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Protection areas of the Unhais da Serra Spa, Portugal

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ABSTRACT: In this paper a case-study about protection areas of a hydrothermal unit in Portugal is presented. According to chemical characterization the thermal mineral water has a large presence of bicarbonate, sodium, carbonate, fluoride and sulphate. The therapeutic indications are rheumatism, skeletal-muscle diseases, digestive and circulatory apparatus, dermatosis and haemorrhoids.

The geomorphological, geological, hydrogeological characterization and vulnerability to pollution are presented. According to Portuguese legislation three protection areas were defined: immediate, intermediate and distant zone. The criteria which define the above mentioned zones are also presented.

1 INTRODUCTION

The thermal balneotherapeutic activity has a long tradition in Portugal (DGGM, 1992). This tradition is due to the high diversity of the chemism of Portuguese mineral waters which is a consequence of the geologic conditions of the Portuguese territory.

The Spa in study is administratively located in Unhais da Serra Village, council of Covilhã, in the Castelo Branco district. It is located in the centre of Portugal on the southern slope of Serra da Estrela (the highest mountain in Portugal, Fig.1).

2 GEOMORPHOLOGICAL AND GEOLOGICAL ASPECTS

The thermal park area presents weak inclination. This situation is due to the intersection of several water lines at the Spa area which filled up the place with rests from old glaciers. The upstream area of the thermal park is very sloping. There is a level difference of 1255 meters between the highest point (Torre) and the Spa, to a straight line distance of 6000 meters approximately. The altitude of the Spa is about 695 meters above sea level.

The shape of the some valleys above the level of the Spa is the “I” form, showing the ice action in wurniana glaciation, the only one which affected Portugal in the Quaternary.

Fig.2 presents a geological outline of the Spa area and of its enveloping zones which are important for the protection perimeter.

The Spa is implanted above glaciofluvial deposits which are placed above granitic rocks.

The Vilarriça fault (NE-SW), where the Alforfa creek is located, must be pointed out because it is the main responsible for the thermal water spring in study. This fault extends several kilometres to NE and associates other mineral water springs.
3 HYDROGEOLOGICAL ASPECTS

3.1 Hydrogeological units

In the thermal zone and its involving areas there are three hydrogeological units:

1) A Unit - it is essentially constituted by glaciofluvial deposits and sometimes by young alluvials. This unit has high permeability;
2) B Unit - it is generally constituted by porphyritic granites (B1) which are sometimes fractured (B2). This unit has medium permeability;
3) C Unit - it is essentially constituted by schists and greywackes, generally with low permeability.

The structural elements (faults) must be emphasized, particularly the Vilarica fault, whose hydraulic characterization is important too.

The outline of the hydrogeological model is presented in Fig. 3. The upstream Spa recharge area has 21 Km², with a hydric surplus of 600 mm approximately. The jointing and the granitic rocks alteration zones favour the infiltration, which sometimes reaches a big depth, because of the "open faults" system.

The water, circulating at a big depth gains a typical chemism and springs in the Spa zone. The spring occurs in this zone, fundamentally for structural reasons (there is an intersection of a secondary fault with the Vilarica fault) and is facilitated by the gained temperature (100 - 120 °C).

In the thermal zone, near to the supply well (ACP1) and in depth, the following situation is verified:

- unconfined aquifer; this aquifer is essentially constituted by glaciofluvial formations of "A Unit"; it is a non-mineral aquifer;
- semiconfined to confined aquifer; this is underlying to the unconfined aquifer; it is constituted exclusively by granites and essentially by the B2 unit; this is the mineral aquifer with artesian water; the piezometric surface in ACP1 well is two meters above topographical surface.
4 VULNERABILITY AND POLLUTION RISKS

To evaluate the vulnerability of the Spa zone the DRASTIC index (Aller et al., 1987) was used. The DRASTIC index values obtained and some qualitative aspects of the main hydrogeological units of the Unhais da Serra thermal zone are presented in Table 2.

In relation to pollution risks in the thermal zone, the following problems should also be taken into account:

1. problems occurring at the topographical surface:
   i) superficial infiltration of contaminated water (irrigation activities);
   ii) abandonment or accidental diffusion of polluted substances (in the thermal area, football field and upstream areas);
   iii) animal excrements (frequent grazing);
   iv) fertilizers, herbicides and pesticides;

2. problems occurring above water table of unconfined aquifer (aquifer with non-mineral water):
   i) septic tanks and cesspools (associated to the thermal building and to the houses in enveloping area);

3. problems occurring bellow water table of unconfined aquifer and bellow piezometric surface of mineral aquifer:
   i) connection between research wells and the definitive supply well;
   ii) direct pollution of ancient captations;
   iii) connection between aquifers.

