Hydrogeoenvironmental Studies for the Attempt to Revive an Old Medical Spa - Termas da Touca - Fundão (Portugal)

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Abstract

This article presents a case study of the essentially hydrogeological nature, serving as an example of a place where a thriving medical spa once operated in the last century, but which, due to various setbacks, closed down, leaving the site almost unpopulated and in ruins. The location of these Thermal Baths is charming in terms of landscape. Because it is served by a deep sulphurous aquifer system, which has water with an extensive and deep underground path, with several thousand years old, it provides the place with unique conditions for the revival of a quality thermal health resort. Thus, after an introduction about the importance of the subject, historical note, and objective, the methodology of the work is presented. The results are presented below, consisting of the geomorphological, geological and hydrogeological framework of Termas da Touca, followed by a detailed presentation of the hydrogeological and other elements associated with the quality of the resource, to optimize the flow rate of a borehole, with water samples collected for microbiological and physical-chemical analysis, for legalization of the resource as natural mineral water for thermalism, by current regulations. The difficulties encountered in the process are explained, which are essentially a consequence of the site's high vulnerability to potential contamination and the poor quality of the current abstraction, preventing the objective from being achieved. It is understood that the solution will involve neutralizing the existing groundwater abstraction and boreholes, as well as installing an adequate drainage system for surface rainwater and groundwater, and finally constructing a new, relatively deep hole to obtain the resource at a depth where the aquifer system is not susceptible to the contamination.

Keywords: *Termas da Touca, Old Medical Spa, sulphureous groundwater, natural mineral water - NMW, Hydrogeological Studies*

1. Introduction

Thermalism activities, i.e., the use of natural mineral water (NMW) in balneotherapy and other related practices, with treatments prescribed by a doctor, in addition to other practices associated with aqua-ludic activities, are an interesting option for building a medical spa (thermal baths) in locations where NMW is available, as this type of facility can boost the local economy through activities related to public health and tourism.

The "Termas da Touca" corresponds to a place in the interior of Portugal (Fig. 1), with that name, because it was once a Medical Spa beneficial to the population and the local economy, but currently corresponds to a depopulated place with the old spa in ruins, as can be seen from Fig. 2.

The waters of the Termas da Touca are special groundwater. They were first mentioned in August 1813 in a publication in the Coimbra newspaper, referring to the Municipality of Alpedrinha and the existence of sulphureous waters [1]. The existence of sulphureous waters was kept secret for some years, but in 1819, after some agricultural work in the area, it became common knowledge [2]. However, those waters began to be used for healing or medicinal treatments, and in 1825 they were considered famous for their healing properties in problems with arthritis, the digestive system, rheumatism, and dermatology [1]. Along the same path, in 1840, the Alpedrinha City Council built a small house with three metal bathtubs, which also served as a shelter for bathers. Those baths became famous in 1866, so much so that that same year, construction began on a new bathhouse, consisting of a ground-floor building with large windows containing five rooms, each with a fine stone bathtub, staff quarters, and other facilities, including a ballroom, completed in 1874 [2]. A year before the end of the construction work, when the municipality of Alpedrinha was abolished and integrated into the municipality of Fundão, the Civil Government of Castelo Branco handed over the operation of the thermal baths to the Municipal Council of Fundão [3].

In 1921, Charles Lepierre conducted a physical-chemical study of the water at Termas da Touca [4], noting that there were four springs, the most important being the water from the cistern, which was clear, transparent, colorless, and had the characteristic smell of sulphureous water. That water was granted a license by the Portuguese State as sodium sulphureous water on 21 November 1925, an extract of which was published in the Government Official Gazette nº 254 - II - Series of 28 October 1926 [4]. The concessionaire was "Emprêsa Águas do Alardo, Lda", and the therapeutic indications were for rheumatic diseases and dermatoses [4,5].

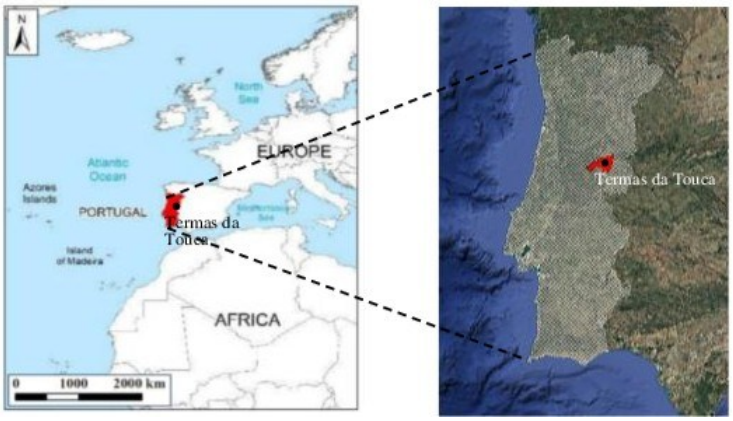

Fig. 1. Geographical location of the ancient Medical Spa (Termas da Touca), in the municipality of Fundão, Portugal.

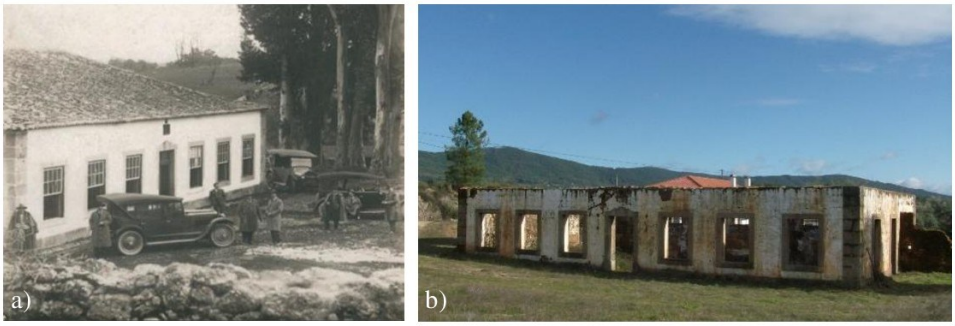

Fig. 2. Images of the ancient Medical Spa - Termas da Touca: a) in the 1940s; and b) currently.

In 1945 the thermal baths officially closed, but were used by local populations until they were considered abandoned in 1973 [3]. At the end of the 1980s, the Alpedrinha Parish Council, in an attempt to revive the Termas da Touca, restored an old building near the ancient medical spa, equipping it with hydromassage and respiratory treatments, but without any medical support, and with water that systematically proved bacteriologically unsuitable, leading to its further abandonment until today.

