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DETECTION OF WATER LEAKS IN THE OUIZERT DAMBY THE TEMPERATURE METHOD

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ABSTRACT

Internal erosion caused by infiltration poses a significant risk to the stability of hydraulic structures. This form of erosion is all the more dangerous because it can cause – without any obvious warning signs – a destruction of the structure when the reservoir is full.Seepage areas in dikes are often subject to erosion processes. For this purpose, it is necessary to detect and delineate infiltration zones from their first stage of development. Continuous inspection and monitoring using reliable and sensitive methods for leak detection are therefore of utmost importance.The method is easy to use, and long sections of dikes can be quickly and inexpensively tested. The temperature of the containment fluid playsthe role of a natural tracer. Infiltration of the containment fluid through the dike, causing temperature anomalies in its material, can be detected and localized fromsoil temperature measurements. This is particularly the case for the Ouizert dam, which is located in arid areas where water resources are becoming increasingly scarce. This dam, located approximately 35 km southwest of the city of Mascara (western Algeria), is known for its considerable water losses. With a capacity of approximately 100 million m^3, the Ouizert dam is intended to increase the degree of regulation of the Oued El Hammam to supply water to the town of Oran and the industrial complex of Arzew, ensure irrigation of the El Habra perimeter north of Mohammadia and finally supply the Bouhanifia dam with discharges. However, this dam, which has never reached its maximum level, is threatened by water leaks through one of its shores and whose importance is clearly changing over time. Water leakage was estimated at 1 m^3/s, which corresponds to a considerable volume of water lost. In this article, we present an observation of the problem of leaks through the dam of Ouizert as well as the results of a study of leak detection by the temperature method.

Keywords: Detection, Leaks, Temperature method, Ouizert dam, Algeria.

INTRODUCTION

The phenomenon of water leakage at dams results in considerable losses of precious and scarce water and seriously threatens the stability of hydraulic dams (ANBT, 2018). In addition, most dams are subject to a loss of capacity due primarily to water leakage, siltation of reservoirs and intense evaporation when located in warm areas (Benfetta and Achour, 2017). In addition to the small amount of water received by our dams because of the drought that has affected the country for twenty years, this amount is threatened by three major hydraulic problems that are intense evaporation, accelerated siltation and water leaks especially through the supports. The problem of leaks is of great importance, especially for arid countries such as Algeria where economic development is linked to the amount of water stored in dam reservoirs. Water leaks are inevitable regardless of the location of a dam. They take place not through the body of the dam but through the banks and foundations. Due to the strong hydrostatic thrust exerted by the water of the reservoir on the bottom and banks of the structure, a volume of water infiltrates and evacuates. Indeed, the average volume lost annually was estimated at 40 million m 3 of water. Among the 52 large dams in operation in Algeria, the leakage rate of some far exceeds normal, such as that of Hammam Grouz, whose average leakage rate is around 50.000 m^3/day. This is also the case of the FoumelGherza dam where the problem of leaks through the supports has become dangerous and thorny, since on the one hand we are witnessing an annual increase in the flow of leaks for the same coast of the lake. On the other hand, the precise lack of knowledge of water circulation areas. We must deal with the problem of leaks through this hydraulic infrastructure, in order to reach a stage where this phenomenon will be controlled. (Toumi and Remini, 2004; 2006). To this end, infiltration studies at the dam level must be initiated using the tracer method. The objective of tracer method is, first, to detect the origin of these infiltrations by the isotopic geochemistry method with stable isotopes (^{2}H, ^{18}O) after analysis and treatment of all the piezometric data of the dam (Benfetta and Ouadja, 2018) and (Ratiat and Meddi, 2020).

