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Hot springs, Heat discharge and Arsenic concentration in Chacana Caldera, Ecuador

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ABSTRACT

Hot springs related to the Chacana Caldera in Ecuador are located in several areas in and out of the caldera border. Physical and chemical characteristics indicate that hot springs are high salinity (>7100 µS/cm) and alkali-chloride secondary geothermal fluids with surface temperature from 59 to 73°C, so it is assumed a possible geothermal reservoir at subsurface in the south of caldera. The other hot springs in Chacana are carbonate fluids and mixed with ground water (high Mg) typical of peripheral areas in a geothermal system. Currently, some hot springs are restricted to direct use for bathing resorts, balneology and swimming pools in Chacana. However, this represents a small amount of energy that Chacana releases considering the hot spring flows. The total flow rate of thermal water is 113 [l/s], and it represents 18.5 MWt, which is the minimum heat discharge. On the other hand, the thermal water has an average As concentration of 4.024 [mg/l], which is pouring naturally per second into the Jamanco river basin. It means around 3 tons of As per year and 757 tons of As accumulated in water and sediments of Papallacta lake located in the lowest part of the river basin. Jamanco and Cachiyacu are currently geothermal pre-feasibility prospects in the south of the Caldera, so this information has to be considered like an environmental and social problem by the main authorities and local communities.

1. INTRODUCTION

The Chacana Caldera is part of the rhyolitc province in the north of the Andes, and it is a potential geothermal field due to its recent volcanic activity. New geological, geochemical and geophysical data indicate geothermal anomalies in the southern part of Chacana related to a possible geothermal resource.

First expressions of this resource are hot springs related to hydrothermal alteration and expansive tectonic. There are several hot springs located in an out of Chacana Caldera border (Beate et al., 2011). It is stated that meteoric water infiltration during the extensive period in a caldera can establish a geothermal field, and its expressions are hot springs at surface (Henley y Ellis, 1983). Thus, hot springs give important chemical information to analyse the present status of the geothermal potential stored in Chacana.

In addition, most of the chemical analyses from hot spring indicate important concentration of trace and harmful elements like arsenic (As) in geothermal systems. This is an extremely toxic element for the human organism. The exposure during a long period to low relative concentrations of arsenic (for example by ingestion of water) has chronic negative effects on health Therefore, Arsenic constitutes a great threat to health for being used for consumption from susceptible surface waters (rivers, lakes, reservoirs) and groundwater (aquifers) (Lillo, 2003).

Jamanco and Chachiyacu areas are located in the south part of Chacana, and these are the main part of the Chacana Geothermal Project in charge of CELEC EP. Thus, knowledge about the status of the hot springs is important in order to advertise to the main and local authorities about the natural pouring of arsenic in the hydrological net in Chacana. This research provides data about the heat discharge in Chacana Caldera using field measurements of natural flow of hot springs, and data about the amount of arsenic that is poured into the El Tambo hydrological basin.

2. GEOLOGICAL BACKGROUND

Continental Ecuador is divided into three physiographic provinces: the Andes, the Oriente, and the coastal zone. The Ecuadorian Andes represent a 650 km-long and 150 km-wide segments of the great Andean mountain chain. This consists of in two parallel mountain ranges, which are the Western or Cordillera Occidental and the Eastern or Cordillera Real. These two cordilleras have average elevations of 3500–4000 m above sea level, upon which are built most of the volcanoes whose summits reach up to 6000 m; they are separated by the intervening structural depression (2000– 3000 m in elevation), known as the Inter-Andean Valley. The western and eastern outer flanks of the Andes, densely covered in vegetation, descend steeply to the western coastal plain and the Amazon basin, respectively (Hall et al, 2008). These physiographic provinces are the result of a convergence plate border. The interaction among South American, Cocos and Nazca plates control the cortical deformation, the high seismicity and the volcanism in the North-Andean Block (Figure 1).

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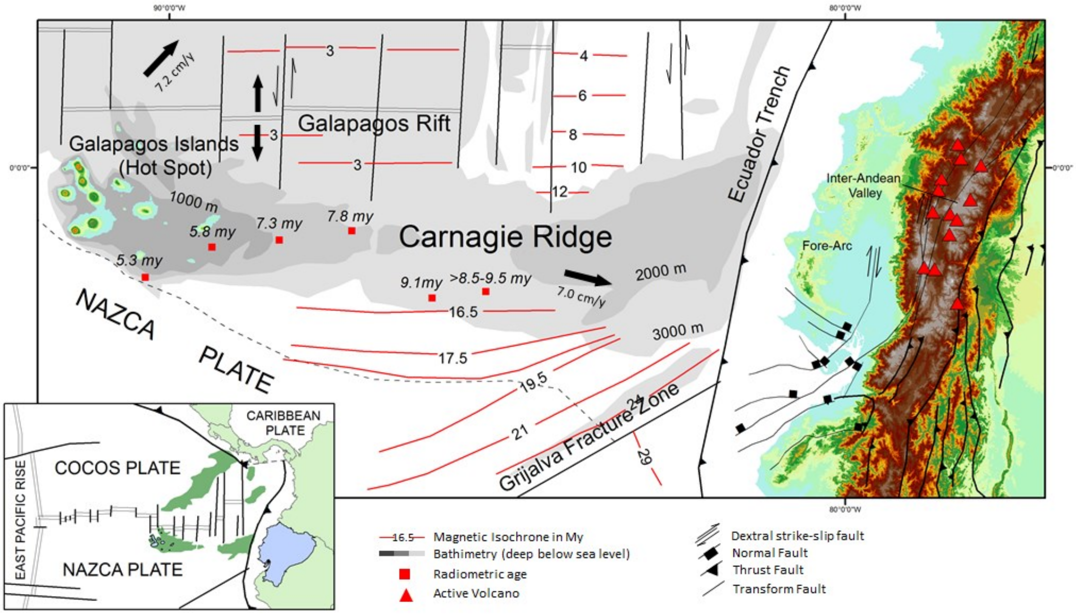