However, the Fundão Municipal Council, aware of the importance of a medical spa in its municipality, has taken steps over time to drill new sulphureous water holes in the area to overcome the problem of poor bacteriological quality of its water. Noteworthy are the works carried out by A. Cavaco in 1999-2000 [6,7], which resulted in the AC1 and AC2 holes, but unfortunately, it has not yet been possible to license the resource as NMW, in light of current legislation in Portugal [8,9], as only then will investors be able to return to build a medical spa following current rules [10].

The academic study entitled 'Hydrogeology of the areas surrounding the Termas da Touca' [11] presented the results of chemical analyses of the water from the Hole AC2, highlighting that it is sulphureous, sodium bicarbonate, and fluoridated water. It has an emergence temperature of around 18 ºC, an alkaline pH of over 8.68, electrical conductivity of around 326 µS/cm, negative Eh of around -102 mV and a dry residue of between 203 and 225 mg/L.

It is worth mentioning at this stage that, due to the scenic potential of the place and its magic connection to nature, several academic works have emerged, with architectural proposals for new spas facilities for the place, concerning the works entitled "Termas da Touca – Alpedrinha, Recovery and expansion of the old Spa", in 2013 [12] and "Termas da Touca – Alpedrinha, Recovery and expansion of the old Spa" in 2021 [13].

It is in this relatively recent context that the Fundão City Council itself has wanted to reopen the Touca Thermal Baths, having carried out hydrogeological studies and work, namely carrying out flow tests in the most recent boreholes, and analyzing the quality of its water, with a view to legalizing it as NMW in accordance with current legislation [8,9]. From this perspective, if there were positive results, a medical-hydrological study would then be carried out, which, if it proved the therapeutic effects of this water, in accordance with current medical regulations, would most likely lead to major investments to build a new medical spa and an associated eco-park.

The objective of this article is to present the geomorphological, geological, and hydrogeological framework of the Termas da Touca area and its associated springs, and in particular, to present basic hydrogeological studies associated with the water quality of Hole AC2, in order to make decisions on the way forward. If the results were favorable, we would move forward with the attempt to legalize the water as NMW and, consequently, with a medical-hydrogeological study. If these results were not positive, the way forward would be to immediately carry out geophysical and hydrogeological studies with new mechanical prospecting boreholes to obtain the resource from greater depths, without mixing with surface water, and therefore less vulnerable to pollution.

Thus, this case study, among the various scientific aspects, aims to show what methodologies and paths can be followed to reopen old thermal baths, to serve as an example for many other cases that exist, and which, due to various vicissitudes, are abandoned, but which need to be restored to dignity, as in general they are places of resurgence of very special groundwater and in very unique and lush landscape locations, favorable to high-quality health tourism.

2. Methodology

The methodology used in this work included: i) bibliographic research; ii) field activities; and iii) office activities. The initial phase (i) led to the creation of the previous item of this article, Introduction, with the current situation, in addition to the synthetic historical note presented, with the appropriate bibliographical references. The fieldwork, initially, allowed direct contact with the various main elements, namely, the state of the old buildings, the survey of the various water points (springs and boreholes/groundwater abstraction), local geological

mapping, among others, in addition to structuring the work on the flow test to be carried out and other associated works, the details of which are presented in item 4. Finally, the office work led to the processing of data and respective interpretations, which essentially led to guidance on the path to follow, so that in the end it would be possible to implement new thermal baths on the site, in accordance with current regulations, and thus contribute to improving the local economy.

3. Geographical, geomorphological and geological framework of the study area

According to Decree Law 244/2002 [14], the studied area is part of Mainland Portugal, located in the Central Region, specifically within the Beiras and Serra da Estrela sub-region (NUTS III). The Termas da Touca area is located in the municipality of Fundão and parish of Alpedrinha.

In geomorphological terms, according to the Tejo Hydrographic Region Management Plan – PGRHTejo [15], the studied area is included in the large Tejo River basin, being inserted in the Ponsul River sub-basin, more specifically in the Ponte da Munheca river basin (Fig. 3). The areas studied in greater detail correspond to the Ameal micro-basin (HB – Ameal), where the Termas da Touca are located, and the surrounding basin, the Touca hydrographic basin, with areas of 1.6 km^2 and 27.5 km^2, respectively.

