Initiative to Select, Label and Protect the World's Most Important Karst Springs

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Abstract

Springs are important to the humanity because they provide potable water to many locations in the world, thus ensuring health, sanitary conditions, food production and economic development. Karst and mineral water springs are particularly important, but springs emerging from karst aquifers are by far the largest—some are even discharging entire underground rivers—whose flow sometimes exceeds 100 m^3/s. Having caused the establishment of permanent settlements and nearby cities, especially in the Roman times, many springs are also historically important. Although some of the best-known karst springs are actively used and very well protected from pollution, many others around the world have been contaminated, devastated by over-pumping or impounded by reservoirs. Taking advantage of the opportunity provided by the 50th anniversary of the IAH Karst Commission (KC) and the involvement of UNESCO in our karst research, this initiative (project MIKAS) aims to bring together both the KC members and many national experts to work, on a voluntary basis, to: 1. develop criteria for the selection of most important karst springs, which inter alia should include historic, aesthetic and scientific values; 2. establish the list of springs; 3. create the Code of Practice for these springs' utilisation and protection; and 4. promote these springs by their in situ labelling and Internet publicising. The idea to identify and protect selected springs does not imply prevention of their further use. To the contrary, this initiative intends to highlight their importance, defend them against possible devastation and ensure that any further intervention considers their protective status.

Keywords

Springs • Karst • Geo-heritage • Protection • Promotion

1 Introduction

Groundwater is a vital resource that provides almost half of all the drinking water that is available in the world. However, for most people, this invisible groundwater is out of sight and out of mind. In addition to many earlier campaigns to promote groundwater and its importance, the UN-Water has decided that the theme for the 2022 World Water Day (WWD) should be "Groundwater: Making the Invisible Visible". Not all groundwater is invisible, though. As aquifers' discharge points, natural springs provide specialists with an insight into underground secrets, and indirectly assess the complexity of groundwater origin and distribution (LaMoreaux and Tanner 2001; Bakalowicz 2005; Kresic and Stevanović 2010; White 2010). Karstic and mineral water springs are particularly important, but springs emerging from karst aquifers are by far the largest, some discharging more than 100 m^3/s (Kresic 2013). They resemble true underground rivers.

Karst covers more than 15% of the continental ice-free land (Goldscheider et al. 2020) and karst aquifers supply approximately 9.2% of the world's population, or close to 678 million people, with potable water (Stevanović 2019). The intakes of springs are the most common tapping structures in karst environment, as channelling gravity springs and diverting water over long distances are still easier that drilling many wells in hard karstic rocks (Stevanović 2018). The latter is the second common way of tapping karst water. Karst springs are important because they provide precious water quality, also sustain ecosystems and maintain the baseflow of many rivers in the world (Cantonati et al. 2006; Bonacci et al. 2009; Stevens et al. 2011).

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The karst environment is so specific that it requires, almost as a rule, a multidisciplinary approach and engagement of specialists from various fields. In 1970, the Karst Commission (KC) was established under the umbrella of the International Association of Hydrogeology (IAH) as an answer to the demand to collectively integrate this highly specialised branch of hydrogeology. More than 50 years old today, the Commission plays the focus point for the exchange of ideas for further development of karst hydrogeology (Milanović and Stevanović 2021). The project of mapping karst aquifers all over the world was recently completed thanks to the support of the KC (Chen et al. 2017; Goldscheider et al. 2020). Through their published books and articles, as well as many activities, members of the KC also largely contributed to marking 2021 as the International Year of Caves and Karst, extended to also include the year 2022. This is why the author of this article is launching the initiative to bring these two together: karst springs and karst experts. The aim is to select, label, protect and promote the most important karst springs at the global and national level. Although the KC should lead this activity, it is expected to receive support from UNESCO (Gunn 2021) and its Intergovernmental Hydrological Programme (IHP) and many national experts who should work on a voluntary basis.

At the annual meeting of the KC IAH held on 23 June 2022 during the Eurokarst 2022 conference in Malaga, this initiative has been approved and following proposal of the author of this contribution the project titled most important karst aquifer's springs (MIKAS) launched. The initial project's advisory board has also been approved and consists of one representative from each continent, chairs of the KC IAH and UNESCO IHP and project's coordinator.

