxygen that aerobic germs require for organic matter decomposition in one liter of water after five days in the dark at a temperature of 20° C.

Total Nitrogen, Nitrites and Nitrates

Nitrates and Nitrates are important water pollution indicators. Nitrogen (N_2) is an essential element for life. When living organisms die, proteins are mineralized. As a result of this process, Nitrogen is found as Ammonium (NH_3) or Ammonia (NH_4^+). Oxidation processes transform these compounds into Nitrites (NO_2^-) and then into Nitrates (NO_3^-). They are absorbed by plants and other organisms that use them to produce new proteins, thus closing the Nitrogen Cycle. In terms of health, a high content of Nitrites is a sign of biological activity. When high contents of Nitrates are found it can be assumed that the source of pollution is far from the sampling location, which means that there has been enough time to produce the total oxidation of nitrogen compounds.

High concentrations of nitrates and phosphates (PO_4^{3-}) have to be carefully studied, because they can trigger the so called eutrophication process in the receiving water bodies. Over extended periods of time, eutrophication can produce accumulations that can change the characteristics of a water body (i.e. lakes) permanently, thus increasing its organic content and community of organisms and ultimately converting it into marsh lands. At present, some studies are being carried out on El Carrizal dam in order to determine the trophic status of water. It is assumed that strong eutrophication processes might be taking place.

Phosphorus

In general, the same considerations for Nitrogen hold for this element.

Electrical Conductivity (EC)

Electrical Conductivity (EC) is widely used to indicate the total ionized water constituents. It is directly related to the sum of the cations (or anions), as determined chemically, and is closely correlated with the total salt concentration. The salinity of soil water is related to, and often determined by, the salinity of irrigation water. Accordingly, plant growth, crop yield and quality are affected by the total dissolved salts in the irrigation water. Likewise, the rate of salt accumulation in the soil, or soil salinization, is also directly affected by the salinity of irrigation water. EC is a rapid and reasonably precise determination and values are always expressed at a standard temperature of 25° C to enable comparison of readings taken under varying climatic conditions. It should be noted that the EC of solutions increases by approximately 2% per °C increase in temperature. The unit used is dS/m

MICROBIOLOGICAL PARAMETERS

Indicator organisms

Indicator organisms are usually non-pathogenic, they always occur in large quantities in feces, and are relatively easy to detect as compared with water-borne pathogens whose diagnosis is much more complicated and time consuming, and hence less suited for routine investigations. Assuming that in cold surface waters pathogens die off faster than indicator organisms, the absence of the latter or their presence in very low numbers ensures that no pathogens are present. The indicator organisms most widely used are the so-called coliform bacteria, which by definition include all aerobic and facultative anaerobic, Gram-negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hs at 35° C.

The microbiological examination of water also comprises a test, called Standard Plate Count, which is indicative of the total number of microbes present per unit of volume in a water sample. The plate count is only indicative of the total number of living microbial cells in a volume of water. The rationale for this test is threefold:

1. A high content of bacteria, even non-pathogenic, indicates that there are significant amounts of biodegradable organic matter which reduces the conveyance capacity of pipes through wall growth, pieces of which also may get disloged and end up in the consumer's tap water.
2. When drinking water is used for industrial processes, e.g. in the food industry, a low non-pathogenic bacterial count is often desirable.

3.When performed on a routine basis and together with the hygienic safety test results, the plate count can provide valuable additional criteria for judging the performance of the water purification process and of the conveyance system. Malfunctioning leading, for instance, to the introduction of non-pathogenic bacteria would not show up as a result of the hygienic safety tests alone.

Coliform and Faecal coliform bacteria

The Coliform group of bacteria comprises mainly species of the genera *Citrobacter*, *Enterobacter*, *Escherichia* and *Klesbsiella* and includes Faecal Coliforms, of which *Escherichia coli* is the predominant species. Since several Coliforms can grow outside the intestine, especially in hot climates, their quantification is unsuitable as a parameter. The Faecal Coliform test may also include some non-faecal organisms which can grow at 44° C, so the *Escherichia coli* count constitutes the most satisfactory indicator parameter.

Other indicator organisms are Faecal Streptococci and *Clostridium perfringens*

Pathogenic parameters can only be considered when wastewater is used for irrigation, and provided suitable laboratory facilities and trained staff are available. They are *Salmonella sp.*, Enteroviruses, Rotaviruses, and Intestinal Nematodes.

ORGANOLEPTIC CHARACTERISTICS OF WATER

Color: it is produced by colloidal particles, especially organic acids resulting from organic matter decomposition. In this paper, this parameter has been reported according to laboratory observations.

Odor: it is produced by gases released from organic matter decay. Here they are also reported according to laboratory observations.

Turbidity

Turbidity in water may be produced by suspended materials, especially of colloidal and dispersed nature, generated by erosion processes, wastes, microorganisms, etc. In fact, turbidity measures absorption or dispersion of the light crossing the water depth. It affects the aesthetics of water.

TRACE ELEMENTS AND HEAVY METALS

A number of elements are normally present in relatively low concentrations, usually less than a few mg/l, in conventional irrigation waters and are called trace elements. They are not normally included in routine analysis of regular irrigation water, but attention should be paid to them when using sewage effluents, particularly if contamination with industrial wastewater discharges is suspected. These include Aluminum (Al), Beryllium (Be), Cobalt (Co), Fluoride (F), Iron (Fe), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Selenium (Se), Tin (Sn), Titanium (Ti), Tungsten (W) and Vanadium (V). Heavy metals are a special group of trace elements which have been shown to create definite health hazards when taken up by plants. Under this group, Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg) and Zinc (Zn) are included. These are called heavy metals because in their metallic form, their densities are greater than 4 g./cc.

PEST CONTROL AGENTS

As a result of pests, man has been confronted with diseases, discomfort and great economic losses. Some of the methods for insect control date back to many centuries ago. Ancient agriculturalists relied almost entirely on the use of natural products and by-products.

Since the turn of this century, synthetic pesticides have exerted a great impact on food and fibre production, both as regards quality and quantity, and have improved and saved human health and lives. The so called "pesticide revolution" dates back to 1942 when DDT was first used as an insecticide. Since that time, an increasing number of synthetic organic pesticides have been produced and have been widely used all over the world.

Pesticides are now part of daily life since most people are plagued, to some extent, by living pests that are troublesome, destructive, or that are vectors of human or animal afflictions. Since unsanitary conditions create an ideal environment for the spread of many diseases, pesticides have widespread beneficial uses in preventive medicine for the control of insect vectors of diseases, ectoparasites, etc., not only in the tropics but also in temperate zones. Therefore, conventional chemical pesticides have become the most powerful and dependable tool to control pest populations; research on alternatives has not yet produced anything that can replace these indispensable chemicals. On the other hand, society has become increasingly critical of the extensive and indiscriminate use of various chemicals, including insecticides. It has been argued that the only reliable way to avoid hazards from pesticides would be to ban them completely. This, of course, is unrealistic; at present, it has been acknowledged that chemical pesticides constitute an important part of integrated pest management.

Pesticides include a wide variety of chemical or biological substances. Although these substances are developed to control pests, the possibility of acute and chronic adverse effects on humans following an excessive exposure is an inherent feature of many of these compounds, especially insecticides.

Each successful use of pesticides to control human diseases creates an additional demand of pesticides in agriculture and crop protection. Those who will not die from malaria or some other vector-borne disease do not later die of starvation or malnutrition. In all these activities, pesticide treatment should be considered as a supplement to basic sanitation and, like drugs, pesticides should always be used with discretion and together with many other general measures in order to achieve effective pest control.

It is essential that the hazards to human health posed by pesticides be viewed in relation to the benefits rendered by their use. In addition, economical use of an insecticide calls for the use of the smallest quantity of the active ingredient compatible with the desired efficacy.

A pest control agent is defined as a substance or a mixture of substances intended to destroy, repel or reduce the harmful effects of pests. A pesticide is a substance or a mixture of substances intended to kill a pest (but the term is often erroneously used to mean "pest control agent"). The term "pest" includes harmful, destructive or troublesome animals, plants or microorganisms except those found in association with live animals or man. The essential component of a pest control agent is the active ingredient. At present, more than 1000 active substances are incorporated in over 10,000 pest control preparations. They include both organic and inorganic chemicals (and more recently bacterial and viral and other living pathogens) of variable composition and function.

Pesticides are used in many fields of human activity, public health and agriculture, this being the most important. The type of untoward effects of a pest control agent on man does not differ whether it is used in agriculture or public health.

The use of agents which persist for a longer period than is necessary to control a given pest, contributes to the contamination of food and the environment, and possibly adversely affects non-target species. On the other hand, an agent which does not persist long enough to effect control is useless. To compromise, a scientifically founded risk-benefit assessment is essential.

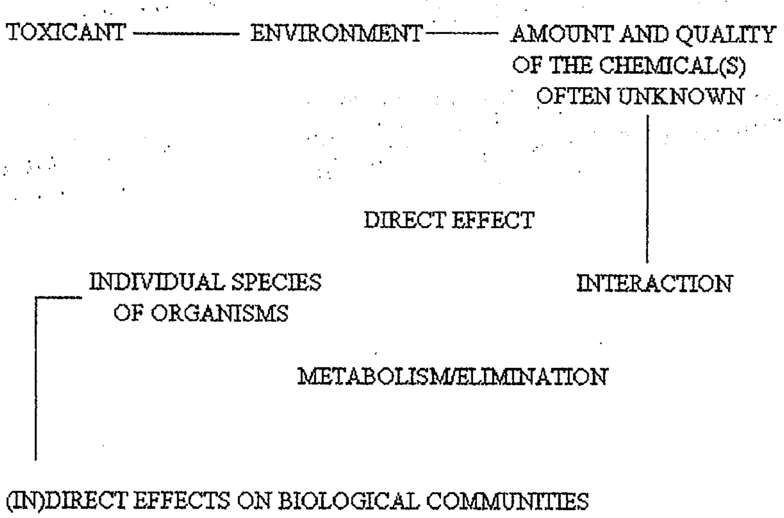
Based on the organism they control, pest control agents may be grouped as:

- acaricides
- attractants
- defoliants
- dessicants
- fungicides
- herbicides
- insecticides
- larvicides
- miticides
- molluscicides
- nematicides
- plant growth regulators
- repellents
- rodenticides

Toxicology and ecotoxicology

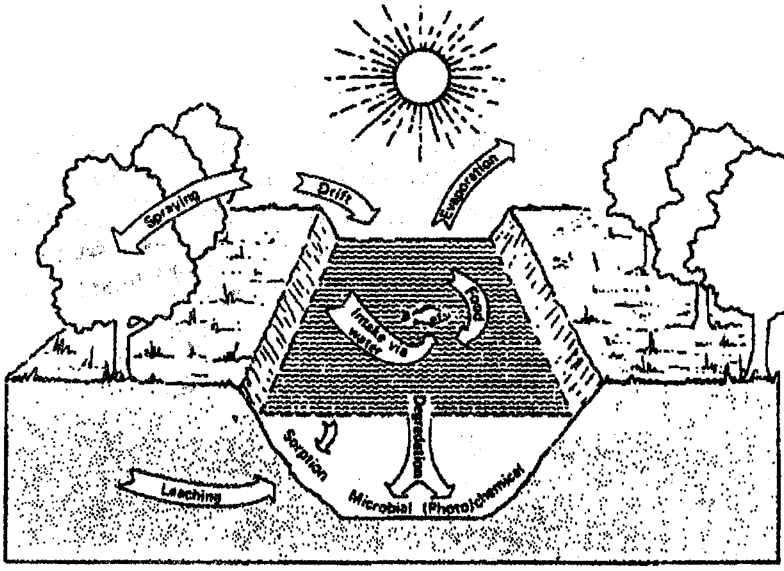
A striking difference between general toxicology and ecotoxicology (the fate of chemical substances in the environment in general) is that the chemical identity and the dose are often unknown. Once a toxicant is introduced into the environment, qualitative and quantitative changes can take place. In this way, one toxicant can generate an unknown number of new chemicals. The toxicant and its metabolites can go from one environmental compartment to another, thereby altering their concentrations.

A second difference is the choice of the target organism. In general toxicology, the main target organism is man and domestic animals. In ecotoxicology, the main targets are all kinds of organisms living in complex ecosystems (the biological community). In this respect, an ecotoxicologist not only has to deal with the interaction of the toxicant with single species, but he must also consider the new properties that are added at the higher levels of the community organization. The difference is visualized in the following figure:



Processes that affect the environmental concentration of toxicants

The next figure shows the processes that may play a role in the dispersion, elimination or concentration of a pesticide used for insect control in an orchard.



