



## THE COLLECTING OF GROUNDWATER BY THE QANATS: A MILLENNIUM TECHNIQUE DECAYING

**REMINI B.<sup>1</sup>, KECHAD R.<sup>1</sup>, ACHOUR B.<sup>2</sup>**

<sup>1</sup>University of Blida, road of Soumaa, Blida 9000, Algeria,

<sup>2</sup>Larhyss laboratory, University of Biskra, Biskra 7000, Algeria

reminib@yahoo.fr , rkechad@yahoo.fr , bachir.achour@larhyss.net

### ABSTRACT

On the Iranian origin, technical qanats are an ancestral hydraulic system is to capture and drain the water from groundwater to the gardens. 3000 years old, this technique has allowed man to move from a system of water collection based on animal or human effort a low performance a system of underground galleries that drains the groundwater to the surface of soil without effort and with high efficiency.

The present study shows that the technique of qanats under different appellations (foggaras, Qanat Khettara, Falaj ...) was performed in 52 arid and semi-arid. Unfortunately, this technique was originally development of several oases, is currently in a degraded state. There are approximately 33000 galleries service a total of 85000 in twelve countries, operational estimated percentage to 38%. The reasons for this decline are environmental and socio-economic type.

**Keywords:** Capturing, Qanats, Tablecloth, Degradation, Cultural Heritage.

### INTRODUCTION

The technique of qanats, one of the best inventions in the history of humanity is to drain the water from the groundwater to the surface by underground slightly inclined. Once the water emerges at the surface, it is delivered to homes and gardens across a network seguias. Developed from mining techniques, the technique of qanat was born in ancient Persian; there are more than 3000 years (Goblot, 1963; Goblot, 1979; Hussain et al., 2008; Kazemi, 2004). From this region, it has spread to most arid and semi arid areas of the planet.

The territory of the Arab world is localized in the dry areas of the world in which combine low rainfall and high temperatures. To compensate for the lack of rainfall, the Arabs developed an original technique of removing water from the basement to fertilize the soil and develop the oasis. If its name differs from one country to another, as *foggaras* in Algeria, *Qanat* in Iran, *Khettara* in Morocco and *Falaj* in the Sultanate of Oman, the operating principle remains the same. This is a tunnel of several kilometers with a number of wells which acts as aeration. If today, its origin is well defined, it is the north east of Iran (Goblot, 1963; Goblot, 1979), by contrast there are doubts about his knowledge transfer. If today we accept the universality of the technique, the exact number in service has never been known by specialists. Everyone agrees on the undeniable contribution of this technique for several centuries in the development of oasis in the four corners of the world and the acquisition of groundwater without providing energy, but today it is either *foggaras* the *Falaj*, the *Qanat* and *Khettara*, the number of *qanats* is in sharp decline. We may even lose the World Cultural Heritage in the short term.

This article is a continuation of the article published in Issue 1 of the Journal of Geographia Technica in 2012. In this section we establish a general statement on the *qanat* in the world. An observation on the number, speed and length of *Qanat* dug in some countries of the world will be the focus of this study. The causes of the degradation of this ingenious process will be highlighted.

## **RELATIONSHIPS: ARIDITY - WATER - OASIS**

Several definitions of an oasis have been proposed by different experts and we chose the following two definitions. Mainguet (2003) defined the oasis as an artificial bioclimatic middle developed from an existing natural site that breaks with environmental aridity transforming the global atmosphere at ground level in the lower atmosphere. By contrast, Dolle (1998) defines an oasis as an intensively cultivated in desert environments or strongly marked by aridity area. An oasis is a cultivated area and arranged in an arid environment. The latter is marked by the continuing lack of water. To adapt and settle in such an environment, humans use ingenious techniques to capture water to irrigate gardens.

