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EVALUATION OF THE QUALITY AND QUANTITY OF THE WATERS OF THE EL TINGO – HUALGAYOC RIVER IN THE FIRST YEAR OF EXPLOITATION BY LA CIMA MINING COMPANY

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ABSTRACT

The main objective of this research was to evaluate the quality and quantity of the water of the El Tingo – Hualgayoc River, in the first year of exploitation by La Cima mining company, this being the main supplier of water for irrigation of the Maygasbamba - El Tingo basin, the determining factors of the quality and quantity of the waters were investigated. in Physical and chemical parameters (Temperature, pH, conductivity, total dissolved solids, dissolved oxygen and flow rate), total metals: (arsenic, cadmium, copper, iron, manganese, lead and zinc), total cyanide, the results obtained were: the water did not present alterations in the physical parameters. The levels of metals: arsenic, cadmium, copper, iron, manganese, lead, electrical conductivity, total dissolved solids and dissolved oxygen exceeded the Maximum Permissible Limits, while the levels of cyanide, chromium, zinc and BOD did not exceed the Maximum Permissible Limits. The quality of the water at the monitored points, downstream, of the El Tingo River, is not suitable for agriculture or for animal drinking, due to the high degree of contamination by heavy metals.

KEYWORDS: Water Quality, El Tingo River, La Cima Mining, Heavy Metals.

INTRODUCTION

In all mining operations there are earth movements, use of chemicals that affect the quality of the water available for rural or urban use and produce changes in the quantity of surface water. In the area of influence of Minera La Cima Hualgayoc, there was no historical data available to determine what factors influence the quality and quantity of water, so in this research the determining factors of the quality and quantity of water, arising from the exploitation of the La Cima Mining Company in 2008, were studied. in the headwaters and their tributaries of the El Tingo River.

The economy in the Department of Cajamarca, especially in the province of Hualgayoc, has always been based on agricultural activity, specifically on traditional crops and livestock, in the background mining activity, which was carried out in a traditional way and/or on a smaller scale. At the beginning of the 90s, mining activity in the Department of Cajamarca has developed rapidly; but in Hualgayoc mining activity has been developed since the 70s of the eighteenth century, which allowed society to adapt to the explosive change of economic, social, cultural and ecological order; A series of problems were generated, including environmental problems.

RESEARCH OBJECTIVES

General:

To evaluate the quantity and quality of the waters of the El Tingo – Hualgayoc River, in the first year of exploitation by the La Cima mining company.

Specific:

a. To determine the characteristics of the water quality with respect to toxics during exploitation by Minera La Cima.
b. To determine the characteristics of the quantity of the waters of the El Tingo River, in the first year of exploitation by the mining company La Cima.

Hypothesis

General:

The quality and quantity of the waters of the El Tingo – Hualgayoc River would be altered in its physical-chemical characteristics and concentration of heavy metals, by mining activities.

Theoretical Framework

Water

Chemically, water is a substance that is made up of two hydrogen atoms and one oxygen atom, its molecular formula is H2O, 71% of the Earth's surface is covered by water, most of this water is saline; 97% of the Earth's water is contained in the planet's oceans, including 3% of water that is fresh, (Chang, 1 999).

In the world, more than 1 billion people do not have drinking water and more than two million people (especially children) die from diarrhea caused by drinking contaminated water, lack of sanitation and drinking water. The percentage of drinking water consumed worldwide from groundwater is 1%." (Womanizer, 1990).

A. Non-metals.

A-1. Cyanide. The term cyanide includes all CN- groups in cyanide compounds that can be determined as such. The complexes that shape are classified into simple and complex cyanides.

It is only deadly when a lethal dose is consumed, so it blocks the transport of oxygen through the cell walls. Cyanide decomposes when exposed to sunlight or neutral pH conditions (Cornejo, 2 003).

B. Heavy metals.

B. 1. Arsenic. - This element can be found in water as a result of a dissolution of minerals from industrial discharges and pesticide use. The solubility in water is so low that its presence is usually an indicator of the existence of earthmoving operations in the riverbed, or that there are agricultural areas where arsenic-containing materials are being used as insecticides. (N.A.S. 1 977)

Typically, the concentration of arsenic in fresh water is less than 1 ug/L, and in seawater, approximately 4 ug/L. High concentrations of arsenic are found where there is contamination from industrial sources or where there are geological outcrops of arsenic minerals. Arsenic is used in metallurgy, in the manufacture of glass and ceramics, as a pesticide and wood preservative" (Department of Water Affairs & Forestry, 1996).

At very low concentrations of arsenic they stimulate plant growth and crop yields decrease at high concentrations. The main effect of arsenic in plants is on the destruction of chlorophyll in the foliage as a consequence of inhibition of enzyme production. Arsenic is toxic to humans; consumption of consumable parts of the plant that contain accumulated arsenic is harmful (Gettar et al., 2002).

B. 2. Cadmium. - "Before the twentieth century, there was no large-scale pollution caused by the presence of cadmium, which has been occurring increasingly and rapidly in recent decades." The uptake of cadmium from the soil to a variety of crops has been well documented, and cadmium is translocated to the top of the plant after absorption through the roots. (Gettar et al., 2 002).

Long-term exposure to cadmium can cause cancer, kidney disease, neurological dysfunction, decreased fertility, changes in the immune system, and congenital malformations (Ministry of Agriculture, 2006).

B. 3. Copper. - Copper can be present in water through contact with minerals it contains or with mineral waste in copper production. Copper is an essential metal for organisms, but when it exceeds certain concentrations, it can produce toxic effects, mainly gastrointestinal and liver disorders. There are suggestions that copper levels above 0.6 mg/L may result in liver damage in dairy cows. (FAO. 2 006).

This element is essential for humans, it is estimated that 2 mg. is the need for copper for an adult person (Thornton, 1 993).

B. 4. Chromium. - This element can be found in water in both hexavalent and trivalent states, although in rare form it can appear in drinking water, chromium values are less than 0.05 mg/L. Non-essential, it has no physiological function in plants. Cr+6 affects growth and reduces plant productivity. Cr+3 is not easy, absorbed by the roots, 90% remains in the roots. It can be reduced with SO2 to Cr+3 or removed by anion exchange. Their presence may be associated with discharges of industrial wastes and they are usually found in surface waters" (CEPIS, 2 004).