Abiotic and biotic processes playing a role in the dispersion, (bio)chemical changes and accumulation of pesticide sprayed in an orchard

The different processes that may affect the concentration of a toxicant in water, air, soil and organisms after being released into the environment are listed below:

Evaporation	volatilization into the atmosphere (volatile compounds; very hydrophobic compounds despite their very low vapour pressure)
Transport	diffusion ·. flow (in molecular form or "bound" to organic material and clay minerals) in water, soil and air ·. transport via biota (e.g. lead, DDT, PCB's in worms, birds, etc.)
Transformation	by physical-chemical processes: oxidation (hydrolysis) ·. reduction ·. photodegradation ·. dissociation (some organics) ·. speciation (metals) by biological processes: metabolism and breakdown
Accumulation	by physical-chemical processes: sorbtion ·. ion exchange ·. precipitation by biological processes: bioaccumulation (= bioconcentration) ·. biomagnification

Further details of these processes are beyond the scope of this paper and will not be discussed here. It can be concluded that the amount, fate and rate of uptake of a toxicant depend on the physical and chemical state of the toxicant and on the organism itself: its morphology, physiology and habitat being the main factors.

THE LOWER TUNUYÁN IRRIGATION AREA

The Province of Mendoza, located in the arid west of Argentina, has an annual rainfall of less than 250 mm. For this reason, the agricultural, urban and industrial activities are distributed in five irrigated oases.

The Tunuyán river area concentrates large part of the provincial productive potential and important urban settlements (San Martín, Rivadavia, Junín). The main characteristics of the area are: high population density, an industrial area distributed all over the oasis, the presence of a pollutant sector at the head of the river and a close contact between water and people (Chambouleyron, 1989). The total area of the oasis of the Lower and Middle Tunuyán is approximately 85,000 ha. The irrigation network is 1000 km long.

Between 1992 and 1994, research was carried out on the pollution levels in six secondary canals, in the Upper Tunuyán watershed, in El Carrizal dam (that receives water from the Upper Tunuyán River), in the Tiburcio Benegas diversion dam, and in six collectors (Chambouleyron, 1995). Lack of funds and time did not make it possible to carry out a more exhaustive monitoring to arrive at valid conclusions in such a vast area. For this reason, a secondary canal, which crosses an important urban center, and a tertiary canal ("hijuela") derived from the former were chosen. The Montecaseros canal crosses the city of San Martín, the most important town of the oasis, until reaching the Cuarta Chivilcoy hijuela. From this canal, water is diverted into several branches ("ramos"). Two properties were selected: one of them receives water from the lower sector of the hijuela and the other receives water from a Collector (Colector Moyano) which is used for irrigation.

In order to draw a comparison between the water quality in this area and the water quality in the upper part of the system, some other sites were selected for regular sampling. These are located on the Canal Matriz Margen Izquierda (a few meters downstream from the Tiburcio Benegas diversion dam) and on the Canal San Martín (a few kilometers before the water crosses the city of San Martín).

The objectives of this research are:

- To assess changes in water quality as the water runs from the diversion dam to the field along the normal agricultural cycle.
- To formulate recommendations for the adequate use of water.
- To identify and test indicators that can be used to quantify and
- qualify the performance of irrigation and drainage.

MATERIAL AND METHODS

Selection of sampling sites

Water samples were collected from seven sites which are described below; the abbreviations used in the tables and graphs are indicated in brackets.

Canal Matriz Margen Izquierda (Matriz): it is a lined canal where water runs at high velocity. A site located some 50 meters downstream from the Tiburcio Benegas diversion dam was selected. There are no agricultural fields in the vicinity of the site. The results of the samples taken at this site show what the quality of the water entering the system is like.

Canal San Martín (San Martín): it is an earthen canal where, in spite of the high volume of water, the water velocity is remarkably lower than in Canal Matriz. The site selected to take water samples is a sector where the canal runs beside the Chileno Herrera street. In the vicinity of the site there are some agricultural properties planted with approximately 80 % of vineyards, 15 % of olive trees and 5 % of fruit trees. The results of the analysis of the samples show the degree of pollution in the upper part of the irrigation system.

Canal Montecaseros (Montecaseros): it is a lined canal where water runs at high velocity. A sampling site was selected downstream from the city of San Martín, a few meters before the diversion to hijuela Cuarta Chivilcoy. This is a typical agricultural area devoted almost entirely to vineyards. No houses were observed in the vicinity of this site. Samples from this site show the pollution levels produced by an urban - industrial center.

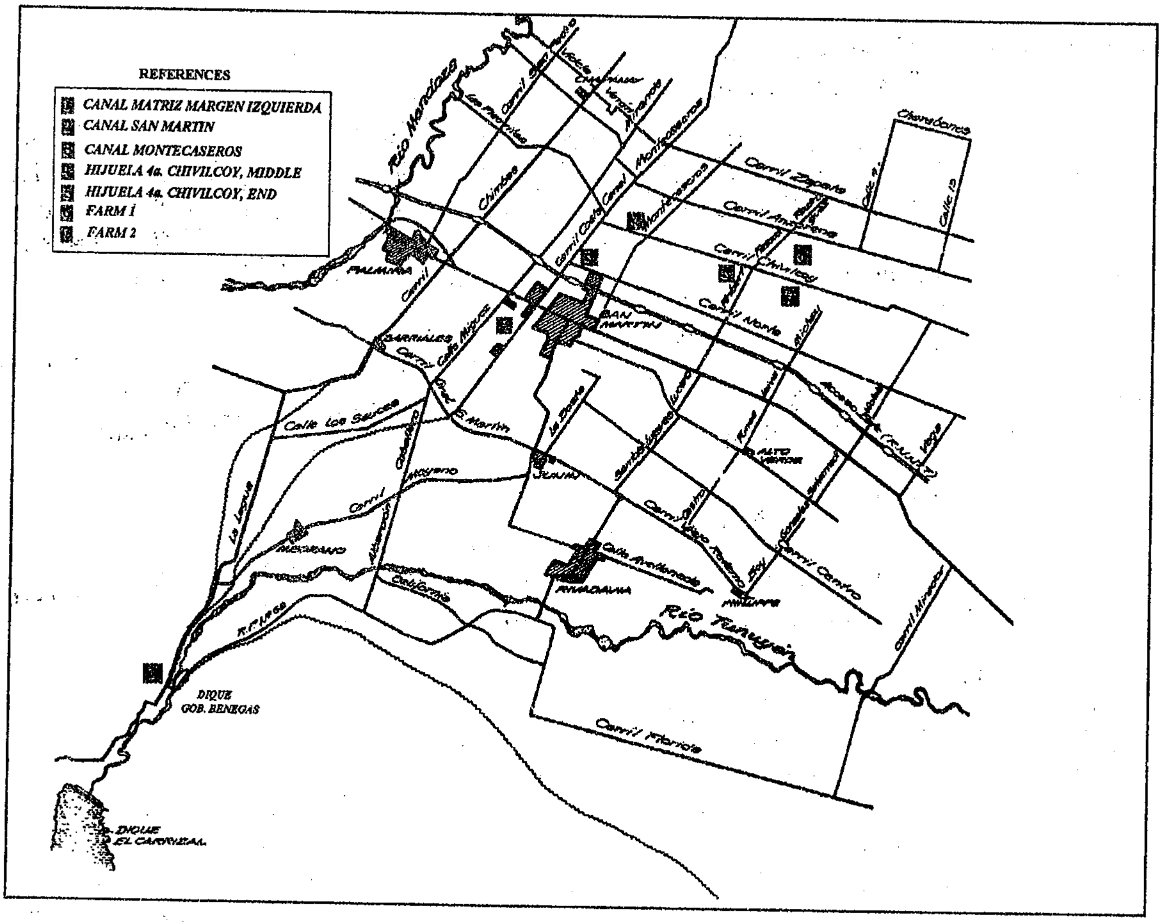
Hijuela Cuarta Chivilcoy, Middle (Hijuela M): this is an earthen canal with a relatively little flow. Sampling is carried out in a site located between Tropero Sosa and Lavalle streets. There are few agricultural properties, which are devoted only to vineyards, and a large number of houses. Sometimes the canal is used for recreational purposes. The water drawn from this canal is used mainly for domestic purposes.

Hijuela Cuarta Chivilcoy, End (Hijuela E): the sampling site is located some 300 meters upstream from Robert street. The agricultural characteristics of this zone are similar to the area previously described. Water drawn from this canal is used for different purposes other than irrigation. The data on this site indicates pollution levels near the end of the unit.

Farm 1 (F 1): sampling is performed at farm level. Irrigation water is diverted from the previously described "hijuela" and conveyed to the farm by a "ramo" (4th level canal). Fruit trees (mainly plum trees), vineyards and corn are grown in this area. The samples show the quality of the water that is used to irrigate the crops.

Farm 2 (F 2): the samples are collected from water conveyed by the Cañada del Moyano collector canal. The farms here are devoted to the cultivation of vineyards, and water is used only for irrigation. As from September 1996, no samples from this site were collected. In fact it does not belong to the irrigation network ending in the "ramos". Furthermore, and after several analysis of samples coming from this site were made, it can be concluded that the water is of good quality.

The following map shows the Lower Tunuyán system with the sampling sites.

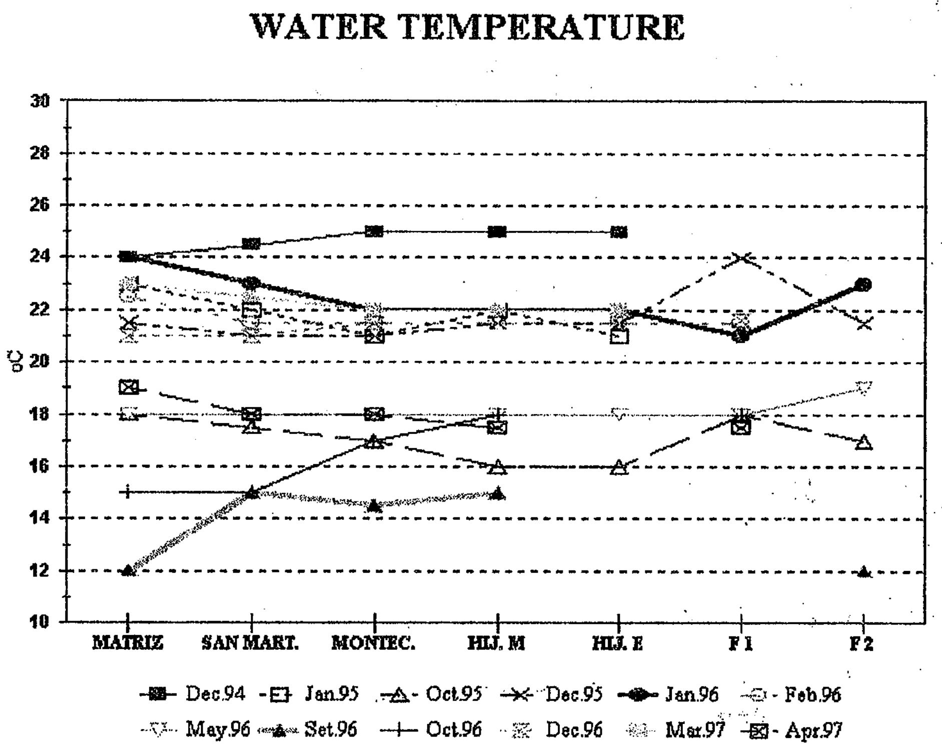

REFERENCES
CANAL MATRIZ MARGEN IZQUIERDA
CANAL SAN MARTIN
CANAL MONTECASEROS
HIJUELA 4a. CHIVILCOY, MIDDLE
HIJUELA 4a. CHIVILCOY, END
FARM 1
FARM 2
Río Mendoza
PALMIRA
SAN MARTIN
RIVADAVIA
Río Tunuyán
DIQUE
GOB. BENEGAS
DIQUE
EL CARRIZAL
Calle Los Sauces
Carril Florida
Carril Zapata
Carril Chivilcoy
Carril Norte
Carril Centro
Calle Avellaneda
California
La Lagua
Chimbas
Calle 13

RESULTS AND DISCUSSION

Sampling began in December 1994. Due to operational problems in the irrigation system, samples were not collected in November 1995 and March 1996. Results of water analyses for the 1994/1995 and 1995/1996 agricultural cycles have already been reported in previous RPIP documents (see Annexes). Results corresponding to samples taken in September and October 1996 are presented in the following table:

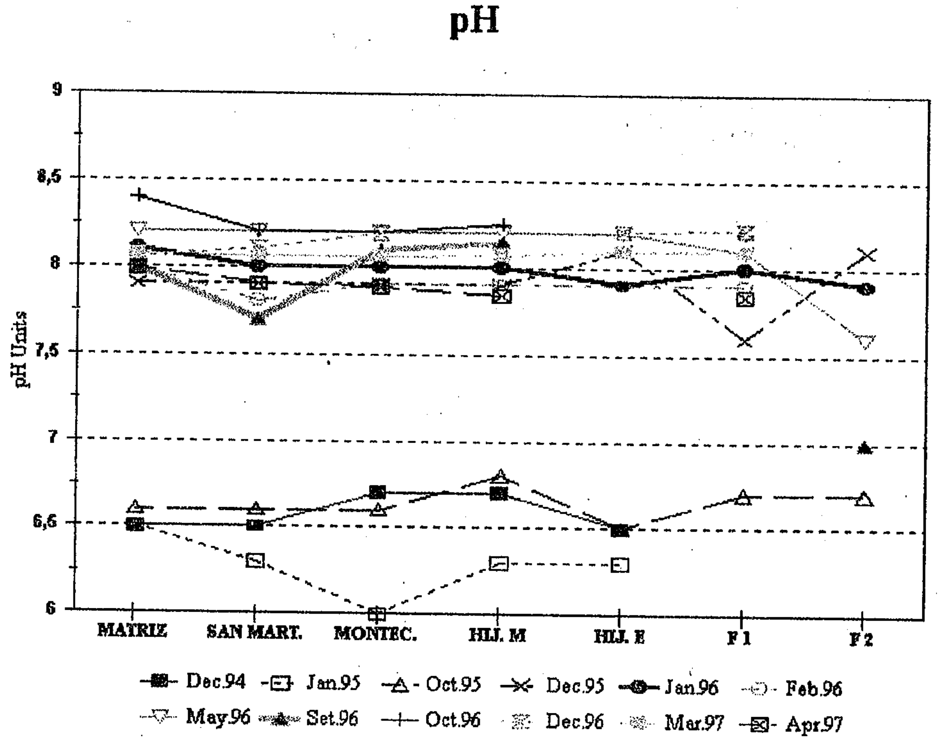
Water temperature

The differences between sites are related to the different air temperatures. The time difference between the first and the last sampling is of more than 3 hours.



