



# CHEMICAL COMPOSITION AND WATER QUALITY OF THE CASTAÑO RIVER, CALINGASTA, SAN JUAN PROVINCE, ARGENTINA

COMPOSICIÓN QUÍMICA Y CALIDAD DEL AGUA DEL RÍO CASTAÑO.  
CALINGASTA, SAN JUAN, ARGENTINA

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## ABSTRACT

The province of San Juan, in arid central-west Argentina, is irrigated by two fluvial systems: the Jachal and San Juan River basins. The Castaño River is one of the two main tributaries to the latter. It crosses the Castaño Viejo mining district, which was a producer of lead, zinc and copper.

To investigate the water quality and the possible hydrochemical variations given rise by the mining activity, a sampling net was devised along the river course for determining concentrations of calcium, magnesium, sodium, carbonates, bicarbonates, sulphates, cadmium, copper, chrome, lead, zinc, aluminium, pH, dissolved solids and electric conductivity.

The results obtained indicate that some chemical parameter of the river water vary in the different seasons of the year.

The salinity, dissolved oxygen and biochemical demand of oxygen were found to be low, no toxic substances were detected in significant amounts, and the water quality has not been affected by the mining activity.

**Key words:** Water Quality. Heavy elements. Centre West Argentina.

## RESUMEN

*La provincia de San Juan, ubicada en el sector árido del centro-oeste de la República Argentina, es irrigada por dos sistemas fluviales importantes como son, los ríos Jáchal y San Juan. El río Castaño, objeto de este estudio, es uno de los principales tributarios del río San Juan*

*que atraviesa el área minera de Castaño Viejo conocida desde 1863, pero explotada intensamente en el período 1956-1964. En el presente trabajo, se definen algunas características hidroquímicas de este sistema hidrográfico, vinculadas a las actividades mineras enunciadas. El desarrollo del trabajo consistió en un muestreo sistemático del agua del río Castaño para conocer particularmente los niveles de concentración de metales pesados, como cadmio, cinc, cobre, cromo, plomo y aluminio, y determinar su incidencia en la composición y calidad del agua. También se determinaron en laboratorio y campo parámetros tales como: pH, conductividad eléctrica y sólidos disueltos en el agua.*

*Los resultados obtenidos indican que algunos parámetros químicos del agua de río, están vinculados a las variaciones de caudales provocadas por las diferentes estaciones del año y por el régimen de alimentación nival del río Castaño.*

*El agua de este sistema hidrográfico no presenta sustancias tóxicas en niveles de contaminación y algunos de los tenores más altos de elementos pesados estarían relacionados con las áreas de afloramientos mineralizados por donde drena el río. Se concluye entonces, que la calidad de este recurso hídrico andino no ha sido afectada por la explotación minera realizada.*

**Palabras claves:** *Calidad del agua, Elementos pesados, centro oeste Argentina.*

## INTRODUCTION

The province of San Juan is situated in the central-western part of the Argentina Republic. It extends from 28°30' to 32°30'S and from 66°30' to 70°30' W. It covers 93,650 km<sup>2</sup> in one of the most arid regions in the country: therefore a rational use of surface and ground water is a paramount importance for the life and development of the province.

The province of San Juan, however, is irrigated by two main fluvial systems, namely the Jachal and San Juan river basins. The latter river takes its name at the junction of the Los Patos and Castaño rivers. Both have their catchment basins in the Andean Cordillera and flow into the Calingasta valley.

This valley, situated at about 120 km west of the capital of the province, is a N-S trending tectonic depression between the Frontal Cordillera, to the west, and the western Precordillera ranges to the east. The Los Patos river, one of the two main streams in the valley, runs from S to N, whilst the other important river, Castaño, runs from NW to SE. As previously said, both rivers, at their junction (the locality called Las Juntas), form the San Juan river (Figure 1). Its importance derives from the fact that this fluvial system supports the life and development of the Tulum valley, with 450,000 inhabitants.

According to Rodriguez (1985) the ground water basin beneath the Calingasta valley is recharged and discharged periodically by the Los Patos and Castaño rivers. Bearing in mind the nival regimen of both, the recharge period coincides with the maximum river discharges, that is, from october to march.