B. 5. Iron. - It is considered an organoleptic element, because it causes stains on washed clothes and plumbing installations, in times of rainfall the clay in suspension can contain acid-soluble iron.

Presumably the ion required in metabolism is ferrous (Fe+2) in which form it is absorbed by the plant, since it is the form of greater mobility and availability for incorporation into biomolecular structures. In acidic soils, iron deficiency can be induced when excess heavy metals such as Zn, Cu, Mn and Ni are present. (Thornton, J. 1 993).

B. 6. Manganese. - It is also considered an organoleptic element since its presence causes stains on washed clothes and plumbing facilities (WHO, 1 998).

In plants it is an essential micro element for the synthesis of chlorophyll, Mn is absorbed by the root in the form of Mn+2 which is the biologically active form. Mn is relatively immobile, but toxic in high concentrations, it affects the aerial part of the plant, producing marginal chlorosis and necrosis in the leaf part, leaf wrinkling (soybean and cotton) and necrotic spots on the leaves (barley, lettuce and soybean). In severe cases of toxicity, plant roots turn brown. Source: Mineral nutrition of plants (CEPIS, 2 004).

A. 7. Lead. - This element is considered among the most important due to its toxicity which accumulates in the body, lead in water can be of industrial, mining and
discharges from smelting furnaces or old lead pipes. (WHO, 1 998.).

In agriculture it is toxic to plants at certain levels of solubility. In the soil many heavy metals are found as inorganic compounds or are attached to organic matter. Lead toxicity occurs only under special conditions. Lead and cadmium toxicity are of interest not only because of phytotoxicity, but also because when absorbed by plants they move in the food chain. (Zirena, 1991).

B. 8. Zinc. - It is an essential micro element that serves as an enzymatic cofactor, with many functions, since Zn must be essential for the activity, regulation and stabilization of the protein structure. Zn is found in soils and rocks in the Zn+2 divalent form. The soluble Zn content increases with decreasing pH and vice versa. Calcium carbonate also strongly reduces its availability. Excessive liming produces a deficiency of this element. (FAO. 2 006).

The EPA and the International Agency for Research on Cancer have classified zinc as non-carcinogenic. However, the EPA recommends that water should contain no more than 5 ppm of zinc. (Cornejo, 2003).

C.- Field parameters.

pH. - It can affect the availability of nutrients: in order for the radical apparatus to absorb the different nutrients, they must obviously be dissolved. Extreme pH values can cause the precipitation of certain nutrients so that they remain in a form not available to plants, pH can affect the physiological process of nutrient absorption by the roots; all plant species have characteristic pH ranges. Outside this range, root absorption is hindered and if the deviation in pH values is extreme, it can deteriorate the plant or present toxicity due to the excessive absorption of phytotoxic elements. With soil and irrigation water pH close to or above 7.5, the correct assimilability of nutrients such as phosphorus, iron, manganese, zinc, copper is affected. (Ministry of Agriculture 2006).

Conductivity. It is defined as the ability of inorganic salts in solution (electrolytes) to conduct electric current.

In most aqueous solutions, the greater the amount of dissolved salts, the higher the conductivity, with two different concentrations with the same conductivity. While harder (presence of calcium and magnesium carbonates). (DESA, 2 006).

Flow. It is the measurement of the flow of water that passes through the cross-section of a conduit (river, stream, channel) of water, it is known as gauging or flow measurement. This flow rate is directly dependent on the cross-sectional area of the stream and the average water velocity. (CEPIS, 2004).

G. Turbidity. - The concentration of water turbidity is given by the presence of rainfall that creates suspension materials such as clays, organic and inorganic matter and some microorganisms (DGESA, 2 006).

H. Dissolved oxygen (DO). Clean surface waters are often saturated with oxygen, which is critical for life. If the level of dissolved oxygen is low, indicating contamination with organic matter, septicization, poor water quality and inability to maintain certain forms of life, Dissolved Oxygen is an indicator of contamination by bacterial load from latrines located on the banks of rivers, while higher is Dissolved Oxygen. indicates that there is less bacterial load (WHO, 1998).

Temperature. It is another factor that influences the level of oxygen concentration in water. The formation of layers of different well-differentiated temperatures prevent the arrival of oxygen to the bottom, this is a physical phenomenon and generally occurs in summer (Miller, 2 000).

Biochemical Oxygen Demand (BOD5). - It is a measure of the oxygen required to oxidize all compounds present in water, both organic and inorganic, by the action of strongly oxidizing agents in an acidic medium and is expressed in milligrams of oxygen per liter (mg O2/L.). (Salazar, R. 2 008)

General Water Law.

The General Water Law has a consensual legal norm that ensures the sustainability of the integrated management of water resources in each of Peru's watersheds. Promoting equity and human development (CEPES, 2009).

In **Article 81** of the Regulations of Titles I, II, III, IV, V, VI of Decree Law No. 17752: "General Water Law" (Supreme Decree No. 007-83-SA), as amended by Article 1 of Supreme Decree No. 007-83-SA, published on 17-03-83, the quality of the country's bodies of water in general, whether terrestrial or maritime, is classified with respect to their uses as follows:

I. Domestic water supply with simple disinfection.
II. Domestic water supply with treatment equivalent to combined mixing and coagulation, sedimentation, filtration and chlorination processes, approved by the Ministry of Health.
III. Water for irrigation of raw vegetables and animal drinking.
IV. Waters from recreational areas of primary contact (bathrooms and similar).
V. Waters of bivalve shellfish fishing areas.
VI. Waters of Aquatic Fauna Preservation and Recreational or Commercial Fishing areas.

Article 82.- In order to preserve the country's water bodies, in accordance with the classification described in the preceding article, the following types and limit values apply (Tables 1 and 2).

Table 1: Limit values of biological parameters for irrigation wáter.