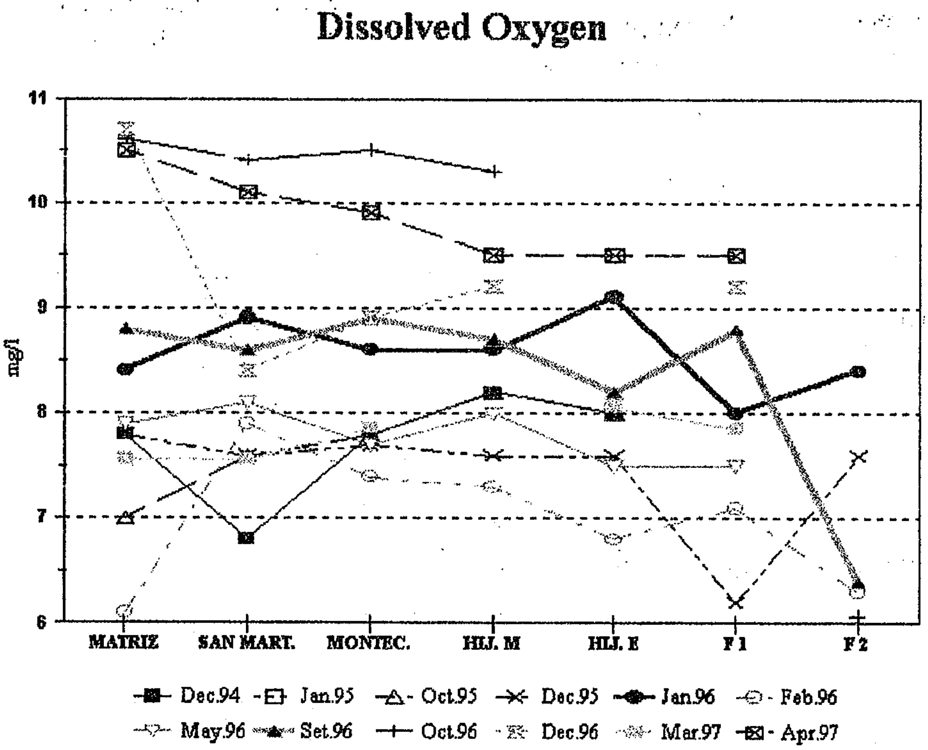
pH

In general, there are small fluctuations in pH values which vary between 7.6 and 8.1. These values show that water is suitable for irrigation and for aquatic life. The differences in the set of values before and after October 1996 are due to the different methods used to measure the pH.



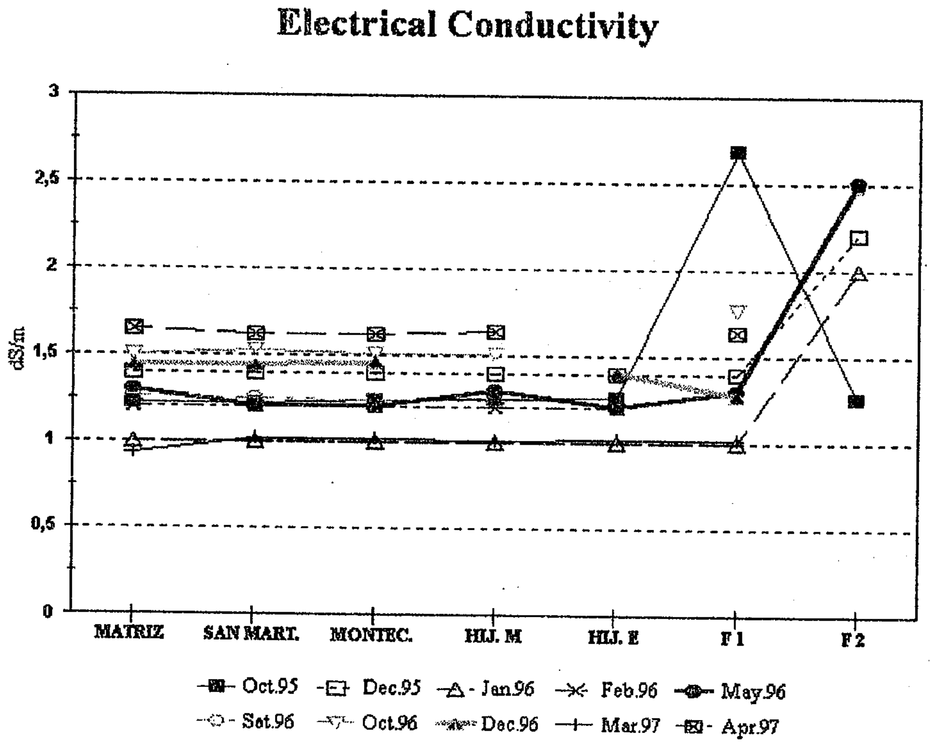
Dissolved oxygen

The available dissolved oxygen ranges between a minimum of 6.1 mg/l and a maximum of 10.7 mg/l. The limit to make life possible is 4 mg/l. From this point of view, all the samples are satisfactory.



Electrical Conductivity

During the irrigation season, EC values vary from 1.0 and 1.77 dS/m. These values show that any kind of crops can be cultivated in the sandy loam soils of the area under study. Though the values rendered by the samples taken in F 2 (drainage water) are higher, up to almost 3 mg/l, even sensitive crops can be irrigated.



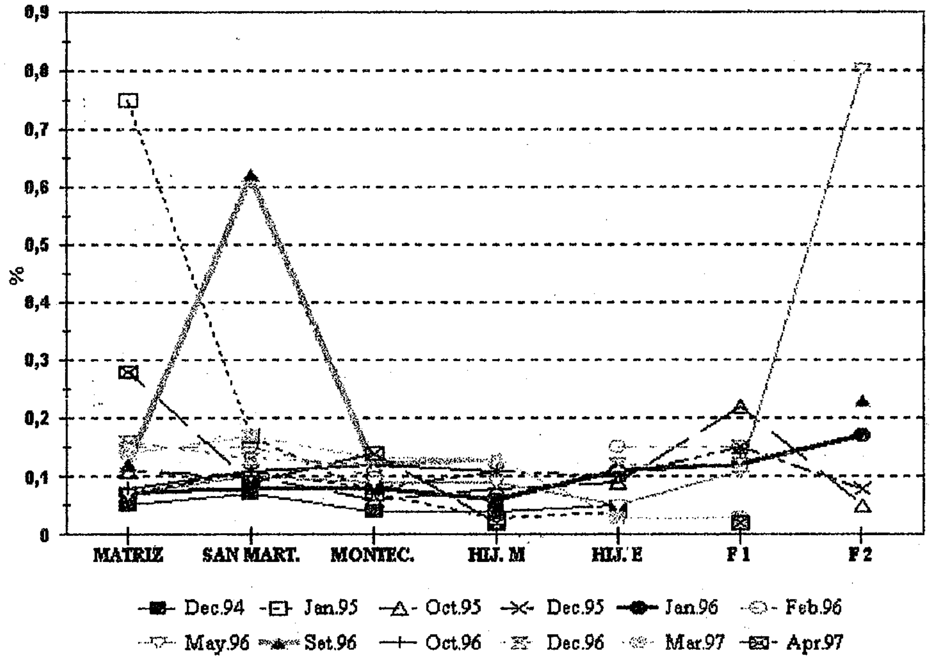
10-minute settleable solids and 2-hour settleable solids

The low values yielded by the 10' analysis and the degree of turbidity show that water does not carry any sediments. Very low values rendered by 2-hour settleable solids (most of them are 0) also show that there is a low amount of organic matter in the water. The results are presented in the attached Annexes.

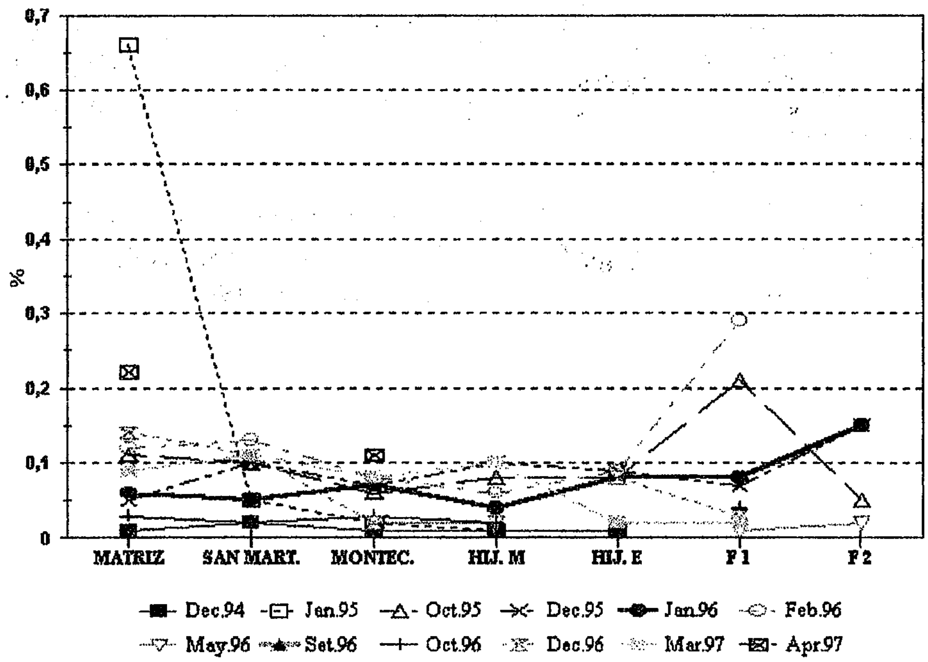
Total, Fixed and Volatile solids

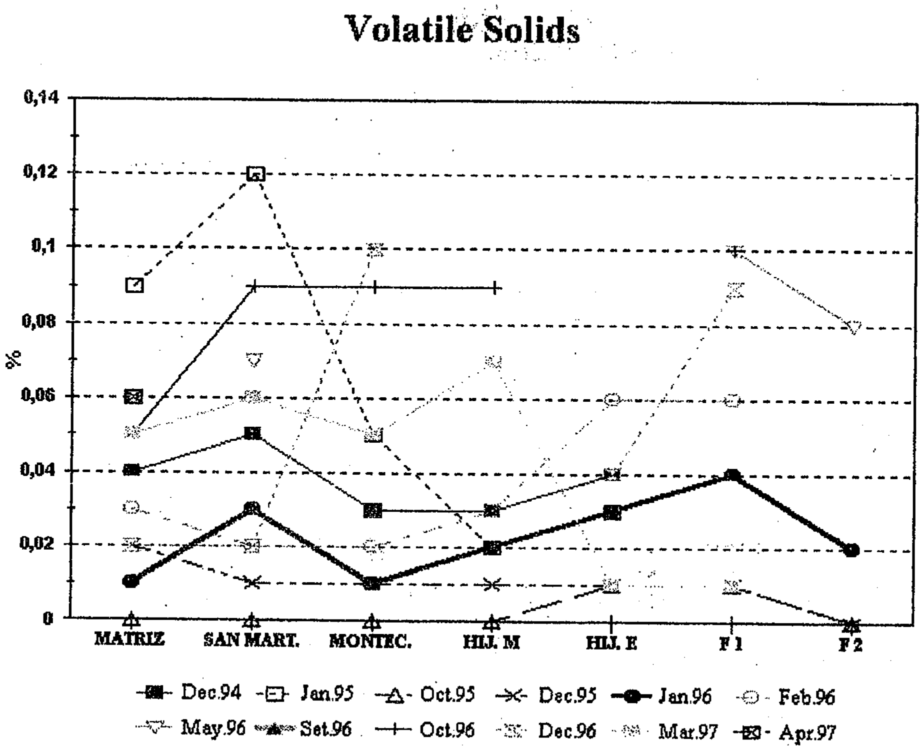
Results show values that range between 0.05 and 0.23 mg/l for total solids. High values for fixed solids correspond to high EC values.

