Larhyss Journal, ISSN 1112-3680, n°29, Mars 2017, pp. 249-263

THE BENI HAROUN RESERVOIR (ALGERIA) IS IT THREATENED BY SILTATION?

LE RESERVOIR DE BENI HAROUN (ALGERIE) EST-IL MENACE PAR L'ENVASEMENT ?

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ABSTRACT

In arid and semi-arid regions such as Algeria, siltation is a hydraulic problem which poses enormous problems to managers of dams including the reduction in capacity. This article discusses the silting of the Beni Haroun Reservoir who considered the largest Algerian dam. Based on the first conducting bathymetric survey in 2013, a volume of mud is 118 million m^3 were deposited during ten years of operation, an annual rate of siltation of 1.2% / year. The Beni Haroun Reservoir is ranked among the most threatened by the phenomenon of silting of dam. In this case, the dam cannot reach one century an operating; a very short time for a large dam. Priority will be given to desalting of dam

Keywords: Dam - Beni Haroun - Siltation - density currents**.**

RESUME

Dans les régions arides et semi arides comme l'Algérie, l'envasement est un phénomène hydraulique qui pose d'énormes problèmes aux barragistes et notamment la réduction de la capacité. Le présent article traite l'envasement du barrage de Beni Haroun qui considéré comme le plus grand barrage Algérien. Sur la base du premier levé bathymétrique effectuait en 2013, un volume de vase de 118 millions de m^3 se sont déposés durant dix années d'exploitation, soit un taux de comblement annuel de 1.2 %/an, ce qui le classe parmi les barrages les plus menacés par le phénomène de l'envasement. Dans ce cas, le barrage ne pourra pas atteindre un siècle d'exploitation ; une durée très courte pour un barrage de grande envergure. La priorité sera donnée au dévasement du barrage

Mots clés : Barrage - Beni Haroun – Envasement – Courants de densité.

INTRODUCTION

Siltation, a hydraulic phenomenon that threatens the ability of reservoir dams. However, the rate of siltation of dams varies from one region to another. The dams in arid and semi arid areas are the most threatened by this phenomenon of siltation: all climatic and geomorphological conditions are met to accelerate soil erosion and bank erosion. This is how the five watersheds in Algeria recorded very high values in eroded lands. According Demmak (1982), over 180 million tons of eroded land is drained to the sea. However, part of the land settles to the bottom of the reservoir dams. A capacity of 45 million m3 annually is deposited in Algerian dams (Remini et al, 2009; Remini and Hallouche, 2007; Remini, 2011). A relatively high quantity is the fine resulting from the settling particles transported by the density currents. It was in periods of flood that the density current plunge below the lake water to travel several kilometers to come and deposited their fine material to the bottom of dams (Remini et al, 2015a; Remini et al, 2015b). So it's during floods dams are silting in arid regions. However, in the same watershed, dams are not necessarily the same speed with silting. In these areas, known by variations of erosion in time and in space, the tracking capability of dams is an indispensable operation for the managers of dams. This is how the height curve - capacity of dam must be updated on a periodic basis, preferably every two years. In this article we address the evolution of silting in the reservoir of Beni Haroun.

MATERIALS AND METHODS

Location and characteristics of the dam

Considered the largest dam in Algeria with a capacity of 1 billion m3, the dam of Beni Haroun is of great economic importance for the entire Eastern region (Fig; 1 and 2). Located 500 km east of Algiers, the Beni Haroun dam was put into operation in 2003 (Fig. 3).

Figure 1: Dyke Beni Haroun dam (Photo. Remini, June 2014)

Figure 2: Lake of Beni Haroun Dam (photo. Remini, june 2014)

