American Journal of Environmental Science and Engineering
2022; 6(1): 44-50
http://www.sciencepublishinggroup.com/j/ajese
doi: 10.11648/j.ajese.20220601.16
ISSN: 2578-7985 (Print); ISSN: 2578-7993 (Online)

Physical and Chemical Study of Water from the Underground of Ichuña, Moquegua, Peru

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To cite this article:
Renee Mauricio Condori Apaza, Erika Cari Mendoza, Sheda Mendez Ancca. Physical and Chemical Study of Water from the Underground of Ichuña, Moquegua, Peru. *American Journal of Environmental Science and Engineering*. Vol. 6, No. 1, 2022, pp. 44-50.
doi: 10.11648/j.ajese.20220601.16

Received: January 17, 2022; **Accepted**: February 5, 2022; **Published**: February 16, 2022

Abstract: The physicochemical study in water of the springs of Ichuña, Moquegua, Peru had as objective to know the quality of water by the direct use and supply of the population, in agriculture and livestock, this town has mineral resources such as; Gold, copper and silver, which are extracted by mining industries at the head of the basin also for their stratigraphic characteristic constituted by: the Yura, Puno, Tacaza and Barroso Group which have volcanic conglomerate and crust of tectonic origin. This activity offers economic benefits, environmental and public health problems arising from the direct and indirect impact of these activities. It was determined the concentration of heavy metals (Pb, As, B and Cd) in the springs of; Mauri, Humalzo, Totorani. Using thee National Water Resources Quality Monitoring Protocol (R. J. 010-2016-ANA) and Atomic Absorption Spectrophotometry (AAS). The following results were obtained; in Mauri: Arsenic 0.08 mg / L, in Humalzo and Mauri: Boron 2.42 mg / L and 0.857mg / L, in Mauri and Humalzo: Lead 0.02 mg / L and 0.017 mg / L and in Mauri, Humalzo and Totorani: <0.003 mg / L. The average pH is 8.0 and the heavy metals are; Arsenic, Boron and Lead in water from Ichuña springs over the Water Quality Standards of Peru and Cadmium are very low.

Keywords: Arsenic, Boron, Lead, Quality, Geomorphology, Heavy Metals

1. Introduction

The district of Ichuña is located in the northeastern area of the Province of Sánchez Cerro, which in turn is located in the northern part of the Moquegua region and in the Western Cordillera of Southern Peru [11]. The study area shows similar socio-economic characteristics to other high-Andean areas of the country: low per capita income, widespread poverty, low levels of nutrition and education, limited urban development, restricted access to basic services in communal areas, limited accessibility road, and relative isolation from local and regional markets.

The hydrography of the Ichuña leaf is subordinated to the Tambo River that crosses the quadrangle from North to Southwest. The Tambo originates in the neighborhoods of Arapa due to the confluence of the Ichuña and Paltuture rivers, which enter through the east and north sides of the quadrangle respectively. The type of drainage is generally dendritic with some exceptions. For example, in the Northwest part of the leaf, corresponding to the Pampas del Solitario, Confital and Patapampa, the drainage is anarchic, and in the Southeast corner (basin of the Jatonejo gorge) the drainage resembles a reticulated design, because of a structural control possibly due to parallel levees [14].

The Ichuña river being part of the upper Tambo basin has great importance for the development of all the activities of the communities that use the water; It has also been for many years of economic value for these populations, using it for human consumption, livestock, agricultural activities, and ecosystem conservation, among others [16].

Springs or groundwater are the primary water source for the population, this causes the water quality to be at risk, due to the cumulative process of pollution generated by populations settled along the riverbed; This pollution is caused by activities of the population such as agriculture, livestock [1], effects of small-scale mining activities developed in the headwaters of the basin also by the characteristic of the tectonic crust. These springs from the springs are captured and consumed directly by the residents causing the deterioration in their health [3, 5].