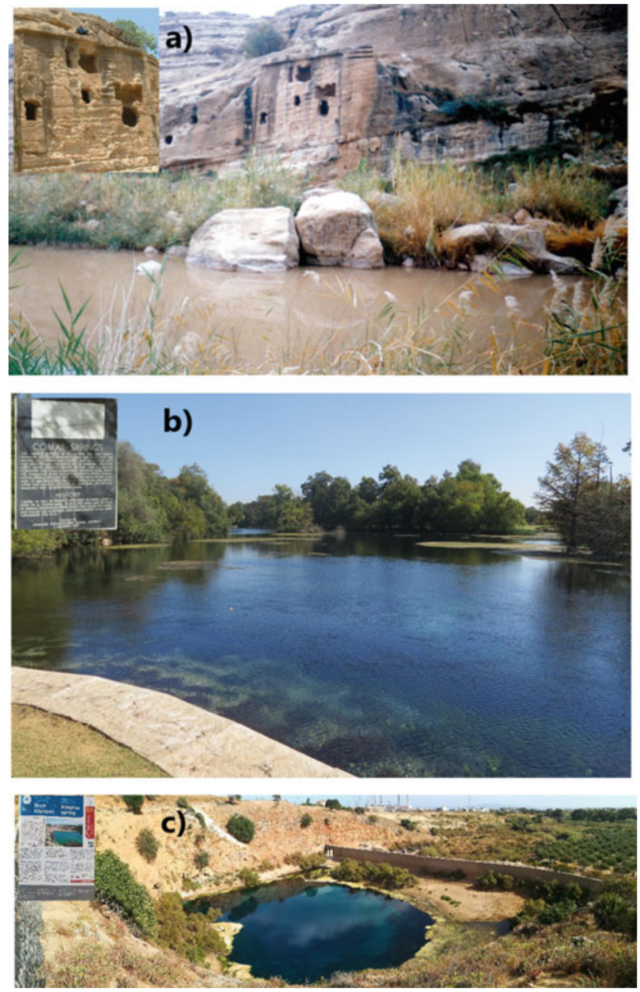

Fig. 1 Some of candidates for global list of springs heritage—existing memorial plates at spring site are posted in left upper corner of each photograph. **a** Khanis spring in northern Iraq, cuneiform inscription carved in rocks; **b** Comal spring in Texas, USA, iron plate; **c** Almyros spring, Crete, Greece, plastic plate. All photos by Z. Stevanović

2 Brief History of Some Karst Springs Utilisation

Tapping spring water is an ancient art. Historically, in order to have easy access to water, people built their settlements near large springs. As a rule, cities with plentiful water drawn from successfully constructed intakes and reservoirs provided a base for prosperous development and a safe haven for their citizens. In contrast, cities that had no water supply from nearby springs were often destroyed or abandoned because they were unable to survive long sieges.

The history of capturing groundwater and diverting water to distant points is linked to ancient China, Mesopotamia and Egypt. However, the golden age was achieved in the Roman times.

The importance of precious spring water and its prevalence over nearby river water had been proven by the Assyrian emperor Sanherib, son of Sargon II (703–681 BC). He constructed the intake systems at the Khanis karstic gravity spring (near Atrush, northern Iraq, Fig. 1) to supply the historical city of Nineveh, located some 16 km away (near today's Mosul in Iraq on Tigris River). The Khanis water structure was one of the very first aqueducts ever constructed (Reade 1978; Stevanović 2010).

During that historical period, Hezakiah, the ruler of ancient Jerusalem, decided to dig a 500 m long tunnel under and through the city walls to ensure supply of water from the Gihon spring, which drains the Turonian limestone aquifer. Before the Assyrian siege of the city, the spring was connected to the Siloam water pool to prevent the spring from falling into the hands of the enemy (Frumkin and Shimron 2006).

The Romans' supremacy and dominance in the ancient world were demonstrated through their knowledge of water, including the art of tapping and delivering spring water. In the narrow historical centre of Rome, there were 23 springs that initially supplied small settlements around the city, while at the height of the Roman Empire, 11 long aqueducts delivered more than 13 m^3/s of water to the city from distances ranging from 16 to 91 km (Lombardi and Corazza 2008). The Roman architect Vitruvius was the first to leave a written record showing that springs on mountain slopes can be recharged by atmospheric precipitation, finding their interaction in the rapid propagation of infiltrated water.

The Romans established many settlements across their empire. Thus, several major cities were constructed around major karst springs in the Adriatic part of the Mediterranean basin: Trieste—Timavo springs, Rijeka—Zvir group of springs, Split—Jadro spring, Dubrovnik—Šumet and Ombla springs, Kotor—Škurda and Gurdić springs (Milanović 1981, 2021; Stevanović 2010).