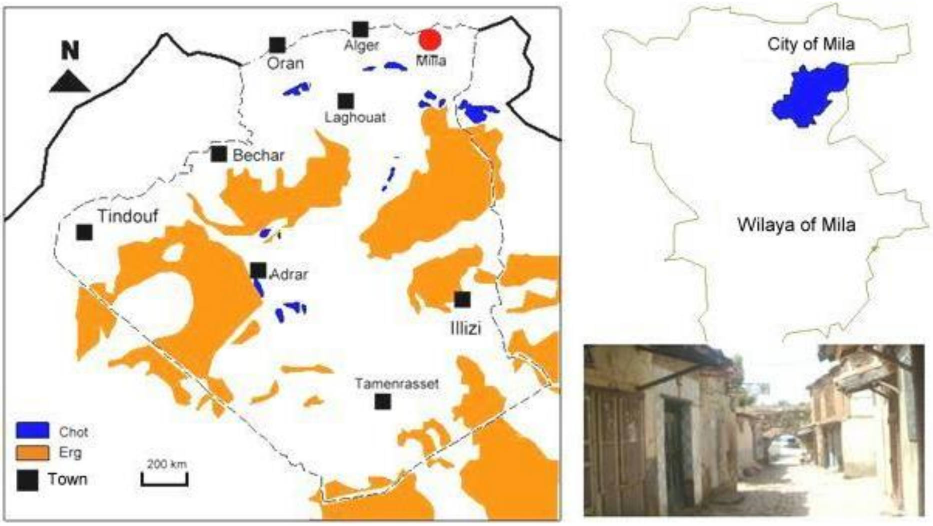

Figure 3: Location of the study area

Data and investigations

We used data from the bathymetric survey conducted by the National Agency of Dams and Transfers during the year 2013. A bathymetric survey conducted by the dam's team in 2013 was a great contribution to this study. To complete the lack of data, we used the method of forecasting the silting of dams in the Maghreb region (Hallouche, 2007, and Remini and Hallouche, 2005).

RESULTS AND DISCUSSION

Density currents in the lake dam of Beni Haroun

The Beni Haroun dam is silting by the density currents. Indeed, the floods charge into fine particles in contact with the lake water at the entrance of the two branches: River of Enndja and River of Rhumel causes the diving fine particles as a well individualized beam propagating on the bottom two wadis. In addition to very high concentrations of fine particles in the flood waters, the configuration of the lake has a favorable geometric shape to the propagation of density current (Fig. 4). The fine particles high load comes from a part of the eroded land of watershed of highly degraded and the other comes from of sapement of banks of wadis Ennedja and Rhumel (fig. 5, 6 and 7). In the branch of the Endja River, density currents flow over a length of approximately 14 km from the diving point (A) to the foot of the dam (G) (fig. 4). In addition to a slope of 0.1% from the bed of the Enndja River and water that can reach a density of 1.08 at the point dive, the Venturi localized in point (D) increases the speed of density currents and gives a second breath to density currents to reach the foot of the dam (G) (fig. 4). It is worth noting that a current density that forms the point of penetration will reach the dam, density currents can disappear at any point of the channel. The distance depends on the concentration of fine particles in flood waters. This is how initial flood autumn generates density currents which easily reach the base of the dam. However, at the confluence of the two branches, designated by the letter (F) is considered fading area density currents. Located at 12 km from the start of the branch of Enndja River the area has a form of a sudden enlargement that promotes braking density currents and therefore the loss of particles at 3 km before reaching the dam. The branch Oued Rhumel with a total length of 19 km from the diving point (B) to the foot of the dam (G) has a drop zone (C) about 5 km from the diving point (B) (fig. 4), low levels of density currents vanish in Area C and cannot spread beyond this threshold. For cons, the currents that move away from Area C continue to spread in the channel arriving to the Venturi E to propel themselves through increased speed and reach the dam (Fig. 4). Some even density currents if they pass the Venturi vanish at the point of confluence in the deposition zone (F); difficulties to overcome enlargement which requires a very high driving force.

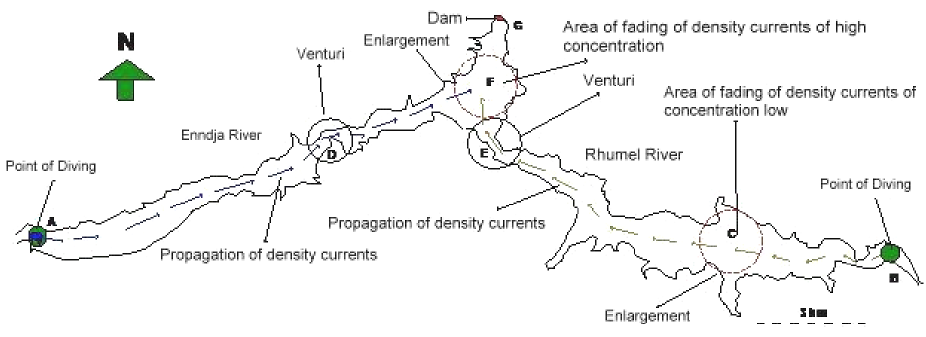

Figure 4: Trajectory of density currents in the lake of Beni Haroun

Figure 5: A view of part of the catchment of Beni Haroun reservoir (photo of Remini, June 2014)