Figure 1: Geodynamical Setting Geodynamic Setting of Ecuador, showing mainland Ecuador on the South American plate and the Galapagos Islands on Nazca plate. (Redrawn after the Plate Tectonic Map of the Circum-Pacific Region - 1981 and modified from Spikings et al., 2001).

Ecuador is a small Andean country with an impressive volcanic arc hosting many active and potentially active volcanoes. Four of these volcanoes have erupted repeatedly since 1999, and dozens more have been identified as being potentially active (Hall et al, 2008). Late Pliocene to present-day volcanism manifests itself along four linear groupings, each having a characteristic morphology, eruptive style, and petrographic and chemical diversity.

Recently a big rhyolite province (region characterized by unusual volcanic rocks rich in silice) has been discovered upon Eastern Cordillera which volcanic chain with 25 km of length is formed by andesitic volcanoes like Cotopaxi and Tungurahua. This volcanic province has three caldera structures and other volcanic centres. The Chacana volcanic complex is the northern and oldest rhyolitic province (Figure 2).

Chacana Caldera is located immediately in the east of Quito upon the Western Cordillera. This Pleistocene volcanic complex measure 50 km length (N-S) and 30 km width (W-E) and has been active until the historical period. Resurge period has occurred between 1.5 to 0.44 Ma, and it was followed by explosive eruptions that placed rhyolitic products dated 210 thousand years ago. There are also volcanic eruptions dated between 180 – 165 thousand years ago. Some lava flows has been identified in the last 40 thousand years being the Papallacta lava flow the last one and dated in 1760 AD.

This lava flow is an important feature in the hydrology basin in the lowest part in Jamanco, for it has blocked the normal flow of the Tambo River, and formed the Papallacta Lake. The Chacana Caldera has many hot springs at different locations related to the recent volcanic activity in an out of the caldera border.

3. CHACANA HOT SPRING LOCATIONS

3.1 Hot Springs Inside of the Chacana Caldera Border

<u>3.1.1 Jamanco Area:</u> Hot springs in this area are located between 3600 to 3400 meters above sea level (masl) in the central - south zone of Caldera de Chacana. The accessibility to these springs is through the Interoceanic Quito-Papallacta highway that runs parallel to the Tambo (Figure 3).

<u>3.1.2 Cachiyacu Area</u>*:* Hot springs are located in the Cachiyacu valley where the Tambo River rises. The hot springs are widthspread in an approximate area of 0.3 km^2 in the southern part of the caldera at 4000 masl. The access is a 5km trail named "Route of the Cóndor".

<u>3.1.3 Papallacta Area:</u> There are several hot springs in the Papallacta valley. Here is located a well-known tourist centre "Termas Papallacta" in the central-east zone of the Chacana Caldera at 3280 masl. First, the access is through the Interoceanic Highway, and after that a road from Papallacta town to the north has to be taken. This area is relative close to Jamanco and Cachiyacu, and it is reached in 2 hour from the capital city Quito.

<u>3.1.4 Oyacachi Area:</u> This is also a touristic centre on the northeast part of the caldera at 3171 masl located in the Oyacachi native village. The access is a second-order-road on the north flank of the caldera and takes about 3 hours from Cayambe the closet population centre.

<u>3.1.5 Salve Faccha Area:</u> This area is located in the Northwest zone of Caldera de Chacana between 3970 and 4010 masl. Hot springs are located in moraine outcrops next to the Salve Faccha Dam. Some of the hot springs are cover by the water level of the dam. The access is a second-order-road through Salve Faccha moorland from the Oyacachi village entrance.