Parámetro Biológicos	Unidad	Vegetales de Tallo Bajo	Vegetales de Tallo Alto
		Valor	Valor
Coliformes Termotolerantes	NMP/100mL	1 000(3)	2 000(3)
Coliformes Totales	NMP/100mL	5 000(3)	5 000(3)
Vibrión Cholerae		Ausente	Ausente
Escherichia Coli	NMP/100mL	100	100
Enterococos	NMP/100mL	20(5)	100
Salmonella Sp.		Ausente	Ausente
Helmintos	huevos/litro	<1(8)	<1(1)

Fuente:

(1) Calidad del Agua en la Agricultura -Rev. 1 - Estudio FAO "Riego y Drenaje 29"
(2) Ley General de Aguas D. L Nº 17752
(3) Norma Técnica Nacional de la Republica de Honduras- 2001
(4) Norma para el Control de la Calidad de los Cuerpos de Agua de Venezuela
(5) Mariano Seoanez Calvo. Ingeniería del Medio Ambiente - Criterios Generales de Calidad para Aguas de uso Agrario. Estado de Ontario – Canadá.
(6) Modificación del D. S 253/79 - Uruguay - Norma para Prevenir la Contaminación Ambiental
(7) Decreto Supremo Nº 003-2003-SA
(8) Organización Mundial de la Salud – OMS
(9) Norma de Calidad para la protección de aguas superficiales 1999 – Chile
(10) Instituto Nacional de Recursos Naturales

In original Spanish language

Table 2: Limit values of physicochemical parameters for drinking water for animals.

Parámetros	Unidades	Valor
Físicos químicos		
Demanda Bioquímica de Oxígeno	mg/L	15,0 (2)
Oxigeno Disuelto	mg/L	7,5 - 9,0
Ph	mg/L	6,5 – 8,5 (1)
Sales		
Fluoruro	mg/L	2,0 (1)
Sulfatos	mg/L	250 (10)
Sulfuros	mg/L	0,005 (2)
Nitratos-N	mg/L	5,0 (10)
Inorgánicos		
Aluminio	mg/L	2,0 (3)
Arsénico	mg/L	0,1 (10)
Berilio	mg/L	0,1 (1)
Boro	mg/L	5,0 (1)
Cadmio	mg/L	0,01 (10)
Cianuro WAD	mg/L	0,1 (7)
Cobalto	mg/L	1,0 (1)
Cobre	mg/L	0,5 (1)
Cromo (6+)	mg/L	1,0 (1)
Hierro	mg/L	1,0 (2)
Litio	mg/L	2,5 (4)
Manganeso	mg/L	0,2 (10)
Magnesio	mg/L	150,0 (2)
Mercurio	mg/L	0,001(10)
Níquel ººº	mg/L	0,2 (9)
Plata	mg/L	0,05 (3)
Plomo	mg/L	0,05 (10)
Selenio	mg/L	0,05 (2)
Zinc	mg/L	24,0 (1)
Orgánicos		
Aceites y Grasas	mg/L	0,5 (2)
S.A.A.M. (detergentes)	mg/L	1,0 (2)
Fenoles	mg/L	0,001(2)
Plaguicidas		
Lindano	mg/L	0,004(9)
Aldrín	mg/L	$0,004x10^{-3}$(9)
Aldicard	mg/L	0,001(9)
Clordano	mg/L	$0,006x10^{-3}$(9)
Dieldrín	mg/L	$0,7x10^{-3}$(9)
DDT	mg/L	$0,001x10^{-3}$(9)
Endrín	mg/L	$0,004x10^{-3}$(6)
Endosulfan	mg/L	$0,02x10^{-3}$(6)
Heptacloro	mg/L	0,01x10-3(9)
Parathion	mg/L	$7,5x10^{-3}$(9)
Parametros Biológicos	**Unidades**	**Valor**
Coliformes Termotolerantes	NMP/100mL	1 000 (2)
Coliformes Totales	NMP/100mL	5 000 (2)
Vibrión Cholerae	Ausente	
Escherichia Coli	NMP/100mL	100,0
Salmonella Sp.	Ausente	
Huevos de Helmintos	huevos/litro	<1,0 (8)
Enterococos	NMP/100mL	20,0 (5)

Fuente:

(1) Calidad del Agua en la Agricultura -Rev. 1 - Estudio FAO "Riego y Drenaje 29"
(2) Ley General de Aguas D. L Nº 17752
(3) Norma Técnica Nacional de la Republica de Honduras- 2001
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(9) Norma de Calidad para la protección de aguas superficiales 1999 – Chile
(10) Instituto Nacional de Recursos Naturales

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METHODOLOGY

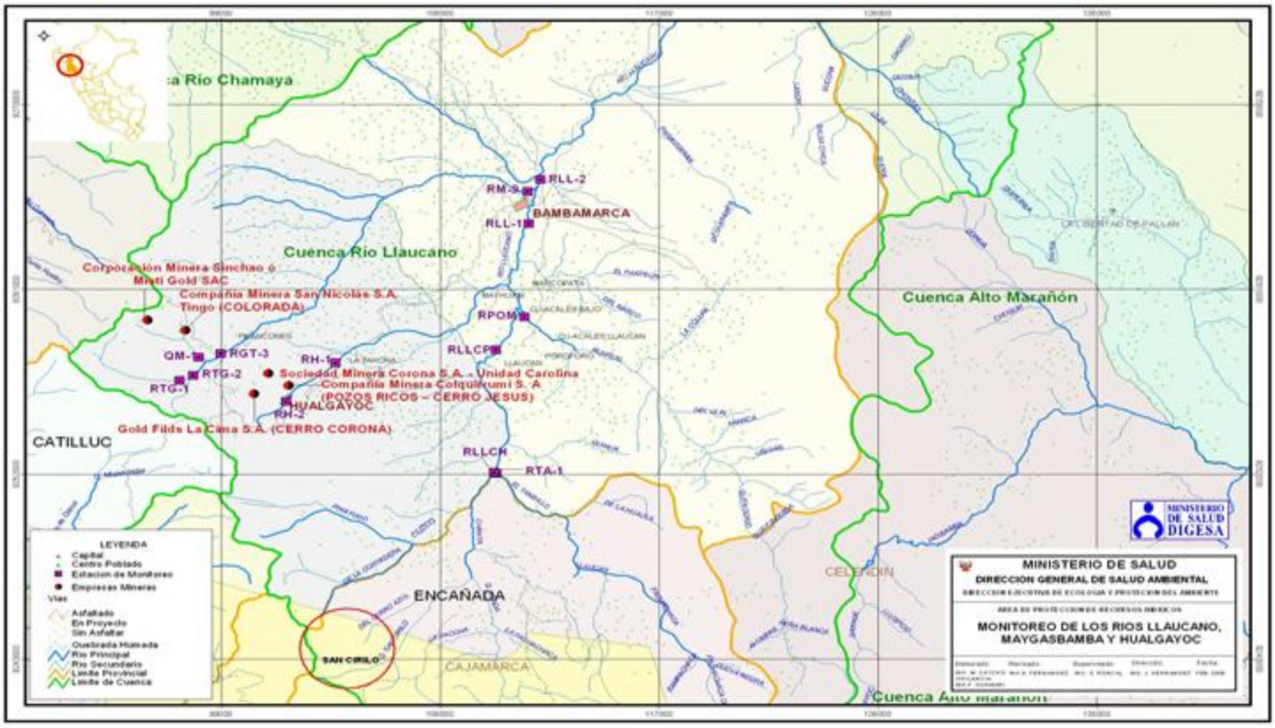
LOCATION OF THE STUDY AREA.