Figure 6: Erosion by gullying in the catchment of Beni Haroun Reservoir (photo of Remini, june 2014)

Figure 7: Sheet erosion in the catchment of Beni Haroun Reservoir (photo of Remini, june 2014)

Can we take advantage of density currents for reducing the silting rate?

The presence of density currents in a lake can be an advantage for the play-off. Indeed, the filling density currents at their reached the foot of the dam can increase the lifetime of the structure. The floods that occur in the Enndja River and Rhumel River bring turbid water of a high concentration that meet the clear waters of the lake (Fig. 8 (a and b)). This contact creates an imbalance of hydrostatic forces which gives "birth" to a density current that flows on the lake bed as a blackish liquid knife synonymous with the presence of a muddy suspension (Fig. 8c). Thanks to the pressure factor characterized by $\Delta\rho$ / ρm, the current density reach the foot of the dam (Fig. 8d). The maneuvers of the discharge sluices at the right time can cause a permanent flow of density current; the flux of silt entering equal to the flux of vase outgoing (fig. 8, 9 and 10). If the valves remain closed while the density current is close to the foot of the dam, the wave is reflected against the dam and back in the opposite direction until a mixture layer is stabilized (Fig. 8 (f and g)). The clayey particles settle out, are bunched together and consolidating. Late opening the valves causing the evacuation of a vase cone near the discharge sluices (fig. 8 h). The pursuit of these maneuvers will cause clogging in the short and medium term valves.

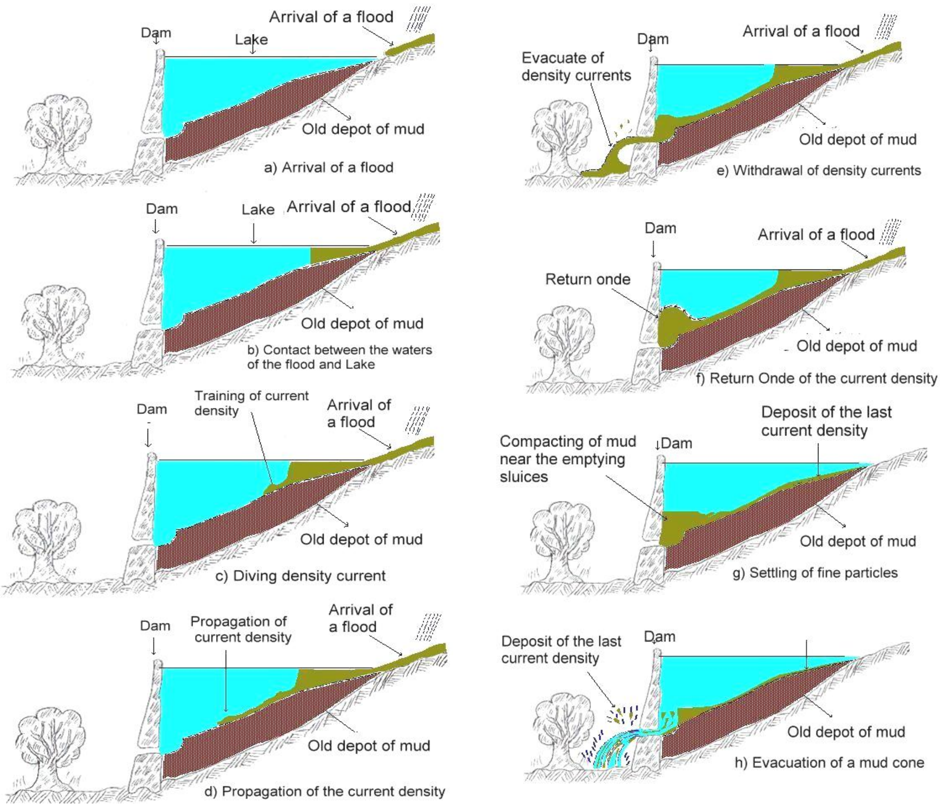

Figure 8: Mechanism of density currents in the Beni Haroun Reservoir

Figure 9: Withdrawal Operation of density currents. (photo. National Agency for Dams and Transfers)