The problem of water leakage is very complex because it threatens the amount of water accumulated in most dams around the world and causes concern about the stability of these structures, especially if this problem persists. Examples include the following dams:

- On December 2, 1959, the Malpasset Dam was removed. The coast of the detention was close to its maximum, and a wave rushed into the valley, killing 421 people. The cause of the accident was the presence downstream of the dam of an upstream dip fault against which the foundation rock (gneiss) was leaning, which was particularly sheared.
- The Saint Etienne dam is subject to severe overpressures, particularly in winter and when the shore of the water body is high. This is due to the opening of cracks in the concrete/rock contact caused by hydrostatic tipping, which is all the more important when the temperature is low (thermal removal of the concrete results in a displacement of the dam downstream).
- When it was launched in 1958, the CANELLES arch dam was the site of major water leaks across the left bank and near the underground power station. The flow reached

1600 l/s for a body of water exceeding the coast by 75 m. The rise of the water level above this coast caused major breakups (Benfetta and Remini, 2008).

However, the study of this phenomenon differs from one dam to another (ANBT, 2018). In Algeria, we have identified fifteen dams whose volume of exfiltered water exceeds one million m^3 per year each. Even better, six of these dams have a leakage volume greater than 5 million m3, and the Ouizert dam is one of them. It was installed on a site extremely favorable to water leaks, and a gradual reduction in its storage capacity was then observed over time (photographs 1 and 2) (ANBT, 2018). The present study aims to present the results of a study of leak detection by the temperature method.

LOCATION OF THE OUIZERT DAM

The Ouizert dam is located in western Algeria approximately 35 km southwest of the Chief Place of the Wilaya de Mascara and 17 km south of the locality of Ain Fekan (Fig. 1). Its coordinates are X: 250.55 Y: 206.80, Z: 396.00 NGA. The area studied is part of the basin of the wadi El hammam, which covers an area of 14389 km^2. The site of this dam is located on the Sahouet wadi, 4 km northwest of the village of Ouizert, in the commune of Taria (wilaya de Mascara). The Ouizert dam is located in the Oued Sahouet, which is the fusion of the Oueds of Taira and Saida. The Sahouet wadi is one of the main tributaries of the El Hammam wadi, on which the Bouhanifia and Fergoug dams were built. One of its main tasks is to increase the degree of regularization of the Oued El Hammam. A volume of water of 12 hm^3 is intended for the irrigation of some 20,000 hectares of agricultural land of the El Habra plain located north of Mohammadia, while 20 hm^3 of water is devoted to the supply of the industrial area of Arzew and to the supply of drinking water to the city of Oran. The average annual intake of this dam is approximately 45 hm^3/year (Toran, 1970). The Ouizert Dam was located on a slightly sloping substratum (5°-10°) a few meters thick and composed of a rock mass formed by marl, sandstone, puddle, limestone, colluplane and alluvium. According to data from geological surveys, the limestone layer, approximately 5 m thick, is very cracked and thus favors the underground flow of water. The rock mass occupying the area of the profile of the dam is interspersed by a system of oblique cracks almost parallel during the wadi.

In addition, a second system of cracks has been identified that is present at the same time almost perpendicular to the course of the wadi and parallel to the axis of the dam (Toran, 1970). To remedy the problem of water leakage from the Ouizert dam, an attempt was made to consolidate by means of an injection of a shroud along the dyke axis, resulting in the water leakage being stopped on the right bank only. Water leaks still persist across the left bank (Photograph 1) with an average interannual volume of 10.42 hm3, according to our own estimates (ANBT, 2018).