The aridity is a global phenomenon located either side of the tropics. At these latitudes combine low rainfall and high temperatures (Clouet and Dollée, 1998). In the northern hemisphere the great elect "dry scarf" which cuts Africa and Asia Arid Sahara to Mongolia (Fig. 1). In these deserts, oasis remains a stopover, a step on the caravan routes. It is around this "arid scarf" that have developed in Africa and Asia arid oasis staked two networks: the "Golden Road" through the Sahara to the African Sahel and the "Silk Road" connecting steppes, desert and oasis Asia (Fig. 2). In these dry areas, oases play a strategic

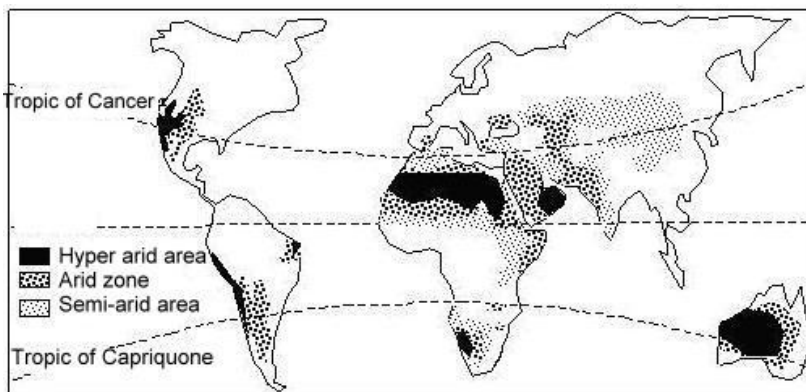
role. With only 150 million of the world's population, they control 30 % of the world's land (Clouet and Dolle, 1998).

In the oases, life is organized around water that remains a most coveted by population oasis valuable resource. So any development of an oasis is made on the basis of the resource. It is from that oasis inhabitants knew invented various ingenious techniques of water catchment (wells, wells rocker, the shaduf ...). The discovery of the art galleries draining for over 3000 years in ancient Iran has greatly facilitated the multiplication of the oasis. The development of oases of intra desert type which manifests in the Sahara, the commercial axis of the silk and the axis of the spread of Islam is directly related to the expansion of technical at qanats (in areas or hydrogeological conditions are favorable).

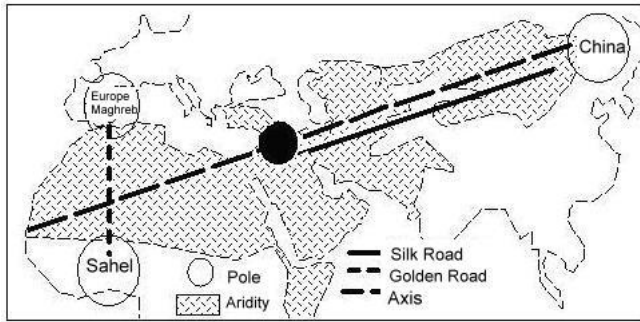
The oases of desert type intra whose palm constitutes the principal vegetation around which revolves the arboricultural, vegetable and forage species. The palm tree is the sacred tree of Muslims. This type of oases locates in the Arab Islamic countries (Maghreb and Mashreq), the Turkish-Islam Mangol (Anatolia to Central Asia), Islam nano-Indian.

The propagation of qanats is related to the axis of development of oasis palm trees (Figs. 3 and 4). Unlike the commercial axis of gold across the Sahara to the African Sahel, the development of trans-Saharan oases is made through other techniques water catchment; draining galleries have not followed the spread of oases in the Islamic countries "black." But the Spaniards, qanats developed in the New World (Fig. 5).