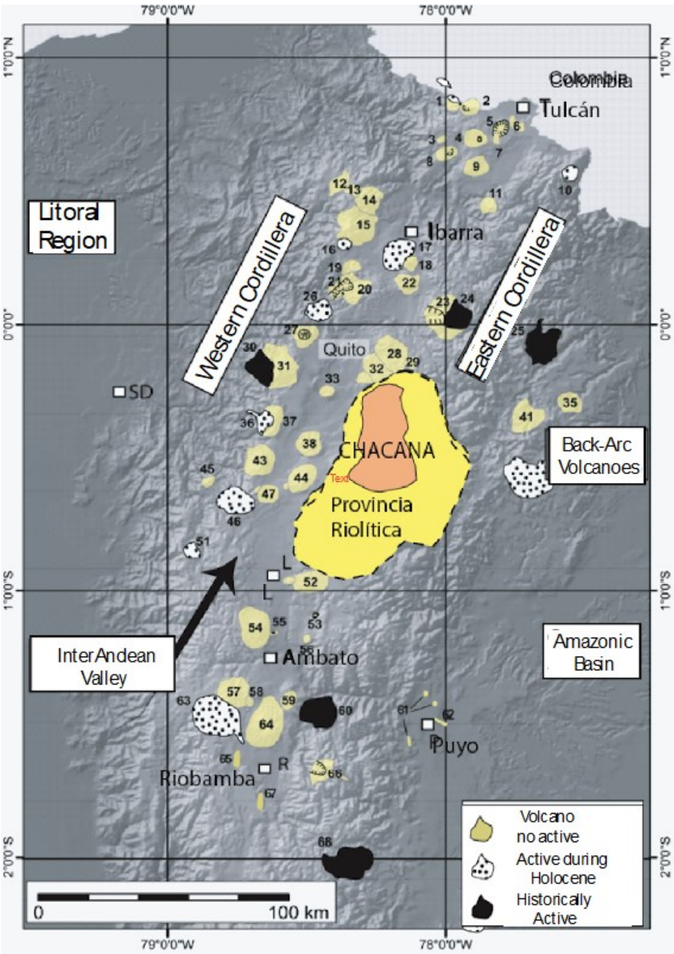

Figure 2: Distribution of Ecuador's continental volcanoes along two principal axes that show Chanaca Rhyolitic Complex (Hall et al, 2008).

3.2 Hot Springs Outside of the Chacana Caldera Border

3.2.1 Guachalá – El Pisque Hot Springs: This is a small resort located at 2630 masl and 19 km out from the caldera border and 700 metres from the equator line on the Quito-Cayambe highway.

3.2.2 Calera de Tolontag Hot Springs: These are located about 4.5 km in the East of Tolontag village on the west flank of the Chacana volcanic complex. The access is a summer-weather road.

3.2.3 El Lisco Hot Springs: These are located in the Lisco River 11 km southwest of the Cachiyacu area at 3458 masl. The access to the hot springs is by the main highway, which runs through Pintag, La Cocha-Secas and El Peñón del Lisco villages.

3.2.4 La Merced, Ilaló and El Tingo Hot Springs: These are very popular spas located at the southern of Ilaló Mountain on the western flank of Caldera de Chacana. The vial net across the Tumbaco valley is the main access to these hot springs. All location mentioned above are summarized in the figure 4.

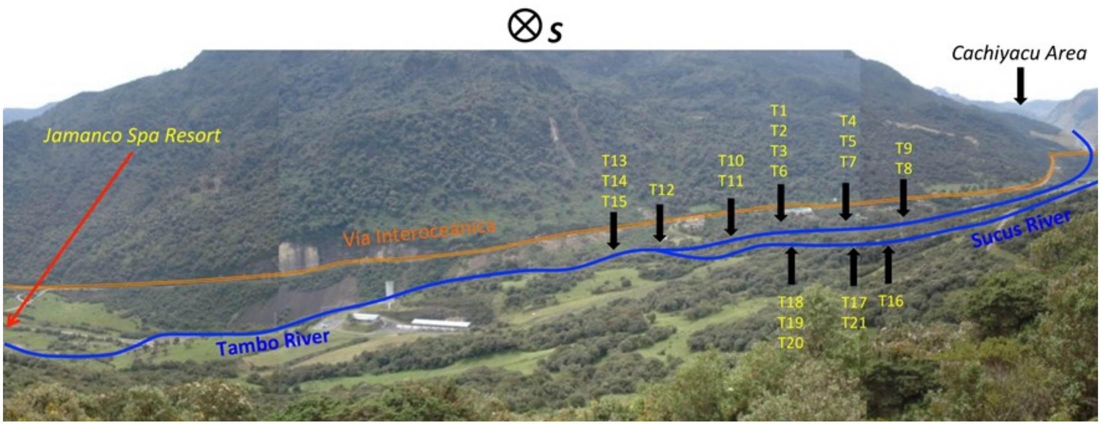

Figure 3: Location of hot spring in Jamanco Area.

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4. METHODOLOGY

The present study is based on collecting information, field observations, hot spring sampling, chemical analysis and mathematic calculations to reach the aims of this investigation.

Collecting information included a deeply revision of available national and international papers and unpublished information based on chemical report of the hot spring and groundwater in the Chacana Area. Sampling hot springs and field observations were obtained during the last week of August 2011. The physical characteristics were measured from the all hot springs and surface water by pH-Temperature meter field device. It was calibrated at the Geophysical Institute of the Polytechnic School of Quito (EPN). The rate flow of hot springs was measured by volumetric method using a scale plastic bucket, chronometer, and PVC pipes.

It was taken 4 different samples from the hottest and flow representatives to analyse cations, anions, trace elements and Deuterium and Oxygen isotopes. (This study only considers the anions and the arsenic concentrations – Appendix 1). The analysis was fulfilled at Palermo National Instituted of Geophysics and Volcanology in Italy. After the analysis, the lab results were plotted in ternary diagrams to determine which type of geothermal fluids Chacana hot springs belong.