In the nineteenth century, water from karst springs continued to be an important source of water supply to cities that were developed nearby. The first 130 km long mountain pipeline was completed in 1873 to supply the city of Vienna from the Kaiserbrunn spring (Fig. 2). The quality of its water is excellent, as it generally requires only chlorination, primarily to clean the distribution pipes. Paris also obtained water from several captured springs 100 to 150 km away from the city, piped by aqueducts built between 1865 and 1893 (Margat et al. 2013).

3 Large Karst Springs Distribution

For the purpose of mapping large karst springs under the World Karst Aquifer Mapping (WOKAM) project, Chen et al. (2017) and Goldscheider et al. (2020) established the basic selection criteria that included the following:

- Permanent karst springs with a minimum discharge > 200 l/s (for print map), > 500 l/s (for database),
- Temporary or highly variable springs with a maximum discharge > 10 m^3/s (50 m^3/s),
- Very important submarine springs (experts' opinion),
- Thermal water springs with discharge > 100 l/s that are > 4 °C warmer than the average air temperature (or 200 l/s and 10 °C warmer than air temperature),
- Karst springs > 100 l/s with peculiar gas composition, such as CO_2 or H_2S (200 l/s).

Due to uneven distribution of karst springs and their most dense distribution in Dinaric karst (Stevanović et al. 2016), a more flexible approach has been applied to the final WOKAM map. Therefore, the number of springs per 1000 km^2 in the Alpine orogenic belt and the Dinaric system was reduced. For instance, in some small countries such as Bosnia and Herzegovina, there are all of 8 springs that regularly discharge more than 2000 l/s. Turkey has the same number of large springs, followed by Montenegro (5).

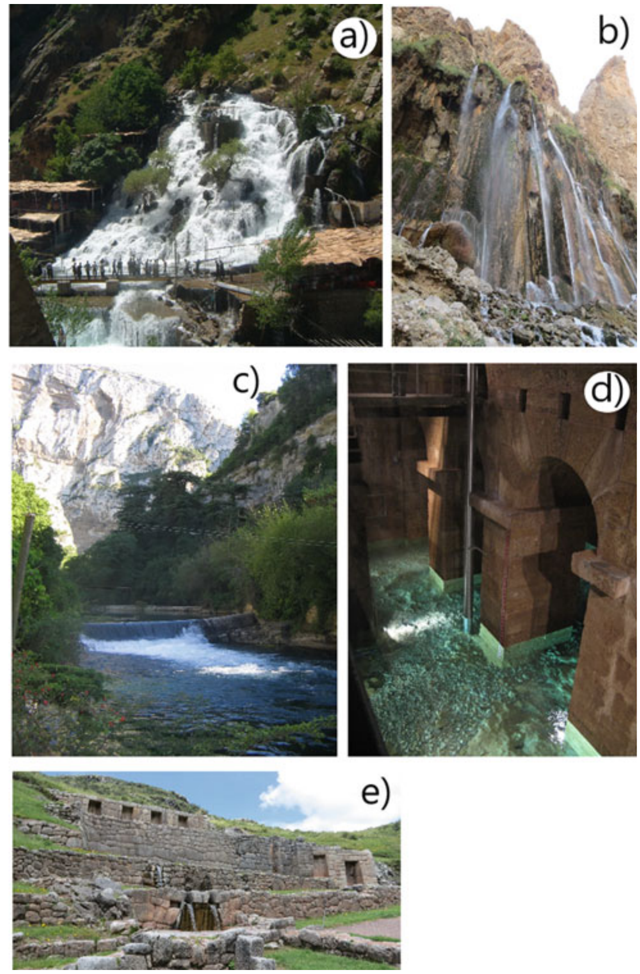

Fig. 2 Some of candidates for global list of karst springs heritage—a) Bekhal spring, Taurids Mts. Iraq; b) Margoon spring, Zagros Mts. Iran; c) Vaucluse spring, Provence, France; d) Kaiserbrunn spring, Rax Mt. Austria; e) Inka's spring, Cusco, Peru. All photos by Z. Stevanović

Whereas, less restrictive criteria were applied for selecting springs in some other parts of the world.

In the Americas, the largest number of springs is located in the southern part of USA (Texas and Florida), Mexico (Yucatan) and Belize. There is a dense distribution of large springs in the Near and Middle East, China and Indonesia, although many regions with a wide distribution of karst rocks do not have very large springs. This is mainly due to the presence of platform type of karst, with a lesser karstification degree (e.g. Canada, South America, Great Britain, northern and eastern Africa).