Total Solids



Fixed Solids



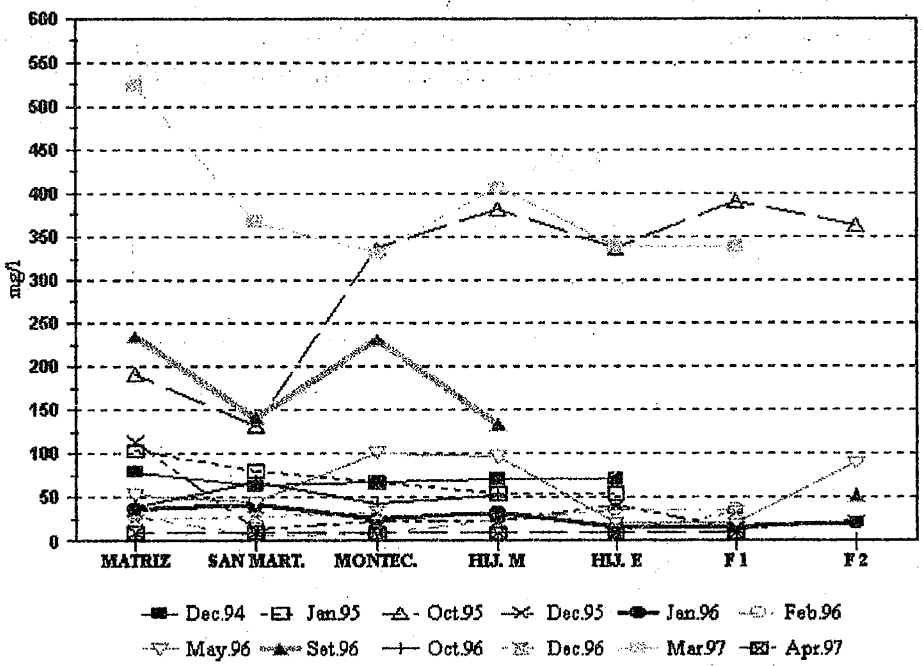


COD and BOD_5

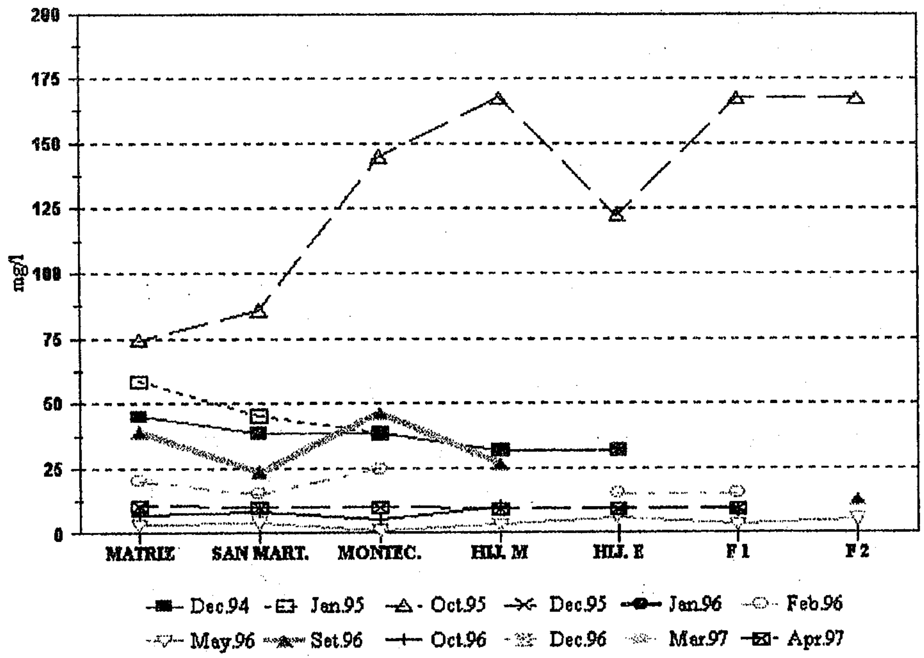
A slight decrease in COD values can be observed from the beginning to the end of the irrigation season. According to the Dissolved Oxygen values reported before and to the COD and BOD_5 values, it can be inferred that an important self-depuration process is taking place in the system.

Water can be used to irrigate any kind of crop (except for vegetables), but cannot be used either for drinking purposes (BOD_5 < 4 mg/l according to Cubillos, 1988) or for direct human contact (critical BOD_5 < 4 mg/l according to Cubillos, 1988).

Chemical Oxygen Demand (COD)



Biochemical Oxygen Demand (BOD 5)

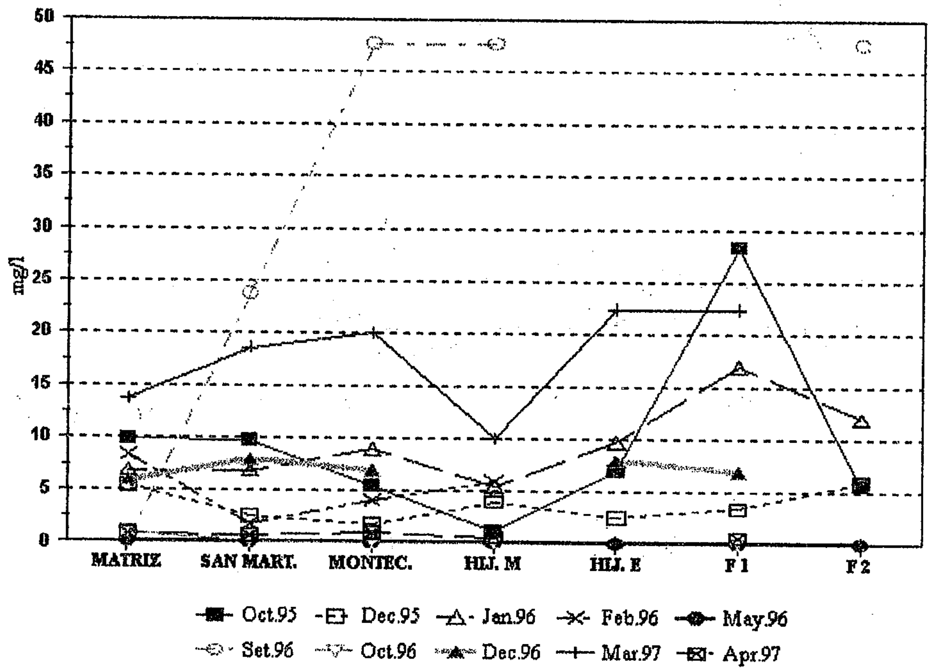


Total Nitrogen, Nitrites and Nitrates

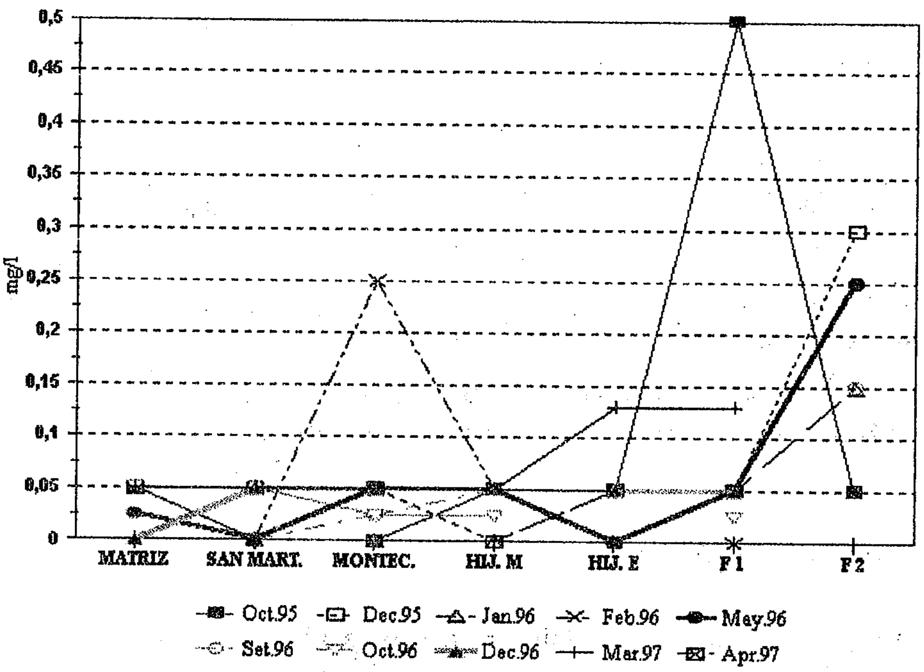
Since there are great fluctuations in the Total Nitrogen content in the samples, no conclusions can be drawn at this time. After the whole period of analysis is completed, we hope to be able to understand how Nitrogen behaves in the system.

Nitrites and nitrates values were lower than the critical values required for drinking water in Argentina: 0.1 mg/l for nitrites and 45 mg/l for nitrates (C.A.A., 1984). The presence of these elements in irrigation water is due to agricultural activities in the upper basin of the Tunuyán river and will probably benefit the crops in the lower parts of the system.

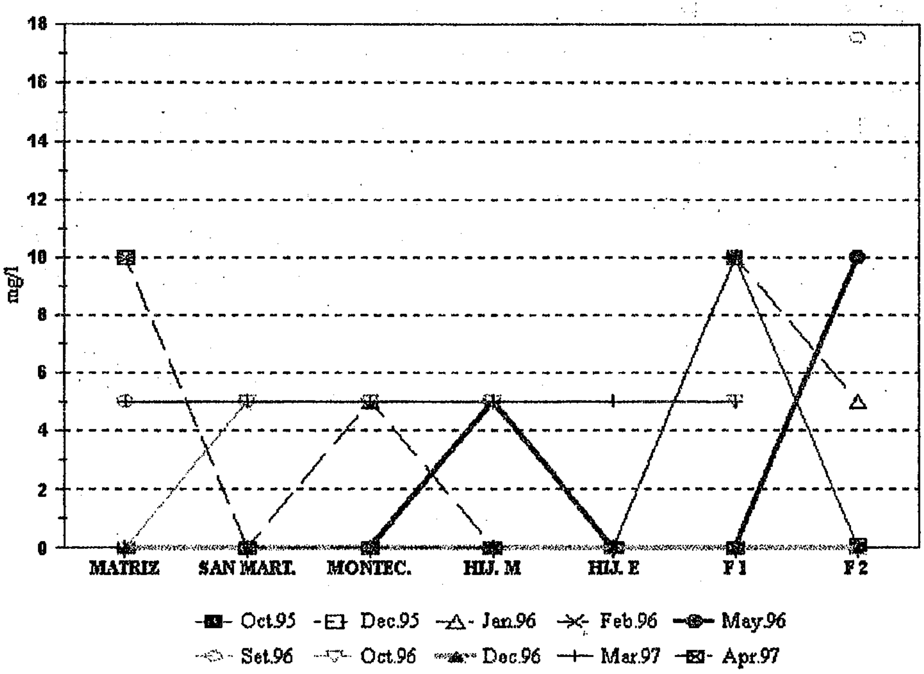
Total Nitrogen



Nitrites



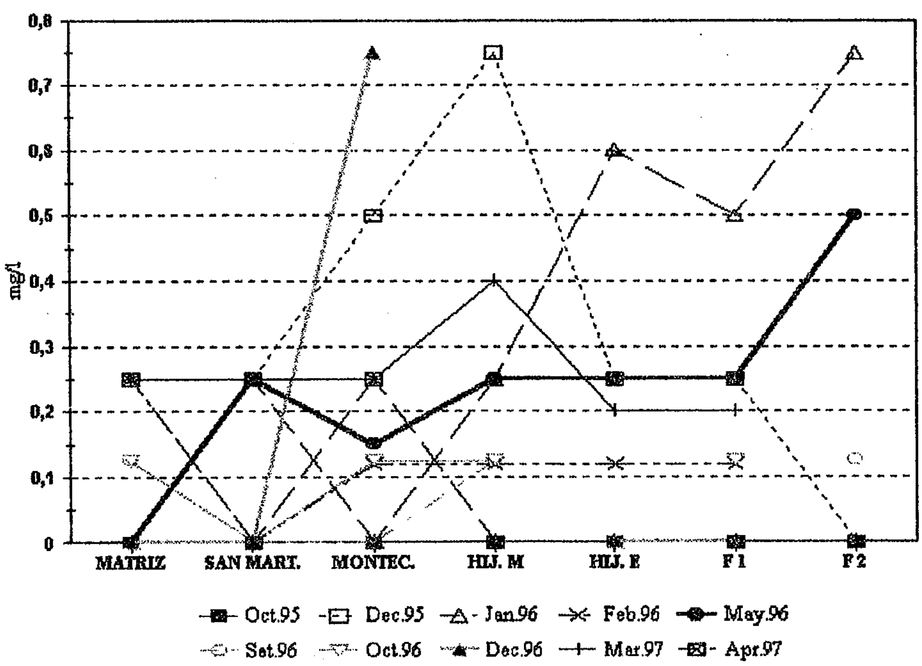
Nitrates



Phosphates

Phosphate samples also showed large fluctuations. According to the Water Resources Secretariat of Argentina, no limits are set for this parameter when water is used for irrigation, drinking purposes or direct human contact.