The heat discharge was calculate using the Head Added formula states as follow:

$$Q = m \times Cp \times \Delta T \qquad \text{(eq. 1)}$$

Where:

Q = Head Added
m = mass [kg] (for this case it was used the density and volume of the geothermal water)
Cp = Specific Heat [kJ/kg°C] (estimated by water temperature values - www.vaxasoftware.com)
ΔT = Temperature variation between hot spring and surface/atmospheric temperature [°C]

The total Arsenic accumulated in the Papallacta Lake was determined using the Arsenic concentration from the lab results and the rate flow of the hot springs. It is important to mention that no all the hot spring has chemical analysis; thus, it was used a concentration average calculated from hot springs which presented analysis. In addition, this analysis was focus only in Jamanco and Cachiyacu area like a part of the Chacana Geothermal Project.

5. RESULTS AND DISCUSSIONS

5.1 Physical and Chemical Characteristics

The hot springs in Jamanco area have the highest temperature (72.9°C). In contrast, the lowest temperatures were recorded at Salve Facha area (6.8 to 16°C). However, previous information states 49.1°C in Salve Faccha (Mothes y Beate, 2002). Similar temperatures were recorded in Cachiyacu and Papallacta areas (63.6 and 62.3 °C respectively). Hot spring temperatures outside on the flank of the caldera are relative lower than inside of the border. These vary from 27 and 42 °C (Figure 4 – Appendix 2).

The conductivity of hot spring reaches values 7100 µS/cm inside of the caldera, but it is similar to surface water (150 µS/cm) in Salve Faccha area. The high conductivity indicates both high salinity and high NaCl concentration as a primary fluid from a deep reservoir. The pH of all hot springs varies from 5.9 to 7.6 analogous to measurements of local water bodies (Annex I). It means interaction with ground water at shallow depths.

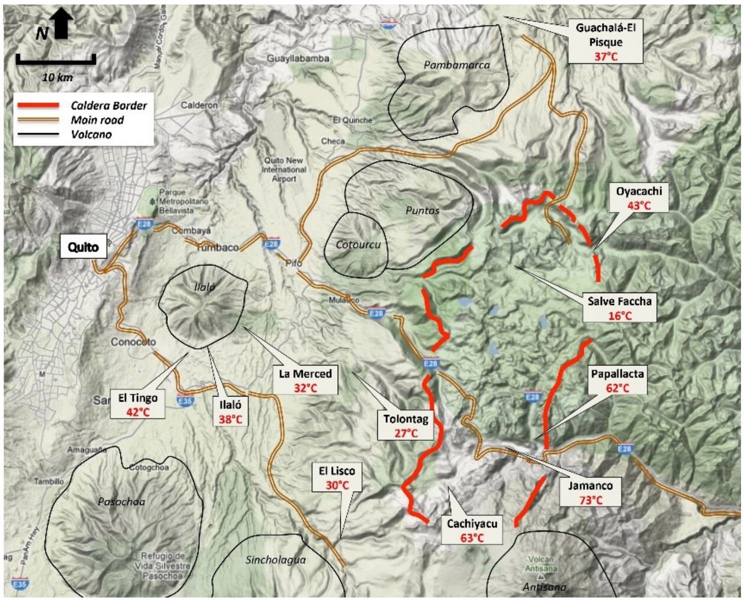

Figure 4: Highest Temperatures of hot springs located in and out of the Chacana Caldera border. (Right) Cl-HCO3-SO4 diagram of Chacana hot springs.

In accordance with Cl-HCO3-SO4 diagram, there are three main groups of water in Chacana. The Jamanco and Cachiyacu hot springs are alkaline-chloride water. These are typical for alkaline hot springs, and they probably come from lower part of the geothermal field where the NaCl fluids dominate and CO2 buffers the pH. Papallacta hot springs are acid-sulphate-chloride water typical for acid sulphate fluids with a magmatic origin and pH controlled by H2SO4. However, field observations do not show characteristics of acid fluids in Papallacta. Inguaggiato (2010) states that Papallacta hot springs are chlorine-sulphate-alkaline waters characterized by high salinity. The last group involves the remaining hot springs, which are bicarbonate waters for carbonate spring typical of peripheral waters of geothermal systems (Figure 5).

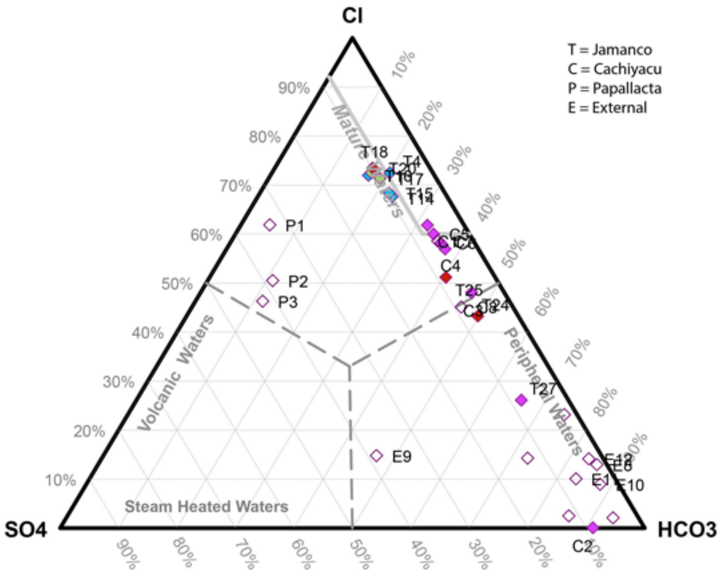

Figure 5: Cl-HCO3-SO4 diagram of Chacana hot springs.