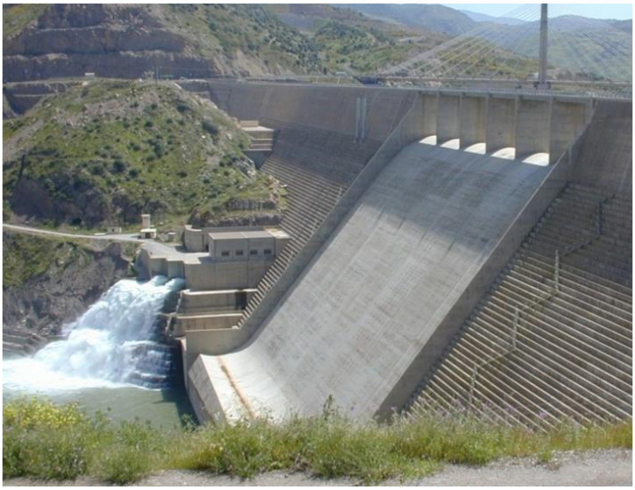

Figure 10: Withdrawal clear waters; synonym of the end of density currents (photo. National Agency for Dams and Transfers)

Ranking of the Beni Haroun Reservoir overlooked siltation

Based on the bathymetric survey conducted by the National Agency of Dams and Transfers in 2013, the normal level of the dam capacity decreased by 998 in 2003 to 958 in 2013, an average annual siltation rate equal to 12 million m^3/year, a filling rate of 12% in 2013. So, filling the annual rate of 1.2%/year. Based on these values the Beni Haroun dam can be classified as a dam with high siltation rate. The amount of 12 million m3 of mud deposited annually into the Beni Haroun dam can only be transported by the current densities in the two branches: Rhumel and Ennedja.

Evolution of siltation in the Beni Haroun Reservoir

To follow the evolution of the silting over the years of operation we need at least a dozen mud volumes. However, there are two bathymetric surveys; the survey of 2004 carried out by the team of the dam and the survey in 2013 conducted by the National Agency of Dams and Transfers. To compensate for the lack of data we used the prediction method of siltation obtained for dams Maghreb (Hallouche and Remini, 2005; Hallouche, 2007). The relationship applied for high siltation rate dams:

$$Wv/Wo = 1{,}62\ t^{0.87}$$

We have shown in Figure 11, the silting a function of time. It is interesting that siltation evolves following two laws: linear and parabolic. The flow, siltation changes linearly: Incoming particles could no longer be evacuated the valve threshold is higher than the bottom. Gradually, as the particles settle to the bottom slope tends towards the equilibrium gradient. The deposit decreases growing in the lake which is compensated by deposits increasingly to the upstream of the dam. In this case, there is a decline in the curve of siltation which takes the form of a parabola.