Phosphates

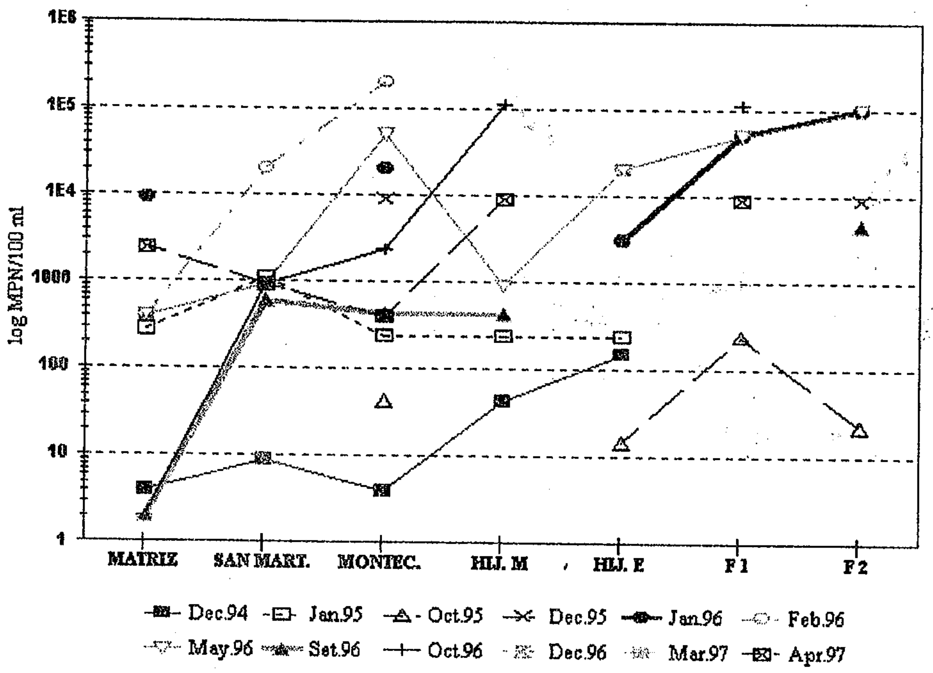


MICROBIOLOGICAL ANALYSIS

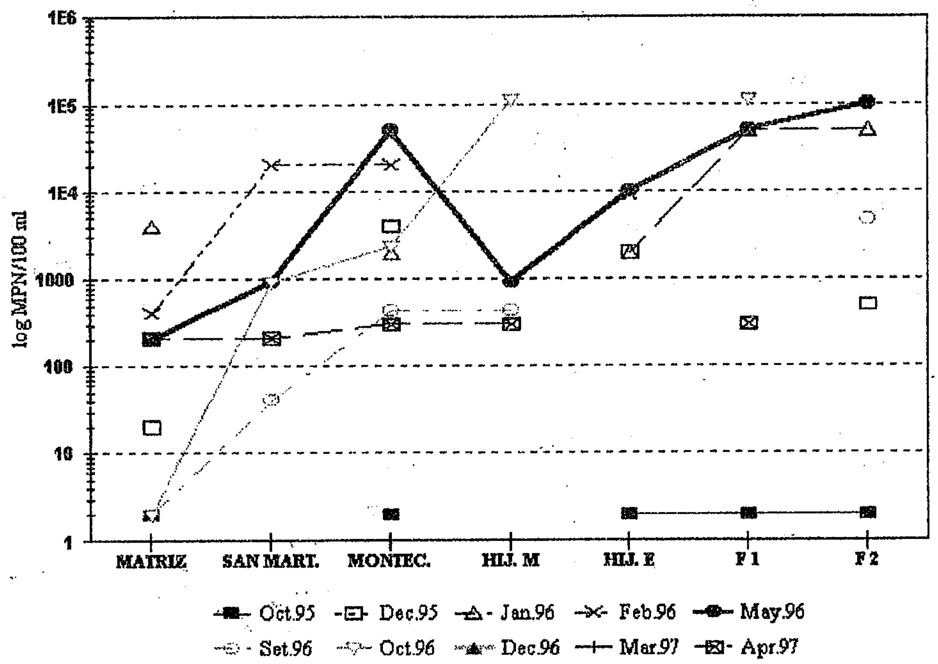
Microbiological analyses have shown large variations through time as well as in different sites along the irrigation network. However, especial attention should be paid to Total Coliform results. They were, many times, higher than the critical value of 200 (which is the limit in case of water used for human contact) and even of 500 (which is the limit for animal use). This, together with the high *Escherichia coli* inventory and the inventory of faecal coliform bacteria, shows that water is polluted by sewage efluents. The analyses also indicate that pathogenic organisms such as *Salmonella*, *Shigella*, etc., are present.

It must be pointed out that microbial pollution has already been detected in the upper reaches of the Tunuyán system. This shows that pollution starts in the upper basin, concentrates in El Carrizal dam, and then enters the lower system.

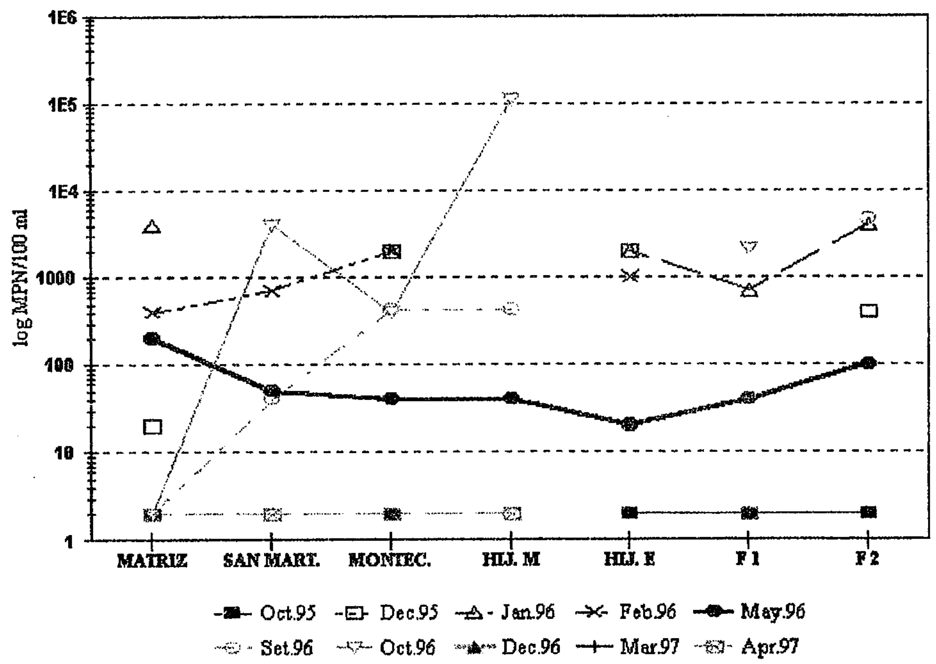
Total Coliform Bacteria



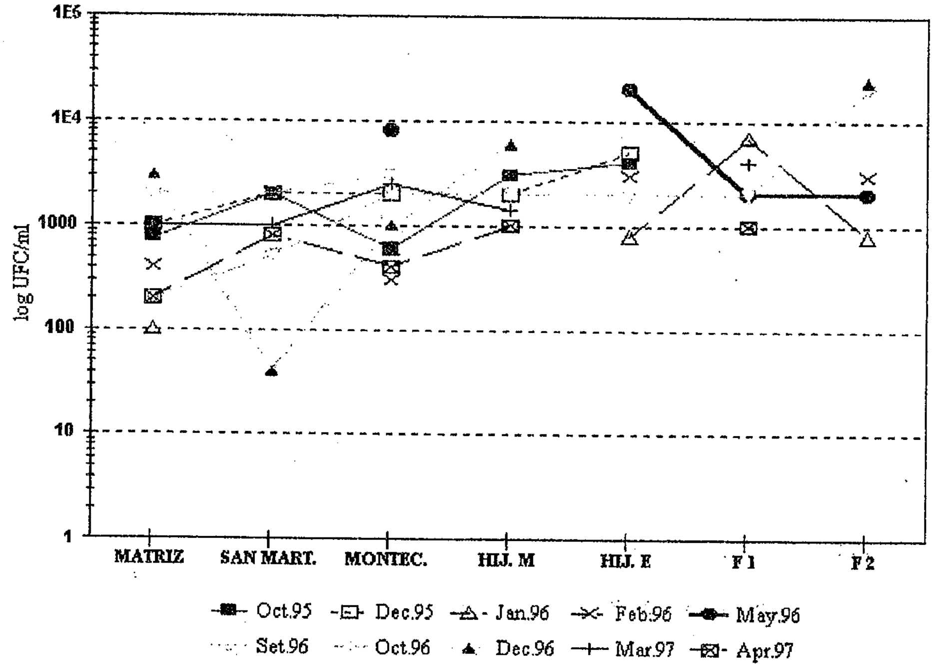
Faecal Coliform Bacteria



Escherichia coli

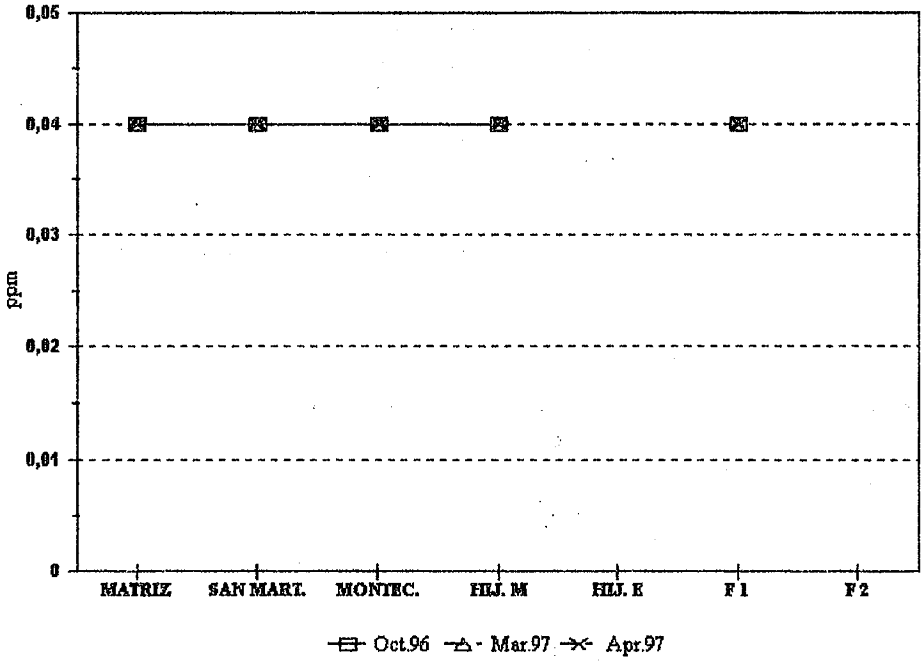


Aerobic Mesophile Bacteria

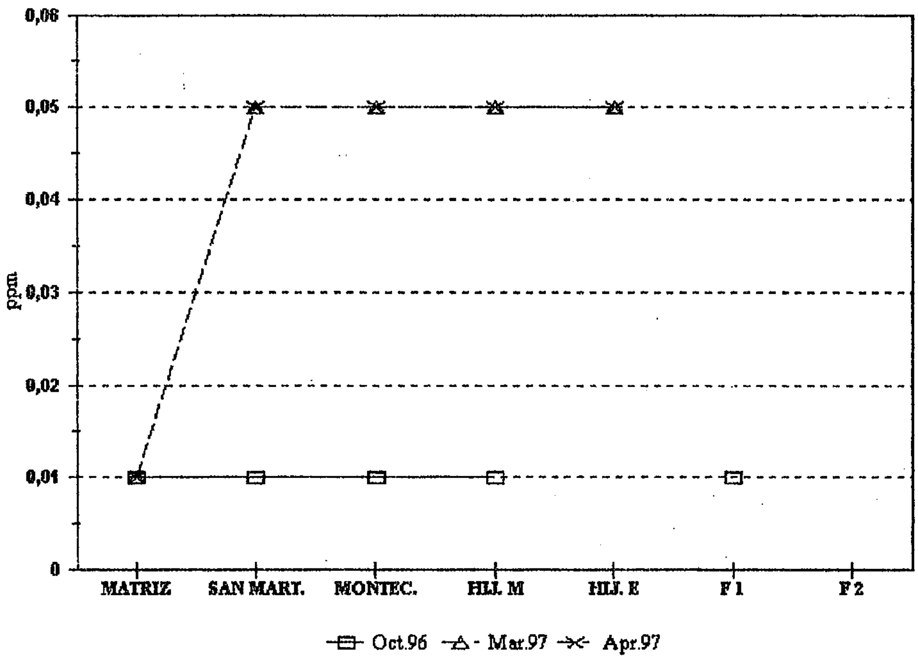


OTHER RESULTS (TRACE ELEMENTS AND HEAVY METALS)