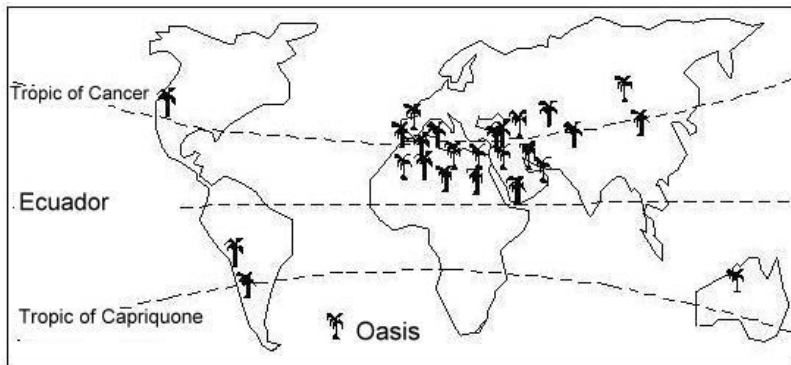
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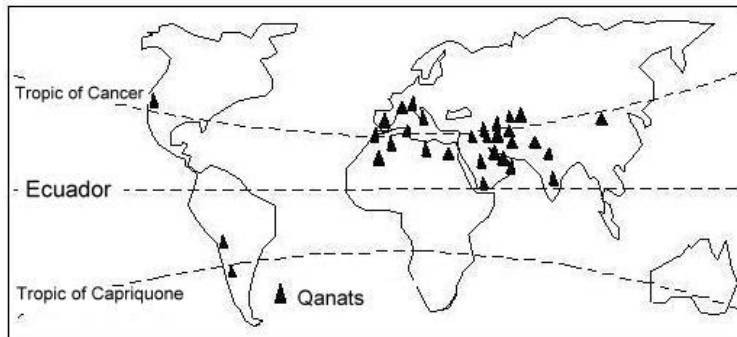
**Figure 1:** Level of aridity (source: Clouet and Dolle, 1998)



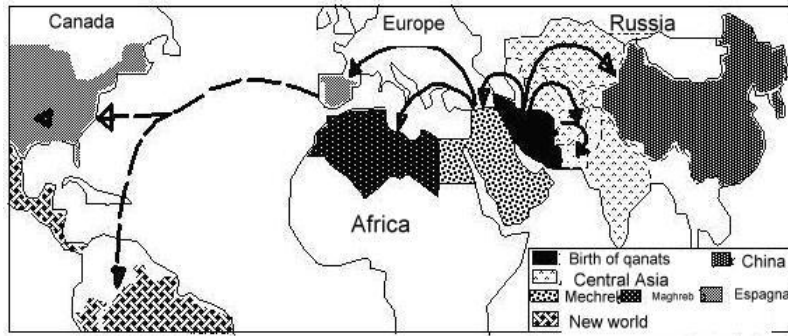
**Figure 2:** Silk Roads and gold (source : Clouet and Dollé, 1998)



**Figure 3:** Development of date palm oasis



**Figure 4:** Propagation of qanats in world



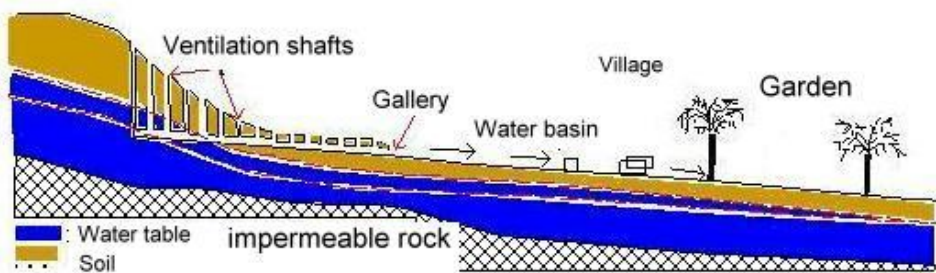
**Figure 5:** Diffusion of qanats in world (source : Goblot, 1979)