The La Cima Project is politically located in the department of Cajamarca, province of Hualgayoc, district of Bambamarca, Peasant Community of El Tingo, La Jalca Property Annex, Coymolache and Pilancones hamlets. Geographically, it is located on the eastern slope of the Western Cordillera of the Northern Andes of Peru, at 3,600 and 4,000 m altitude. It mainly involves the basins of the Tingo/Maygasbamba, and Hualgayoc/Arascorgue rivers.

Table 3: Monitoring Stations of the waters of the El Tingo River DESA- Cajamarca- In original Spanish language.

Código de campo	Origen de la fuente	Punto de muestreo	Localidad	Distrito y Provincia	Departamento	Altitud msnm.	UTM	
							Este	Norte
RTG-1	Río Tingo	Naciente del río Tingo	El Tingo	Hualgayoc	Cajamarca	3 630	17760016	9252316
RTG-2	Río Tingo	Puente carretera al sector las Águilas	El Tingo	Hualgayoc	Cajamarca	3 599	17760581	9252554
RTG-3	Río Tingo	Bocamina El Tingo, socavones de la mina corona	El Tingo	Hualgayoc	Cajamarca	3 486	17761722	9253594
QM-1	Quebrada la Eme	A 800 m. salida del Pad Minera San Nicolás	El Tingo	Hualgayoc	Cajamarca	3 550	17760803	9253435

Source: DESA-CAJAMARCA Ecology and Environmental Protection Unit – UEP. In original Spanish language



RESULTS AND DISCUSSION

1. Cyanide.

In those where the waters were analyzed, the levels of cyanide recorded do not exceed the maximum permissible limit. At the RTG-1 and RTG-2 monitoring points, the cyanide level found was less than 0.003 mg/L, attributable in part to the upstream location of the mines of these monitoring points, throughout the evaluation time space. For the RTG-3 point, cyanide levels ranged from minus 0.003 to 0.050 mg/L., with the highest cyanide level found in May 2007. While at the QM-1 monitoring point, the cyanide values recorded varied from minus 0.003 to 0.071 mg/L, being in the months of May-2007 and July 2008, with amounts of 0.071 and 0.064 mg/L, respectively, the highest values of this mineral were recorded in the waters of the Tingo River.

Cuadro 1. Concentración de Cianuro en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
RTG-2	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	<0.003
RTG-3	0.050	0.005	0.018	<0.003	0.004	0.034	0.018	0.024	<0.003	0.005
QM-1	0.071	0.023	0.025	<0.003	0.019	0.064	0.0308	0.050	<0.003	0.023
LMP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Fuente: Unidad de Ecología y Protección Ambiental DESA - Cajamarca

In original Spanish language

In the comparison of the results during the period 2008 - 2009, the General Water Law No. 17752 has been taken as a basis, which establishes Maximum Permissible Limits for certain parameters such as: WAD cyanide, arsenic, cadmium, copper, chromium, iron, manganese, lead, zinc, fecal coliforms, total coliforms, pH, temperature, conductivity, total dissolved solids, dissolved oxygen, BOD5 (CONAM, 2 005).

In graph 1, the regression equation, the significant relationship between cyanide content and time in years is shown, it is observed that the relationship is positive, the longer the mining activity time, the higher the cyanide content in the river, the model of the linear form y = 0.0189 + 0.0039X, with an r^2 = 16.54%, if so, the growth of Cyanide, in 18 years, the contents will be deadly.

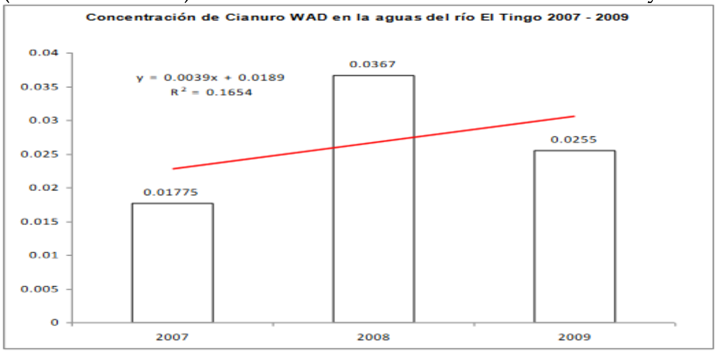


Figure 1: Regression analysis for the concentration of WAD cyanide (mg/L) in the El Tingo River (2 007 – 2 009). In original Spanish language.

2. ARSENIC

At the RTG-1 monitoring point, the arsenic level registered values below 0.0005 mg/L and in the month of January-2008 it registered 0.0062 mg/L. For the RTG-2 point, the values ranged from 0.0028 to 0.0496 mg/L, for the months of March 2009 and January 2008, respectively. While at the RTG-3 and QM-1 monitoring points, the arsenic values recorded were very close to the maximum allowed, being the month of April 2008 at the QM-1 point, with 0.236 mg/L, the one that exceeded the limit, for the RTG-3 point the maximum arsenic value was recorded in January-2 008, with 0.1559 mg/L.