However, Ichuña has natural wealth that translates into development potentials and at the same time will cause adverse impacts [8]. The most important thing, in economic terms, lies in its mining resources. There are mining companies in operation and in the preliminary stage of operation of gold, copper and silver in the area. This activity offers potential economic benefits, but also environmental and public health problems arising from the direct and indirect impact of the activities of this type of industry.

Water analysis is widely used as an environmental indicator to assess the extent of pollution in an aquatic system, which continuously interacts with sediments. Water as a receiver and possible accumulator of pollution [7, 8], behaves as a reservoir of contaminants. The mobilization and availability of components depend on physical, chemical and biological processes. This study focused on determining the concentration of heavy metals, physical, chemical and organoleptic parameters present in the aquatic systems of the Mauri, Humalso and Totorani springs since these sources are those that mainly supply the communities of the District of Ichuña.

2. Study area

2.1. Physiography

The physiography of Ichuña corresponds to a watershed division where fluvial, fluvioglacial and tectonic geomorphological processes have been identified. The mountain system is characteristic of a strongly rugged mountain slope, its system of hills and hills are high and medium hills, also low hills and rolling hills. They are of high Andean plains moderate and strongly dissected. It has a fund of alluvial and fluvioglaciar valleys, also with a valley in the canyon phase [14].

From bottom to top its stratigraphic column is constituted by: the Yura Group of the Upper Jurassic-Lower Cretaceous; the Matalaque volcano of probable Lower Cretaceous age; the Puno Group of the late Cretaceous Upper than the Middle Tertiary, composed of the following units: Ciguaya conglomerate, Pichu formation, Tolapalca volcano and Quemillone formation; the Tacaza group, from the middle to upper Tertiary; the Maure group, composed of a lower lacustrine part and a volcanic upper part (Sencca tufos), of the upper Tertiary; the Barroso group composed of the volcanic Chila and Barroso, from the Pleiocene-plio; and finally the recent spills and ashes of the volcanic Ubinas [14].

2.2. Geomorphology

The Geomorphologically Ichuña is located northeast of the Moquegua Region on the western flank of the Western Andes Mountain range, where highland areas are also identified. The area has a variety of lithologies that correspond to stratigraphic litho units, whose origin ranges from Paleozoic to tertiary, as well as quaternary coverage. A determining pattern at the regional level corresponds to the presence of the Puna surface, which has been formed during the Tertiary period as a consequence of the Andean orogeny [8]. This area has also been strongly modeled by glacial erosion during the Pleistocenic period, which has defined the morphology of the undulating plains and during the Halocene period, by the erosive action of the rivers, mainly those belonging to the Pacific basin.

The study area corresponds to two regional geomorphological units; the unit "Mountainous slope and steep to steep hill" and "Wavy plateau" both of the High Andean Region [11].

The main drainage is the regional level of the Ichuña, Crucero and Jayumayo rivers. The Ichuña River runs from east to west. The River Cruise that will later be part of the Ichuña River runs from south to north and then from east to west. The Jayumayo River runs from north to south. All of these will make up the Tambo River basin [8].

The geomorphology of the high-tambo basin in the area are the Andean valleys, such as Ichuña, with a height of less than 3,900 m.a.s.l., are places where erosion processes occur, and therefore flooding and accumulation of materials. The erosion is mainly vertical, whose agent is the water through the rivers causing in some cases small landslides and very local settlements, also accumulating polluting particles in its route [16].

The geomorphological process comes from the dominant internal or external geological process responsible for the origin and development of the geoforms. Geomorphological processes can be classified as: Fluvial, glacial, fluvioglaciar, periglacial, lacustrine, tectonic, volcanic, mass removal, coastal marine by dissolution and wind.

According to U.S. EPA, [6]. Under certain physical and chemical conditions, the concentration of heavy metals can have adverse effects on the biota which would serve as a bioindicator, as well as transferring toxic compounds along the trophic chain by bioaccumulation [1].

Calmano, [4]. The natural mobility of heavy metals in soils is a consequence of biological activity, solid-liquid interactions and the action of water.