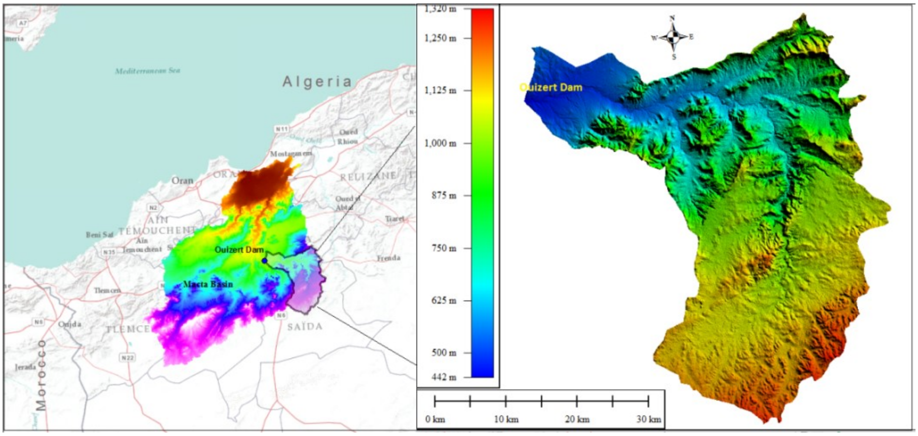

Figure 1: Location of Ouizert Dam (Benfetta and Ouadja, 2018)

Photograph 1: General view of the Ouizert Dam – Algeria (Benfetta, 2018).

Photograph 2: Water leaks on the left bank next to the SB13 piezometer at Ouizert Dam (Benfetta, 2018)

Photograph 3: Meeting of the three Water Leaks on the left bank below the Ouizert Dam (Benfetta, 2018).

DATA USED

To perform our work, we used the following data (Benfetta and Achour, 2017; Benfetta and Remini, 2008; Toran, 1970; ANBT, 2018):

- water leaks
- piezometric coast
- distances between the piezometers
- physicochemical parameters
- water level of the lake
- threshold heights: different water sampling depths of the piezometers (Profiles).

MATERIALS AND METHODS

During the years 1999 to 2018, we carried out measurements of the physicochemical parameters of water samples taken at different depths at the piezometer level. We used hydraulic data made available to us by the services of the Agence Nationale des Barrages –Algiers during the period from 1986 to 2018 to monitor the evolution of these parameters over time. The measurements of the physico-chemical parameters were carried out in situ as well as those of the depths of water samples, time and volume taken by dust. To carry out all these measures, we used the following equipment (ANBT, 2018):

- A limnimetric scale used to read the level of the lake coast.
- A sounding probe that allowed the measurement of the water level in the piezometers. It is composed of two electrodes connected to a multidecameter. The probe emits an audible signal when the electrodes touch the water level in the piezometer, and the multidecameter then indicates the depth value of the water column.
- A water sampling device that we carried out in order to carry out water samples at both the piezometers and the lake.
- A conductivity meter was used to measure the temperature, conductivity and pH of the various samples in situ.
- A water tank was used to measure the volumes of water leakage flows at the left bank.
- A stopwatch was used to measure the filling time of the tank.

Photograph 4: Conductivity meter

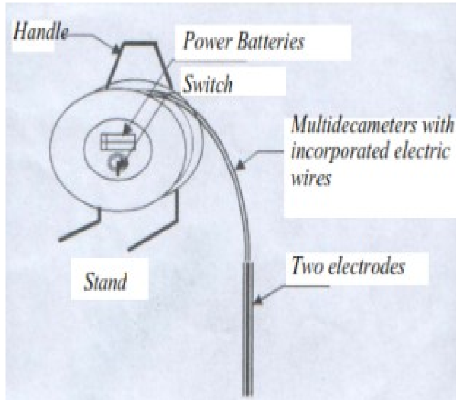

Figure 2: Sound Signal Probe Diagram

Photograph 5: Water Removal from Piezometers on the Left Bank of the OuizertDam (Benfetta, 2018)

Photograph 6: Tractor - means of transport for sampling (Benfetta, 2018)

PROCESSING DATA AND DISCUSSION OF RESULTS

To address the problem of water leaks at the Ouizert Dam, we initiated a temperature leak detection study to locate and delineate seepage areas from their early stages of development. Temperature measurements were applied to locate the various leakage areas. Disturbances and temperature anomalies are caused by infiltration and the existence of water leaks, but the normality and stability of temperatures confirm the absence of leaks. We carried out a campaign of temperature measurements at all the piezometers which gave the same results whether at the level of the left bank or at the level of the body of the dike. We present in our article the results of some piezometers representative of all the piezometers. We cannot present them all at the same time since they gave the same result (Benfetta and Ouadja, 2018; ANBT, 2018).

