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# QANATS BETWEEN MENIKION AND PANGEON MOUNTAINS. A FORGOTTEN AND ENDANGERED RESOURCE FOR LOCAL WATER SUPPLY

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**Abstract:** Due to the growing water shortage in the summer-dry Eastern Mediterranean, the question of water supply has become an important issue. Since antique times subsurface channels (qanats) have been built, which gather groundwater and take it due to the natural slope to places, where the water is needed. In Greece qanat technology has definitely been used during the Ottoman period. After the liberation and the following Greek-Turkish population exchange the knowledge about the systems has disappeared. There is evidence that many of the subsurface galleries are decayed. On the foothills of the Menikion and Pangeon Mountains active qanate systems have been investigated only recently in order to check their activity, contribution to the local water supply and water quality. The results reveal still working qanate systems, which are endangered by regional land use as well as by system-destructive building measures.

**Keywords:** Qanat, water supply, water pollution, water shortage, sustainable water use

## 1. Introduction

In the year 1992 March 22nd was appointed as World Water Day by the United Nations, in order to annually remember one of the most serious problems on our planet – the supply with clean water. The freshwater resources are an indispensible part of all ecosystems and there is no aspect of life without need of water. The enormous population growth on our planet as well the disproportional urbanization gives a new dimension to the aspect of water supply, especially concerning the growing water demand for food production (Scheumann, 2001). To cope with the water demand various technical solutions are applied to defeat water shortage, mostly without implementation of principles of sustainability.

The socio-economic development of societies was ever since dependent from freshwater resources. Especially in the drier regions of the world with little or almost no precipitation it was necessary to develop techniques for water supply as a means of livelihood.

Many ancient remains indicate highly developed technical methods of water utilization in perished civilizations and cultures within dry regions (Garbrecht, 1995). One of the most fascination techniques was and still is the subsurface water use by qanats.

## 2. Qanats in Mediterranean Europe

Although qanats are even found in central European areas like Luxembourg (Kayser and Waringo, 2003) and Trier (Kremer, 2003), linked to the former influence of the Roman Empire, in Europe qanats are mainly bound to adjacent regions of the Mediterranean Sea, where the regional climate supports the development of a dry summer period or a even longer dryness, especially on the southern borders of the Mediterranean. This climatic situation is linked to the remarkable summer influence of the Azores High in the West Mediterranean and the steady blowing dry Etesian winds (Meltemia) in the East.

An overview about typical climate regimes in the Mediterranean (Fig. 1) reveals dry periods in the southern Mediterranean for almost the whole year (e.g. Mersa Matruh). But in Spain and in the East Mediterranean the dry summer period can reach similar dimensions. Thus water shortage is a common consequence. Generally qanats are found where precipitation is less than 500 mm / year. Mostly they are inclined to an annual precipitation between 100 and 300 mm (Bazza, 2007).

A short glance at the distribution of qanats in the Mediterranean reveals a concentration to central and southeastern Spain (Weingartner, 2007). The Spanish capital Madrid was supplied by qanat water until the 19th century (Braun 1974). But qanats can be found in the northern Adriatic (island of Pag, Croatia) and in southern Italy (e.g. Palermo) as well. On the island of Pag (Croatia) a water conduit with shafts up to 44 m and a total length over 1.160 m with a gentle slope of 1 ‰ leads to the city of Novalja (Božić, 2001). As the actual knowledge about the qanat distribution – especially in the European Mediterranean - is very fragmentary it is too soon to draw further conclusions.

Within the region of the Mediterranean borderlands Morocco, Algeria, Tunisia, Libya and Egypt qanats are well known. Here they were already responsible for early state formation (Wilson, 2003). At the moment qanats are still in use in these countries although many of them have dried up due to groundwater drawdown, usually connected to water overuse and dam construction (Lightfoot, 2003).