The Castaño river, which is the one studied here, runs across the mining district of Castaño Viejo, which has been known since 1863, and was intensively exploited from 1956 to 1964 (Angelelli, 1937; 1984). The ores developed occur in veins, as sulfides: blende, galena, pyrite, chalcocite, covelline ant tetrahedrite,

embedded in a carbonate and quartz gangue. The host rock is andesitic, locally altered with formation of pyrite and silica (Cardó, 1999). During the exploitation period, concentrates of lead, zinc and copper were obtained by flotation (Gramage, 1983). This author indicates, that during this period, the production

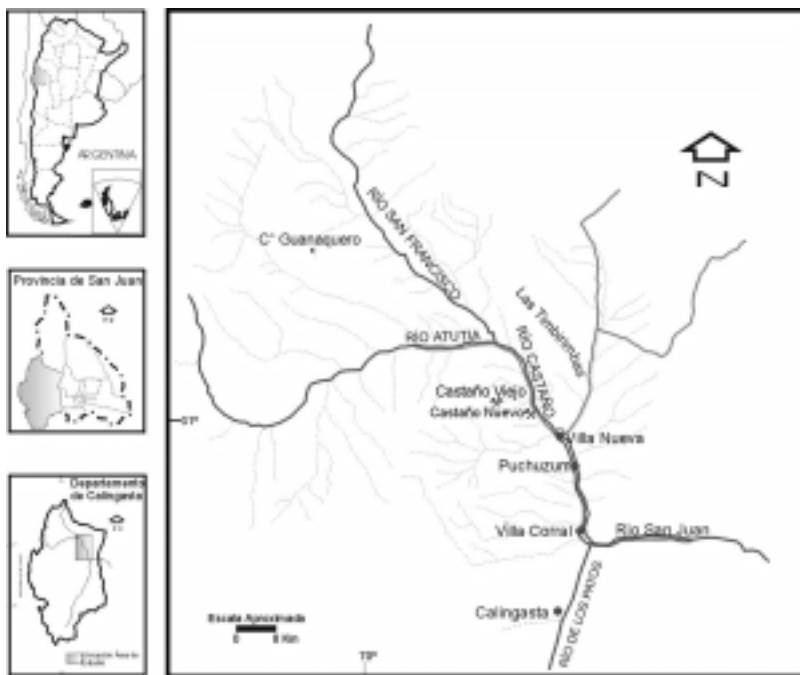


Figure 1. Situation of the area under study  
 Figura 1. Ubicación del área de estudio

obtained amounted to: lead concentrates, 46,640 tonnes with 73 to 78% of lead; zinc concentrates, 75.588 tonnes with 50 to 60% of zinc and copper concentrates, 8,000 tonnes with 14 to 21% of copper.

Bearing in mind these mining operations, the present study was approached as a systematic sampling of the water of the Castaño river, in order to

determine its most important hydrochemical features, particular consideration was given to the concentrations of heavy metals, such as cadmium, zinc, copper, chrome, lead and aluminium, with the purpose of determining the probable incidence of the mining activity on the water composition and quality. Other determinations were pH, electric conductivity and dissolved solids.

The Castaño river water is used at present for human consumption, and irrigation in the localities of Villa Nueva, Villa Corral and Puchuzum.

## **MATERIAL AND METHOD**

The available hydrological information of the area studied was compiled, especially data on the discharges and composition of surface and ground water (Rose *et al.*, 1987; Rodriguez, 1985; Rodriguez Fernández *et al.*, 1998, Arroqui *et al.*, 1999, Carrascosa, 2002; Córdoba, 2001; Rago *et al.*, 1984). Subsequently a sampling network was established along the Castaño river and its main tributaries, the San Francisco and Atutia. The design of this network was made bearing in mind all those factors that could give rise to hydrochemical changes, such as new contributions to the system, lithological changes, incoming of effluents produced by agricultural, industrial or other human activities, and formation of new population settlements (Lohn, 1978; Rankama & Sahama, 1950). On this basis five sampling campaigns were carried out in March (high season), May (low season) and November (medium season) in 1999. Two additional samplings were made in December 2000 (high season) and April 2001 (low season). In every sampling site a water sample of two liters was taken for general laboratory analysis, and two complementary samples of half a liter each. One of the latter was preserved with nitric acid for determining iron and manganese, and the second one was kept at a temperature no higher than 0°C for the determination of biochemical demand of oxygen (DBO). These second samples were collected in a PVC vessel

and their preservation was done following the norms of the internationally used Standard Methods for the Examination of Water. Subsequently the samples were sent to the laboratory for their physicochemical analysis.