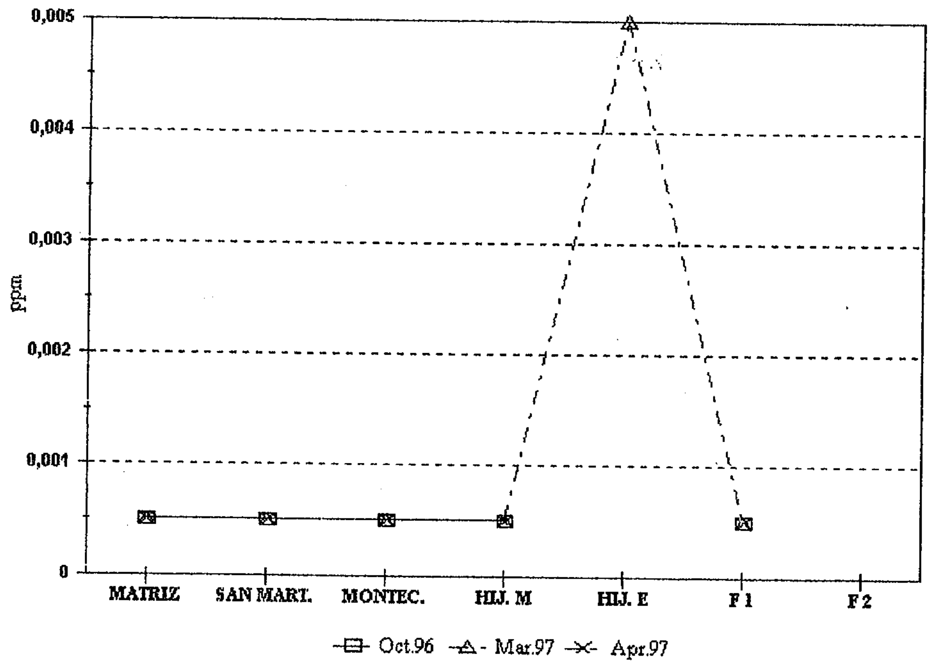
Chrome



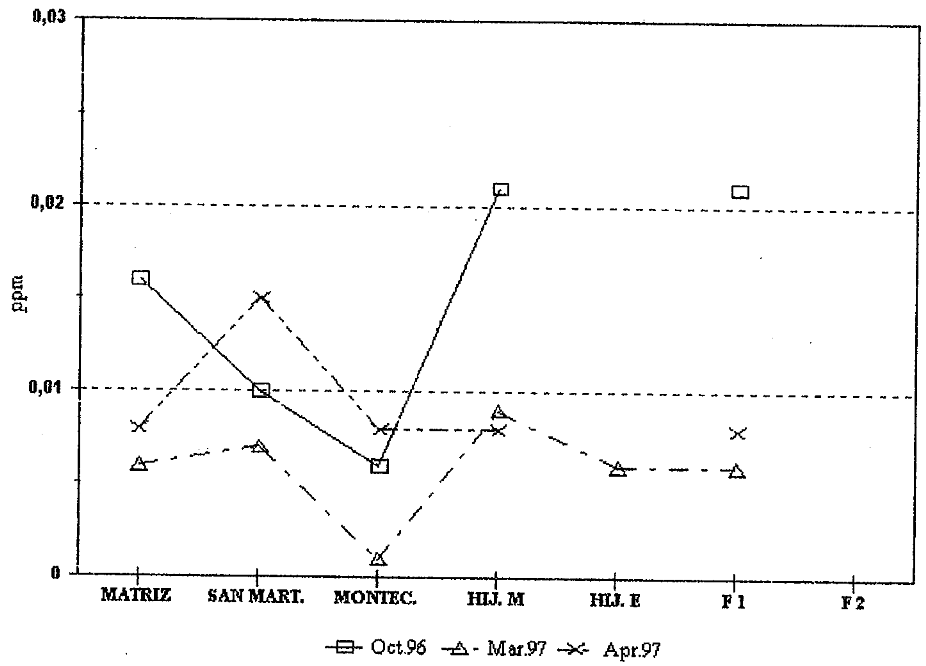
Lead



Mercury



Arsenic



WATER POLLUTION INDICATORS

As shown in previous reports, some of the selected water pollution parameters (EC, BOD_5, COD, total Nitrogen, Phosphates and CFU) were calculated in two different ways.

First, the indicators were calculated following the procedures described at the beginning of this program:

$$\frac{\textbf{New Value - Old Value}}{\textbf{Old Value}}$$

New Value: on-site
Old Value: upstream

Since the above calculation rendered unsuitable results, it was necessary to carry out a second calculation, expressed as follows:

$$\frac{\textbf{Actual Value}}{\textbf{Critical Value}}$$

Actual value: resulting from the analysis of the sample
Critical value: limiting value according to certain criteria

Calculation procedures and indicator values for some selected parameters are herein presented according to the second calculation. Tables containing the results of the original indicators are included in the attached Annexes.

1.Relative change of EC

$$\text{Relative change of EC} = \frac{\text{real EC}}{\text{critical EC}}$$

Critical EC: 0.75 dS/m

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-	-	-	-	-	-
Jan.'95	-	-	-	-	-	-	-
Oct. '95	1.63	1.63	1.65	1.67	1.68	3.57	1.68
Dec.'95	1.69	1.71	1.68	1.69	1.69	1.71	3.04
Jan.'96	1.41	1.40	1.41	1.39	1.41	1.41	2.63
Feb.'96	1.59	1.59	1.59	1.59	1.57	1.57	-
Set. '96	1.68	1.67	1.65	1.65	-	-	3.31
Oct. '96	2	2.04	2.01	2.01	-	2.36	-
Dec. '96	1.92	1.92	1.96	1.95	1.71	1.88	1.71
Mar. '97	1.25	1.36	1.35	1.36	1.35	1.36	1.36
Apr. '97	2.2	2.16	2.16	2.19	-	2.19	-

2. Relative change of BOD_5

$$\text{Relative change of } BOD_5 = \frac{\text{real } BOD_5}{\text{critical } BOD_5}$$

Critical BOD_5: 4 mg/l

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	11.3	9.6	9.6	7.9	7.9	-	-
Jan.'95	14.6	11.3	9.6	8.0	8.0	-	-
Oct. '95	18.6	21.4	36.2	41.9	30.6	41.9	41.9
Dec.'95	-	-	-	-	-	-	-
Jan.'96	-	-	-	-	-	-	-
Feb.'96	5.1	3.8	6.2	-	3.8	3.8	-
Set. '96	9.79	5.9	11.55	6.63	-	-	-
Oct. '96	1.82	2.07	1.325	2.57	-	-	-
Dec. '96	-	-	-	-	-	-	-
Mar. '97	-	-	-	-	-	-	-
Apr. '97	1.25	1.475	1.475	1.125	-	1.125	-

3.Relative change of Nitrates-N

$$\text{Relative change of Nitrate-N} = \frac{\text{Real Nitrate-N}}{\text{Critical Nitrate-N}}$$

Critical Nitrate-N: 30 mg/l

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Oct. '95	0	0	0	0	0	0.33	0
Dec.'95	0	0	0	0	0	0	0.0033
Jan.'96	0	0	0.167	0	0	0.33	0.167
Feb.'96	0	0	0	0.167	0	0	-
Set. '96	0.167	0.167	0.167	0.167	-	-	0.583
Oct. '96	0	0.167	0.167	0.167	-	0.167	-
Dec. '96	0	0	0	0	0	0	0
Mar. '97	0.11	0.11	0	0.11	0.11	0.11	0.11
Apr. '97	0.33	0	0	0	-	0	-

4.Relative change of CFU

$$\text{Relative change of CFU} = \frac{\text{real CFU}}{\text{critical CFU}}$$

Critical CFU: 100

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	7.5	20.0	6.0	30.0	40.0	-	-
Jan.'95	10.0	20.0	20.0	20.0	50.0	-	-
Oct. '95	70.0	8.0	-	8.0	6.0	0.1	-
Dec.'95	4.0	-	30.0	-	-	30.0	30.0
Jan.'96	10.0	-	80.0	-	160.0	20.0	20.0
Feb.'96	20.0	20.0	30.0	-	70.0	-	-
Set. '96	30	0.4	10	60	-	-	24
Oct. '96	10	10	25	14	-	40	-
Dec. '96	14	40	50	20	50	20	-
Mar. '97	20	70	100	100	400	400	-
Apr. '97	2	8	4	10	-	10	-

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the results yielded by the water analyses, the following conclusions and recommendations can be made:

1. As regards Temperature, pH and Dissolved Oxygen, the water in the system is suitable for life development and there seems to be a good self-purification mechanism.
2. EC values and sandy-loam soils render it possible to cultivate any kind of crop.
3. On the basis of settleable solids analyses and BOD5 and COD values, the organic matter load seems to be low. The last two parameters in samples taken during the first month of the irrigation season are high.
4. Farmers, the local population and consumers of some crops such as vegetables grown in the area are confronted with the risk of contracting diseases. This means that water can be used to irrigate vineyards, olive trees and fruit trees as long as sprinklers are not used. As for vegetables, it is recommended to use groundwater. The local population must be warned about the risk of using water from the canal for domestic or recreational uses. If faced with the need to use such water, it should be previously boiled or chlorinated.
5. For other parameters, like Total N, Nitrites, Nitrates and Phosphates, no conclusions can be drawn so far until they are further analyzed.
6. A comparison of the two above mentioned calculations shows that the second (which uses critical values) is better. This is so because, in this case, a positive value can always be calculated for the first site upstream. However, it is sometimes very difficult to define critical values as is the case of Total Nitrogen and Phosphates. These elements, which are present in irrigation water, are beneficial to crops and as such there is no limiting value for them. There are no critical values either, when water is used for human contact (swimming, bathing, etc.).
7. New critical values must be set for some parameters according to local conditions. If limiting values are lacking, it will be necessary to calculate them according to some quality criteria.
8. In order to assess irrigation water quality, EC, BOD5, COD, CFU, MPN of Faecal Coliform bacteria and pH values should be analyzed.
9. If water quality must be assessed for domestic or recreational uses, analyses of Nitrates, Nitrites, Dissolved Oxygen and *Escherichia coli* should be added to the above mentioned parameters.
10. As regards sampling and analysis frequencies, every two months seems to be a reasonable period. The collection of samples should made during the first month of each irrigation season.