The full-scale WOKAM map includes 201 selected karst water sources, i.e. 162 continental freshwater springs, 16 submarine springs, 8 thermal springs and 15 water abstraction structures (Goldscheider et al. 2020). The World Karst Spring Hydrograph Database (WOKAS) has also been prepared (Olarinoye et al. 2020) to complement data included in the WOKAM database.

4 Karst Springs Heritage—Selection Criteria and Application

The purpose of this initiative is to make a global karst springs heritage list. The list should be made based on common criteria but adapted to local conditions and recognising the specific circumstances of each country. Something that is important in one country does not have to be important in others. The above discussed karst springs' discharge can be viewed as an important but not critical criterion for selecting springs that should, in the end, be declared geo-heritage sites. The point of the project is not to make a long list, but to instead identify the most important springs in each of the karst countries, and propose that they be labelled, better protected and used in a sustainable fashion. Some large countries may have more than ten, while some others may have just one or two, maybe even no springs at all that would meet the listing criteria. However, some sense of balance between these two extremes is always recommendable.

The initiative proposes that the following steps be taken:

1. Developing criteria for the selection of most important karst springs;
2. Drafting the list of springs;
3. Creating the *Code of Practice* for these springs' utilisation and protection; and
4. Promoting the springs by their in situ labelling and Internet publicising.

The selection criteria should include, *inter alia*[1]:

- Historic,
- Aesthetic,
- Economic,
- Ecologic and
- Scientific values.

Some illustrations of great historic values were provided in the previous chapter. However, there are numerous springs in the world that have historic and/or cultural significance for local nations or community development (Figs. 1, 2).

The aesthetic criterion is always tricky, as *de gustibus non est disputandum*. However, something like a waterfall, a huge cliff or a cave behind a spring should commonly be judged as a nice and acceptable landscape for the list (Fig. 2).

[1] The criteria should be established through the joint work of the project's Editorial Board.

The economic-management value should consider a spring's active use. Spring water can be used for potable water supply, irrigation or for supplying the local industry. In a few words, it can support the local economy by generating food and income to the local community or the country as a whole. Some springs are used for generating hydropower, providing geothermal energy or are applied in balneology and recreation.

Even if not tapped, water from karst springs can be essential from ecological point of view, to sustain ecosystems, maintain the baseflow of rivers or fill large reservoirs.

The scientific value may take into account specific discharge mechanisms of the springs such as large maximal yield, intermittent flowing, gas bubbling, changing water quality in coastal areas (fresh, brackish and saline) or some other properties that could be of research interest to the hydrogeological community.

Further discussion on selecting the criteria and drafting the *Guidelines* for inquiry should be the task of the project's Advisory Board representatives of different regions of the world. The *Code of Practice* for these springs should be prepared along with the *Guidelines* or as a part thereof. The idea of identifying and protecting selected springs does not imply prevention of their further use. On the contrary, the aim of the initiative is to highlight their importance, defend them from possible devastation and ensure that any further intervention takes into account their protected status.

Following in the footsteps of the WOKAM and WOKAS projects, members of the Advisory Board should call on regional and national experts to support the project by providing proposals and supporting the project's implementation in the field. The idea is to create unique panels with basic information (in local languages and English) about the springs, their history and importance, morphological characteristics, discharge mechanisms and other specific facts. The content and form of these unique panels should also be included in the *Guideline* prepared by the Advisory Board.

Information about the springs in question, presented on the Internet and in brochures, would help their promotion and could generate additional income for the local communities from geotourism. In case a spring is actively used for water supply, which would necessitate its greater protection, there would still be space for visits of organised groups during designated time slots.

5 Conclusions

Springs in karst are precious "eyes" that give insight into the often complex mechanism of groundwater creation and distribution. Many are properly utilised or flowing freely to ensure the existence of ecosystem, while others are over-pumped or improperly protected from pollution. The initiative to identify, label and promote the most important karst springs at the global level would spread knowledge about their presence and value, while the prepared and applied *Code of Practice* would help with their protection and more sustainable use.

By decision of the IAH Karst Commission, this initiative has been converted into a project MIKAS, to be led by its members and voluntarily engaged the Advisory Board. However, the MIKAS project would require the involvement of many regional and local experts, and the employment of their knowledge in the process of identification, description and further promotion of selected springs including in situ labelling by commonly agreed unique panel with emblems of the KC, respective national or local community authority and probably UNESCO IHP.

Eurokarst 2022 and the KC annual meeting were an excellent opportunity to present and discuss the project's concept, create the Advisory Board consisting of regional representatives and plan further steps.

The project further extension on selection of mineral and thermal springs for creation of their global list should be a task of the IAH Commission on Mineral and Thermal Waters.

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