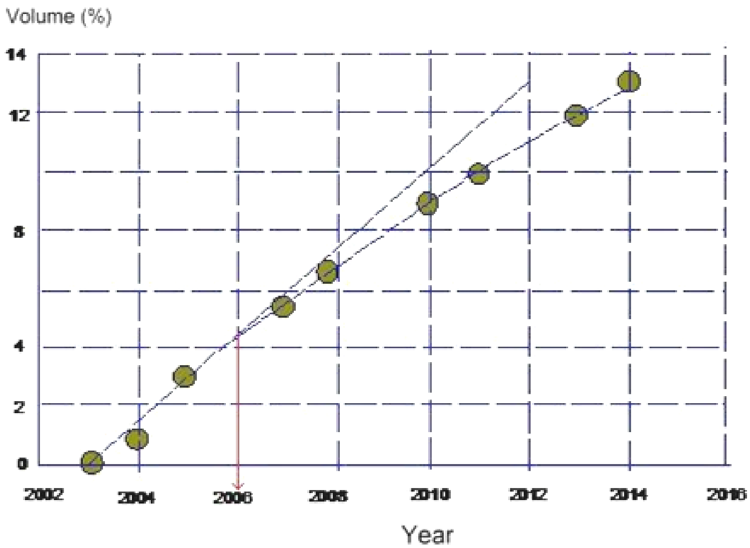

Figure 11: Evolution of silting a function of time

The graph of siltation dam of Beni Haroun

The graph of siltation dam is an essential tool for dam managers. The graphical representation consists of the height curve - initial capacity of water (2003), the vase height -volume curve at different dates and schema evolution silt in the dam. The graph of siltation dam proposed by Remini (1997) to track the evolution of volumes of mud and water in space you time. Figure 12 clearly mentions the increased silt deposits and the decrease in the volume of water the height of the dam during the years: 2004, 2008, 2013 and 2014. It is interesting to note that the amount of mud lost in the dam 2014 is around 130 million m3, a filling rate of 13% in 11 years of operation; considered a very high value because the dam will be out before the year 2099. A very short life for such a large dam like the one Beni Haroun. It is time for that the services concerned are mobilized to increase the lifespan of the dam. Adjustments need to be made in of the catchment upstream of the dam. Strict instructions will be given to the jump-off to conduct extractions operations of density currents arrival of floods. The monitoring of the silting of the dam should be by bathymetric measurements lifted every two years.

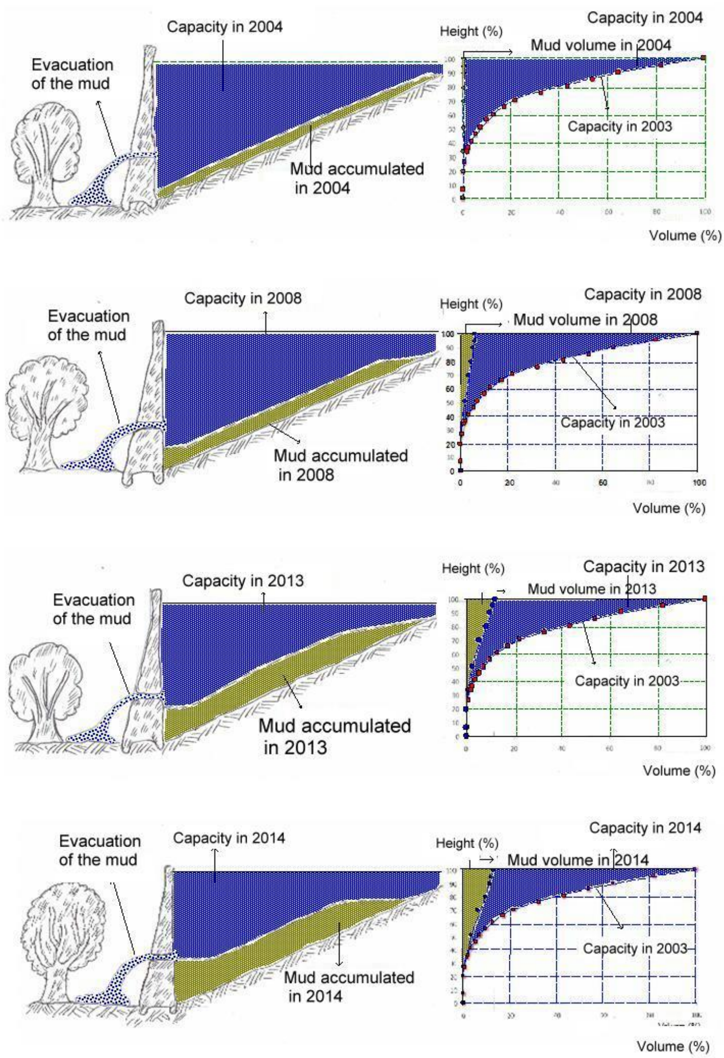

Figure 12: Graphs of siltation of the Beni Haroun Dam for the years 2004, 2008, 2013 and 2014