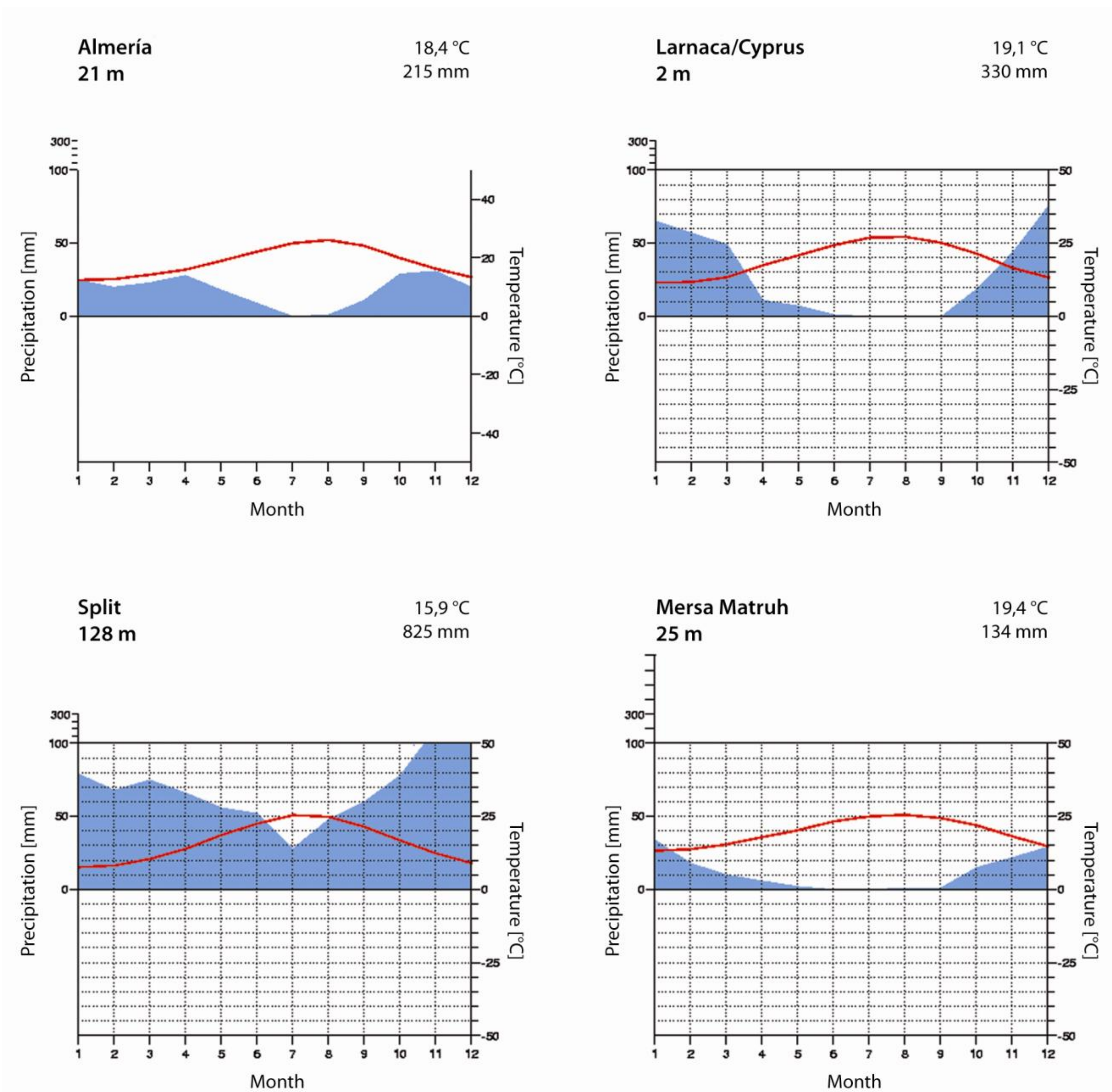


Fig. 1. Mediterranean Climate – typical climographs (Source: www.klimadiagramme.de)

In central Europe – after the fall of the Roman Empire–evidence of qanat construction is missing. However similar water supply conduits reappear together with monasteries. During the Middle Ages the Fulbert-gallery (Maria Laach, Germany) and the Mönchsbergtunnel (Salzburg, Austria) are refereed as the most important tunnels built with qanate technique (Garbrecht, 1995).