At each sampling site non preservable parameters were determined, such as temperature, pH, conductivity and dissolved oxygen. These determinations were made with portable equipments: HANNA for temperature and pH; WTW LF 330/SET for electric conductivity and WTW OXI 330/SET for dissolved oxygen. The samples were labeled for identification and sent to the laboratory of the Institute for Mining Research of the National University of San Juan. The following determinations were made. 1) principal ions, as calcium, magnesium, sodium, potassium, carbonates, bicarbonates, sulphates and chlorides, 2) minor elements, as chrome, cadmium, copper, lead, iron and aluminium, 3) physicochemical determinations, as temperature, potentiometric pH and specific electric conductivity at 25°C.

The laboratory results obtained for cadmium, copper, lead, zinc and aluminium have been compared with: a) Standard values for potable water established by WHO (World Health Organization), b) proportion of elements established as background for surface water; c) amounts permitted for sources of water for human use established by Argentine Law N° 24.585, which regulates environmental protection in areas with mining activities.

Simultaneously a comparative analysis was made of the average annual discharges

of the Castaño river during a reference period of 34 years, from 1951 to 1987, but with no date for 1984 and 1985, because the gauging station was out service (Fig. 2). At first sight a notable increment of the discharges was observed along a period of recurrence of five years. The lowest values were recorded from 1968 to 1972, whilst the increased discharges were measured

from 1977 to 1987, with the exception of the two years without data.

The obtained results are part of a mining environmental base line, executed within the framework of an institutional project denominated “Studio of environmental base line in the river basin of the Castaño river, Calingasta San Juan”, of IIM – UNSJ.

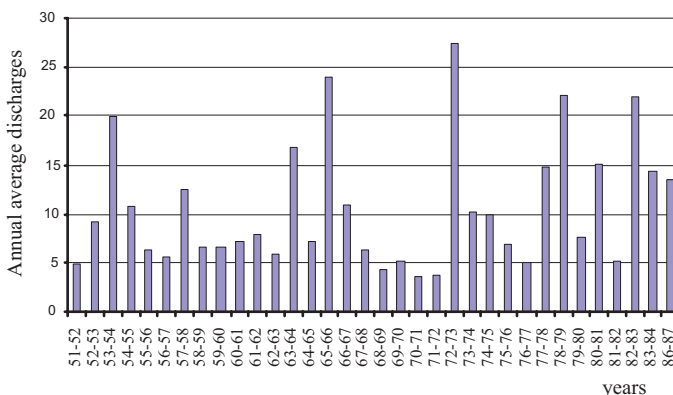


Figure 2. Annual average discharges of the Castaño river (1951-1987)

Figura 2. Descarga media anual del río Castaño (1951-1987)

## RESULTS

### Heavy elements (Table 1)

Table 1. Results compared with standard values

Tabla 1. Resultados comparativos con valores estándar

Element	Value obtained µg/l	W.H.O Standards µg/l	Content in surface water µg/l	Guidelines in Law N° 24,585 µg/l
Cadmio	<10	50	0,03	5
Cobre	8 30	3000	3	1000
Cromo	2 5	50	s/d	50
Plomo	1 12	100	3	50
Zinc	1	5000	20	5000
Aluminio	680 750	s/d	10	200

## Conductivity

The conductivity values obtained in the river water show very distinct variations along the stream and for each sampling season, as shown in Figure 3a, 3b, and 3c.

## DISCUSSION

*Concentrations of heavy metals:* along the river course the concentrations tend, generally, to low values.