5.2 Heat Discharge and Arsenic concentration

One of the methods for transmitting heat to surface is convection in the Chacana areas. Surface water is infiltrated to the subsurface where it is heated and rises up as hot spring due to the difference of density. This heat added is measured using the equation 1.1.

The total water flow rate from 22 hot springs measured is about 29.3 l/s in Jamanco. It means 6.5 MWt or 0.85 MWe (13% of MWt). However, there are many hot springs not accessible due to topographic location. The same analysis was performed at all hot springs accessible. The total water flow rate from 12 hot springs measured is 7.4 l/s in Cachiyacu. It means 1.3 MWt or 0.7 MWe. The total flow rate in Papallacta is about 21 l/s. Thermas Papallacta Company provided this information. Field reports and own observations state 17 hot springs in Papallacta (CELEC EP, 2017). It means 3.9 MWt or 0.5 MWe. Oyacachi and Salve Faccha have two and three hot springs respectively, and it sums 8 l/s (1.1 MWt). As mentioned above, there are hot springs covers by water of the Salve Faccha dam. The external hot springs sum 46.9 l/s (5.4 MWt). This information is based on previous reports and specific measurements carried out through indivudual field works during this study (Table 1).

The total flow rate of thermal water is 113 l/s, and it represents 18.5 MWt. In addition, it is equal to 39300 barrels of oil. The average closing price of a barrel of oil is 67.22 US dollars in 2018, so the total flow rate in Chacana considering only the thermal water is estimated around 2.64 million US dollars. This value represents an economical loss in past and a reference value for future developments.

Table 1: Heat discharge and electrical potential calculated from flow thermal water of Chacana hot springs.

Area	Total Flow [l/s]	Termal Potential [kJ/s]	Termal Potential [MWt]	ElectricalPotential [MWe]
Jamanco	29.36	6548.47	6.55	0.85
Cachiyacu	7.39	1327.16	1.33	0.17
Papallacta	21.00	3994.39	3.99	0.52
Oyacachi	4.58	639.81	0.64	0.08
Salve Faccha	3.0	562.74	0.56	0.07
External	46.96	5479.44	5.48	0.71
Total	**112,79**	**18552,00**	**18,55**	**2,41**

Currently, some of the hot springs measured are restricted to direct use for bathing resorts, balneology and swimming pools in and out of Chacana Caldera border. This is minimal utilization of the total heat discharge in Chacana (less than 16%, Pilicita, 2013). The Other are pouring naturally to surface forming travertine terraces, and it is assumed other hot springs unknown due to accessibility and the large area that Chacana covers.

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5.3 Arsenic Contamination in the Tambo basin (As)

The trace element analysis from surface water samples show that the As concentration in both Tambo and Sucus rivers (which flow through Cachiyacu and Jamanco areas) varies from 0.333 to 0.099 mg/l (Appendix 1). Surface water samples without As contamination taken from Cachiyacu show 1.95 µg/l of As. Thus, there is an increment of 2 times of As concentration in the water of the rivers. This concentration considerably exceeds the permissible limits of drinking water and agricultural activities (0.05 mg/l) given by both the Ecuadorian Environmental Regulation and the World Health Organization (Guevara, 1996 and T.U.L.A.S., 2003).

The As concentration in thermal water varies from 3 to 6.5 mg/l from 14 hot spring in Jamanco and Cachiyacu. It is estimated an average concentration of 4.02 mg/l of As in each of the remaining hot springs (20). The total flow of thermal water pouring naturally to basin in Jamanco and Cachiyacu is 36.75 l/s (Figure 6). To obtain the average flow rate of thermal water per year, the factor 0.63 is added (Beate and Urquizo, 2015), so the annual flow rate is about 23.25 l/s. Considering these data, the 93.06 mg/s are been pouring to the area, and it means 2.93 tons per year.

Figure 6: Natural pouring of thermal water to Sucus River in Jamanco.

An important geological feature for this analysis is the Papallacta lava flow. It is dated 1760 A.D (Hall, 2011), and it cut the natural flow of the Tambo river in the lower part of the Jamanco area forming the Papallacta Lake. Therefore, the water in the hydrology system of Cachiyacu and Jamanco (mainly Tambo river basin) flows and is captured in the lake (Figure 7). Considering the age of Papallacta lava flow, it is estimated the Papallacta Lake is 258 years old. As a result, the total amount of As in the water and sediments in the Papallacta Lake is 757 tons in the last two and a half centuries.

The population in Tambo village located in the Jamanco area are very depending on tourism activities related to natural hot springs in the area. These include spa services and fish farming using water from the Tambo River and even agriculture activities. It is well known for the local and parish communities that the governmental intention is to establish the Chacana Geothermal Project in Jamanco and Cachiyacu. Currently, parish and local authorities have expressed the support to the project by the local population. However, the heat discharge and arsenic concentration are unknown factors by the stakeholders in the area, and the current problem placed many years ago can be attributed to recent or future activities. Therefore, the timely intervention by the main authorities must be executed base on technical and social information.