### *3. The qanats of Nea Zichni and Angista*

Apart from qanats of ancient and antique times (Crouch, 1993) modern ones have been described as recently as 1993 (Vavliakis). They appear at the margins of the Menikion and Pangeon Mts and are situated at a very typical topographical position, as these mountains have a lasting effect as a big catchment area and are responsible for the recharge of the groundwater flow. Moreover, the mentioned water conduits are qanats in every sense, comparable to the original ones in the homeland of qanats – Iran.

There are indicators for 18 qanats in the region and there is high evidence and proof that the qanats in Phyllis have been built after the occupation of Greece by the Turks, the youngest ones only in 1895 (Vavliakis, 1989). Due to the population exchange between Greece and Turkey knowledge about the communal water supply systems disappeared.

#### *3.1. Water discharge of the qanats of Nea Zichni and Angista*

The Nea Zichni qanat is strictly bound to a dry valley, which is incised into Quaternary conglomerates. The Angista qanat traverses ridges and valleys, thus reaching maximum depths of 25-30 meters (Vavliakis, 1989). From a hydrological point of view, the subsurface geological border between Neogene clay and Quaternary conglomerates acts as the key element for the construction and the course of the galleries.

At the bottom of the subsurface waterways the groundwater is collected and forced to move along the gallery. The starting point of the qanat is usually characterized by peripheral tributary galleries, in order to optimize the drainage of the subsurface water source.

Outside, the dry valleys serve to gather and concentrate the surface water inflow. The qanat water in Nea Zichni is discharged through a pipe of 235 mm diameter. Using a flowmeter the runoff in the pipe was measured continuously (liters per hour) during several periods since the year 2006.

The runoff-scheme in Nea Zichni is clearly marked by 2 different discharge periods. During the winter period distinct runoff oscillations are visible. The rest of the year is characterized by rather uniform discharge and only little oscillations occur (Fig. 3). The hourly runoff displays volumes up to 43 $m^3$. Similar observations were made during the measuring period 2006-2007 (Weingartner 2008). The striking periodic discharge difference and the oscillations in winter may be allocated to the karst environment of the greater catchment area of the qanat - the Menikion Mountains.

The monthly runoff oscillates between 1.908 $m^3$ (January) and 8.918 $m^3$ in November. The whole

Fig. 2. Dry valley with subsurface qanat (dried up part), Nea Zichni.

period reveals a water discharge of almost 55.000 $m^3$.

The Angista qanat reveals a different environment.

a) There is evidence of a subsurface gallery length of 4 km (Vavliakis 1989)
b) The immediate roots of the surface catchment area are in the Pangeon Mountains
c) The geology is dominated by crystalline bedrock

This situation reveals a stronger influence of surface water inflow (compared to Nea Zichni). The flowmeter in the qanat of Angista never registered a drying-up of the system. Obviously the lengths of the system as well as its catchment area have an important influence on the permanent water discharge. Generally the discharge amount of both qanats is reduced due to human impact on the qanat system by system-destructive building measures (concrete shafts which disturb regular water flow).

Several sudden water discharge peaks occur during the measuring period. Usually a clear correlation between precipitation and qanat water discharge can be concluded. The 18th November 2007 precipitation event (Fig. 4), which caused extensive flooding in the region, resulted in a significant rise of qanat water runoff! Within 3 hours only, the amount of qanat water flow increased from 9.66 to 60.12 $m^3$.

### *3.2. Contemporary qanat water use and water quality*

Currently the water of the known active qanats of the area is used for drinking (Rodolivos) as well as