### **SIMILARITY BETWEEN DRAINING GALLERIES IN THE WORLD**

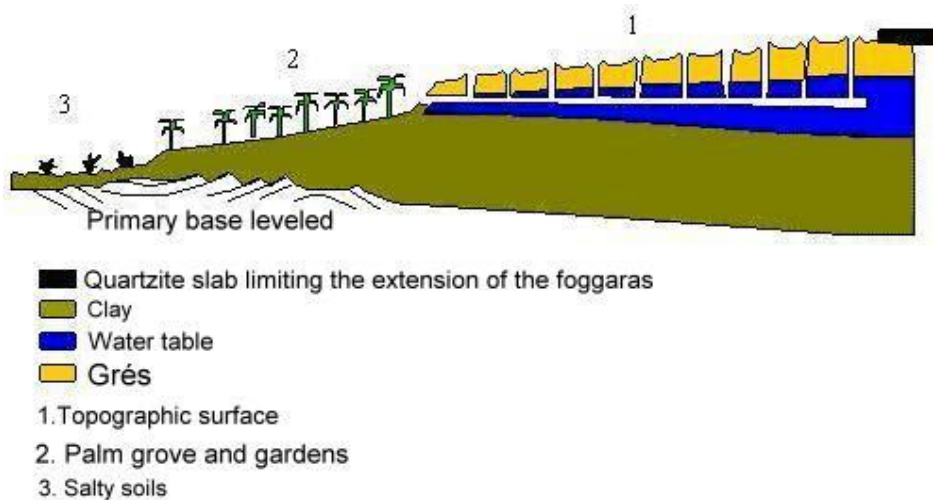
Qanats as the name suggests is a slightly inclined underground tunnel, carrying a water groundwater to the surface. The gallery is equipped with a multitude of ventilation shafts. The operating principle of galleries is the same as it is for the qanats of Iran, foggaras of Algeria, Khettara of Marroco, the Karez of Afghanistan and Flaj of Oman, it is based simply on a flow horizontal groundwater to the surface equipped with a gallery multitude of wells.

As shown in Figures 6, 7, 8 and 9, the diagrams of qanats as khettara the foggaras the qanat and Karez reported by different authors have the same similarities.

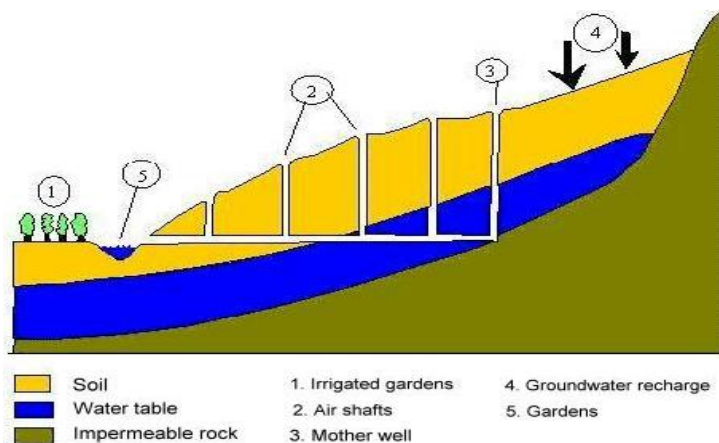
However, there are differences in the distance between the wells, gallery length and depth of the wells. The average distance between the wells foggaras of Algerian Sahara is 13 m. It is 18 m for the qanats and Karez. Contrary to foggaras or well depth not exceeding 30 m, it can reach 300 m for the qanats. This shows that each item is suitable for geological and hydrogeological conditions of the area. By cons there is a major difference between the foggaras of Algeria and the qanat of Iran at the geometrical shape of the galleries section. The gallery section of foggaras of the Algerian Sahara is composed of a lower section of rectangular narrow width. It is intended for the drainage of the water. The upper takes the circular to facilitate movement when cleaning foggaras. The section of a qanat or karez takes the rectangular form rounded in the upper part.



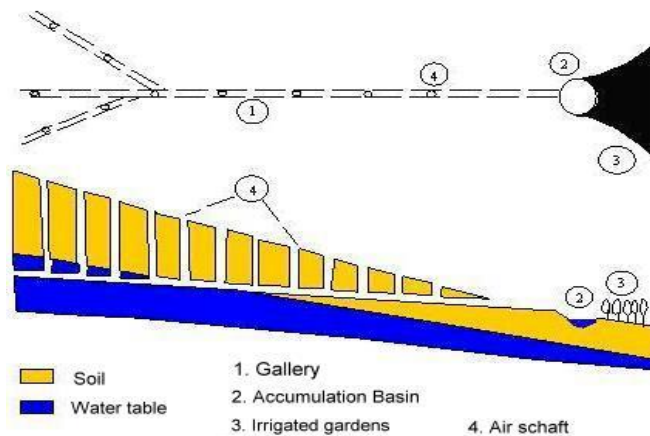
**Figure 6:** Schematic diagram of a khattara (Menjo et al., 2007)