Table 2: Arsenic concentration in the water of the El Tingo River during May 2 007-August 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	< 0.0005	< 0.0005	< 0.0005	0.0062	0.0006	<0.0005	<0.0005	<0.0005	0.0031	<0.0005
RTG-2	0.0043	0.0063	0.0082	0.0496	0.005	0.0082	0.0065	0.0075	0.0028	0.0063
RTG-3	0.1168	0.1168	0.0184	0.1559	0.106	0.1168	0.116	0.1165	0.0037	0.1168
QM-1	0.1958	0.1952	0.0293	0.1775	0.236	0.1942	0.1945	0.1955	0.003	0.195
LMP	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: DESA Ecology and Environmental Protection Unit – Cajamarca. In original Spanish language

In graph 2, regression, the significant relationship between arsenic content and time in years is shown, it is observed that the relationship is positive, the longer the mining activity time, the higher the arsenic content in the river, the model of the linear form y = 0.00678 + 0.033X, with an r^2 = 75.6%, if so, The growth of arsenic will be deadly.

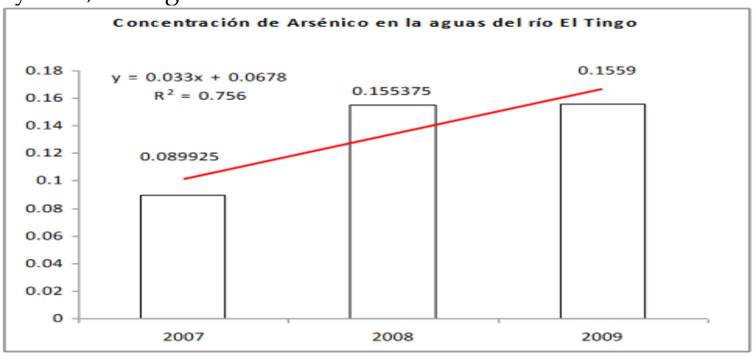


Figure 2: Regression analysis for the concentration of Arsenic (mg/L) from the El Tingo River (2 007 – 2 009). In original Spanish language.

3. CADMIUM

In the months that the waters were analyzed, cadmium levels ranged from minus 0.003 to minus 0.05 mg/L. For the RTG-1 and RTG-2 monitoring points, the cadmium level found registered values lower than 0.050 mg/L. For point RTG-3, the maximum value recorded was in May 2 007, with 0.05 mg/L, a value that is above the limit. While at the QM-1 monitoring point, the arsenic values recorded varied from minus 0.01 to 0.071 mg/L, with the month of May 2 007 being the highest value

Table 3: Cadmium concentration in the water of the El Tingo River during May 2 007-August 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	<0.003	<0.010	<0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
RTG-2	<0.003	<0.010	<0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
RTG-3	0.050	<0.010	<0.050	<0.010	<0.010	<0.010	0.010	<0.010	<0.010	<0.010
QM-1	0.071	<0.010	<0.050	0.014	0.014	<0.010	0.020	0.011	<0.010	<0.010
LMP	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Fuente: Unidad de Ecología y|Protección Ambiental DESA – Cajamarca

In original Spanish language

In graph 3 of regression, the significant relationship between cadmium content and time in years is shown, it is observed that the relationship is negative, the longer the mining activity time, the lower the cadmium content in the river, the model of the linear form y = 0.02-0.005X, with an r^2 = 100%, noting a decreasing value of cadmium.

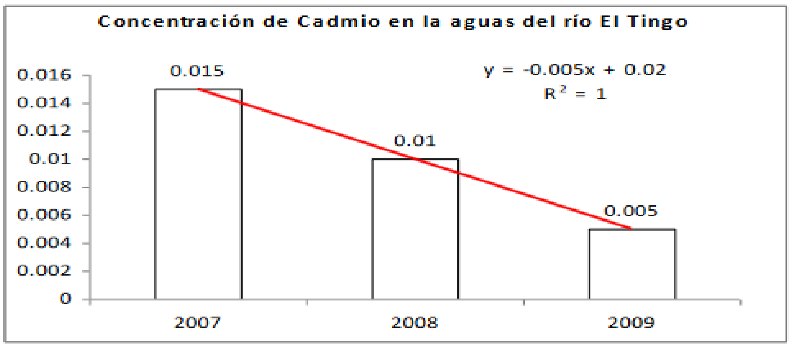


Figure 3: Regression analysis for the concentration of Cadmium (mg/L) El Tingo River (2 007 – 2009). In original Spanish language.

4. COPPER

The recorded copper levels exceed the maximum permissible limit at the RTG-3 and QM-1 monitoring points. At the RTG-1 and RTG-2 monitoring points, the levels of copper found varied from minus 0.005 to 0.156 mg/L., with the peak of the presence of copper being the month of January-2 008, at the RTG-2 point, the low values with respect to those found at the RTG-3 and QM-1 points, is attributable to the downstream location of the mines and generally coincides with the months of greatest rainfall. for the RTG-3 point, copper levels varied from 0.130 mg/L. to 3.221 mg/L, for the months of July 2 008 and May 2 007, respectively. While at the QM-1 monitoring point, the copper values recorded exceeded the limits in almost all evaluations, being the month of May 2007 in which 9,438 mg/L was registered, which the highest values of this mineral were recorded in the waters of the Tingo River.

Cuadro 4. Concentración de Cobre en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	0.013	0.007	0.011	<0.005	0.010	0.006	0.006	0.006	0.014	0.007
RTG-2	0.019	0.009	0.041	0.156	0.021	<0.005	0.007	0.034	0.024	0.009
RTG-3	3.221	0.705	0.142	1.088	0.827	0.130	1.985	0.936	5.53	0.705
QM-1	9.438	1.629	0.885	3.561	2.040	0.420	2.883	0.703	0.474	1.629
LMP	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Fuente: Unidad de Ecología y Protección Ambiental DESA - Cajamarca

In original Spanish language

In graph 4, regression, the significant relationship between copper content and time in years is shown, it is observed that the relationship is positive, the longer the mining activity the higher the copper content in the river, the model of the linear form y = 406.05 + 203.58X, with an r^2 = 25.3%, if so, Copper growth will be toxic.