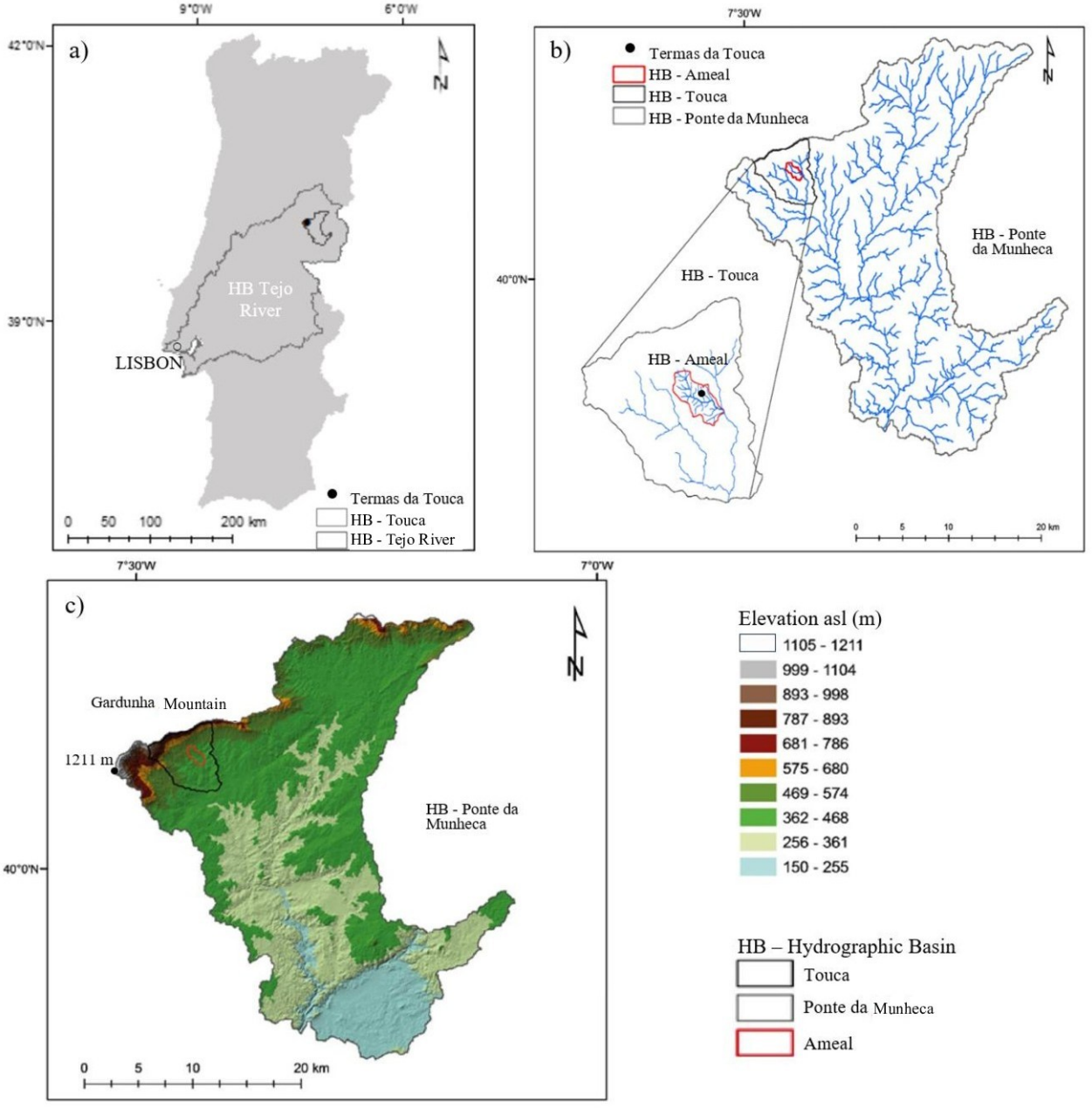

Fig. 3. Geomorphological framework of the study area: a) in relation to the Tejo River; b) locally, in the micro-basin of the Ameal, Touca, and Ponte da Munheca brooks; and c) in terms of altitudes based on the digital terrain model.

The HB - Ameal, where the springs of the Termas da Touca are located, at an altitude of approximately 426 m, has a general direction of NW-SE, with the main watercourse, the Ameal brook, with generally smooth relief, inclining slightly to the SE. Its intermediate and terminal sections generally have a perennial regime; however, in years of greater drought, they have a seasonal runoff regime. The topography presented by the HB of Ponte da Munheca is characterized by being quite mountainous, especially in its NW sector, as in this area there is an important Portuguese mountain range, called Serra da Gardunha, where altitudes are essentially reached of around 1100 to 1200 m, with its highest point at 1227 m.

In geological terms, the studied region is located in one of the large structural units of the Iberian Peninsula, the Central Iberian Zone - CIZ [16]. The CIZ is characterized by the large extension occupied by granitoid rocks associated with pre-orogenic to post-orogenic phases of the Variscan cycle, which intruded metasediments affected by variable degrees of metamorphism. Cenozoic continental sediments are deposited on these rocks, arranged in discontinuous outcrops with a preferential NE-SW orientation, especially in the E and SE regions of the area (Fig. 4) [17]. The geological unit that occurs in the Termas da Touca area corresponds to medium to coarse-grained porphyroid monzonitic granites of Hercynian age. The occurrence of large geological faults, often with a global NE-SW direction, stands out, which, being relatively extensive in plan, are also admitted to be extensive in depth. It is understood that these play a preponderant role in the percolation of groundwater from the highest areas of the Serra da Gardunha to the Termas da Touca area.