A survey was conducted to assess the perception of the population with regard to drinking water, resulting in a disapproval of drinking water by the population which claims for the installation of a water purification plant. In this sense, this study will favor the generation of data on the quality of water that is possessed in the springs that supply the district of Ichuña and in turn are tributaries of the upper Tambo basin, it is very important to have a greater vision in the levels of treatment that should be applied to the resource for both human consumption and agriculture in our region.

According to the current environmental regulations in our country, it tells us that water is an essential element for living beings. In this study we take as reference the Environmental Water Quality Standards (ECAs), (D. S. No. 004-2017-MINAM), General Environmental Law No. 28611.

3. Materials y Methods

For the present investigation it was considered to study the springs of; Mauri, Humalzo, Totorani and apply the methodology of the National Protocol for Water Quality Monitoring (Headquarters Resolution 010-2016-ANA) [2], water samples were taken at the surface level and the respective parameters indicated in said law as dissolved oxygen, T (°C), pH and conductivity respectively, as well as the determination of the heavy metals studied (Pb, As, B and Cd).

3.1. Location

The project was carried out in three springs belonging to the Ichuña district located in the Northwest and West zone of the Ichuña leaf belong to the Arequipa region and the rest to the General Sánchez Cerro province, of the Moquegua region. The extension of the district of Ichuña is 3025 km^2, it is one of the largest districts of the province. Although part of the same district, Ichuña is divided into two marked topographic zones: the upper zone and the lower zone. The upper zone is characterized by being arid, with little vegetation and in the process of desertification, while the lower zone has greater access to water and a less rugged climate.

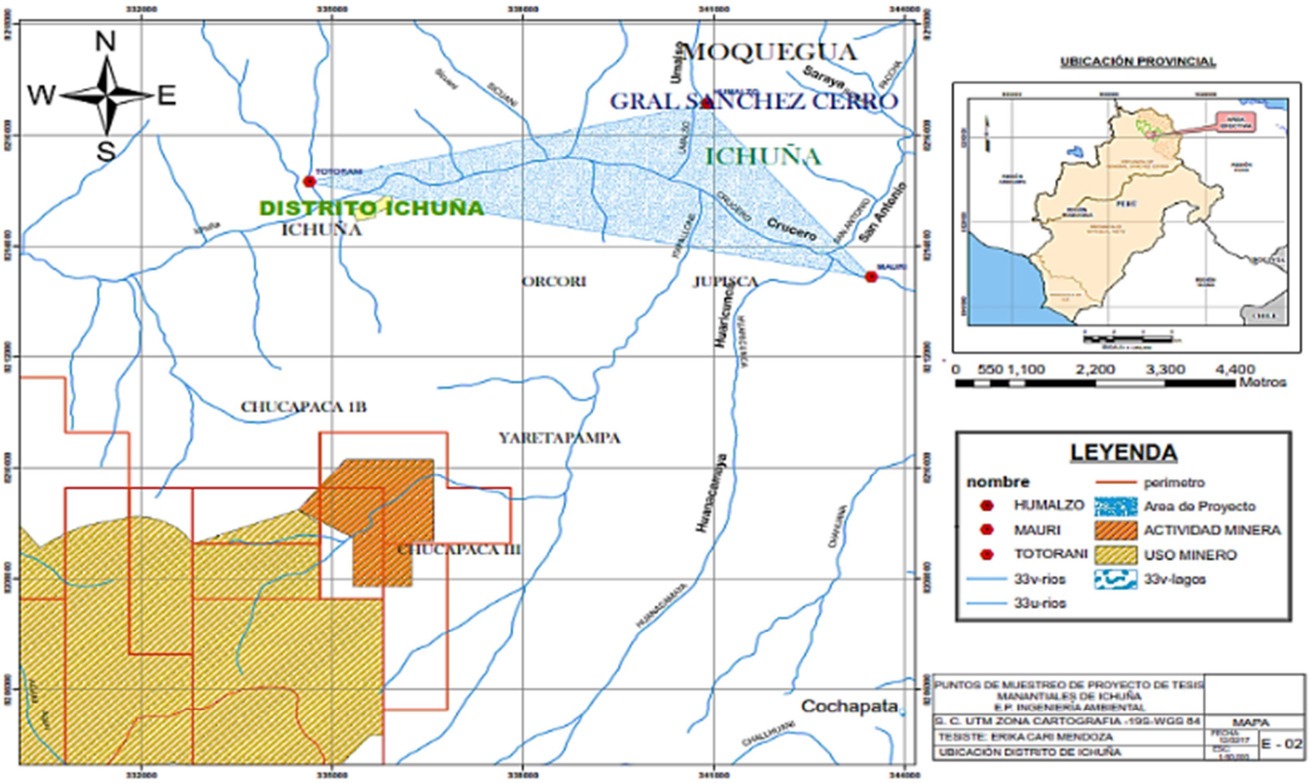
The district of Ichuña has a strategic location as it is close to the regions of Puno and Arequipa [9]. The district of Ichuiña is located between the geographical coordinates; 71° 00´ and 70° 30´ west longitude and 16° 00´ and 16° 30´ south latitude; at a height of 3750 m.a.s.l.