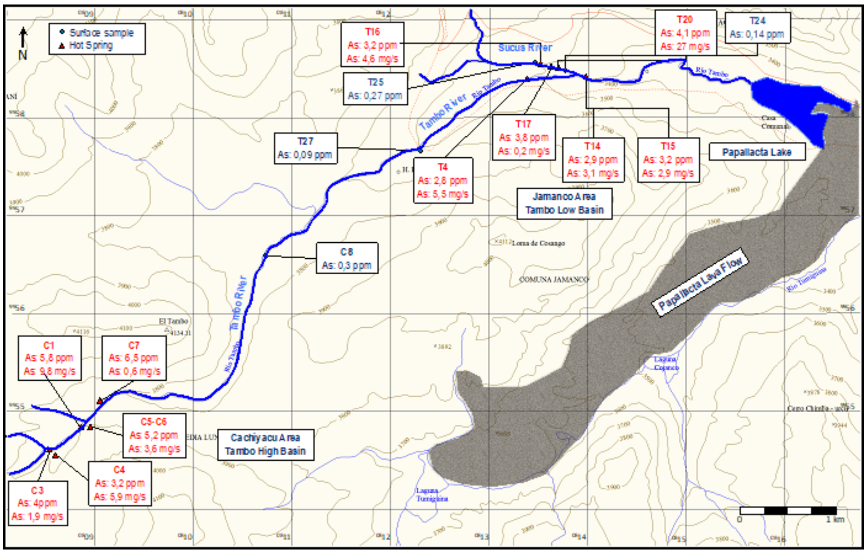

Figure 7: Hydrology basin of Tambo River that shows the Papallacta Lake, the Papallacta lava flow, and As concentrations at different locations.

6. CONCLUSIONS AND RECOMMENDATIONS

The highest temperature of thermal water was recorded in Jamanco (72.9 °C), followed by Cachiyacu and Papallacta (63.6 and 62.3 °C). Oyacachi, Salve Faccha and external hot springs has temperature <40 °C. The conductivity reaches up 7100 µS/cm (relative high NaCl concentration), and the pH varies from slightly acidic (5.9) to slightly alkaline (7.65). Monitoring of hot springs during specific period of time (weekly or monthly) would allow including physic-characteristic variations to heat discharge analysis.

Jamanco and Cachiyacu hot springs are alkaline-chloride waters often restricted to lower parts of geothermal field. Papallacta hot springs are acid-sulphate-chloride waters typical for sulphate fluid and the external hot fluids are bicarbonate-waters characterized by a medium to high salinity and by high total dissolved carbon, probably because of dissolution of CO2 (peripheral waters).

The total heat discharge in Chacana is about 18.55 MWt (2.41 MWe) estimated from 113 l/s of thermal water of Chacana hot springs. It is similar to burn 39300 barrels of oil and 2.64 million US dollars. Thus, it is a referential value to plan future project related to direct utilizations.

The natural contamination source of As in El Tambo hydrology basin is the hot springs. These discharge 93.06 mg/s of As into Tambo River. It is equivalent to 2.93 tons per year, and it means 757 tonnes of As accumulated in the waters of Papallacta Lake since its formation. A deep analysis of water consumption base on an environmental base line has to be handle by the main and local authorities considering the current activities of the local communities in order to figurate the magnitude of the real consumption of As in the area. Precisely and opportunely communications about the current status in Chacana basins can develop real solution and avoid future problems for the local communities and adjacent projects.

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APPENDIXES

Appendix 1: Chemical composition of Chacana hot springs)