**Figure 7:** Schematic diagram of a foggaras of Algerian Sahara (Bisson, 1992)



**Figure 8:** Diagram summarizing a Iranian Qanat (L'Hote Y., 1990)

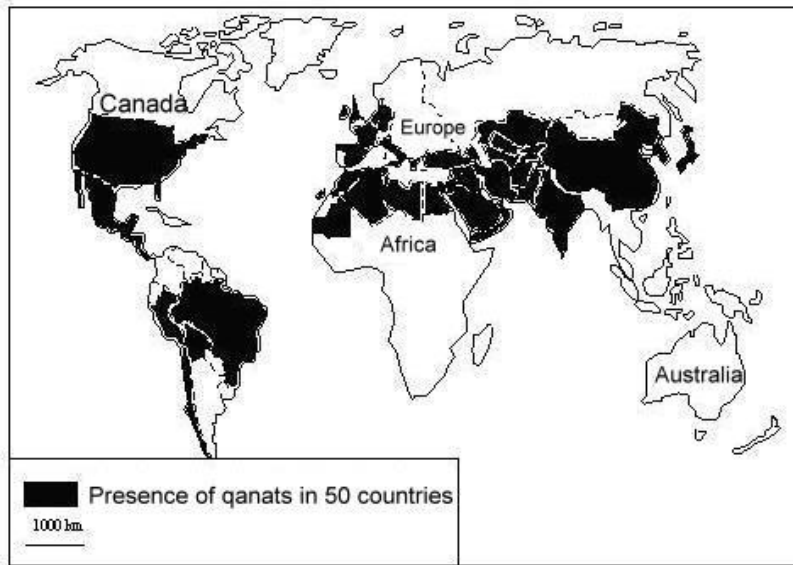


**Figure 9:** Schematic diagram of a Karez (L'Hote Y., 1990)

### **THE QANAT: THE UNIVERSALITY OF A HYDRAULIC STRUCTURE**

Discovered in Iran for over 3000 years, the technique of qanats propagated in arid and semi arid regions of the planet. It is very difficult to know exactly the number of countries that have adopted this ancient technique. Not many authors cited holders' countries qanats. In 1995, Karim Khan and Mr. Nawaz referred to the number of 22 countries that have adopted the traditional hydraulic structure. According Adin (2006), qanats exist in 34 countries worldwide. Hofman (2007) emphasizes the existence of qanats in 35 countries. Boustani in 2008 was reported as the number of 35 countries holding qanats.

Based on fifty scientific articles treating the subject at galleries, we identified 52 countries which have adopted this technique (Fig. 10 and Table 1). About 60000 galleries in these countries is currently estimated 30000 qanats in operation, representing 50% of total..



**Figure 10:** Presence of qanats in the world



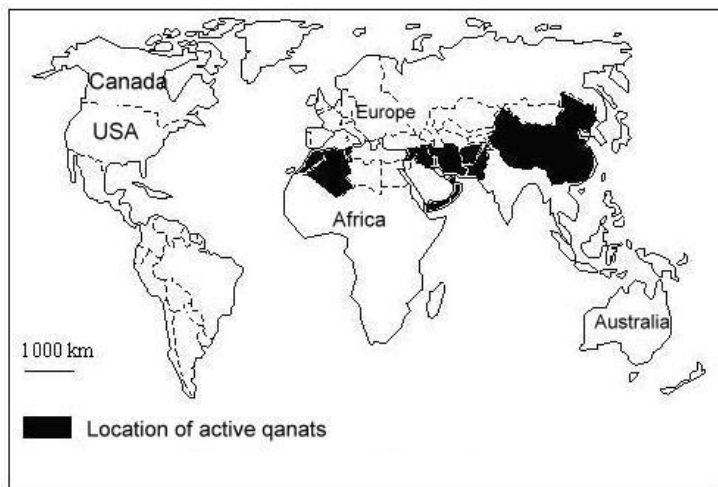
**Table 1:** Qanats in the world

Références : Daanish and Muhamed, 2007; Cristini and Langlais, 2004; Guillermou, 1993; Wessels and Hooggeveen, 2002; Ben Brahim, 2003; Boustani, 2008; Abdin, 2006; L'Hote, 1990; Goblot, 1963; Digard and Briant, 2001; Wulf, 1968; Lynn Teo Simarski, 1992; Goblot, 1979; Cnesta, 2003; Azzi, 1992; Al Sulmani et al., 2007; Viqueira et al., 2001; Bezza 2006; Hofman, 2007; Karimi, 2003; Pierre, 2001; Banks and Soldal, 2002; Gonzalez Andricani and Bazurco, 2004; Wattmann and al., 2000; Kobori, 1980; Kobori, 1982; Kobori, 1990; Kobori et al., 1980; Arrus, 1985; Al Gharfi et al., 2000; Simarski, 1992; Rizk and Al Sharhan, 2003.