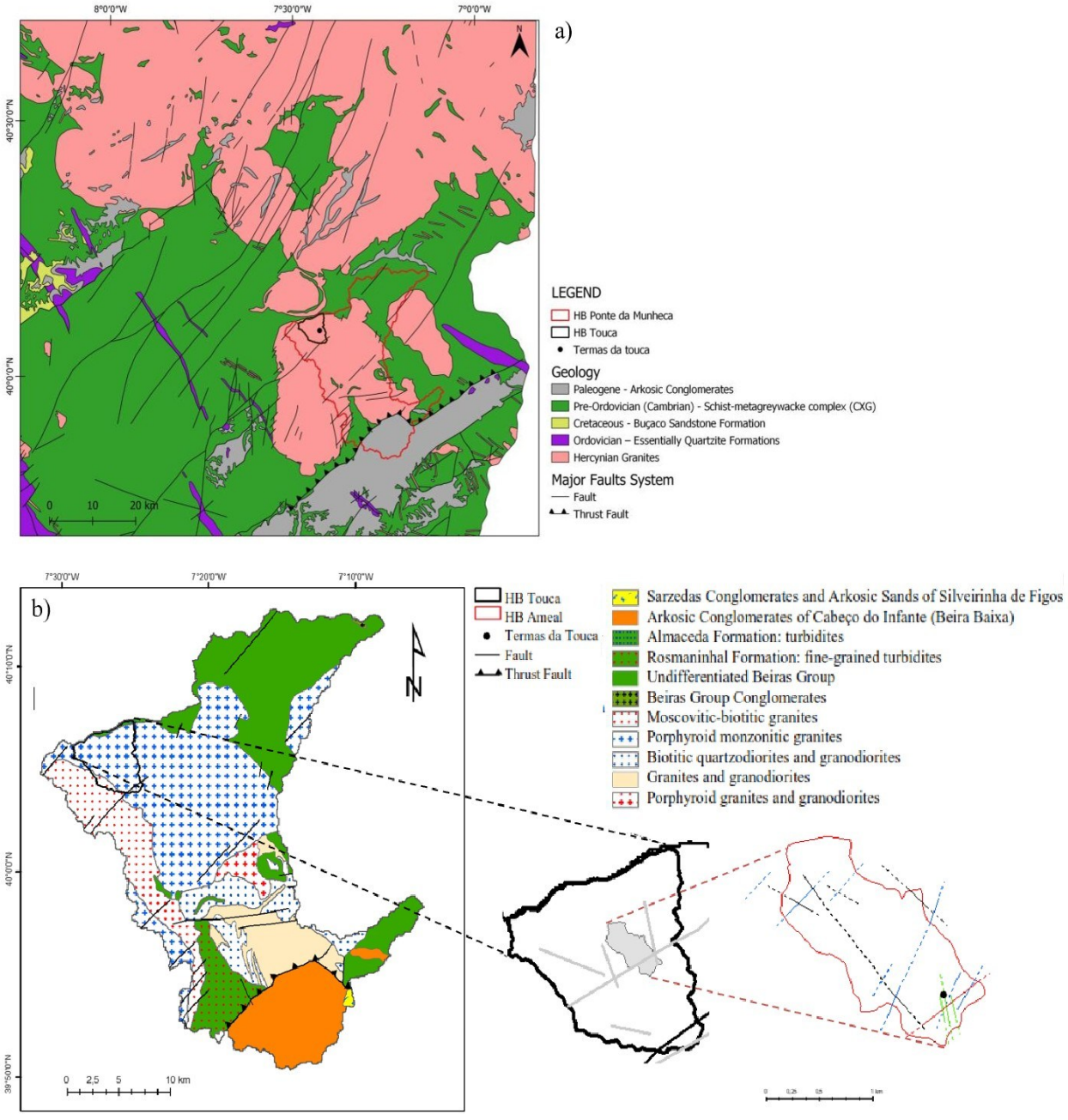

Fig. 4. Geological framework of the study area: a) regional geological map (from [18]; b) Local geological-structural framework [(from [11]).

The global conceptual hydrogeological model of the study area is shown in Fig. 5. In the Termas da Touca area, there are two main aquifer systems: i) a porous to porous-fissured unconfined aquifer, and, ii) a deep, confined to semi-confined, fissured aquifer of hydrothermal nature. It is the confined to semi-confined aquifer system that supplies the Touca springs with sulphureous water.

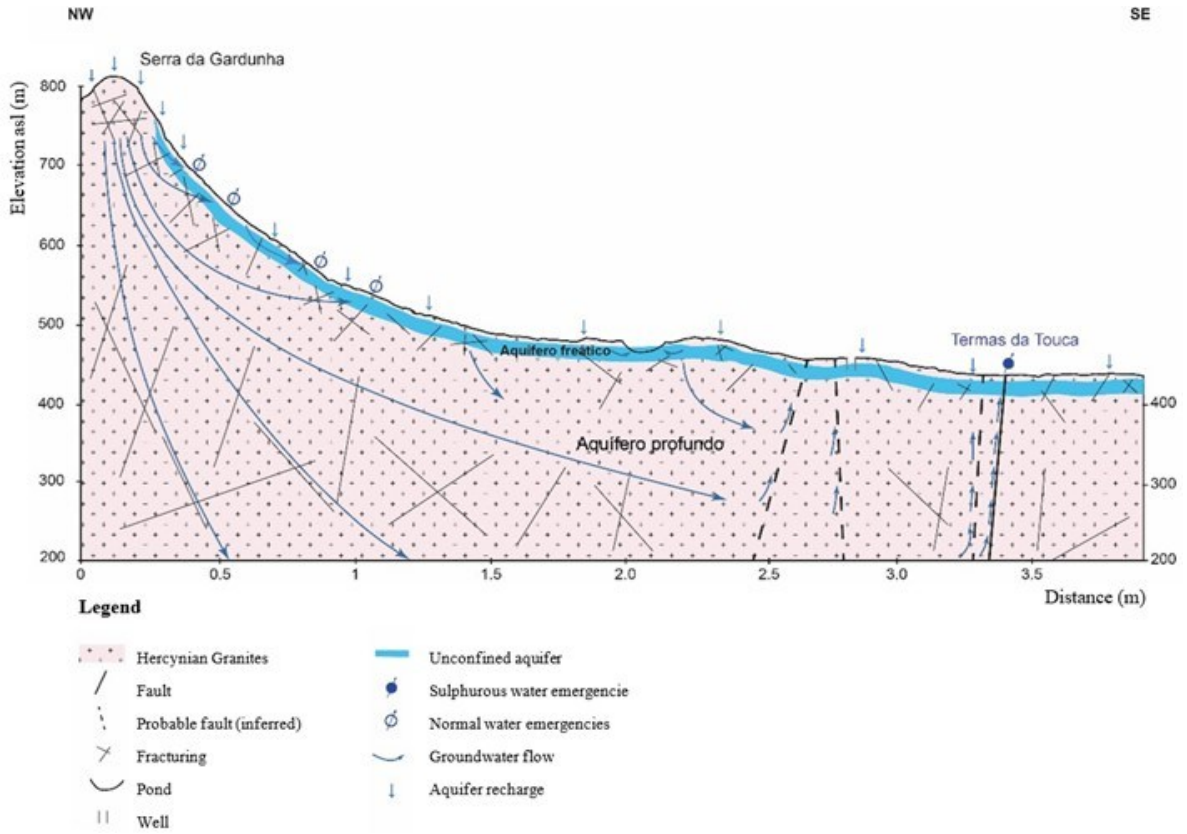

Fig. 5. Conceptual hydrogeological model of the Termas da Touca region (from [11,19]).

4. Hydro geo environmental studies

From the survey of the various water points in the Termas da Touca area, carried out in 2009/2010 [20], it was possible to verify the following occurrences (Fig.6):

- AS, ancient spring inside a well in the 'most recent bathhouse'; currently, no water flows from this location;
- Well, a water collection point that supported the operation of the ancient thermal baths; the well consists of a large area (approximately 15 m^2), with a reinforced concrete slab as partial cover, where a pump house is located;
- Hole Fv (Old borehole), built in 1994, 129 m deep, lined with PVC throughout its entire length, with a drained section along almost its entire length, and converted into a piezometer in 2000 by A. Cavaco [6];
- Hole AC1, drilled in 2000 [6], 130m deep, in an open hole (without casing) for almost most of its length, with only about 2m of normal iron casing, associated with the head of the same;
- ASHole AC2, drilled in 2000 [6], 151m deep, casing with AISI 304 stainless steel from the surface to 50m, drains between 22 and 30m, gravel in its annular space between approximately 14 and 50m and insulation with cement-bentonite from 14m to the surface; this hole had a pump installed at 18m.