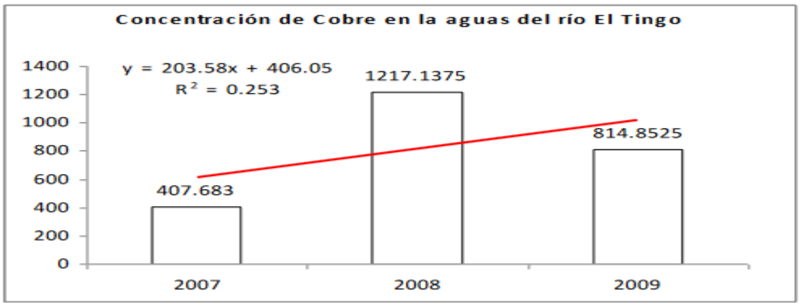


Figure 4: Regression analysis of the concentration of copper (mg/L) of the El Tingo River (2 007 –2 009). In original Spanish language.

5. CHROMIUM

At the monitoring points, with respect to the levels of chromium in the waters of the Tingo River, it was found that the levels of chromium were minus 0.05 mg/L. For the RTG-1 and RTG-2 monitoring points, the chromium level found registered values lower than 0.050 mg/L. For RTG-3 and QM-1 points, in previous evaluations they presented high concentrations with respect to the first monitoring points, they did not show variability in the records and the values recorded were less than 0.05 mg/L.

Cuadro 5. Concentración de Cromo en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
RTG-2	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
RTG-3	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
QM-1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
LMP	1	1	1	1	1	1	1	1	1	1

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca

In original Spanish language

6. IRON

The iron levels recorded exceed the maximum permissible limit at the RTG-3 and QM-1 monitoring points. At the RTG-1 and RTG-2 monitoring points, the levels of iron found varied from 0.055 mg/L. to 6.860 mg/L., being the maximum point of iron presence in the month of January-2008, at the RTG-2 point, the low values with respect to those found at the RTG-3 and QM-1 points, is attributable to the location downstream of the mines of these. For the RTG-3 point, iron levels varied from 0.953 mg/L to 20.570 mg/L for the months of July 2008 and January 2008, respectively. While at the QM-1 monitoring point, the iron values recorded exceeded the limit in almost all evaluations, being the month of January 2008 in which with 35,960 mg/L., the highest values of this mineral were recorded in the waters of the Tingo River.

Cuadro 6. Concentración de Hierro en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	0.272	0.07	0.055	0.218	0.159	0.124	0.225	0.18		
RTG-2	1.985	0.668	0.913	6.860	0.562	0.282	0.365	3.33		
RTG-3	12.9	7.728	1.774	20.570	7.440	0.953	6.300	4.440		
QM-1	25.96	14.679	4.487	35.960	21.700	0.746	8.360	2.930		
LMP	5	5	5	5	5	5	5	5	5	5

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca.

In original Spanish language

7. MANGANESE

The levels of manganese recorded exceed the maximum permissible limit at the RTG-3 and QM-1 monitoring points. At the RTG-1 and RTG-2 monitoring points, the levels of manganese found varied from minus 0.025 to 1.728, with the maximum point of manganese presence being the month of May-2 007, at the RTG-2 point, the low values with respect to those found at the RTG-3 and QM-1 points, is attributable to their geographical location. For RTG-3 and QM-1 points, manganese levels registered values that varied from 0.928 to 8.592 mg/L, for the months of October 2 007 and May 2 007, respectively, the manganese values recorded exceeded the limit in almost all evaluations in evaluations of the waters of the Tingo River.

Cuadro 7. Concentración de Manganeso en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	0.041	0.041	<0.025	0.064	0.049	0.042	0.052	0.038		
RTG-2	1.728	0.511	0.612	0.566	0.450	0.211	0.310	0.238		
RTG-3	8.592	2.746	6.230	2.867	4.990	3.220	2.790	0.955		
QM-1	2.598	1.376	0.928	3.094	2.040	1.100	3.536	0.999		
LMP	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca.

In original Spanish language

The manganese levels did exceed the maximum permissible limits at points RTG-2, RTG-3 and QM-1 in the years 2007 and 2008, due to the presence of mine tailings from both the Cima and the Pad San Nicolás.

In graph 7, regression, the significant relationship between manganese content and time in years is shown, it is observed that the relationship is positive, the longer the time of mining activity the higher the copper content in the river, the model of the linear form y = 2661.5 + 73,268X, with an r^2 = 100%, if so, the growth of manganese will be toxic as the exploitation of mining companies based in the upper part of the El Tingo river basin advances.

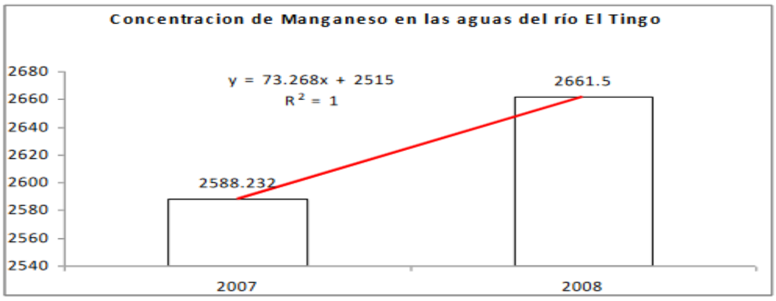


Figure 7: Regression analysis for the concentration of manganese (mg/L) in the El Tingo river (2 007 – 2 009). In original Spanish language.

8. LEAD

The levels of lead recorded exceed the maximum permissible limit at the RTG-3 and QM-1 monitoring points. At the RTG-1 and RTG-2 monitoring points, the levels of lead found varied from minus 0.025 mg/L to 0.552 mg/L, with the maximum point of lead presence being the month of January 2008, at the RTG-2 point, the low values with respect to those found at the RTG-3 and QM-1 points, is attributable to their geographical location. For points RTG-3 and QM-1, lead levels varied from minus 0.025 mg/L to 0.167 mg/L., with August 2009 being the highest value of the presence of this metal in the waters of the Tingo River.