Table 1. *Location of monitoring.*

SPRINGS	POINTS	SAMPLES	LOCATION BY CORDINATES DATUM WGS89				HEIGHT
			UTM		GEOGRAPHICAL		
			EAST	NORTH	SOUTH	WEST	METERS
MAURI	P1	P1 - M1 DBO_5 P1 - M2 Heavy Metals	19K 0344701	8212953	16°09'31.6"	70°27'09.1"	3856
HUMALZO	P2	P1 - H1 DBO_5 P2 - H2 Heavy Metals	19K 0340888	8216583	16°07'32.6"	70°29'16.6"	3919
TOTORANI	P3	P3 - T1 DBO_5 P3 - T2 Heavy Metals	19K 0344704	8216826	16°07'23.2"	70°32'44.6"	3995

3.2. Sample Size

The type of sampling of the present investigation is of probabilistic method for convenience according to W. Creswell. Since the main sampling points are sources of water for human consumption. The sampling period was carried out during the summer, autumn-winter and spring season of 2017. Water samples were collected in bottles of volume 1000 ml. The frequency is quarterly during the four seasons, performed each sampling the same day. The sample was taken in the center of the springs in all cases a simple sample.



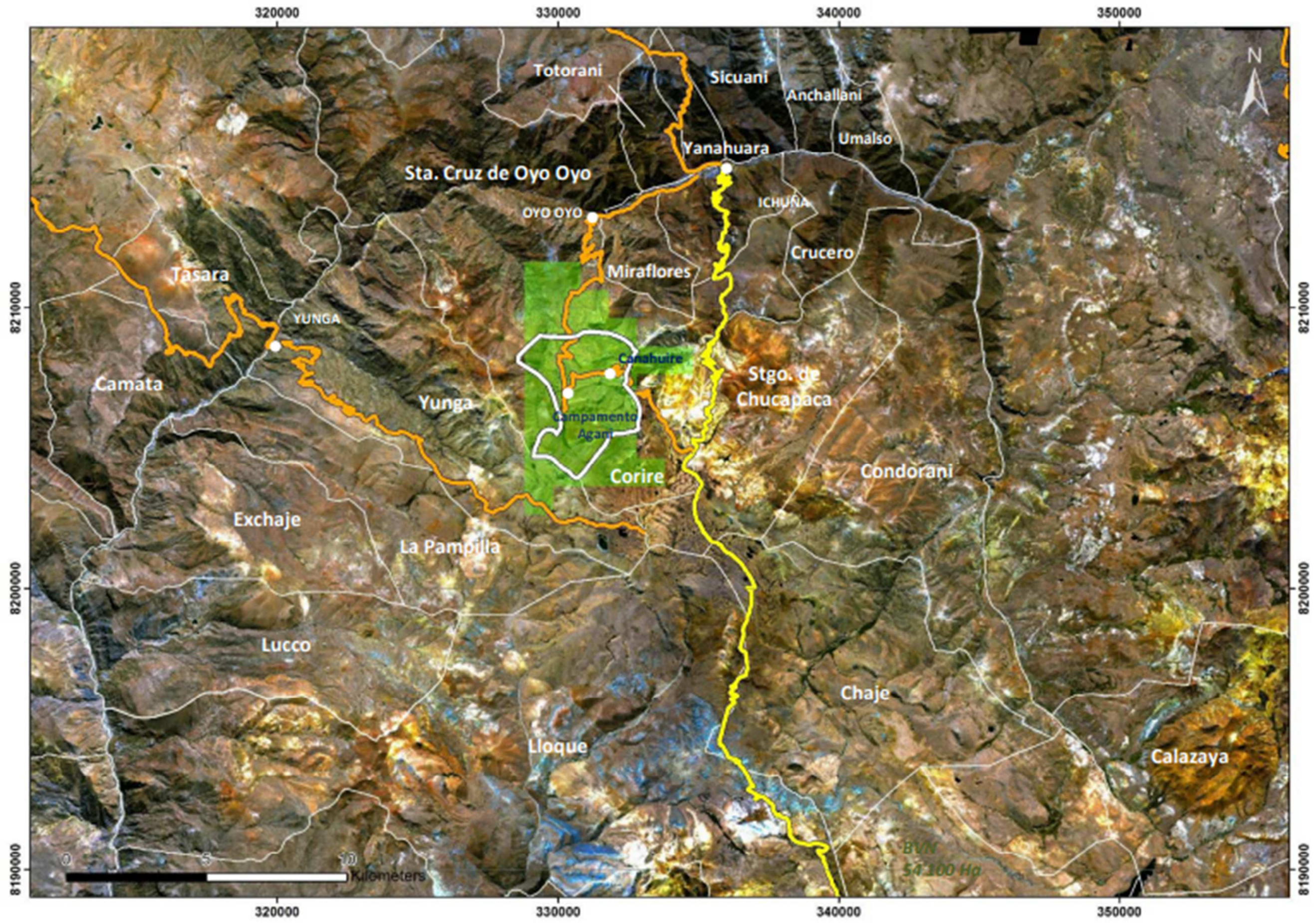


Figure 1. *Water map of the Ichuña springs.*

3.3. Instruments