After some analysis and reflection on the scenario of water points found, and taking into account in particular the characteristics of Hole AC2 (Fig. 7), the following actions were established:

. Task 1 - Slight improvements to Hole AC2,

. Task 2 - Pumping test in Hole AC2,

. Task 3 - Analytical control of groundwater from Hole AC2 over 12 consecutive months. According to Portuguese legislation [8,9,21], to license groundwater as natural mineral water for thermalism, this control essentially corresponds to monthly analyses, of a summary physical-chemical type (global parameters and main ions) and microbiological analyses, as well as a complete physical-chemical analysis, which, in addition to the parameters measured in the summary analysis, also measures trace elements, radiological parameters, organic compounds, among others [21].

. Task 4 – Analysis and interpretation of previous elements, with preparation of a hydrogeological report.

The possibility/need to neutralize AS, the Well, and even FV and AC1, was left open to minimize potential contamination from these points by lowering the piezometric level.

The work integrated in Task 1, and in particular the improvements in Hole AC2, consisted of the following: i) disinfection of the pump and associated systems; ii) reinstallation of the pump at 18 m; iii) installation of level controllers at 14 m (on) and 15 m (off); iv) installation of accessories (Fig. 8) to improve the exploitation of sulfurous groundwater.

As part of Task 2, the pumping test was carried out on 2009/08/05 with pumping in Hole AC2, and level measurement in Hole FV, Hole AC1 and also in the Well. Physical parameters of the water extracted from Hole AC2, using an Eutech Instruments PC650 device, were recorded, according to: electrical conductivity (C), pH, temperature (T), and redox potential (Eh). It should be noted that no water resurfaces at the AS site.

It should also be noted at this stage that there is a small fountain in the area of Termas da Touca (Fig. 6), which some people believe to be related to the resource (sulphureous water). However, its characteristics were measured (T = 19.5ºC; pH = 6.33; electrical conductivity = 86 µS/cm; Eh = 11 mV) and information about it has been gathered, leading to the conclusion that, in addition to having nothing to do with the resource, the water that occurs there is the result of canalization from a pond about 100 m upstream.

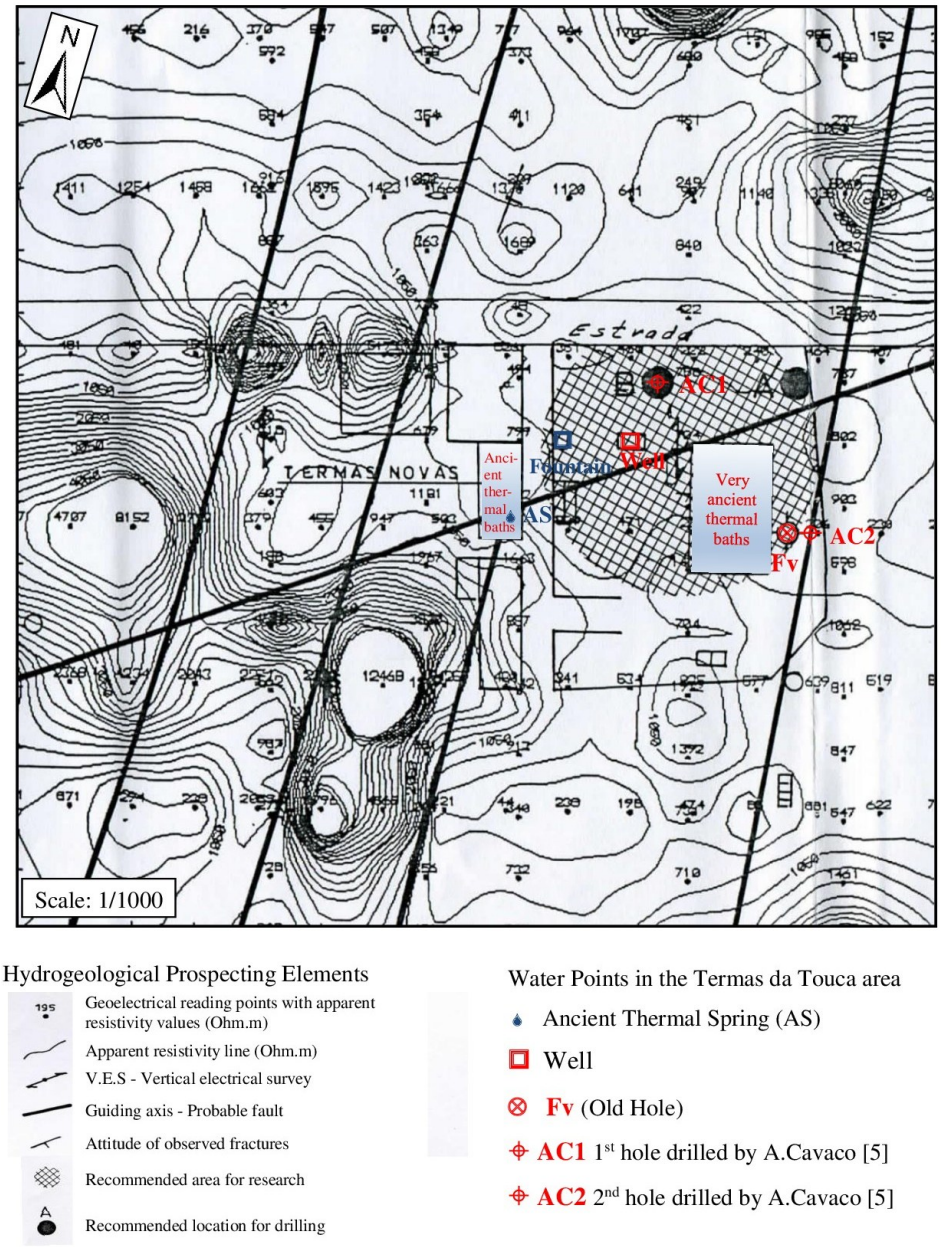

Fig. 6. Map showing the location of the main water points in the Termas da Touca area (from [6]).

It was also possible to measure the parameters of the water in the well, with the following results: T= 25.2ºC; pH=7.22; C = 218 µS/cm; Eh= -42 mV. At this stage, information emerged that the bottom of the well contains inert materials from Panasqueira mine waste, which is a negative situation, as this type of material commonly contains heavy metals that could end up contaminating the well water.

The results of the pumping test are shown in detail in Fig. 9a. From these results, assuming the evolution of the old hole (Fv) levels corresponding to the lowering of Hole AC2, due to their proximity (only 3 m apart), the equivalent characteristic curve is obtained, shown in Fig. 9b, which indicates an admissible flow rate of 0.43 L/s. That value was understood to be the maximum flow rate to be used when pumping water samples for quality control for the next phase of work.