3.2 Hydraulic characterization

The results presented in this part are essentially based on studies made by A. CAVACO (1994). For the mineral aquifer the hydraulic characterization was based on a model about groundwater flow, according to the Cooper-Jacob approximation. From pumping tests in AC1, AC2, AC3 and ACPI wells, the hydraulic parameters were determined for the principal hydrogeological units of the thermal zone, which are presented in Table 1.

The stabilized discharge at the definitive supply well (ACPI) was 9 l/s with pumping and 4 l/s in artesianism.

3.3 Hydrochemical characterization

From the chemical point of view, there are two hydrochemical systems in the thermal zone:
- the "mineral system"; this system has hot water ($\approx 40 \, ^{0}\Celsius$), a conductivity of approximately 300 $\mu$S/cm$^{-1}$ and a pH between 8.5 and 8.8;
- the "non-mineral system"; this system has cold water ($\approx 15 \, ^{0}\Celsius$), a conductivity below 40 $\mu$S/cm$^{-1}$ and a pH below 6.0.

From an ionic point of view the Unhais da Serra mineral water type is called "sodium bicarbonate, carbonated, fluorinated and sulfidrated" water.

<table>
<thead>
<tr>
<th>Units</th>
<th>Transmissibility (m$^{2}$/day)</th>
<th>Hydraulic conductivity (ms/day)</th>
<th>Coerc. of storage</th>
</tr>
</thead>
<tbody>
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<td>A-Fluvio-glacial deposits</td>
<td>$\approx 250$</td>
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<td>0.15</td>
</tr>
<tr>
<td>B1-Granites</td>
<td>25-60</td>
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</tr>
<tr>
<td>B2-Fractioned granites</td>
<td>$\leq 177$</td>
<td>2.3-3.1</td>
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</tr>
<tr>
<td>Vilarica fault</td>
<td>$\approx 20$</td>
<td>0.7</td>
<td>$10^{4}$</td>
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</table>

Table 1 - Hydraulic parameters of the main hydrogeological units of the thermal zone of Unhais da Serra Spa (A. CAVACO, 1994)
Table 2-DRASTIC Index values and vulnerability of main hydrogeological units of U. da Serra Spa zone.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Parameter *</th>
<th>Characterization</th>
<th>Value</th>
<th>Weight</th>
<th>DRASTIC Index Partial</th>
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(*) Parameters: 1 - Depth to the water table (m); 2 - Net recharge (mm); 3 - Aquifer material; 4 - Soil type; 5 - Topography-slope; 6 - Unsaturated zone; 7 - Hydraulic conductivity of the aquifer (m/day).

5 PROTECTION AREAS

The protection areas are intended to reduce the pollution risks of the Unhais da Serra mineral aquifer or, in case of an accident, to protect the mineral water (of the supply well) from dangerous concentrations.

A.CAVACO (1994) made a study about this protection area. UBI (1995) maintained the essential of that study when officially proposing that protection area to the IGM (Geological and Mining Institute - Portuguese entity which supervises these situations); the main criteria were the following:

1. studies with classic equations of underground water flow, according to a continuous model;
2. estimation of the propagation time in an unsaturated zone, admitting a model of piston flow;
3. estimation of the advective transportation time in a saturated zone, admitting a continuous model and considering the limits:
   - Immediate zone - 1 day;
   - Intermediate zone - 50 to 365 days;
   - Distant zone - 25 years and/or the alimentation limits of hydrographical basin.

Additionally, semi-quantitative techniques were considered, how:

i) local estimation of vulnerability to pollution according to the DRASTIC index;

5.1 - The Immediate zone

The Immediate zone is the most vulnerable protection area to the mineral aquifer pollution, to be explored by definitive supply well (ACP1).

According to item "5" presented in point 3, we can obtain 16 meters distance from ACP1 well.

On the other hand, it is important to point out the following:

1. the superficial ground (glaciofluvial deposits) of the Spa area has high vulnerability (See Table 2);
2. elevated discharges in ACPI well can provoke appreciable drawdowns in piezometric surface;
3. the ancient captations and the AC1 well are in "perfect communication" with the mineral aquifer and are more than 30 meters away from ACPI.