Siltation of the central part of the Beni Haroum Reservoir

According Remini (1997), the reservoir of dam is delimited into three parts: the upper designated zone 3, the central portion designated zone 2 and the lower part designated zone 1 (Fig. 13). Silt deposits in the central portion are immune to disturbances due to maneuvering valves and variations in water level caused by the arrival of the flood. Therefore the successive deposits are distributed uniformly over the whole central part of the lake. Figure 14 confirms this trend: the evolution of silting in zone 2 follows a linear relationship based on the water level for the periods: 2003-2004, 2003- 2008, 2003-2013 and 2003-2014. In these cases, the roof runs parallel to the tank bottom. In 2014, the filling rate of the central part is around 10% of the initial capacity of the dam.

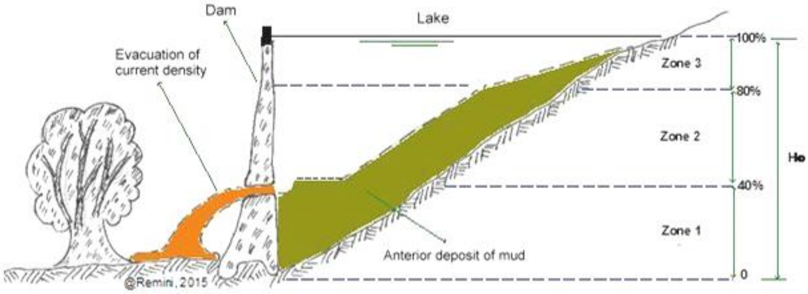

Figure 13: Delimitation of Lake of dam into 3 zones (Remini, 1997)

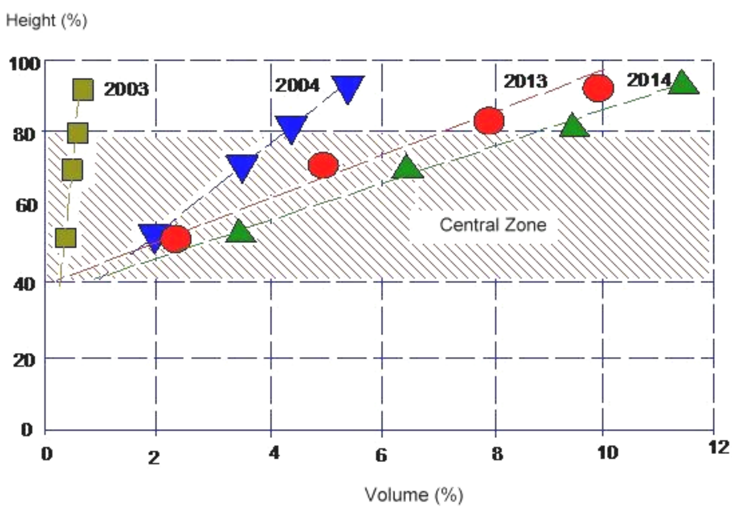

Figure 14: Evolution of siltation in the central part of the Beni Haroun Reservoir

Siltation of the lower part of the Beni Haroum Reservoir

The mud deposits in the lower part are generally influenced by the effects of maneuvering of vanes. If racking of density currents were well conducted. All particles drained by streams have been completely evacuated; the vessel roof remains constant over time. By cons, extractions or opening the valves arrive only to extract a small amount of mud, the mud roof evolves over time and reaches the blockage of discharge sluices. The evolution in time of silting in zone 1 is characterized by moving the point of intersection (I) curves for different silting bathymetric surveys. Figure 15 represents the evolution of mud accumulated in function of depth in the lake for periods: 2003-2004, 2003-2008, 2003-2013 and 2003-2014.Il is interesting that the point (I) climbed from 25% to 40% in zone 1. This is explained by the successive deposition of fine particles in the period: 2008-2014. Extractions were unable to evacuate a good amount of mud.