From the results obtained, it can be noted that the influence of levels was clearly felt in Hole AC1 (Fig. 9a); in the Well, this influence was not detected. In any case, it is admitted that in hydraulic terms there may be communication along the fractures of the rock mass between the Well and Hole AC2, but the visibility of this influence may eventually be minimized because it is a large diameter Well.

Regarding the evolution of physical parameters such as pH, Eh, C and T (Fig.10) in the order of magnitude of the various flow rates used, they do not significantly influence water quality, despite slight trends being observed such as an increase in temperature and Eh and a decrease in pH and electrical conductivity.

The average physical parameters obtained for the water from Hole AC2 during the pumping test are: T = 18.5°C; pH = 8.9; C = 346 µS/cm; Eh = -140.5 mV. Considering these values, as well as the strong hydrogen sulphide odor and characteristic taste of the water, everything points to this water falling into the group of Portuguese sulphureous waters, which includes the waters of São Pedro do Sul [22,23], which have been the main Portuguese Medical Spa for several decades, based on their leadership in the national ranking for revenue from thermalism.

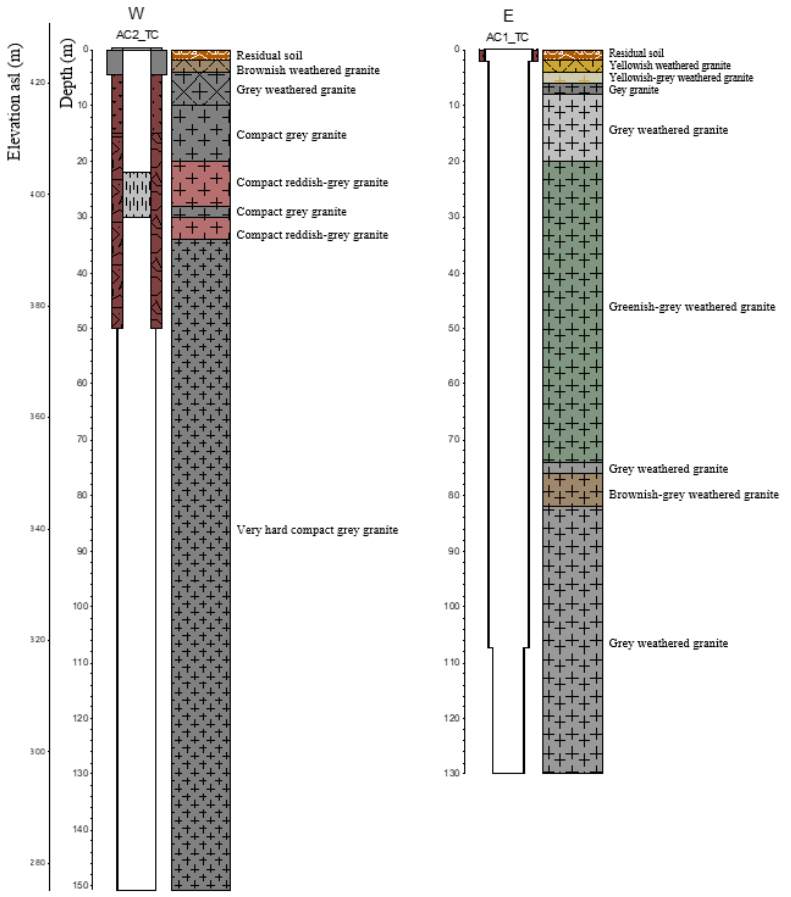

Fig. 7. Geometry of the holes drilled by A.Cavaco in 1999-2000 in the Termas da Touca area (adapted from [6]).

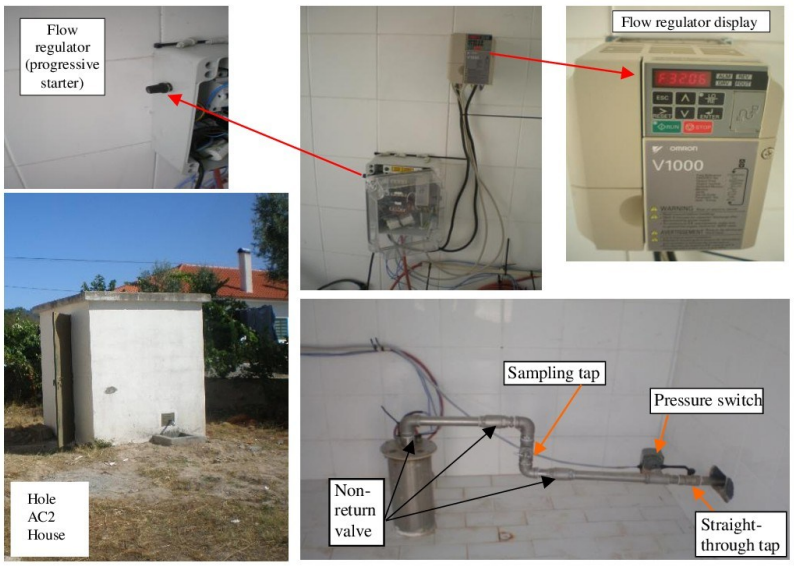

Fig. 8. Elements associated with the Hole AC2 at Termas da Touca to optimize the exploitation of sulphureous water.

In view of the results obtained, it was decided to proceed to Task 3, i.e., analytical control, in order to carry out the various analyses with the water obtained from Hole AC2, with a maximum flow rate of 0.43 L/s, after 24 hours of pumping.

Microbiological analyses were performed by the ARSC Laboratory – Castelo Branco Health Sub-Region, and physical-chemical analyses were performed at the Analysis Laboratory of the Instituto Superior Técnico of the Lisbon, generally following the methodologies presented in Directive 80/778/EEC [24].

The results obtained for the microbiological and physical-chemical analyses are presented in Tables 1 and 2, respectively. During the first month, all microbiological analyses carried out at weekly intervals showed the effectiveness of the previous tasks and led to higher than expected results, as the first analyses were expected to be unsatisfactory following the various interventions. However, in the following months, it seems that, in microbiological terms, an ‘earthquake’ occurred, meaning that the analyses became continuously unsuitable. This situation is attributed to a consequence of infiltrations in the vicinity of the abstraction point, following the rainy season, which was relatively very rainy in that hydrological year.