*Concentration of other elements:* the results obtained in the present study indicate that:

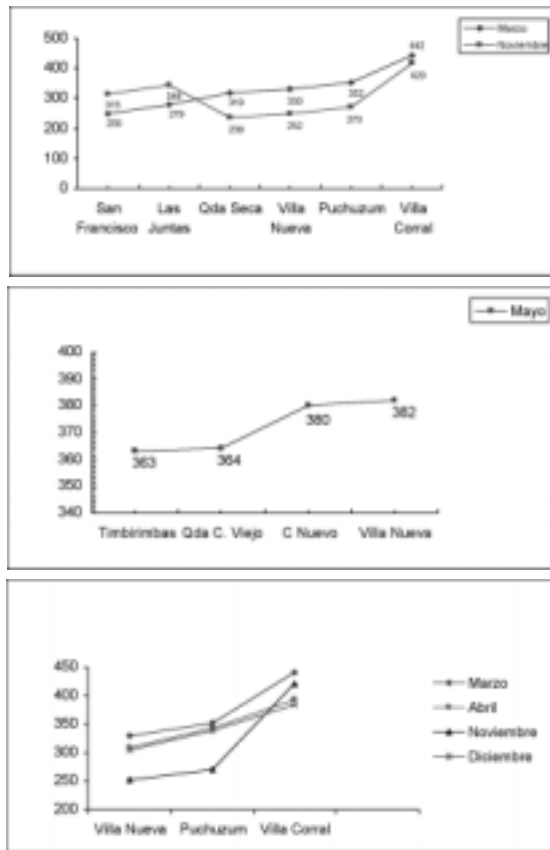


Figure 3. Conductivity variations along the Castaño river course during different periods of discharges: 3a. low (March, April, May), 3b. medium (November) and 3c. high (December)

Figura 3. Variación de la conductividad eléctrica a lo largo del río Castaño durante diferentes periodos de descarga: 3a. baja (marzo, abril, mayo), 3b. media (noviembre) y 3c. alta (diciembre)

**Cadmium:** the concentration of cadmium remains constant along the river course: less than 0.001 mg/l, without showing changes in the different sampling sites and in the time of recollection of each sample.

**Copper:** its concentration varies between a maximum of 0.03 mg/l and a minimum of 0.008 mg/l. The higher values were detected in the samples taken during the seasons of maximum discharge (December). It is very likely that the high content of copper in the river water is due to an increase of solids in suspension caused by frequent flash floods which descend from the steep valleys of the tributaries of the Castaño river.

**Chrome:** this element was found to occur in low concentrations: 0.002 mg/l (minimum) and 0.005 mg/l (maximum).

**Lead:** its presence was expected because the river course goes across highly mineralized zones. Nevertheless, the laboratory data are relatively low: less than 0.001 mg/l (minimum) and 0.012 mg/l (maximum).

**Zinc:** this element, closely related to lead, was found to have average concentrations of 0.001 mg/l, a value within the range of the standards established for drinking water.

**Aluminum:** the detected values of this element are high. The minimum content was 0.68 mg/l and the maximum, 0.75 mg/l. WHO does not consider aluminium in its standards for water to be used by humans. For this reason it is not possible

to determine if the presence of this element in the Castaño river water is compatible with human use. Nevertheless, the values obtained in the present study are notably higher than those established in the guidelines of Law 24585, which, as stated above, regulates the environmental protection in areas with mining activity.

**Electric conductivity:** this parameter increases downstream. From the junction of rivers San Francisco and Atutia to the locality of Villa Corral, values rise from 250 microSiemens/cm to 440 microSiemens/cm. In general the results obtained indicate that these conductivities are low, and the increase at Villa Corral is relatively slight. Moreover, the yearly records with higher conductivities have been obtained from samples taken in March (low discharge).

**pH:** remains constant and slightly alkaline, averaging from 7.9 and 8.

**Dissolved solids:** the values detected are variable. In the localities under study were obtained averages about 330mg/l, with a considerable increase at Villa Corral, where more than 400 mg/l were detected. Along the tract between the junction of the rivers San Francisco and Atutia and the Castaño river at Quebrada Seca, the values increase from 250 mg/l in the former to 320 mg/l in the latter. The amount of dissolved solids is lower in the Castaño river at the Quebrada Castaño Viejo: 260 mg/l.