N°	Country	Designation		Country	Designation
01	Alegria	Foggara	29	Russia	
02	Marrocco	Khettara, Rhettara	30	Armenia	
03	Tunisia	Kriga, Foggara	31	Turkey	Felledj
04	Libya	Foggara	32	Cyprus	
05	Egypt	Ain, Ayounes (pluriel)	33	Greece	
06	Mauritania		34	Italy	Ingruttato
07	Saudi Arabia		35	France	
08	Oman	Falaj, Aflajs (pluriel)	36	Germany	
09	Bahreïn	Qanat	37	Belgium	
10	Qatar		38	Espagna	Gallarias, Mina
11	Arab Emirates	Falaj	39	Holland	
12	Yémen	Falaj, Ghayl, Miyán	40	Portugal	
13	Syria	Qanat Romani	41	Luxembourg	
14	Jordan	Qanat Romani	42	Peru	Pukios
15	Libanon		43	Brasil	
16	Iraq	Khariz, Qanat	44	Bolivia	Galarias
17	Iran	Qanat	45	Mexico	
18	Pakistan	Karez, Kariz	46	Argentina	Galarias
19	Afghanistan	Karez	47	Chile	
20	India	Surangam	48	USA	
21	China	Kanerjing	49	Czech Republic	
22	Japan	Mambo-mappo	50	Island	
23	Korea	Man-nan-Po	51	Cambodia	Kanerjing
24	Turkmenistan	Felledj	52	England	
25	Azerbaïdjan				
26	Ouzbékistan				
27	Kazakhstan				
28	Tadjikistan				

### Evolution of the discharge of qanats

The technique of qanats has proven its effectiveness in arid and semi arid region during 3000 years. For over half a century, the technique of qanats was neglected to the detriment of modern techniques such as drilling and motor pumps. This technique was abandoned in 40 countries, but continues to operate in 10 countries as the Algeria, Iran, Syria, Morocco, Oman, China, Afghanistan, Jordan, Yemen and Tunisia (Fig. 11). If the digging of a drainage gallery is virtually impossible today, maintaining the number and discharge of galleries remains functional operation more difficult. Table 2 gives an idea about the decline of this technique in the world.



**Figure 11:** The qanats in service worldwide in 2009

**Table 2:** Characteristics of qanats in few countries in the world

Références : Boustani , 2008; Wulf, 1968; Stiros. 2006; Balland, 1992; Al Marshudi, 2007; Al Gharfi et al., 2003; Lighthfoot, 1996; Bezza, 2006; Gonzalez Andriami, 2004; Karimi, 2003; Viqueira et al., 2001; Hofman, 2007; Adin, 2006; Ghorbanai, 2007; Goldsmith and Hildyard, 1984; Ben Brahim, 2003; Ben Brahim, 2004; Rizk and Al Sharhan, 2003; Hussain et al., 2008; Remini and Kechad, 2012, Walther, 2009.

Country	Number of initial qanats	Number of qanats in service	Discharge (l/s)	Length of the gallery (km)
Iran	50000	22000	274000	250000
Afghanistan	20000	6000	100000	
Pakistan	1000	730		
Oman	4112	3012	680	2900
Syria	239	29		
Algeria	1400	903	2781	
Yemen	94	02		
Emirates Arabes Unis		07	315	
Saudi Arabia	4000 à 5000			
Jordan		05		
Iraq	100			
Mexico	150			
Bolivia	64			
Marocco (Tafilalt)	570	150		450
China (Turpan)	1400	400	11360	5000
Tunisia	09	02		