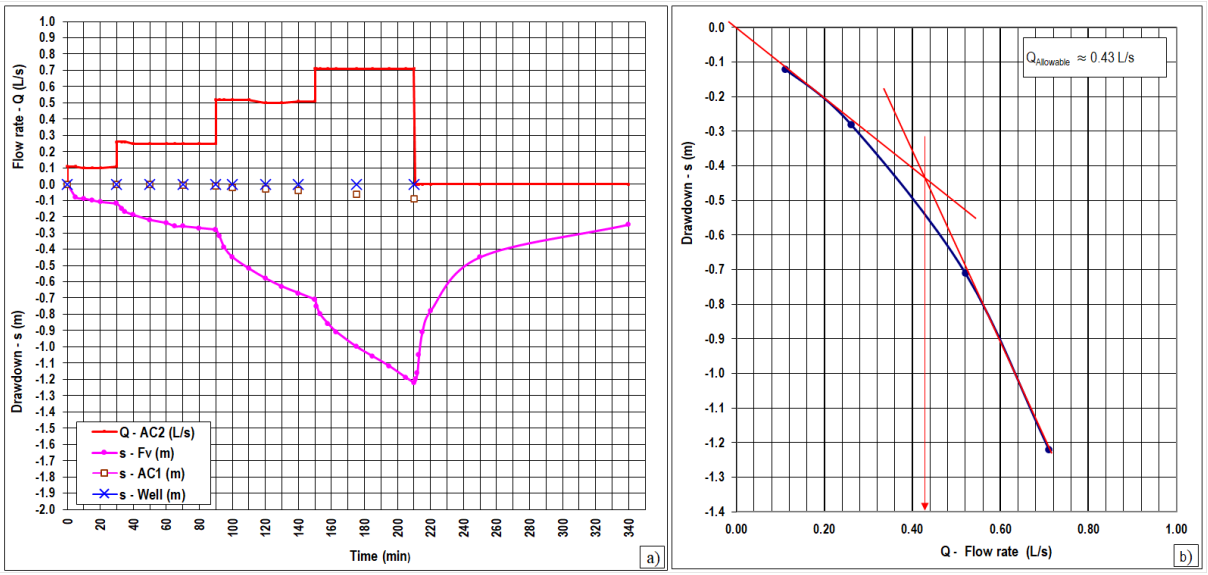

Fig. 9. Pumping test results: a) overall results, b) equivalent characteristic curve.

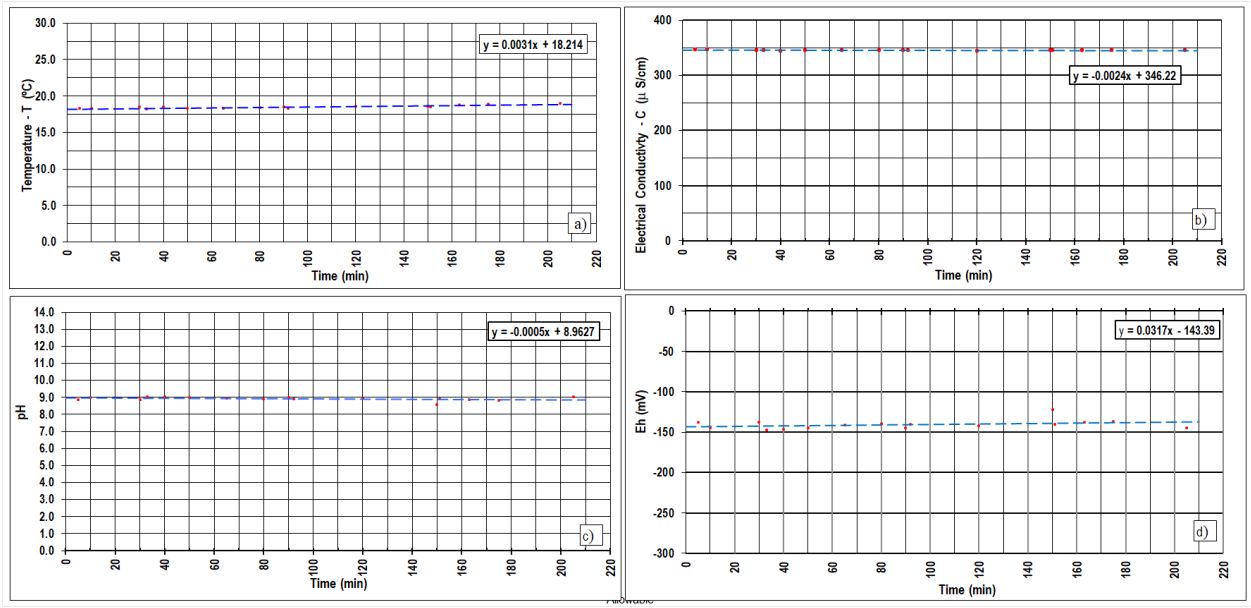

Fig. 10. Evolution of temperature (a), electrical conductivity (b), pH (c), and Eh (d) in groundwater extracted from Hole AC2 during the pumping test.

The water resulting from precipitation, when passing through contaminated surface soils, easily enters Hole Fv in particular, and this, as it has no insulation, enhances the evolution to Hole AC2, especially when there is pumping in it. It should be noted that the Hole AC2 is by no means optimal, but it is lined with AISI 304 stainless steel from the surface to a depth of 50 m, with drains between 22 and 30 m (Fig. 7), and insulated with cement-bentonite in the first few meters near the topographic surface.

In view of the results, the analysis process was halted in order to proceed with some operations to improve the underground environmental conditions in the Termas da Touca area. The proposed works in this regard were presented in detail in C.R.[20] and can be summarized as follows:

- neutralization of the AC1 and Fv holes and also of the Well that supplied the thermal baths for several years;
- cleaning the interior of the Ancient Spring (AS) and possibly waterproofing its bottom and neutralizing it completely;
- Install rainwater and groundwater drainage networks from the unconfined aquifer throughout the area closest to the thermal baths, to intercept contaminated flows and collect them in an area far from the Hole AC2.