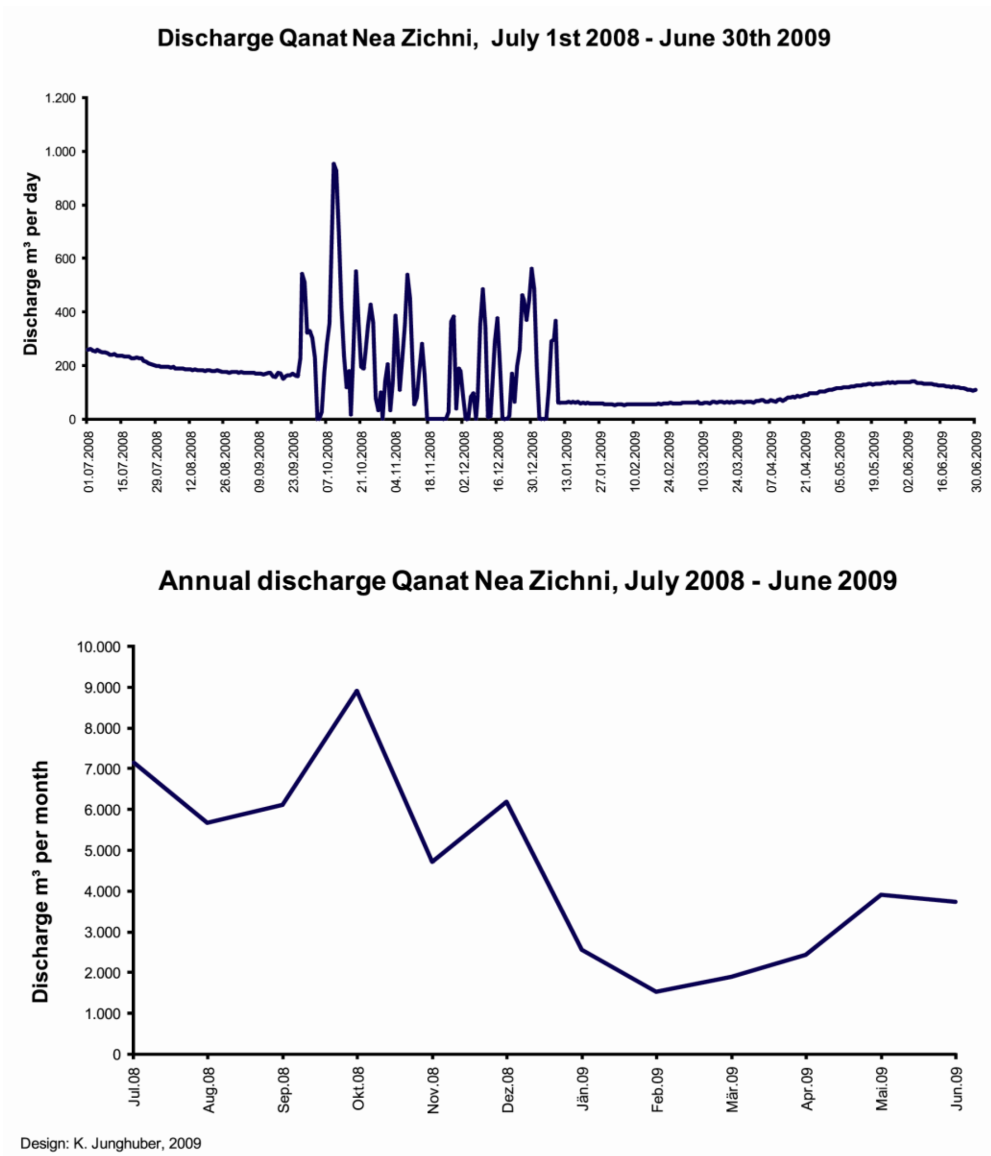


Fig. 3. Discharge and annual course of discharge, Qanat Nea Zichni, July 1st, 2008 – June 30th, 2009.

for irrigation and animal water supply (Nea Zichni and Angista). The contribution of qanat water to the entire water supply of the communities is still a matter of discussion. But the measurements indicate a reliable contribution to the local human and animal water consumption.

The hitherto existing field and laboratory chemical water analyses show the following results: Field as well as laboratory water analyses display conformity with the European Drinking Water Directive (EUDWD). Only two significant deviations occurred: The contents of heavy metals as well as the amount of nitrate ($NO_3$). The excessive nitrate level can be explained by the rather intensive use of fertilizer within the catchment of the qanat (Angista). An explanation of the heavy metal contents seems to be difficult. Field observations indicate a possible connection to illegal dumping. Further research will be necessary to explain the high heavy metal and nitrate concentrations.