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ANNEXES

WATER POLLUTION INDICATORS (first calculation)

1.Relative change of EC= $\frac{\text{New EC value - Old ECvalue}}{\text{Old EC value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-	-	-	-	-	-
Jan.'95	-	-	-	-	-	-	-
Oct. '95	-	0	0.016	0.008	0.008	1.127	-
Dec.'95	-	0.008	-0.015	0.008	0	0.008	-
Jan.'96	-	-0.009	0.009	-0.019	0.019	0	-
Feb.'96	-	0	0	0	-0.008	0	-
Set. '96	-	- 0.0079	0.008	0	-	-	-
Oct. '96	-	0.02	- 0.013	0	-	-	-
Dec. '96	-	0	0.021	0.014	- 0.123	0	-
Mar. '97	-	0.09	- 0.01	0	- 0.01	0.01	-

2.. Relative change of BOD_5 = $\frac{\text{New } BOD_5 \text{ value - Old } BOD_5 \text{ value}}{\text{Old } BOD_5 \text{ value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-0.146	0	-0.174	0	-	-
Jan.'95	-	-0.227	-0.150	-0.173	0	-	-
Oct. '95	-	0.144	0.690	0.155	-0.269	0.367	-
Dec.'95	-	-	-	-	-	-	-
Jan.'96	-	-	-	-	-	-	-
Feb.'96	-	0.621	-	-	-	0	-
Set. '96	-	0.015	0.95	-0.426	-	-	-
Oct. '96	-	0.137	-0.36	0.94	-	-	-
Dec. '96	-	-	-	-	-	-	-
Mar. '97	-	-	-	-	-	-	-

3. Relative change of COD = $\frac{\text{New COD value - Old COD value}}{\text{Old COD value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-0.200	0.063	0.057	0	-	-
Jan.'95	-	-0.227	-0.165	-0.175	0	-	-
Oct. '95	-	-0.307	1.542	0.135	-0.120	0.160	41.9
Dec.'95	-	-0.880	0.669	0	0.802	-0.667	-
Jan.'96	-	0.030	-0.399	0.331	-0.500	0	-
Feb.'96	-	-0.778	0.286	2.00	0.502	0	
Set. '96	-	0.0025	0.011	0.0025	-	-	-
Oct. '96	-	0.7	0.0095	0.027	-	-	-
Dec. '96	-	0.16	- 0.28	0.14	0	- 0.625	-
Mar. '97	- 0.3	- 0.011	- 0.01	0.23	- 0.17	- 0.17	

4. Relative change of Total N = $\frac{\text{New Total N value - Old Total N value}}{\text{Old Total N value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-	-	-	-	-	-
Jan.'95	-	-	-	-	-	-	-
Oct. '95	-	-0.01	-0.44	-0.782	4.833	3.042	-
Dec.'95	-	-0.527	-0.308	1.222	-0.350	0.308	-
Jan.'96	-	0	0.304	-0.389	0.782	0.735	-
Feb.'96	-	-0.786	1.277	0.463	-	-	-
Set. '96	-	-	0.084	0.021	-	-	-
Oct. '96	-	0	-	-	-	-	-
Dec. '96	-	0.33	- 0.12	- 0.12	0	0.14	-
Mar. '97	-	0.36	0.14	0.07	- 0.5	1.24	-

5. Relative change of Nitrate-N = $\frac{\text{New Nitrate - N value - Old Nitrate - N value}}{\text{Old Nitrate - N value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Oct. '95	-	-	-	-	-	1	-
Dec.'95	-	-	-	-	-	-	-
Jan.'96	-	-	-	-	-	1	-
Feb.'96	-	-	-	-1	-1	-	-
Set. '96	-	-	-	0	-	-	-
Oct. '96	-	-1	-	0	-	-	-
Dec. '96	-	0	0	0	0	0	-
Mar. '97	0	- 1	0	0	0	0	-

6. Relative change of Phosphates = $\frac{\text{New Phosphates N value - Old Phosphates value}}{\text{Old Phosphates value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-	-	-	-	-	-
Jan.'95	-	-	-	-	-	-	-
Oct. '95	-	0	0	0	0	0	-
Dec.'95	-	0	1	0.5	-0.66	0	-
Jan.'96	-	0	-1	0	1.40	-0.167	-
Feb.'96	-	-1	0	0	0	0	-
Set. '96	-	0	0	-	-	-	-
Oct. '96	-	0	0	0	-	-	-
Dec. '96	0	-	-	- 1	0	0	-
Mar. '97	0	0	0	0.6	- 0.5	- 0.5	-

7. Relative change of CFU = $\frac{\text{New CFU value - Old CFU value}}{\text{Old CFU value}}$

Indicators:

	Matriz	San Martín	Montec.	Hijuela M	Hijuela E	Farm 1	Farm 2
Dec.'94	-	-	-	-	-	-	-
Jan.'95	-	-	-	-	-	-	-
Oct. '95	-	-0.866	-	-	-0.25	-0.833	-
Dec.'95	-	-	-	-	-	-	-
Jan.'96	-	-	-	-	-	-0.875	-
Feb.'96	-	0	-0.5	-	-	-	-
Set. '96	-	-0.99	24	5	-	-	-
Oct. '96	-	0	1.5	-0.44	-	-	-

RESULTS OF WATER ANALYSES

December 1994

	MATRIZ.	SAN MARTÍN.	MONTEC.	HIJUELA	HIJUELA E
temp. (oC)	24	24,5	25	25	25
pH	6,5	6,5	6,7	6,7	6,5
S.S.10' (mg/l)	0,01	0,01	>>0.01	0,01	0,01
S.S.2 hs (mg/l)	0,01	0,01	>>0.01	0,01	0,01
Tot. Sol. (%)	0,05	0,07	0,04	0,04	0,05
Fixed Sol. (%)	0,01	0,02	0,01	0,01	0,01
Vol. Sol. (%)	0,04	0,05	0,03	0,03	0,04
Diss.Oxy.	7,8	6,8	7,8	8,2	8
COD (mg/l)	79,4	63,5	67,5	71,4	71,4
BOD 5 (mg/l)	45,1	38,5	38,5	31,8	31,8
MPN/100 ml	>3	9	>3	43	150
UFC/ml	750	2000	600	3000	4000

January 1995

	MATRIZ	SAN	MONTEC.	HIJUELA	HIJUELA E
temp. (oC)	23	22	21	22	21
pH	6,5	6,3	6	6,3	6,3
S.S.10' (mg/l)	0,01	>>0,01	0,01	0,01	0,01
S.S.2 hs (mg/l)	0,01	>>0,01	0:01	0,01	0,01
Tot. Sol. (%)	0,75	0,17	0,07	0,03	0,04
Fixed Sol. (%)	0,66	0,05	0,02	0,01	0,01
Vol. Sol. (%)	0,09	0,12	0,05	0,02	0,03
Diss.Oxy.	7	7,6	7,8	8,2	8
COD (mg/l)	103,6	80,1	66,9	55,15	55,15
BOD 5 (mg/l)	58,6	45,3	38,6	31,9	31,9
MPN/100 ml	280	1100	240	240	240
UFC/ml	1000	2000	2000	2000	5000

October 1995

	MATRIZ	SAN	MONTEC	HIJUELA	HIJUELA	F 1	F 2
temp. (oC)	18	17,5	17	16	16	18	17
pH	6,6	6,6	6,6	6,8	6,5	6,7	6,7
S.S.10' (mg/l)	<<0.01	<<0.01	<<0.01	<0.01	0,1	0,1	<<0.01
S.S.2 hs (mg/l)	<<0.01	<<0.01	<<0.01	<0.01	0,1	0,1	<<0.01
Tot. Sol. (%)	0,11	0,1	0,06	0,08	0,09	0,22	0,05
Fixed Sol. (%)	0,11	0,1	0,06	0,08	0,08	0,21	0,05
Vol. Sol. (%)	0	0	0	0	0,01	0,01	0
Diss.Oxy. (mg/l)	7,8	7,6	7,7	7,6	7,6	6,2	7,6
COD (mg/l)	190,9	132,3	336,3	381,7	336,3	390,8	363,5
BOD 5 (mg/l)	74,5	85,75	145	167,5	122,5	167,5	167,5
MPN/100 ml	<3	n.d.	43	n.d.	15	240	23
UFC/ml	100	n.d.	600	n.d.	800	7000	800
Fae.colif. (MPN/100	<3	n.d.	<3	n.d.	<3	<3	<3
E.coli (MPN/100 ml)	<3	n.d.	<3	n.d.	<3	<3	<3
NO2- (mg/l0	0,05	0	0	0,05	0,05	0,5	0,05
NO3- (mg/l)	0	0	0	0	0	10	0
PO4 3- (mg/l)	0	0	0	0	0	0	0
E.C. (dS/m)	1,22	1,22	1,24	1,25	1,26	2,68	1,26
Total N (mg/l)	98,56	98,56	54,88	10,84	69,44	98,56	54,88
Color	c.less	c.less (lake)	c.less	c.less	c.less	c.less	c.less
Odor	o.less	o.less	o.less	o.less	o.less	o.less	o.less
Turbidity	0/+	0/+	0/+	0/+	0/+	0/+	0/+

December 1995

	MATRIZ	SAN	MONTEC	HIJUELA	HIJUELA	F 1	F 2
temp. (oC)	21,5	21	21	21,5	21,5	24	21,5
pH	7,9	7,9	7,9	7,9	8,1	7,6	8,1
S.S.10' (mg/l)	<<0.1	<<0.1	<<0.1	0,1	0,1	0,1	<<0.1
S.S.2 hs (mg/l)	0	0	0	0	0	0	0
Tot. Sol. (%)	0,07	0,11	0,08	0,11	0,1	0,15	0,08
Fixed Sol. (%)	0,05	0,1	0,07	0,1	0,09	0,07	0,15
Vol. Sol. (%)	0,02	0,01	0,01	0,01	0,01	0,01	0
Diss.Oxy. (mg/l)	8,4	8,9	8,6	8,6	9,1	8	8,4
COD (mg/l)	113,6	13,6	22,7	22,7	40,9	13,6	22,7
BOD 5 (mg/l)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MPN/100 ml	400	n.d.	9000	n.d.	20000	n.d.	9000
UFC/ml	400	n.d.	300	n.d.	3000	n.d.	3000
Fae.colif. (MPN/100	20	n.d.	4000	n.d.	2000	n.d.	500
E.coli (MPN/100 ml)	20	n.d.	2000	n.d.	2000	n.d.	400
NO2- (mg/l0	0,05	0,05	0,05	0	0,05	0,05	0,3
NO3- (mg/l)	0	0	0	0	0	0	0,1
PO4 3- (mg/l)	0,25	0,25	0,5	0,75	0,25	0,25	0
E.C. (dS/m)	1,4	1,4	1,4	1,4	1,4	1,4	2,2
Total N (mg/l)	5,5	2,6	1,8	4	2,6	3,4	6
Color	c.less	c.less	c.less	c.less	c.less	c.less	c.less
Odor	o.less	o.less	o.less	o.less	o.less	o.less	o.less
Turb.	0	0	0	0	0	0	0

January 1996

	MATRIZ	SAN	MONTEC	HIJUELA	HIJUELA	F 1	F 2
temp. (oC)	24	23	22	22	22	21	23
pH	8,1	8	8	8	7,9	8	7,9
S.S.10' (mg/l)	0,07	0,05	0,1	0,1	0,1	<0,1	<0,1
S.S.2 hs (mg/l)	0	0,05	0,02	0	0,05	0	0
Tot. Sol. (%)	0,07	0,08	0,08	0,06	0,11	0,12	0,17
Fixed Sol. (%)	0,06	0,05	0,07	0,04	0,08	0,08	0,15
Vol. Sol. (%)	0,01	0,03	0,01	0,02	0,03	0,04	0,02
Diss.Oxy. (mg/l)	6,1	7,9	7,4	7,3	6,8	7,1	6,3
COD (mg/l)	36,7	40,8	24,5	32,6	16,3	16,3	20,4
BOD 5 (mg/l)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MPN/100 ml	9000	n.d.	20000	n.d.	3000	50000	100000
UFC/ml	1000	n.d.	8000	n.d.	20000	2000	2000
Fae.colif. (MPN/100	4000	n.d.	2000	n.d.	2000	50000	50000
E.coli (MPN/100 ml)	4000	n.d.	2000	n.d.	2000	700	4000
NO2- (mg/l0	0	0	0	0	0,05	0,05	0,15
NO3- (mg/l)	0	0	5	0	0	10	5
PO4 3- (mg/l)	0,25	0,25	0	0,25	0,6	0,5	0,75
E.C. (dS/m)	1	1	1	1	1	1	2
Total N (mg/l)	6,9	6,9	9	5,5	9,8	17	12
Color	c.less	c.less	c.less	c.less	c.less	c.less	c.less
Odor	o.less	o.less	o.less	o.less	o.less	o.less	o.less
Turbidity	0	0/+	0/+	0/+	0/+	0/+	0

February 1996

	MATRIZ	SAN	MONTEC	HIJUELA	HIJUELA	F 1	F 2
temp. (oC)	22,5	21,5	21,5	21,5	21,5	21,5	n.d.
pH	8	7,8	7,9	7,9	7,9	7,9	n.d.
S.S.10' (mg/l)	<<0.1	0,2	0,1	<0,1	0,2	0,2	n.d.
S.S.2 hs (mg/l)	0	0	0	0	0	0	n.d.
Tot. Sol. (%)	0,15	0,15	0,1	n.d.	0,15	0,15	n.d.
Fixed Sol. (%)	0,12	0,13	0,08	0,06	0,09	0,29	n.d.
Vol. Sol. (%)	0,03	0,02	0,02	0,03	0,06	0,06	n.d.
Diss.Oxy. (mg/l)	7,9	8,1	7,7	8	7,5	7,5	n.d.
COD (mg/l)	28,4	6,3	8,1	24,3	36,5	36,5	n.d.
BOD 5 (mg/l)	20,3	15,3	24,8	n.d.	15,3	15,3	n.d.
MPN/100 ml	400	20000	200000	n.d.	20000	n.d.	n.d.
UFC/ml	2000	2000	3000	n.d.	7000	n.d.	n.d.
Fae.colif. (MPN/100	400	20000	20000	n.d.	9000	n.d.	n.d.
E.coli (MPN/100 ml)	400	700	2000	n.d.	1000	n.d.	n.d.
NO2- (mg/l)	0,05	0	0,25	0,05	0	0	n.d.
NO3- (mg/l)	0	0	0	5	0	0	n.d.
PO4 3- (mg/l)	0,25	0	0,12	0,12	0,12	0,12	n.d.
E.C. (dS/m)	1,2	1,2	1,2	1,2	1,2	n.d.	n.d.
Total N (mg/l)	8,4	1,8	4,1	6	n.d.	n.d.	n.d.
Color	c.less	c.less	c.less	c.less	c.less	c.less	n.d.
Odor	fish	o.less	vague	soil	o.less	o.less	n.d.
Turbidity	0	0	0	0	0	0	n.d.