Of course, the ideal solution would be to drill a new hole, approximately 350 m deep, to have at least 150 m of surface piping with 316 stainless steel, intact (without drains), with the annular space filled with impermeable material, to extract the resource between 150 and 300 m, in an uncontaminated zone. This situation, in relative terms, is extremely costly and, for this reason in particular, it was decided to make an effort to try to legalize the resource at that stage from Hole AC2, after carrying out environmental improvement operations.

Those studies and works were carried out in 2009/2010, and unfortunately, no further action has been taken to try to legalise the use of the Hole AC2.

However, we welcome the recent study on geophysical surveys of the Termas da Touca area and its surroundings [25], which leaves open the possibility of drilling several mechanical prospection holes. That study, along with the results of the mechanical prospecting to be carried out, among other things, is expected to be the subject of future articles by the authors.

Tab. 1. Results of microbiological analyses carried out on water from the **Hole** AC2 at Termas da Touca.

Parameter [a]	**MRV**	**MAV**	**Analysis number - Date**									
			1 2009/09/10	2 2009/09/17	3 2009/09/14	4 2009/09/30	5 2009/10/07	6 2009/10/28	7 2009/11/11	8 2009/11/18	9 2009/12/09	10 2009/12/16
1	5	20	1	1	0	0	0	0	7	9	25	0
2	20	100	20	12	19	2	8	82	31	300	103	63
3	0	0	0	0	0	0	44	41	1	17	5	4
4	0	0	0	0	0	0	0	0	0	17	0	0
5	0	0	0	0	0	0	0	0	0	17	0	0
6	0	0	0	0	0	0	0	3	0	8	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	4	0	5	0	0
Conclusion [b]			**P**	**P**	**P**	**P**	**I**	**I**	**I**	**I**	**I**	**I**

[a] Parameter:
1- Total germs (37ºC, 24 h)
2- Total germs (22ºC, 72 h)
3- Total coliforms
4- Fecal coliforms
5- Escherichia coli
6- Fecal streptococci
7- Sulphite-reducing Clostridium
8- Pseudomonas aeruginosa

[b] Notations:
MRV - Maximum Recommended Value
MAV - Maximum Admissible Value
A - Acceptable
P - Proper
I - Improper

Tab. 2. Results of the summary physical-chemical analyses carried out on the water from the Hole AC2 at Termas da Touca.

Parameter		**Analysis number - Date**				**Statistical values**				
		1 2009/09/10	2 2009/10/07	3 2009/11/11	4 2009/12/09	min	ave	max	Std dev.	n
pH [a]		9.06	9.17	9.00	9.07	9.00	9.08	9.17	0.06	4
Conductivity ($\mu S.cm^{-1}$) [a]		312	321	324	326	312	321	326.00	5.36	4
Total sulphuration (in $I_2$0.01N- mL/L)		9.1	11.0	8.2	8.1	8.1	9.1	11.00	1.16	4
Silica (mg/L)		35	22	28	28	22	28	35.00	4.60	4
Dry residue (at 180ºC) - (mg/L)		222	211	220	225	211	220	225.00	5.22	4
Total Mineralization (mg/L) [b]		273	262	274	279	262	272	279	6.20	4
Cations (mg/L)	Na^+	75.0	76.0	76.0	77.0	75.0	76.0	77.0	0.71	4
	Ca^{2+}	1.90	2.10	2.30	3.90	1.9	2.6	3.9	0.79	4
	K^+	0.86	1.40	1.60	1.60	0.9	1.4	1.6	0.30	4
	Mg^{2+}	< 0.10	< 0.10	< 0.10	0.24	<0.10	-	0.24	-	4
	NH_4^+	0.25	0.36	0.33	0.31	0.3	0.31	0.36	0.04	4
	Li^+	0.65	0.69	0.66	0.65	0.65	0.66	0.69	0.02	4
	Fe^{2+}	<0.03	<0.03	<0.03	0.06	< 0,03	-	0.06	-	4
Cations (mg/L)	HCO_3^-	100.0	100.0	106.0	106.0	100.0	103.0	106.0	3.00	4
	CO_3^-	5.7	8.3	6.1	6.1	5.7	6.6	8.3	1.02	4
	Cl^-	16	15	16	17	15.0	16.0	17.0	0.71	4
	SO_4^{2-}	10.0	10.0	18.0	20.0	10.0	14.5	20.0	4.56	4
	F^-	16	16	15	14	14.0	15.3	16.0	0.83	4
	NO_3^-	<0.3	<0.3	<0.3	<0.3	<0.3	-	-	-	4
	NO_2^-	<0.010	<0.010	<0.010	<0.010	<0.01	-	-	-	4
	SH^-	1.5	1.7	1.3	1.3	1.3	1.5	1.7	0.17	4
	$H_3SiO_4^-$	9.4	7.7	5.7	6.6	5.7	7.4	9.4	1.38	4

[a] values relative to the temperature of 20 to 22ºC

5. Conclusion

The Termas da Touca, currently in ruins (Fig. 2), was once a medical spa offering treatments for rheumatic and dermatological diseases, enjoying a golden age in the 1930s. The operating license, granted by the Portuguese State, was issued in 1925.. However, they officially closed in 1945.

The groundwater at the base of Termas da Touca is sulphureous (Table 2), basic (pH=9.05), bicarbonated, sodium-rich, and fluoridated, with total mineralisation of around 272 mg/L.

The land in the abstraction area is highly vulnerable to contamination, and as soon as local surface water infiltration occurs, resulting from precipitation or other causes, it percolates into the rock mass and flows into the main aquifer system, particularly into the Hole AC2, which is currently the best abstraction of sulphureous groundwater in the area, but still, with some limitations.

However, in recent decades there have been some studies and special projects in an attempt to obtain high-quality sulphureous groundwater, in accordance with current regulations, from the Hole AC2, but in particular there is a tendency for the microbiological results to be poor, making it impossible to legalise that groundwater as natural mineral water and, consequently, preventing the resumption of thermalism activities.

Thus, a recent geophysical prospecting campaign was carried out in 2024, showing favorable productive areas with sulphureous groundwater in different locations relatively close to the current abstraction. The exact locations of several mechanical boreholes, with significant depths, were proposed in order to capture sulphureous groundwater in areas that are not sensitive to contamination. Everything indicates that, with the accumulation of knowledge about the aquifer system in the study area and with the current advanced knowledge in the construction of groundwater abstraction systems, the result will finally be a high-quality abstraction system, which will consequently allow the return of a thermal spa to the area, as the local populations and the interior of Portugal need.

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