### ***Qanats in Iran***

In Iran Karimi (2003) admitted that existed between 27000 and 50000 qanats in service. According Molle et al. (2003) excavated qanats are 30000-40000 in Iran. Nezaad Safi (1992) estimated that in the early fifties, 50000 qanats were operational. The value of 50000 qanats was retained in Table 1. This valeur has declined in recent years over 50% for the reasons cited above. According to Hofman (2007), the number of functional qanats is 27481 in 1999. Stiros (2006) suggested the number of 22000 qanats in service in Iran. Ghorbani (2007) estimated the number of qanats operating in Iran at 18400. Adin (2006) estimated the number of qanats in service in Iran at 32164. Boustani (2008) gave the value of 22000 operational qanats in Iran. Goldsmith and Hildyard (1984) estimated the number of functional galleries Iran 22000. The number 22000 of qanats was raised again in 1968 by Wulff. According Nazad Safi (1992) on the 20800 number identified qanats in Iran in 1973 only 15500 were in service.

### ***The Karez in Afghanistan***

The number of karez in Afghanistan is much lower than the qanats of Iran. This is how Afghanistan had initially 20000 karez according Heard Bej and Colin de Verdure (1999) advanced the number of 20000. That figure is much larger than those provided by other sources. Bezza (2006) gives the number 6500 karez for irrigation of 168000 hectares of gardens. This valeur was revised downward in 1967, since according to Balland (1992) 6000 karez were identified to irrigate 162000 hectares. According to Hussain (2008), Afghanistan had 6741 karez and irrigating 163000 hectares in the south and southwestern of Afghanistan. According to the same author, in recent years, 60-70% of total karez are off, about.

### ***The karez of Pakistan***

In Pakistan, galleries are called karez. They have been for the last 2500 years an integral part of the agricultural landscape of the province of Baluchiston of Pakistan (Rahmani, 1981) According to the same author, karez in Pakistan was introduced from Afghanistan and not Iran. According Fazle Karim Khan and Nawaz (1995), the number of karez in service in the region of Balusciston exceeds 400. In 2008, Hussain brings more accuracy based on the report of Chaudhry (2002), the province of Balusciston had 1000 464 karez which have an appreciable discharge, 226 drain low discharge and 270 are dry.

### ***Aflajs of Oman***

Despite the drop in discharge of Aflajs, they still constitute an effective means of irrigation in the Sultanate of Oman. In Arabia, 11000 Aflajs were dug. About 4000 Aflajs were dug in the Sultanate of Oman (Bezza, 2006). According to Al Murshudi (2007) and Al Gharfi et al. (2003), 4112 Aflajs were dug and remains today 3017 Aflajs in service in regions: Muscat, Al Batimah, Al Dhahira, Ad Dhakhiya and Ascharquia of Sultanate of Oman (Table 1.2).

### ***The Aflajs of Arab Emirates United***

As Oman, galleries are called Aflajs. The discharge provided by the Aflajs be 630 l/s (Rizk and Al Sharhan, 2003). We do not have information on the number of Aflajs dug in the Emirates. It is certain that Aflajs of Emirates are significantly lower than those of the Sultanate of Oman. According Heard Bej and Colin de Verdure (1999), the oases of El Ain are powered by 7 Alajs still operating with discharge of 315 l/s.

### ***The Auyouns of Saudi Arabia***

Saudi Arabia had between 4000 and 5000 auyounes which functioned for 1250 years (Hussain, 2008). Today, the exact number of operating auyounes remains unknown. However, the Ain the best known in the kingdom is the Ain of Zubaida, located east of Mekka Moukarama. With a length of over 27 km, equipped with 130 of ventilation shaft, it was operational until 1974 at discharge of 450 l/s.

### ***The Khettaras of Morocco***

There is not an exact number of khettaras throughout the Moroccan territory. Khettaras exist in regions Tafilalat and Marrakech. Several studies have been conducted on khettaras of Tafilalet area. According to Ben Brahim (2003), about 570 khettaras dug in the Tafilalet region, 250 khettaras were operational in 1997 and only 150 in 2000.