Muestra	Localidad	T	Li	Na	K	Mg	Ca	F	Cl	Br	SO_4	HCO_3	δD	$\delta^{18}O$	As
		°C	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l			µg/l
T4	Jamanco	50,7	9	1338	66,3	10,5	231,7	2,1	2190,7	4,8	222,2	610	-82	-11,42	2811
T14	Jamanco	52,4	6,9	1047,7	51,6	11,9	204,8	2,1	1523,9	6,7	211,7	518,5	-84,4	-11,48	2998
T15	Jamanco	49,6	0,7	1072,9	50	8,8	208,2	2,7	1598,8	3,2	221,8	518,5	-84	-11,52	3163
T16	Jamanco	59,3	7,5	1203,5	50	10,2	250,7	2,1	1962,5	4	307,2	457,5	-81,6	-11,63	3167
T17	Jamanco	65,5	8,8	1346,3	63	10,7	237,1	3	2031,1	4	273,1	542,9	-82,9	-11,53	3853
T18	Jamanco	69,6	7,9	1227,7	55,1	9,1	239,9	2,3	2107	5,2	305,3	494,1	-83	-11,7	3767
T20	Jamanco	72,9	9	1393	66,1	10,6	253,1	2,1	2278,4	4,4	303,8	518,5	-83,1	-11,46	4085
T24	Jamanco	10	0,3	50,1	3,9	3,6	18,6	0	68,8	0,2	11	79,3	-82,7	-12	141
T25	Jamanco	21,2	0,6	94,3	5,9	4,5	28,7	0,2	131,3	0	21,6	103,7	-83,6	-11,62	275
T27	Jamanco	9,3	0,1	23,7	3,1	3,3	9,8	0,1	26,6	0,1	8,2	67,1	-84,4	-11,97	99,3
C1	Cachiyacu	63,6	8,9	987,4	88,4	28,9	112	0,8	1358	1,8	137,8	701,5	-89,4	-11,11	5771
C2	Cachiyacu	8,5	1,9	6,2	1,8	7,9	16,4	0,1	0,1	0,2	11,2	115,9	-87,8	-12,35	1,94
C3	Cachiyacu	30,9	4,6	510,8	50	17	153,5	0,6	707,7	1,5	82,1	683,2	-86,7	-11,45	4029
C4	Cachiyacu	38,8	5,9	664,2	61	21,5	104	0,8	911,4	0	90,7	597,8	-82,8	-11,37	3245
C5	Cachiyacu	62,1	8,9	990,2	88	34,5	111	0	1381,8	1,7	141,1	780,8	-82,8	-11,01	5234
C6	Cachiyacu	35,5	8,2	920,3	82,9	31,3	105	0,8	1212,8	0	121	750,3	-83,1	-10,46	3698
C7	Cachiyacu	51,6	11	1220,1	94,6	72,6	133,1	0,8	1727,3	3,4	181,4	1043,1	-85,6	-10,63	6499
C8	Cachiyacu	10,4	7	80,5	8,2	6,4	20	0,1	119,4	0,2	23,3	122	-86,1	-12,07	333
P1	Papallacta	58,9	2,43	546,3	10,2	3,7	311,8	1,8	980,7	3,2	526,2	79,3	-82	-11,8	-
P2	Papallacta	47,2	1,39	310	5,9	2,2	201,2	1,5	496,1	23,2	377,1	109,8	-81	-11,8	-
P3	Papallacta	54,2	1,39	285,6	6,3	1,7	166,2	1,9	404,3	2,4	369	100,6	-80	-11,8	-
E8	Pisque	37	0	347,4	41,8	82,9	36,8	0,6	175	0,8	22,4	1155,5	-95	-13,4	-
E9	Tolontag	27,2	1,94	1136,5	53,5	53	244	3,8	496,8	7,2	1297,1	1576,2	-91	-11,1	-
E10	La Merced	32,5	0	120,5	14,1	54,5	39,6	0,5	60,7	0,8	21,4	597,6	-82	-11,8	-
E11	Ilaló	37,7	0	212,3	26,2	81,6	58	0,6	108,6	0,8	73,3	902,4	-83	-11,9	-
E12	El Tingo	42,1	0	520	27,3	169,9	27,4	0,9	297,5	2,4	52,9	1756,1	-93	-13	-
E19	El Lisco	29,9	0,21	240,7	26,6	68,9	60	0,8	236,1	1,6	21,9	762,2	-96	13,1	-
E5	Papallacta	9	0	2,6	0,8	2,4	16,6	0,1	1,4	0	2,9	62,8	-79	-11,7	-
E6	Papallacta	10,5	0	12,1	1,2	2,4	22,4	0,1	14,3	0	12,9	73,2	-79	-11,7	-
E18	Antisana	7,5	0,07	10,5	3,5	6,1	10	1,1	2,1	1,6	10	73,2	-110	-14,6	-
E17	Oyacachi	7	2,57	989,8	33,2	55,2	98,8	0,8	658,2	0,8	84,3	2012,2	-85	-10,8	-
SF1	Mapayacu	-	-	-	-	-	-	-	1,5	-	24	5	-	-	-
SF2	Tola Alta	-	-	-	-	-	-	-	2,5	-	5	15	-	-	-
SF3	Salve Faccha	-	-	-	-	-	-	-	625	-	60	655	-	-	-

Appendix 2: Physic parameter and heat discharge of hot springs in Chacana.