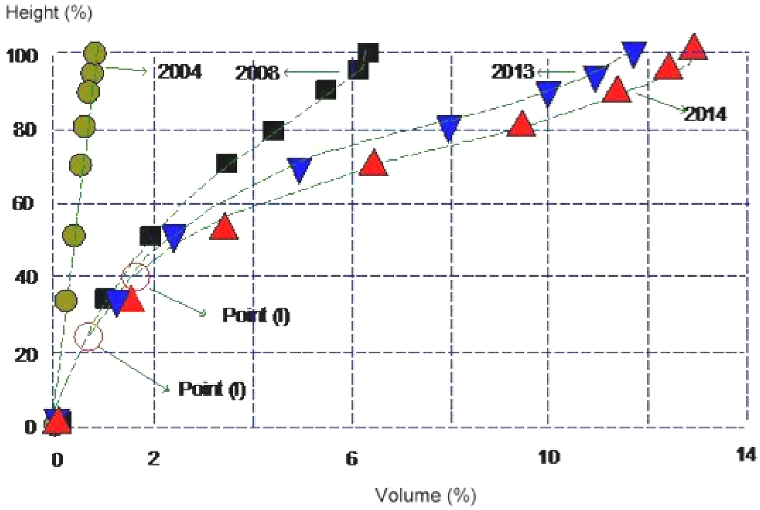

Figure 15 : Evolution of silting in the lower part of the Beni Haroun Reservoir

Siltation of the upper part of the Beni Haroun dam

The upper part of the dam is characterized by the deposition of coarse sediments which form a delta material. Even the fine particles in small proportion are left behind by the diving of density currents. Changes in the free surface of the lake following the arrival of floods affecting the stability of silt deposits in the zone 3. At the beginning of the operation of a dam, muddy deposits are uniform on the lake bottom. Then, the deposit is accelerated; the upper part is drawn with the formation of a coarse sediment delta. The shrinking of the lake begins with the occupation of the area 3. Then zone 2 and finally the zone 1. Figure 16 shows the evolution of silting in the upper part of the dam for the periods: 2003-2004, 2003-2008, 2003-2013 and 2003-2014. It is interesting that the evolution was linear. The muddy deposits were not disturbed by variations of the plan during the 4 periods. In these cases, a change in siltation is the same in the central and high parts: the relationship is linear.

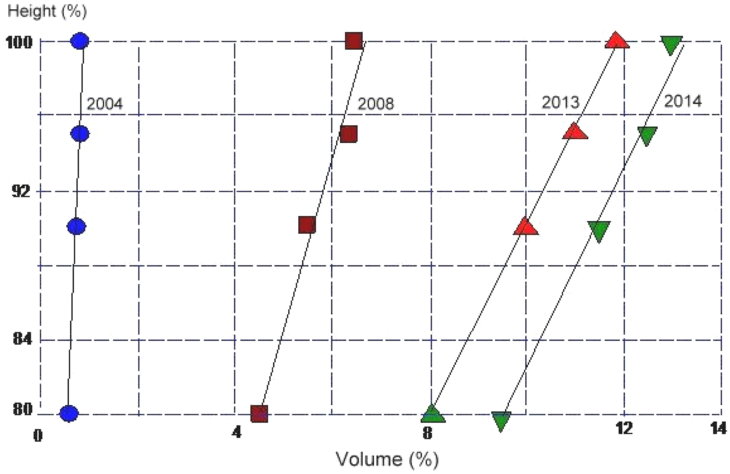

Figure 16: Evolution of siltation in the upper part of the Beni Haroun dam

CONCLUSION

Thanks to an annual filling rate of 1.2%, the Beni Haroun dam is ranked among the Algerians dams most threatened by siltation. If provisions against siltation were not taken in the short and medium term, the dam would be extinguished before 2099. The dam at the confluence of wadis and Ennedja Rhumel received 130 million m3 of silt during the period: 2003-2014, which slashed its initial capacity of 998 billion m3 of volume by 13%. Density currents that occur in periods of floods in two branches: Oued Ennedja and Oued Rhumel, draining an average of 12 million m3 of mud: a high res valeure which is the result of soil erosion, of the catchment and bank erosion. To prolong the life of the structure, technical means of struggle against the silting is needed in the short to medium term. A short-term investigative work is needed on the watershed to search and monitor gullies. Bathymetric surveys must be performed on a periodic basis (every two years) to follow the evolution of siltation in the dam. Technical means of struggle against the silting is needed in the short to medium term. This is the treatment and watershed management, in particular through the torrential correction. Racking of density currents should be a common practice with the arrival of flood at the lake of dam.

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