Thus, to be adequate, the Intermediate zone of the Unhais da Serra Spa should have its centre in well ACPI and a radius of 50 meters, comprising an extension of 0.785 x 10^6 m² (Fig. 2).

5.2 - Intermediate zone

Based on all the studies made, the definition of this zone takes fundamentally into account geologic-structural and hydrogeologic criteria and pollution vulnerability.

In the Intermediate zone the water line located in the West Spa (Fig. 2) is included, because apart from canalising the surface flows to the Immediate zone it also includes a fault that could be an obstruction to the underground flows which circulate from North also carrying them to the Immediate zone.

The East limits of the Intermediate zone coincide with the Unhais da Serra creek, being this creek associated to faults which are a barrier to eventual underground flows from East; on the other hand, the creek is responsible for the transportation of superficial waters to a large distance from the Unhais da Serra thermal area.

In the North and South limits fundamentally topographical criteria were used.

The area defined as Intermediate zone of protection (Fig. 2) has a total extension of 28 x 10^6 m².

5.3 - Distant zone

Because the mineral aquifer is a fissured aquifer it is considered acceptable that all the large complex of fractures located upstream the Spa are included. So, all the hydrographical basin of Unhais da Serra creek upstream is included as Distant zone (Fig.2); this zone occupies the total extension of 2 138 x 10^6 m².

6 FINAL CONSIDERATIONS

During the last years the present thermal unit was closed because of problems of bacteriological contamination. That situation required a set of studies and made the present work possible.

Nowadays, according to what was presented in item 4, a set of pollution risks still exists. Even though, at the moment, the situation can be considered acceptable because the exploration goes on with recharges inferior to 4 l/s in artesianism, keeping the piezometric surface of mineral aquifer above the water table of unconfined aquifer.

In the sequence of the enlargement of the thermal unit the exploration recharge is expected to be increased; by that time all pollution risks should be completely eliminated so that no new mineral water contamination can occur, as that would lead to serious dangers, mainly for public health.

REFERENCES


Aller, et al. (1987). A standardized system for evaluation ground - water pollution potential using hydrologic setting NWWA, NTIS, OIH, USA.


The earth, this amazing system and the only suitable habitat we have, is a closed system and its resources are limited. With the explosion of development in the last decades, the expansion of cities, the excessive land use, the big infrastructure works and the problem of disposal of waste material, environmental protection has become a matter of first order priority. In the mean time, man keeps always his obligation to use and exploit the environment for his survival and development. Engineering Geology together with other geosciences include the ingredients which may be necessary to assess all the relevant geoscientific questions related to the environment. Engineering Geology from knowledge and experience, being aware of the behaviour and reaction of the earth, is in an excellent position to contribute in a dynamic way; not only by protecting, but also by supporting development without harming at the same time, the environment. Papers included in these Proceedings provide a world-wide experience and promote the role of Engineering Geology, and the interdisciplinary collaboration with Hydrogeology, Geochemistry, Geomorphology, Soil and Rock Mechanics, Mining Engineering and others.

La terre, notre habitat unique, est un système fermé et ses ressources sont limitées. Compte tenu du développement explosif des dernières années, de l’expansion des villes, de l’utilisation excessive des sols et des problèmes liés à la gestion des déchets, la protection de l’environnement est devenue une priorité absolue. En même temps, l’homme maintient son obligation d’exploiter l’environnement pour en survivre et se développer. La géologie de l’ingénieur, en cooperation avec d’autres disciplines géologiques, dispose de toutes les données permettant de prendre en compte les vraies questions des Sciences de la Terre concernant l’Environnement. La géologie de l’ingénieur, grâce à ses connaissances et à son expérience du comportement du sol et du sous sol, se trouve dans une position excellente pour y contribuer de façon dynamique; non seulement pour la protection, mais aussi en aidant le développement tout en veillant à ce que l’environnement n’en souffre pas. Les articles inclus dans ce Comptes Rendus fournissent une expérience globale et universelle, supportent le rôle de la géologie de l’ingénieur et promouvent la collaboration interdisciplinaire avec l’hydrogéologie, l’hydrochimie, la géologie, la mécanique des sols et des roches, le génie minier et autres.