### ***Foggaras in Algeria***

Several studies have been conducted on the role of regions in foggaras of Touat, Gourara and Tidikelt in southwest Algeria. The initial number of foggaras dug in the Touat, Gourara and Tidikelet would 1400. Three surveys were conducted for 50 years; it is the 1963, 1973 and 1993. This was done by National Agency of Hydraulic Resources (NAHR) gave the number of 903 functional foggaras.

### ***Foggaras in Tunisia***

Under the project "Foggara, inventory and valuation of the technique of galleries in the Sahara and Europe", resulting the INCO MED program, a team of the Institute of Arid Regions in Tunisia has been reported 9 foggaras in Tunisia. Only the foggara of Oum Ejdour (Kasserine) which is in service. Depending on the region, galleries in Tunisia carry the following name: foggaras, Mkoula, Ain, and Guenria Khriga. We have no information about the flow, the length of the galleries and the initial number of foggaras.

### ***Qanats Romani of Syria***

According to Lightfoot (1996), about 239 qanats inventoried, only 29 have remained operational. This number was confirmed by Bezza (2006), as he felt

the qanats romani in service in Syria to 12% of the initial number equal to 239. The operational galleries, they are at number of 30 (Wessels et al. 2003).

### ***The Aflajs of Jordan***

According to Lightfoot, on 32 Aflajs inventoried in Jordan, only 5 are operational. Bezza (2006) refers to the number 8 Aflajs in service which irrigate an area of 600 hectares.

### ***Qanats of Yemen***

According to Lightfoot (2001), in eastern Yemen, about the 77 qanats dug, 23 qanats are still operational. In western countries, of the 17 qanats dug, 11 qanats in operation until 1960. In the plain of Sana'a, 9 qanats remained in operation until 1970. Today there is only two qanats in service.

### ***The kanerjing of China***

Xinjiang had 1400 kanerjing (Rizk and Al Sharhani, 2003). Balland (1992) mentioned the number of 984 kanerjing of length of 5000 km and discharge of 11360 l/s are inventoried in the Xinjiang region. Hussain (2008) estimated the number of 1000 qanats. According to the same author, the number of kanerjing in the region of Xinjiang would be 1784. Currently, the oases of Turfan in Xinjiang region are powered by 400 qanats in service (Rizk and Al Sharhani, 2003). As for Hussain (2008), the number of qanats in service would rather 617. Note that oases of Turfan are considered the largest production area Raisin in the world.

### ***Qanats of Mexico***

Viqueira et al. (2001) refers to the number of 150 galleries inventoried. We do not have information on the number of operational qanats.

### ***Qanats of Bolivia***

According Andriami Gonzalez (2004), Bolivia had 64 galleries. No information on the number of qanats in service.

## **Problems of degradation of qanats in the world**

Technical, environmental and socio-economic problems have contributed to the abandonment of several qanats in worldwide. This is the contribution of drilling and motor pumps in the oases that favored the decline of qanats. Periodical maintenance of the qanats which require considerable effort and low discharge of qanats were compensated by the simplicity of modern techniques and the importance of their discharge of water. Repeated droughts in these regions over the last 30 years have dramatically reduced the discharge of these of qanats. The socio-economic problems, such as the rural exodus, the population migration to large cities and heritage facilitated the decline of these traditional techniques. It should be noted that many farmers currently use modern techniques preferring individual irrigation with a high volume of water. This has created adverse consequences by promoting individualism at the expense of the collective. Wastage of water has prevailed on saving water. This generated upwelling in some places and the depletion of ground water in other places. In addition to difficulties of payment of the invoice is often expensive electricity, the farmer abandoned his garden.

## **CONCLUSION**

As we mentioned earlier in this article, the technical of qanats under different names has been practiced in more than fifty countries of arid and semi-arid. From Iranian origin and old over 3000 years origin, qanat joining the social and technical was considered the most effective method of water catchment until the appearance of motor pumps and boreholes.

If today, draining galleries yet compete with modern techniques to capture in a dozen countries, against, they are completely abandoned in more than 40 countries. As estimated, the number of operational qanats today is around 30000 in the world that remains far from the initial number difficult to estimate. Iran alone had between 40000 and 50000 qanats.

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