**Other results:** the water of the Castaño river is predominantly calcic, and the concentrations of the ion calcium vary

from a minimum of 29.2 mg/l at the Quebrada Seca to a maximum of 42 mg/l at Villa Corral. The ion bicarbonate maximum concentration was found in the sampling site at Castaño Nuevo downstream from the mine, averaging

58.14 mg/l. The sulphate content is important. It varies from 94.08 mg/l in the river San Francisco to 143.89 mg/l in Castaño Nuevo. The values for chlorides are low, from 8.73 to 14.73 mg/l (Fig. 4).

Table 2. Hydrochemistry of the Castaño river (average values in mg/l)

*Tabla. Hidroquímica del río Castaño (valores medios en mg/l)*

Sampling sites	Ca calcium	Mg magnesium	Na + K Sodium plus potassium	CaCO <sub>3</sub> total alkalinity	HCO <sub>3</sub> bicarbonates	Cl chlorides	SO <sub>4</sub> sulphates
R. San Francisco	27.9	7.98	34.72	31.07	38.02	8.73	94.08
Las Juntas	31.6	8.41	37	34.65	42.41	9.74	104.95
R. Castaño- Qda. Seca	29.2	8.11	35.82	39.62	48.49	11.13	120
R. Castaño- Timbirimbas	33.2	9.23	40.73	45.06	55.15	12.66	136.48
R. Castaño- Qda. C. Viejo 1	33.4	9.29	40	45.36	55.51	12.74	137.37
R. Castaño- Qda. C. Viejo	33.3	9.25	38.81	45.16	55.27	12.69	136.77
R. Castaño- C. Nuevo 1	34.6	9.60	42.36	46.88	57.37	13.17	141.96
R. Castaño- C. Nuevo 2	35.0	9.73	42.95	47.51	58.14	13.35	143.89
R. Castaño- Villa Buena	31.2	9.42	38.87	35.82	49.98	10.06	112.30
R. Castaño- Puchuzum	32.8	9.54	40.35	35.05	40.13	8.79	97.78
R. Castaño- Villa Corral	42.0	8.72	47.7	47.31	55.53	14.76	140.66

*Note: C. Viejo 1: upstream from the Quebrada de Castaño Viejo, C. Viejo 2: downstream from the Quebrada de Castaño Viejo, C. Nuevo 1: upstream from the Castaño Nuevo mine, C. Nuevo 2: : downstream from the Castaño Nuevo mine*



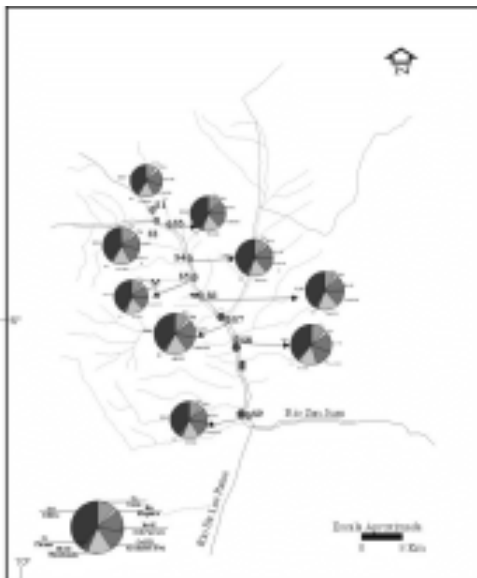


Figure 4. Hydrochemistry  
 Figura 4. Hidroquímica

## CONCLUSIONS

The values of some chemical parameters of the Castaño river water were found to be related to variations in the discharges during the different seasons of the year and to the nival feeding regimen of the river. For instance, the higher conductivities were detected in the samples collected in the low season (March). As to the higher concentrations of heavy metals have also been detected in the samples taken in summer, very likely due to the increase of solids in suspension. The pH does not experience changes related to seasons.

The water has low salinity, as expected in a river fed by snow-fall in the Andean Cordillera.

The low values of dissolved oxygen and of the biochemical demand of oxygen

(BDO) indicate absence of organic matter, for which reason the water can qualify as good for human use.

The river water does not contain toxic substances in amounts liable to contaminate. Some higher values of heavy elements could be related to the areas with mineralized outcrops along the course of the river.

The quality of this Andean water resource has not been affected by the mining activity carried out.

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