Leak detection by temperature measurements in the left bank

In this section, we will present the variation in water leakage rates as a function of time (Fig. 3), then the temperature measurements and their variation as a function of depth in the same piezometer and their variation from one piezometer to another. The results are shown in Figs. 4 to 9 (Benfetta and Ouadja, 2018; ANBT, 2018).

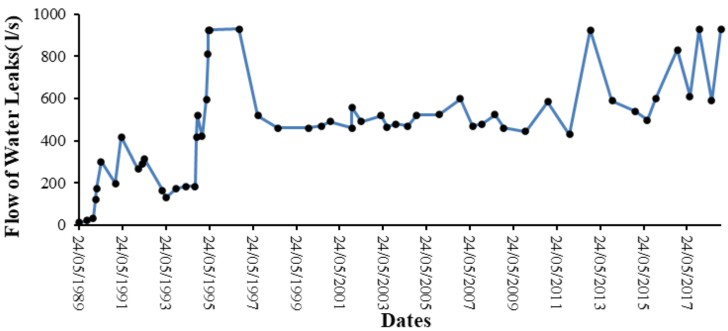

Figure 3: Variation in the leakage rate of the Algerian dam of Ouizert

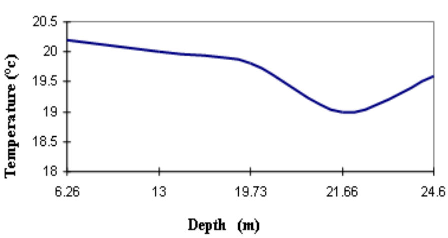

Figure 4: Graphical representation of temperature as a function of depth -SB13-left bank

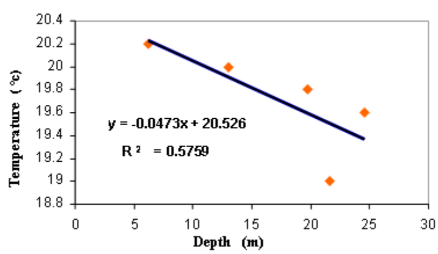

Figure 5: Graphical representation of temperature as a function of depth -SB13-left bank

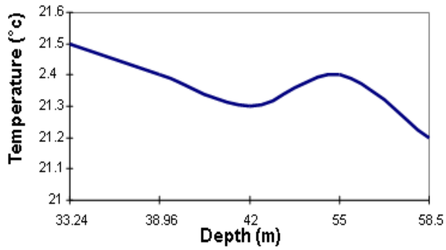

Figure 6: Graphical representation of temperature as a function of depth–SB5-left bank

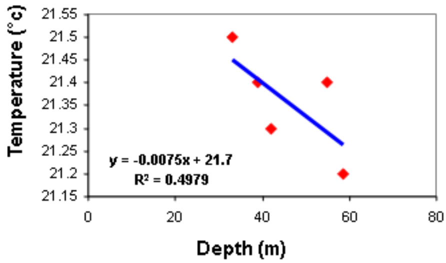

Figure 7: Graphical representation of temperature as a function of depth –SB5--left bank

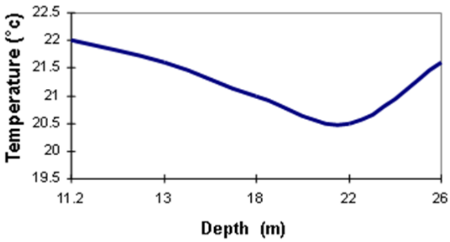

Figure 8: Graphical representation of temperature as a function of depth –SB12-left bank