Sample	Location	UTM WGS 84		Elevation	T	pH	Cond	Flow	Cp	Ta	ΔT	Heat Added
		E	N	m.s.n.m	[°C]		microS/cm3	[l/s]	kJ/kgK	[°C]	T-Ta	kJ/s
T1	Jamanco	813648	9958434	3527	66,2	8,69	5530	0,09	4,186	7,1	59,06	22,25
T2	Jamanco	813649	9958448	3464	67,6	7,65	5890	0,15	4,188	7,5	60,08	37,742
T3	Jamanco	813572	9958400	3489	66,1	6,27	5980	0,05	4,188	7,4	58,73	12,298
T4	Jamanco	813382	9958376	3507	50,7	6,94	2600	1,95	4,181	7,3	43,44	354,164
T5	Jamanco	813372	9958385	3517	55,1	5,97	5060	0,81	4,183	7,2	47,9	162,296
T6	Jamanco	813513	9958441	3508	62,7	6,88	5800	0,01	4,186	7,3	55,45	2,321
T7	Jamanco	813399	9958380	3545	43,9	5,97	4380	0,13	4,179	7	36,87	20,03
T8	Jamanco	813343	9958363	3546	43,7	6,29	4200	0,11	4,179	7	36,68	16,861
T9	Jamanco	813328	9958365	3551	47,5	5,9	3950	0,64	4,18	7	40,51	108,372
T10	Jamanco	813691	9958408	3559	54,7	6,06	5360	0,26	4,182	7	47,75	51,92
T11	Jamanco	813691	9958408	3559	36,6	6,72	3330	0,09	4,178	7	29,65	11,149
T12	Jamanco	813896	9958324	3488	45,6	7,49	4710	0,17	4,18	7,4	38,23	27,166
T13	Jamanco	813974	9958332	3470	41	6,1	4260	0,33	4,179	7,5	33,52	46,226
T14	Jamanco	813988	9958412	3414	52,4	6,58	5400	1,05	4,181	7,8	44,58	195,708
T15	Jamanco	813988	9958412	3414	49,6	6,59	5520	0,91	4,184	7,8	41,78	159,075
T16	Jamanco	813536	9958522	3520	59,3	6,84	6080	1,47	4,184	7,2	52,12	320,563
T17	Jamanco	813551	9958493	3517	65,5	6,71	6850	0,06	4,187	7,2	58,3	14,646
T18	Jamanco	813652	9958479	3550	69,6	6,68	6100	1,45	4,189	7	62,6	380,236
T19	Jamanco	813652	9958479	3550	65,1	5,94	6020	0,56	4,187	7	58,1	136,228
T20	Jamanco	813652	9958479	3550	72,9	6,61	7100	6,62	4,192	7	65,9	1828,794
T21	Jamanco	813549	9958493	3518	65,3	6,23	6080	5,45	4,187	7,2	58,11	1326,021
C1	Cachiyacu	808743	9954811	3905	63,6	6,94	5270	1,7	4,186	4,9	58,73	417,934
C3	Cachiyacu	808596	9954639	3911	30,9	6,85	3080	0,49	4,178	4,8	26,07	53,371
C4	Cachiyacu	808632	9954586	3907	38,8	7,1	3580	1,81	4,178	4,9	33,94	256,66
C5	Cachiyacu	808787	9954836	3916	62,1	6,87	5200	0,98	4,186	4,8	57,3	235,061
C6	Cachiyacu	808787	9954836	3916	35,5	6,75	4540	0,1				
C7	Cachiyacu	809035	9955125	3851	51,6	7,09	6060	0,1	4,182	5,2	46,41	19,409
C9	Cachiyacu	809068	9955157	3855	52,1	6,3	6010	0,01	4,182	5,2	46,93	19,626
C10	Cachiyacu	808865	9954280	3929	23,3	6,84	2900	1,63	4,18	4,7	18,57	0,776
C11	Cachiyacu	808660	9954576	3912	40,6	6,34	3570	1,63	4,179	4,8	33,77	9,879
C12	Cachiyacu	808731	9954778	3911	38,6	6,25	2420	0,07	4,179	4,7	35,99	19,552
C13	Cachiyacu	808623	9955152	3931	40,7	6,07	4910	0,13	4,179	4,8	44,63	69,041
C14	Cachiyacu	808632	9955116	3922	49,4	6,1	5650	0,37	4,181	9,3	33,73	645,586
O1	Oyacachi	824137	9976120	3171	42,6	7,42	4260	4,58	4,179	7,2	52,12	320,563
O2	Oyacachi	824137	9976120	3171	43	7,57	4160					
SF1	Salve Faccha	814951	9975026	3977	16,7	7,38	88,3	0,2	4,184	4,4	12,26	10,259
SF2	Salve Faccha	814588	9975183	4013	6,8	7,52	202	0,3	4,198	4,2	2,58	3,249
SF3	Salve Faccha	815739	9974403	3916	49,1	-	-	3	4,181	4,8	44,3	555,655
VTE 01	Papallacta	817378	9960378	3318	52,5	7,24	0,294	21	-	8,5	46,1	405,53
VTE 01A	Papallacta	817129	9969976	3333	53,5	7,3	0,299					
VTE 02	Papallacta	817419	9960192	3328	62,3	6,98	0,484					
VTE 03	Papallacta	817375	9959998	3327	37,4	7,21	0,275					
VTE 04	Papallacta	817591	9960350	3324	54,6	7,28	0,233					
VTE 05	Papallacta	817675	9960350	3319	46,4	7,27	0,22					
VTE 07	Papallacta	817690	9960336	3319	46,2	7,31	0,227					
VTE 08	Papallacta	817839	9960372	3332	49,6	7,32	0,227					
VTE 09	Papallacta	817675	9960350	3319	47,7	7,51	0,227					
VTE 10	Papallacta	817675	9960350	3319	-	-	-					
VTE 11	Papallacta	817690	9960336	3319	51,1	7,48	0,233					
VTE 14	Papallacta	817441	9960354	3326	51,7	7,29	0,289					
VTE 15	Papallacta	817454	9960122	3319	50,8	7,37	0,562					
VTE 17	Papallacta	817359	9960412	3352	32,8	7,58	0,246					
VTE 4A	Papallacta	-	-	-	49,8	7,34	0,21					
VTE 5B	Papallacta	817525	9959998	3306	44,8	7,2	0,217					
VTE 00	Papallacta	817330	9959871	3294	44,5	7,37	0,1912					
P1	Papallacta	817152	9959806	3334	58,9	6,82	3980					
P2	Papallacta	817133	9959942	3304	47,2	6,56	2900					
P3	Papallacta	817327	9959988	3278	54,2	7,08	2170					
E8	Guachalá	814103	778	2633	37	6,33	2100	1,121	4,179	12,5	27	126,486
E9	Tolontag	798869	9961844	3426	27,2	7,17	5720	0,37	4,179	7,7	19,46	30,09
E10	La Merced	790000	9967700	2586	32,5	6,67	1085		-	12,8	-	-
E11	Ilaló	791380	9968134	2571	37,7	6,48	1540		-	12,9	-	-
E12	El Tingo	785059	9968280	2454	42,1	7	3160	45	4,179	13,6	28,32	5325,718
E19	El Lisco	798851	9949012	3458	29,9	6,1	1780	0,47	4,178	7,6	22,35	43,888