For the determination of the concentration of heavy metals such as Pb, As in mg/L and was performed through atomic absorption spectrophotometry (EAA), PERKIN ELMER "AANALYST 3100". Which is an analytical method of choice for the analysis of traces of heavy metals and metalloids in various matrices [15, 17]. Likewise, the UV-Visible spectrophotometry method based on the extraction of boric acid with 2-methyl-2,4-pentanediol in MIBC from hydrochloric solutions [10]. The determination of B and Cd is performed by UV-Visible spectrophotometry. In the laboratories of LABINVSERV of the National San Agustin University of Arequipa.

4. Results

After Result of the water quality in rain times of the points in table 1, in the summer season.

Table 2. *Physicochemical parameters of water quality.*

FIELD CODE	SAMPLING POINT	UNIT.	BOD_5	UNIT.	COD	(As)	(B)	(Pb)	(Cd)
P1 - M1 DBO_5	MAURI		52.19		141.03				
P1 - M2 MP						0.020	0.420	0.011	0.003
P2 - H1 DBO_5	HUMALZO	mg/L O_2	10.56	mg/L (ppm)	29.50				
P2 - H2 MP						0.0077	2.09	0.008	0.002
P3 - T1 DBO_5	TOTORANI		8.89		22.80				
P3 - T2 MP						0.0068	0.460	0.005	0.002

Result of water quality conditions in table 2, for the dry season in the autumn and winter season; the climatic characteristics change abruptly showing strong winds and temperature below zero.