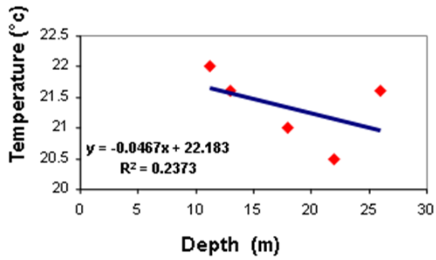

Figure 9: Graphical representation of temperature as a function of depth –SB12-left bank

In Figs. 5, 7 and 9, we obtained very small correlation coefficients (0.57, 0.49, 0.23), which explains that there is no relationship between the two parameters and that there is a disturbance in the temperatures at each depth level. This means that there is a high water circulation and disturbance in the water circulation and the groundwater flow is not uniform and varies sharply. The infiltration of the retaining fluid through these layers causes temperature anomalies in its material. Figs. 4 to 9 illustrate well the disturbances and temperature anomalies caused by infiltration and the existence of leaks and indicate the different areas where water infiltrates. The recognized infiltrations result from the degraded state of the geological layers crossed by these piezometers (Benfetta and Ouadja, 2018; Heinrich, 2001).

Variation in the piezometric line of the left bank piezometers for different shores of the lake

To confirm the results of the study of temperature measurements in the left bank, we present in Fig. 10 the variation in the piezometric line of piezometers located in the left bank of the dam for different shores of the lake.

Fig. 10 shows that the current lines have a strong curvature, and the groundwater flow is not uniform and varies sharply, which means the presence of highly permeable geological layers due to the existence of cracks that present preferred routes for water leakage in the left bank of the dam (Benfetta and Ouadja, 2018; Heinrich, 2001).

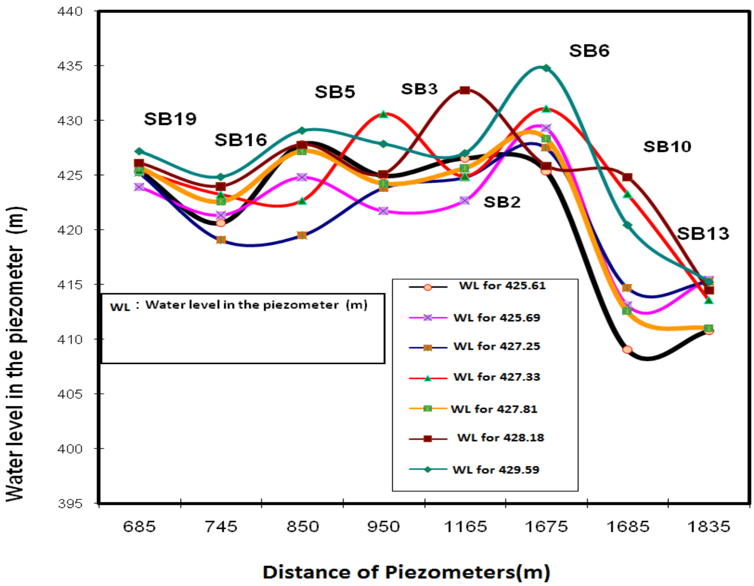

Figure 10: Piezometric variation as a function of lake level – left bank - Ouizert Dam

Detection of water leaks by temperature measurement – dike body

In this section, we will present the study of water leaks in the body of the dike.

In Figs. 11 to 14, we obtained very high correlation coefficients (0.91, 0.90), which explains that there is a very good relationship between the two parameters and that there is stability in temperatures at each depth level. The groundwater flow is uniform and does not change abruptly. They show that there is a good correlation that tells us about the normality and stability of temperatures, thus confirming the absence of leaks and infiltrations in the body of the dike (Benfetta and Ouadja, 2018; Heinrich, 2001).