May 1996

	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	18	18	18	18	18	18	19
pH	8,2	8,2	8,2	8,2	8,2	8,1	7,6
S.S.10' (mg/l)	<<0,05	<<0,05	<<0,05	0,05	<<0,03	0,05	0,2
S.S.2 hs (mg/l)	0	0	0	0,05	0	0	0
Tot. Sol. (%)	0,07	0,1	0,09	0,09	0,05	0,11	0,8
Fixed Sol. (%)	n.d.	n.d.	0,02	0,02	n.d.	0,01	0,02
Vol. Sol. (%)	n.d.	0,07	n.d.	0,07	n.d.	0,1	0,08
Diss.Oxy. (mg/l)	8,8	8,6	8,9	8,7	8,2	8,8	6,4
COD (mg/l)	52,7	44,6	101,3	97,3	20,3	20,3	89,2
BOD 5 (mg/l)	3,1	4,1	1	3,1	6,1	3,1	5,1
MPN/100 ml	400	900	50000	900	20000	5000	100000
UFC/ml	200	500	2000	2000	2000	2000	20000
Fae.colif. (MPN/100	200	900	50000	900	10000	5000	100000
E.coli (MPN/100 ml)	200	50	40	40	20	40	100
NO2- (mg/l0	0,025	0	0,05	0,05	0	0,05	0,25
NO3- (mg/l)	0	0	0	5	0	0	10
PO4 3- (mg/l)	0	0,25	0,15	0,25	0,25	0,25	0,5
E.C. (dS/m)	1,3	1,2	1,2	1,3	1,2	1,3	2,5
Total N (mg/l)	0	0	0	0	0	0	0
Color	c.less(alga	c.less(lake)	c.less	c.less	c.less	c.less	c.less
Odor	o.less	o.less	o.less	o.less	o.less	o.less	o.less
Turbidity.	0/+	0/+	0/+	0/+	0/+	0/+	0/+

September 1996

	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	12	15	14.5	15	n.d.	n.d.	12
pH	8.0	7.7	8,1	8,15	n.d.	n.d.	7,0
S.S.10' (mg/l)	<<0.1	<<0.01	<<0.1	<0.1	n.d.	n.d.	0,8
S.S.2 hs (mg/l)	<<0.1	<<0.1	<<0.1	0.1	n.d.	n.d.	1.1
Tot. Sol. (%)	0,12	0.62	0.12	0.13	n.d.	n.d.	0.23
Fixed Sol. (%)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Vol. Sol. (%)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Diss.Oxy. (mg/l)	10.6	10.4	10.52	10.3	n.d.	n.d.	6.07
COD (mg/l)	235	141.8	231	133.7	n.d.	n.d.	52.7
BOD 5 (mg/l)	39.17	23.67	46.20	26.53	n.d.	n.d.	13.2
MPN/100 ml	<3	600	430	430	n.d.	n.d.	4600
UFC/ml	3000	40	1000	6000	n.d.	n.d.	24000
Fae.colif. (MPN/100	<3	40	430	430	n.d.	n.d.	110000
E.coli (MPN/100 ml)	n.d.	40	430	430	n.d.	n.d.	4600
NO2- (mg/l0	0-0.05	0	0-0.05	0.05	n.d.	n.d.	0.15
NO3- (mg/l)	0-10	0-10	0-10	0-10	n.d.	n.d.	10-25
PO4 3- (mg/l)	0-0.25	0	0	0-0.25	n.d.	n.d.	0-0.25
E.C. (dS/m)	1.26	1.25	1.24	1.24	n.d.	n.d.	1.77
Total N (mg/l)	0	23.8	47.6	47.6	n.d.	n.d.	47.6
Color	c.less	c.less	c.less	c.less	n.d.	n.d.	dark-
Odor	o.less	o.less	o.less	o.less	n.d.	n.d.	fish
Turbidity.	0	0	0	+	n.d.	n.d.	++++

October 1996

	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	15	15	18	18	n.d.	n.d.	18
pH	8.4	8.2	8,2	8,25	n.d.	n.d.	8.2
S.S.10' (mg/l)	<<0.05	<0.1	<<0.05	<0.05	n.d.	n.d.	0.1
S.S.2 hs (mg/l)	0	0	0	0	n.d.	n.d.	0
Tot. Sol. (%)	0.08	0.11	0.12	0.11	n.d.	n.d.	0.14
Fixed Sol. (%)	0.03	0.02	0.03	0.02	n.d.	n.d.	0.04
Vol. Sol. (%)	0.05	0.09	0.09	0.09	n.d.	n.d.	0.1
Diss.Oxy. (mg/l)	10.7	8.4	10.2	9.2	n.d.	n.d.	9.2
COD (mg/l)	40	68	12	52	n.d.	n.d.	32
BOD 5 (mg/l)	7.3	8.3	10.3	10.3	n.d.	n.d.	8.3
MPN/100 ml	<3	900	2300	110000	n.d.	n.d.	110000
UFC/ml	1000	1000	2500	1400	n.d.	n.d.	4000
Fae.colif. (MPN/100	<3	900	2300	110000	n.d.	n.d.	110000
E.coli (MPN/100 ml)	<3	4000	400	110000	n.d.	n.d.	2100
NO2- (mg/l0	0.05	0.05	0.05	0-0.05	n.d.	n.d.	0-0.05
NO3- (mg/l)	0	0-10	0	0-10	n.d.	n.d.	0-10
PO4 3- (mg/l)	0-0.25	0	0	0-0.25	n.d.	n.d.	0-0.25
E.C. (dS/m)	1.50	1.53	1.47	1.51	n.d.	n.d.	1.77
Total N (mg/l)	0.95	0	0.95	0	n.d.	n.d.	0
Color	c.less	c.less	c.less	c.less	n.d.	n.d.	dark-
Odor	o.less	fish	fish	gamexane	n.d.	n.d.	dirty
Turbidity.	0	0	0	0	n.d.	n.d.	0/+
Chrome (ppm)	<0.05	<0.05	<0.05	<0.05	n.d.	<0.05	n.d.
Lead (ppm)	<0.02	<0.02	<0.02	<0.02	n.d.	<0.02	n.d.
Mercury (ppm)	<0.001	<0.001	<0.001	<0.001	n.d.	<0.00	n.d.
Arsenic (ppm0	0.016	0.01	0.006	0.021	n.d.	0.021	n.d.

December 1996

	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	21	21	21.5	n.d.	n.d.	n.d.	21.6
pH	8.05	8.11	8,2	n.d.	n.d.	n.d.	8.21
S.S.10' (mg/l)	<0.1	<0.1	0.20	n.d.	0.20	n.d.	0.1
S.S.2 hs (mg/l)	<0.1	<0.2	0.20	n.d.	0.20	n.d.	0.1
Tot. Sol. (%)	0.16	0.13	0.12	n.d.	0.12	n.d.	0.12
Fixed Sol. (%)	0.14	0.11	0.02	n.d.	0.08	n.d.	0.03
Vol. Sol. (%)	0.02	0.02	0.1	n.d.	0.04	n.d.	0.09
Diss. Oxy. (mg/l)	7.56	7.56	7.86	n.d.	8.06	n.d.	7.86
COD (mg/l)	24.19	28.22	32.26	n.d.	12.09	n.d.	32.26
BOD 5 (mg/l)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MPN/100 ml	280	7000	280	11000	28000	11000	n.d.
UFC/ml	1400	4000	5000	2000	5000	5000	n.d.
Fae.colif. (MPN/100	< 3	700	280	2800	2800	2800	n.d.
E.coli (MPN/100 ml)	< 3	280	40	280	280	280	n.d.
NO2- (mg/l0	0	0.05	0.05	n.d.	0.05	n.d.	0.05
NO3- (mg/l)	0	0	0	n.d.	0	n.d.	0
PO4 3- (mg/l)	0	0	0.75	n.d.	0	n.d.	0
E.C. (dS/m)	1.44	1.44	1.46	n.d.	1.41	n.d.	1.28
Total N (mg/l)	6.0	8.0	7.0	n.d.	8.0	n.d.	7.0
Color	c.less	c.less	c.less	n.d.	c.less	n.d.	c.less
Odor	soil	soil/lake	lake	n.d.	rotten	n.d.	lake
Turbidity.	0	0	0	n.d.	0	n.d.	0

March 1997

	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	23	22.5	225	22	22	22	n.d.
pH	8.07	8.06	8.05	8.07	8.10	8.10	n.d.
S.S.10' (mg/l)	0.1	0.1	0.2	0.2	0.2	0.1	n.d.
S.S.2 hs (mg/i)	0	0	0.05	0.1	0.1	0.1	n.d.
Tot. Sol. (%)	0.14	0.17	0.13	0.13	0.03	0.03	n.d.
Fixed Sol. (%)	0.09	0.11	0.08	0.1	0.02	0.02	n.d.
Vol. Sol. (%)	0.05	0.06	0.05	0.07	0.01	0.01	n.d.
Diss. Oxy. (mg/l)	10.5	10.1	9.9	9.5	9.5	9.5	n.d.
COD (mg/l)	524	367	331	407	339	339	n.d.
BOD 5 (mg/l)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MPN/100 ml	400	11000	280	10000	4600	4600	n.d.
UFC/ml	2000	7000	10000	10000	40000	40000	n.d.
Fae.colif. (MPN/100	70	280	110	4600	280	280	n.d.
E.coli (MPN/100 ml)	< 3	< 3	< 3	< 3	< 3	< 3	n.d.
NO2- (mg/l0	0.05	0.05	0.05	0.05	0.13	0.13	n.d.
NO3- (mg/l)	5	5	5	5	5	5	n.d.
PO4 3- (mg/l)	0.25	0.25	0.25	0.40	0.20	0.2	n.d.
E.C. (dS/m)	0.936	1.02	1.02	1.01	1.02	1.02	n.d.
Total N (mg/l)	13.7	18.6	20	10	22.4	22.4	n.d.
Chrome (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	n.d.
Lead (ppm)	<0.01	<0.1	<.01	<0.1	<0.1	<0.1	n.d.
Mercury (ppm)	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	n.d.
Arsenic (ppm0	0.006	0.007	0.001	0.009	0.006	0.006	n.d.

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	MATRIZ	SAN	MONTEC	HIJUELA.	HIJUELA	F 1	F 2
temp. (oC)	21	22	21	21	n.d.	21	n.d.
pH	7.99	7.90	7.89	7.84	n.d.	7.84	n.d.
S.S.10' (mg/l)	0.5	0.1	0.1	0.1	n.d.	0.1	n.d.
S.S.2 hs (mg/l)	0.5	0.1	0.1	0.1	n.d.	0.1	n.d.
Tot. Sol. (%)	0.28	0.09	0.14	0.02	n.d.	0.02	n.d.
Fixed Sol. (%)	0.22	n.d.	0.11	n.d.	n.d.	n.d.	n.d.
Vol. Sol. (%)	0.06	n.d.	0.03	n.d.	n.d.	n.d.	n.d.
Diss. Oxy. (mg/l)	8.5	8.8	9.2	8.1	n.d.	8.1	n.d.
COD (mg/l)	42.9	43.3	40.8	43.5	n.d.	43.5	n.d.
BOD 5 (mg/l)	5.0	5.9	5.9	4.5	n.d.	4.5	n.d.
MPN/100 ml	2400	930	400	9000	n.d.	9000	n.d.
UFC/ml	200	800	400	1000	n.d.	1000	n.d.
Fae.colif. (MPN/100	210	210	300	300	n.d.	300	n.d.
E.coli (MPN/100 ml)	< 3	< 3	< 3	< 3	n.d.	< 3	n.d.
NO2- (mg/l0	0.05	0.00	0.00	0.05	n.d.	0.05	n.d.
NO3- (mg/l)	10.0	0.00	0.00	0.00	n.d.	0.00	n.d.
PO4 3- (mg/l)	0.25	0.00	0.25	0.00	n.d.	0.00	n.d.
E.C. (dS/m)	1.65	1.62	1.62	1.64	n.d.	1.64	n.d.
Total N (mg/l)	0.8	0.7	1.0	0.6	n.d.	0.6	n.d.
Chrome (ppm)	<0.05	<0.05	<0.05	<0.05	n.d.	<0.05	n.d.
Lead (ppm)	<0.1	<0.1	<.01	<0.1	n.d.	<0.1	n.d.
Mercury (ppm)	<0.001	<0.001	<0.001	<0.001	n.d.	<0.001	n.d.
Arsenic (ppm)	0.008	0.015	0.008	0.008	n.d.	0.008	n.d.

References:

n.d.=	no data
o.less=	odorless
c.less=	colorless