Table 3. *Physicochemical parameters of water quality.*

FIELD CODE	SAMPLING POINT	UNIT.	BOD_5	UNIT.	COD	(As)	(B)	(Pb)	(Cd)
P1 - M1 DBO_5	MAURI	mg/L O2	48.00	mg/L	146.82				
P1 - M2 MP						0.019	0.85	0.027	0.003

FIELD CODE	SAMPLING POINT	UNIT.	BOD_5	UNIT.	COD	(As)	(B)	(Pb)	(Cd)
P2 - H1 DBO_5	HUMALZO		27.49		95.23				
P2 - H2 MP						0.0071	2.32	0.023	0.002
P3 - T1 DBO_5	TOTORANI		20.78		91.26				
P3 - T2 MP						0.0068	0.460	0.009	0.002

Result of water quality conditions in table 3, for spring season; the climatic characteristics are changing showing frosts, strong winds, temperature below zero and occasional rains.

***Table 4.** Physicochemical parameters of water quality.*

FIELD CODE	SAMPLING POINT	UNIT.	BOD_5	UNIT.	COD	(As)	(B)	(Pb)	(Cd)
P1 - M1 DBO_5	MAURI		18.05		57.00				
P1 - M2 MP						0.0137	2.85	0.022	0.002
P2 - H1 DBO_5	HUMALZO	mg/L O_2	13.04	mg/L	42.08				
P2 - H2 MP						0.0071	2.32	0.023	0.002
P3 - T1 DBO_5	TOTORANI		12.04		38.50				
P3 - T2 MP						0.0132	0.50	0.012	0.002

Average physicochemical conditions of the water quality of the sampling points compared to the National Environmental Quality Standards for water, with an average annual water flow of 3.2 L/s.

***Table 5.** Physicochemical parameters of water quality.*

SAMPLING POINT	HEIGHT m.a.s.l.	HUMIDITY	ENVIRONM. TEMP.	WATER TEMP.	CONDUCT. (µS)	DISSOLVED OXIGEN
MAURI	23834	25%	15°C	10°C	0.83 µS	4.82 ppm
HUMALZO	23836	22.5%	18.2°C	10.6°C	0.64 µS	6.56 ppm
TOTORANI	23838	29.5%	7.9°C	11.23°C	0.17 µS	5.49 ppm

***Table 6.** Physicochemical parameters of water quality V.S. ECAs.*

SAMPLES		M1 - BOD_5	M1 – COD	As	B	Pb	Cd	pH
MAURI		39.41	114.95	0.08	0.857	0.020	0.003	7.78
HUMALZO		17.03	55.603	0.0095	2.42	0.0177	0.002	8.08
TOTORANI		13.903	50853	0.0089	0.473	0.0087	0.002	8.16
	C1-A1 2008	3	10	0.01	0.5	0.01	0.003	8.5
	C1-A1 2008	5	20	0.01	0.5	0.05	0.003	9.0
	C1-A3 2008	10	30	0.05	0.75	0.05	0.01	9.0
	* C1-A1 2015	3	10	0.01	2.4	0.01	0.003	8.5
ECAs	*C1-A2 2015	5	20	0.01	2.4	0.05	0.005	9.0
	*C1-A2 2015	10	30	0.15	2.4	0.05	0.01	9.0
	#C1-A1 2017	3	10	0.01	2.4	0.01	0.003	8.5
	#C1-A2 2017	5	20	0.01	2.4	0.05	0.005	9.0
	#CA-A3 2017	10	30	0.15	2.4	0.05	0.015	9.0

The Biochemical Oxygen Demand (BOD_5) and the Chemical Oxygen Demand (COD) exceed water quality standards in all categories of use, BOD_5 > 8 ppm of O_2 is considered contaminated water. The average biodegradability index (BOD_5/COD) is 3.21 means that the contaminants are biodegradable.