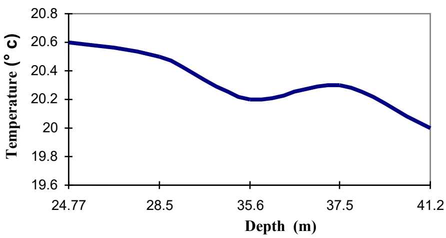

Figure 11: Graphical representation of temperature as a function of depth -PII(20)-Dike body

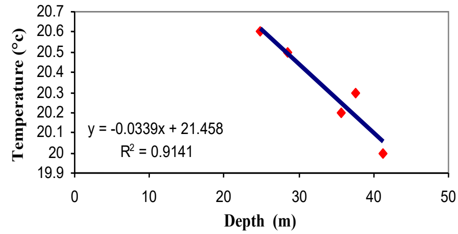

Figure 12: Graphicalrepresentation of temperature as a function of depth -PII(20)-Dike body

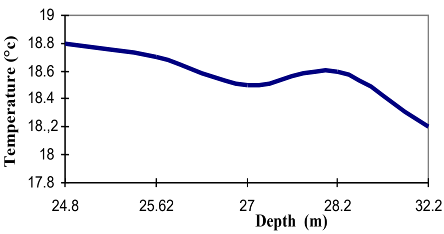

Figure 13: Graphical representation of temperature as a function of depth -PIII(10)-Dike body

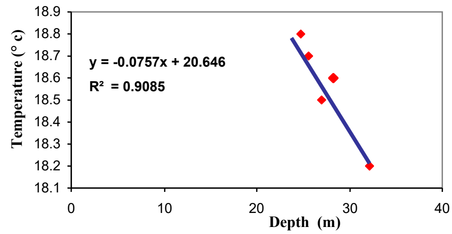

Figure 14: Graphical representation of temperature as a function of depth -PIII(10)-Dike body

Variation in the piezometric line according to the shore of the lake in the body of the dike

To confirm the absence of water leaks in the body of the Ouizert dam, we present in Fig. 15 the variation in the piezometric line of piezometers located in the body of the dam dam for different shores of the lake (Benfetta and Achour, 2017; Heinrich, 2001).

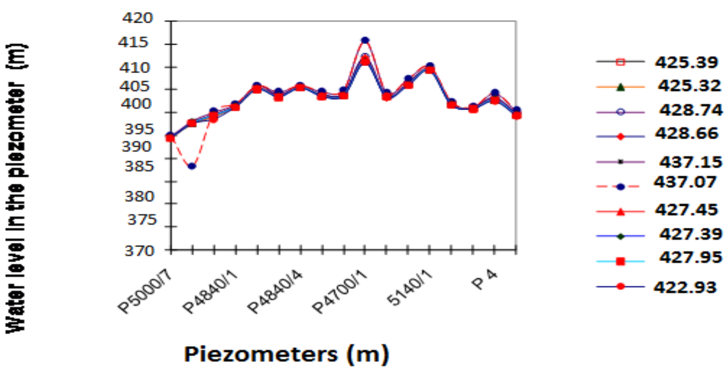

Figure 15: Piezometric variation as a function of lake level – dike body- Ouizert Dam

According to Fig. 15, we note that the curvature of the piezometric lines is small, and the piezometric lines are parallel and confused (liquid sections of the current are flat and the flow varies gradually and not abruptly), which means the presence of low permeable geological layers reflecting the absence of cracks and water leaks in the dam body (Benfetta and Achour, 2017; Heinrich, 2001).

According to our study, we can draw the following important discussion:

In Figs. 5, 7, and 11, we obtained very small correlation coefficients (0.57, 0.49, 0.23), which explains that there is no relationship between the two parameters and that there is a disturbance in the temperatures at each depth level. This means that there is high water circulation and disturbance in the water circulation, and the groundwater flow is not uniform and varies sharply. The infiltration of the retaining fluid through these layers causes temperature anomalies in its material.

Fig. 10 shows that the current lines have a strong curvature, and the groundwater flow is not uniform and varies sharply. This means the presence of highly permeable geological layers due to the existence of cracks that present preferred routes for water leakage in the left bank of the dam.