In any case, although qanat water reveals a high potential as a drinking water resource, it displays that even 6 m of soil and sediments (and more) above the qanat channels cannot prevent the groundwater from local human land use impact. Furthermore it has to be taken into account, that qanat water catchments include – from a hydrographic point of view – vast areas of the mountain foothills as well as relief controlled surface water from the adjacent mountains. Thus, mapping of the (still unknown) subsurface qanat water ways is an important future challenge to get more information about the distribution and surface/subsurface relations of the qanat systems.

## *4. Conclusion and outlook*

From a global point of view qanats are of significant meaning for the development of human culture. Considering the global water shortage, especially within dry areas, qanat systems represent an ecological sustainable system with a considerable potential in water supply. Some main advantages of qanats are:

- Saving of energy: No additional input of energy is needed.
- Efficiency: No water loss through evaporation (e.g. in comparison to reservoirs).
- Improvement of quality: Clean water is being produced by the natural process of interaction between water and substrate. The water is largely protected from atmospheric immissions. Water quality enhancement through ventilation (shafts).
- Continuity of the system: Water is available during dry periods.
- Landscape ecological sustainability: Negative secondary effects like salinisation are avoided.
- Contribution to a balanced water household. No burden for the water balance of the area where water is used.

The recent investigation results clearly demonstrate the meaning of qanat water and its contribution to a more sustainable use of water resources. Further research will be necessary to recover the forgotten subsurface water ways in order to get closer insight to their local or even regional water supply potential.

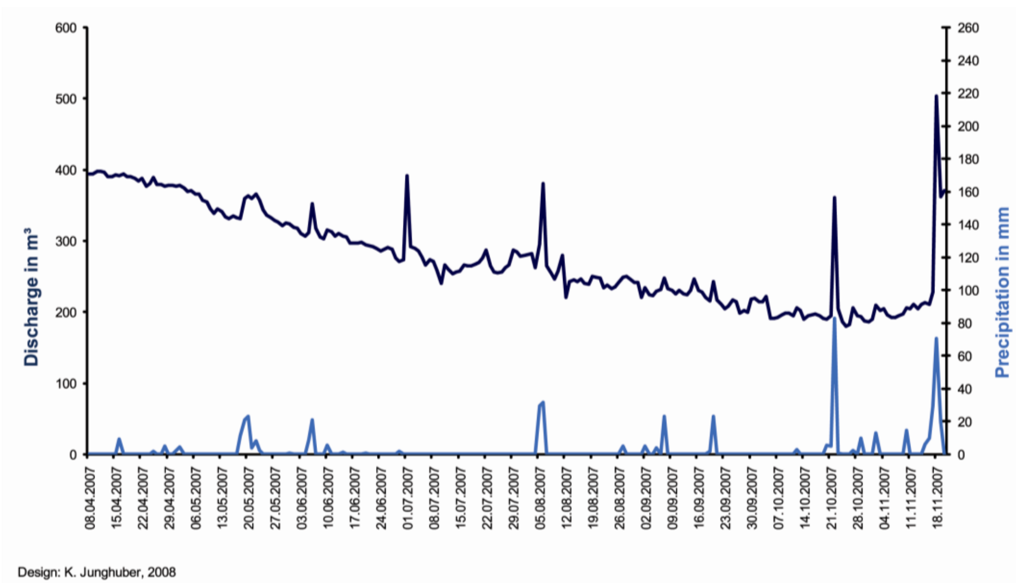


Fig. 4. Discharge and precipitation, Qanat Angista, April – November 2007.