Cuadro 8. Concentración de Plomo en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

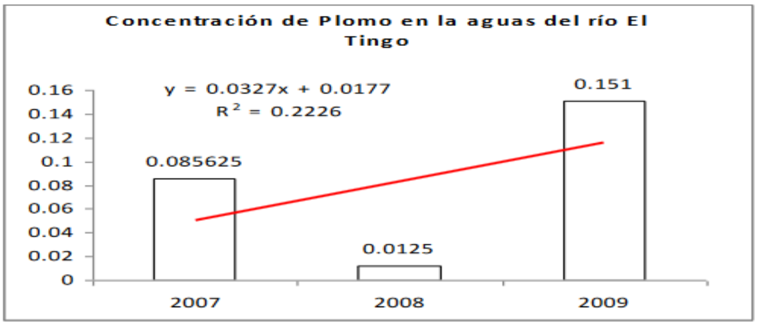
PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.027	0.025
RTG-2	0.044	<0.025	0.025	0.052	<0.025	<0.025	<0.025	<0.025	0.036	0.025
RTG-3	0.012	0.167	0.028	0.094	0.033	<0.025	<0.025	0.037	0.067	0.167
QM-1	0.268	0.135	<0.025	0.042	0.053	<0.025	<0.025	0.037	0.049	0.135
LMP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca

In original Spanish language

Lead levels exceeded the maximum permissible limits at RTG-3 and QM-1 points in the years 2008 and 2009. In the months of May (0.268 mg/L.) and July, 0.135 (mg/L.), in 2 007 and in August (0.135 mg/L.), in 2 009. While at the monitored points RTG.1 and RTG-2 do not exceed maximum permissible limits of 0.1 mg/L. according to the General Water Law.

In graph 8, of regression, the significant relationship between lead content and time in years is shown, it is observed that the relationship is positive, the longer the time of mining activity the higher the lead content in the river, the model of the linear form y = 0.0177 + 0.0327x, with an r^2 = 22.26% if so, The growth of lead will be toxic.



Graph 8, Regression analysis for the concentration of Lead (mg/L) in the El Tingo River (2 007 – 2 009). In original Spanish language

9. ZINC

At the monitoring points RTG-3 and QM-1, RTG-1 and RTG-2, the levels of zinc found varied from minus 0.038 mg/L. to 0.267 mg/L., with the peak of zinc presence being the month of May 2007, at point RTG-2, the low values with respect to those found at points RTG-3 and QM-1, it is attributable to the geographical location of the area. For RTG-3 and QM-1 points, zinc levels varied from 0.136 mg/L. to 8.482 mg/L., with March 2009 being the highest value of the presence of this metal in the waters of the Tingo River.

Cuadro 9. Concentración de Zinc en el agua del río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	0.043	<0.038	<0.038	<0.038	<0.038	<0.038	<0.038	<0.038	0.017	<0.038
RTG-2	0.267	0.165	0.169	0.038	0.046	0.045	0.091	0.045	0.025	0.165
RTG-3	3.599	1.166	0.509	1.408	1.820	0.267	1.680	0.452	8.482	1.166
QM-1	2.808	0.91	0.464	2.778	1.740	0.136	2.240	0.249	0.278	0.910
LMP	25	25	25	25	25	25	25	25	25	25

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca

In original Spanish language

10. DETERMINATION OF PH.

At the monitoring points, in the waters of the Tingo River, it was found that in the month of January 2008 the acidity was 4.78 at the QM-1 sampling point, in the rest of the sampled points the pH parameters were found between 6.52 and 8.80, which reflects the behavior of the waters is in the presence of limestone rocks and influenced by the presence of rainy months in the area under study.

Cuadro 10. Determinación del pH en el agua del río El Tingo durante mayo 2 007-agosto 2 009.

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	7.45	7.42	7.26	7.72	7.63	6.52	6.76	7.82	7.98	7.92
RTG-2	7.96	7.42	7.99	8.72	7.70	7.09	6.18	8.27	7.5	7.92
RTG-3	7.01	8.8	8.33	8.21	7.27	7.31	6.01	7.89	7.32	7.84
QM-1	7.41	7.36	7.96	4.78	6.84	7.39	6.02	7.85	8.17	7.96

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca

In original Spanish language

11. DETERMINATION OF TEMPERATURE.

At the different monitoring points, it was determined that this parameter was from 8.5 °C to 14.60 °C at the QM-1 sampling point, in the month of July it presented the lowest temperature, which, in the month of April with 14.6 °C, which reflects the behavior of the waters with the different times of the year and influenced by the presence of rainfall and the speed of the winds in the area under study.

Cuadro 11. Determinación de la temperatura (°C) en el río El Tingo durante mayo 2 007-agosto 2 009.

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	9.0	10.8	11.2	12.4	11.7	8.5	12.8	13.2	12.3	12.3
RTG-2	9.0	12.0	14.5	12.0	11.1	8.5	12.6	12.5	12.6	12.2
RTG-3	8.0	12.5	13.9	13.4	13.5	8.8	11.6	13.4	12.4	11.7
QM-1	9.0	11.6	12.9	10.1	14.6	8.6	12.0	13.2	12.4	11.7

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca.
In original Spanish language

12. DETERMINATION OF CONDUCTIVITY.

At the sampled points, this parameter was 129 uS/cm. At point RTG-1 of May 2007 and at point and in March 2009 with 1,578 uS/cm, which indicates that in many months sampled the maximum permissible limits have exceeded these values (< 700 uS/cm), which reflects the behavior of the waters with the presence of calcium and magnesium carbonates) in the area under study.

Cuadro 12. Determinación de Conductividad (uS/cm) en el río El Tingo durante mayo 2 007-agosto 2 009

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	129	354	472	633		347	320	320	445	342
RTG-2	285	534	891	1192	237	451	509	509	462	377
RTG-3	538	780	1073	934		668	659	659	1578	687
QM-1	506	518	615	633		716	682	682	1124	750
LMP	< 700	< 700	< 700	< 700	< 700	< 700	< 700	< 700	< 700	< 700

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca
In original Spanish language

13. DETERMINATION OF TOTAL DISSOLVED SOLIDS.

After determining the amount of total dissolved solids in the monitoring site, it has been determined that in the months of greatest rainfall it has been determined that the amount of solids have exceeded the maximum permissible limits, being in the months of January and April 2008 and March 2009, in all the monitored points, which are: RTG-1, RTG-2, RTG-3 and QM-1 with values of 64.2 mg/L. and 1 122 mg/L. exceeding the maximum permissible limits in several of the points whose limit for irrigation waters according to the General Water Law is less than 450 mg/L

Cuadro 13. Determinación de los Sólidos Totales disueltos en el río El Tingo. Mayo 2 007-agosto 2 009.