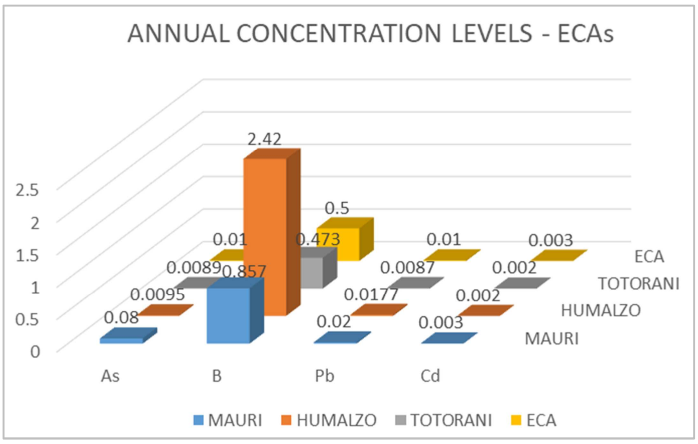


***Figure 2.** Annual concentration levels of heavy metals.*

5. Discussion

The level of arsenic concentration in the summer season where there is a higher rainfall shows that the levels exceed the permitted by ECAs [13, 12] also in the autumn and winter seasons are kept below what is allowed. The concentration of Boron exceeds the ECAs according to table 5, in the spring season where only occasional rainfall is recorded, it is also evidenced in similar scenarios such as the study in the Duero River basin [18].

Lead concentration slightly exceeds ECAs for category C1-A1 according to graph 1 for waters that can be treated with disinfection. Cadmium levels are below the ECAs, according to graph 1, it is observed that the concentration increases slightly in summer and spring where there is the presence of rainfall.

Groundwater quality is usually constant over time; however, changes in hydrogeological conditions and geomorphology can cause differences in water quality [3] over a relatively short distance. Groundwater chemistry is influenced by the composition of the aquifer and by the chemical and biological processes that occur when water infiltrates through the aquifer [5], added by anthropogenic processes.

6. Conclusions

The population of Ichuña is divided into 11 communities, the center of Ichuña being the largest community of 4006 families of 27% of the families and the second community with the largest number of families is Santa Cruz de Oyo Oyo with 150 families [9]. The rest of the communities are significantly smaller and the number of families ranges from 55 families.

According to Boron concentrations, they exceed the Environmental Quality Standards (DS-004-2017-MINAM) for water of category 1: Population and Recreational, in the three subcategories having a high content of this significant metal an imminent health risk of the general population.

High levels of Boron concentration at the Humalzo point (P2) exceeds ECA by 400% of subcategory A1. It is presumed that it is due to the geomorphology and tectonic presence of the area, this spring supplies the population of the capital of the district of Ichuña and the annex of Humalzo, which represents 80% of the total population.

The concentration of Arsenic exceeds the ECAs in Mauri (P1), in categories 1 and the three subcategories, possibly due to its geomorphology and presence of a thermal source in the upper part of the area.

Lead concentration levels exceed ECAs at the Mauri (P1) and Humalzo (P2) sampling points; in category 1 and subcategory A1, 100% and 77% with respect to the established base.

Cadmium levels are almost below the ECAs established in the three sampling points, having a deviation from the concentration increase in the dry season (autumn-winter).

The presence of these trace metals in the water is due to the geology and geochemistry of the area that together with the large hydrographic presence cause these metals to dissolve and leach. Also due to the movement of soils carried out by mining industries in the area.

The levels of BOD_5 and COD are above the established ECAs, with greater significance at the point of Mauri (P1), due to the direct entry that exists in times of avenue, increasing the flow and therefore generating more oxygen and greater degradation of organic matter by natural damping of water, the COD is due to the oxidative force of the liquid due to the movement of water in times of avenues.

Acknowledgements

Thanks for their support to the research to Dr. Washington Zeballos Gamez and Dr. Alberto Bacilio Quispe Cohaila of the National Moquegua University and to Ruth Begazo Guillen of the chemical laboratory of LABINVSERV UNSA.

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