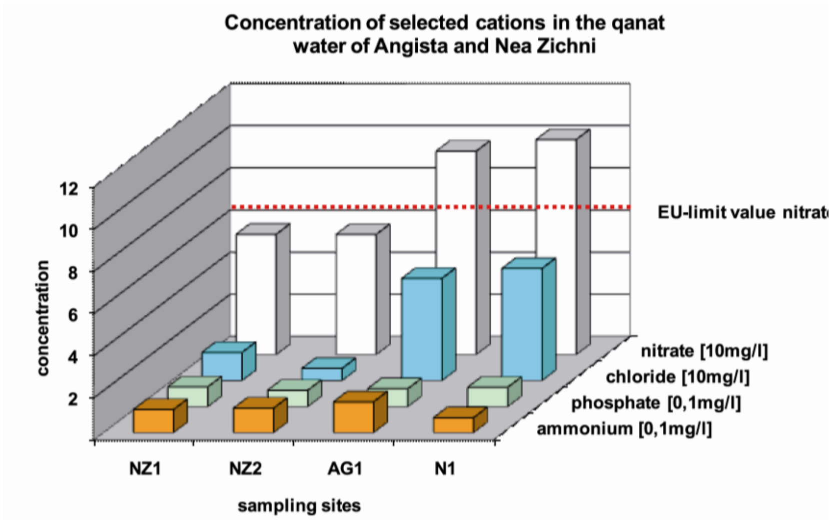


Fig. 5. Concentration of selected cations in the qanat water of Angista and Nea Zichni.

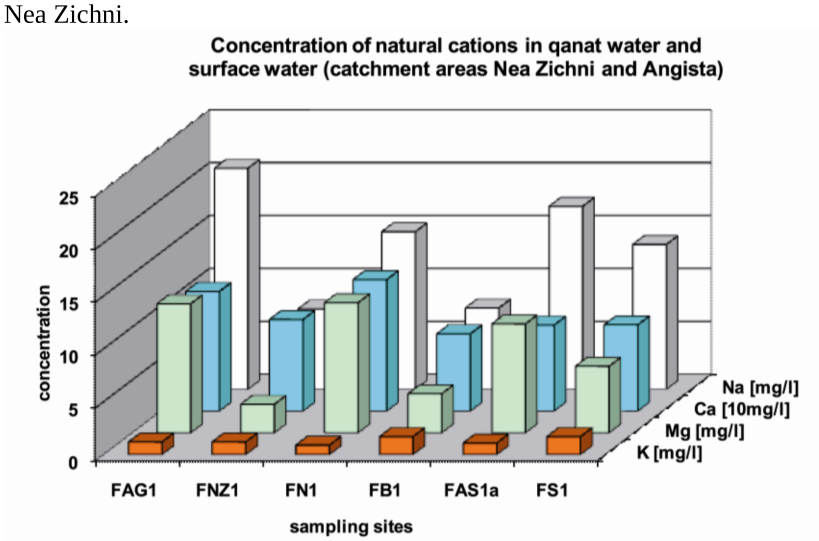


Fig. 6. Concentration of natural cations in qanat water and surface water (catchment areas Nea Zichni and Angista).

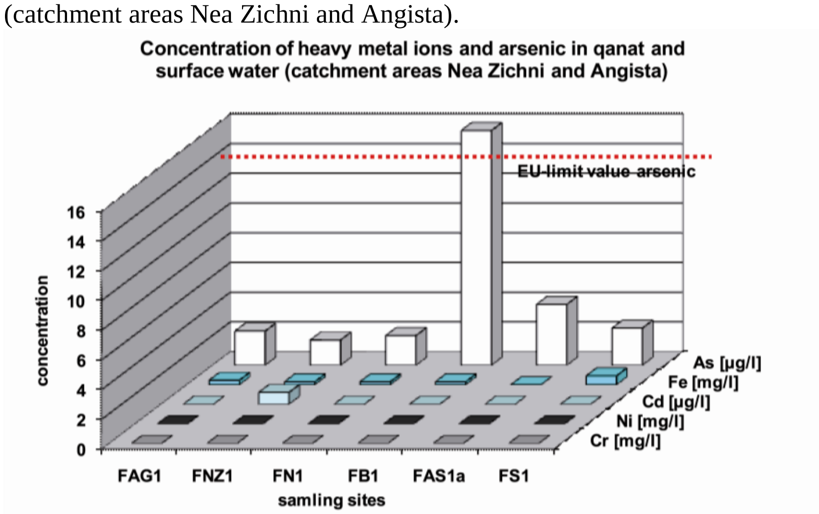


Fig. 7. Concentration of heavy metal ions and arsenic in qanat and surface water (catchment areas Nea Zichni and Angista).

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