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	64.2	176.2	236	503	503	175.6	220	175	222	167
RTG-2	140	267	448	1122	1122	230	345	265	233	186
RTG-3	267	393	541	816	816	335	442	396	789	337
QM-1	252	259	307	539	539	360	305	256	561	369
LMP	< 450	< 450	< 450	< 450	< 450	< 450	< 450	< 450	< 450	< 450

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca
In original Spanish language

14. DETERMINATION OF DISSOLVED OXYGEN.

After determining the amount of dissolved oxygen in the waters of the Tingo River, it has been determined that in all the monitored points there are values of 4.12 mg/L. and 11.45 mg/L. at the monitored point RTG-3 in the months of January and September.

Cuadro 14. Determinación de Oxígeno Disuelto en el río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1				6,61	6,20	4,72	4,45	5,31		
RTG-2				6,12	5,10	8,31	8,95	4,56		
RTG-3				4,12	7,14	4,56	11,45	4,12		
QM-1				7,23	7,60	4,12	5,04	4,20		

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca.

In original Spanish language

15. DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND (BOD5).

At the sampled points: RTG-1, RTG-2, RTG-3 and QM-1, it was determined that the amount of biochemical demand in the waters of the Tingo River has not exceeded the maximum permissible limits, referring to the General Water Law (15 mg/L.).

Cuadro 15. Determinación del DBO (mg/L) en el río El Tingo durante mayo 2 007-agosto 2 009 (mg/L).

PUNTOS DE MONITOREO	2007			2008					2009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1				4,1	4,2	3,9	< 2	5,4		
RTG-2				< 2	3,2	5,4	< 2	8,9		
RTG-3				6,2	2,7	8,9	< 2	5,2		
QM-1				< 2	2,0	5,2	< 2	3,5		
LMP	15	15	15	15	15	15	15	15	15	15

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca.

In original Spanish language

16. FLOW DETERMINATION.

After the sampling of the flows of the waters of the Tingo River, at the different points that: RTG-1, RTG-2, in the months of July, October, September and August the flows have been minimal, which determined that in the months of rainfall the flows increase considerably from 3 L/s - 958.3 L/s.

Cuadro 16. Determinación del Caudal (L/s) en el agua del río El Tingo durante mayo 2 007-agosto 2 009.

PUNTOS DE MONITOREO	2 007			2 008					2 009	
	MAY	JUL	OCT	ENE	ABR	JUL	SET	DIC	MARZ	AGOST
RTG-1	35,0	3,0	4,5	91,7	52,6	3,5	2,5	80,0	54,5	3,0
RTG-2	25,0	5,0	3,0	97,8	58,6	5,5	3,0	95,0	59,0	5,3
RTG-3	25,0	12,0	22,0	771,0	620,0	15,0	18,0	650,0	520,0	12,0
QM-1	35,0	15,0	28,0	958,3	77,06	25,0	24,0	835,0	760,5	21,0

Fuente: Unidad de Ecología y Protección Ambiental DESA – Cajamarca

In original Spanish language

In Graph 16, it can be seen that the values determined at the sampled points RTG-1, RTG-2, RTG-3 and QM-1, The flows were varied ranging from: 3 l/s. to 958.27 l/s., which means that the highest flows coincide with the presence of rainfall.

In graph 16, of regression, the significant relationship between the content of the water resource and the time in years is shown, it is observed that the relationship is negative, the longer the time of mining activity the lower the flow of the waters of the El Tingo River, the model of the linear form y = 21.5 – 1,375 x, with an r^2 = 45.15%, if so, than the flow of the waters of the El Tingo River.

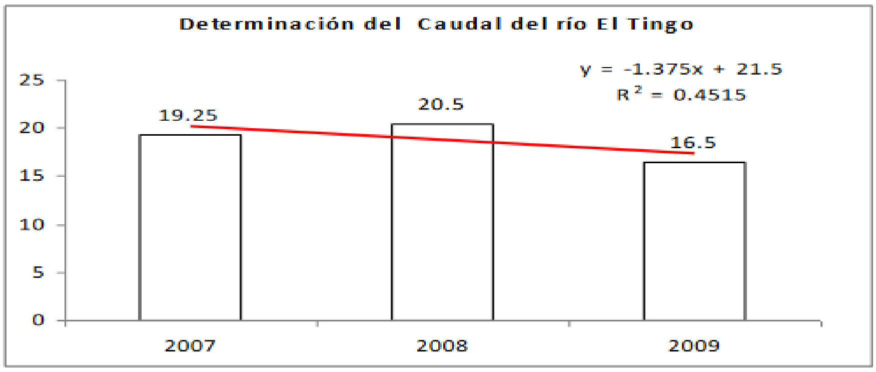


Figure 16: Regression analysis for determination of the flow (L/s) of the El Tingo River (2 007 – 2 009). In original Spanish language.

CONCLUSIONS

According to the results obtained during the years 2008 and 2009 in which the In the waters of the Tingo River, the following is concluded:

- Chromium, zinc and cyanide levels did not exceed LMPs at any sampling point.
- Manganese levels exceeded LMPs at the RTG-2 monitoring point.
- The levels of cadmium, copper, iron, manganese, lead exceeded the LMPs at the RTG-3 monitoring point.
- Levels of arsenic, cadmium, copper, iron, manganese, lead exceeded LMPs at monitoring point QM1.
- No significant levels of Biochemical Oxygen Demand (BOD) were found at any sampling point.
- The pH ranged from 4.78 at QM1 to 8.8 at RTG3.
- Conductivity surpassed LMPs at RTG2, RTG3 and QM1 monitoring points in a few months.
- Total Dissolved Solids and Dissolved Oxygen exceeded LMP at the four monitored points in some months.
- The flow was very varied, influenced by various factors such as rainfall.

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