In Figs. 11 to 14, we obtained very high correlation coefficients (0.91, 0.90), which explains that there is a very good relationship between the two parameters and that there is stability in temperatures at each depth level. The groundwater flow is uniform and does not change abruptly. They show that there is a good correlation that tells us about the normality and stability of temperatures, thus confirming the absence of leaks and infiltrations in the body of the dike.

According to Fig. 13, we note that the curvature of the piezometric lines is small, and the piezometric lines are parallel and confused (liquid sections of the current are flat and the flow varies gradually and not abruptly), which means the presence of low permeable geological layers reflecting the absence of cracks and water leaks in the dam body.

Figs. 4 to 9 illustrate well the disturbances and temperature anomalies caused by infiltration and the existence of leaks and indicate the different areas where water infiltrates. The recognized infiltrations result from the degraded state of the geological layers crossed by these piezometers.

Based on these results, we confirm that the Ouizert dam is located on a site constituted by a rather cracked and faulty rock complex. This cracking is much more marked on hard rocks (limestone, sandstone, shale) than it is on marly rocks. Local cracks are also visible on the dust deposits but are of lesser importance.

On the right bank, the rock complex was dislocated and lowered. Subsidence of the boulder is assumed to have occurred along two roughly parallel fracture lines during the wadi. Water leakage is unlikely from the right bank, as the faults observed are virtually parallel to the direction of the layers and subsequently to the dam axis.

On the cliffs of the left bank, downstream of the dam, significant discontinuities are visible (cracks and faults), and the directions of extension are almost parallel and perpendicular during the wadi. These discontinuities promote water losses from the reservoir.

CONCLUSION

The reservoir of the Ouizert dam faces a very serious hydraulic problem namely the high water leaks through the left bank which generate significant losses thus increasing the total losses of this dam. The situation at the Ouizert dam is worrying since this hydraulic phenomenon generates considerable losses and threatens the stability of this structure in the long term. The study of leaks by the method of temperatures allowed us to confirm the results obtained by the physico-chemical and piezometric study that we carried out at this dam before. Based on the analysis of the results obtained by the temperature method, we can conclude that water leaks are manifested at the left bank downstream of the dam and are favored by the presence of cracks of roughly parallel and perpendicular directions during the wadi and also by the gradient which is relatively strong, while on the side of the right bank, the absence of water losses due to the direction of the cracks that is parallel to the axis of the dam , the low gradient and the existing injection wall along the axis of the dike which allowed the suppression of leaks at the right bank . Based on the excellent results obtained, we confirm that the Ouizert dam is located on a site consisting of a rather cracked and defective rocky complex. This cracking is much more marked on hard rocks (limestone, sandstone, schist) than on marl rocks. Local cracks are also visible on dust deposits but are of lesser importance. Faced with these facts, the management of this problem in the immediate future is very necessary by making a sealing veil in order to eliminate water leaks in the left bank and increase the storage capacity and ensure the safety of this dam.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

NATIONAL AGENCY FOR DAMS AND TRANSFERTS. (ANBT). (2018). Detection of water leaks in dam reservoirs. Internal report. Algiers, 50 p.

NATIONAL AGENCY FOR DAMS AND TRANSFERTS. (ANBT). Annual assessment of dam operations (1986-2018). Algiers.

BENFETTA H., OUADJA A. (2018). Enhancement of the study of water leaks in the Algerian dam of Foum El Gherza, Arabian Journal of Geosciences, Vol. 10, Issue 22, pp. 1-18. DOI: 10.1007/s12517-017-3281-9.

BENFETTA H., ACHOUR B. (2017). Techniques for detecting the progress of the leaks in dams and other artificial reservoirs, Larhyss Journal, No 30, pp. 361-390.

BENFETTA H., REMINI B. (2008). Water leaks in the Algerian Ouizert dam. Journal Drought of France, Les fuites d'eau dans le barrage algérien de Ouizert, Revue Sécheresse, No 3, pp. 1-15.

HEINRICH W. (2001). Detection of water leakage by temperature method, French Documentation Edition, France, 10 p.

RATIAT A; MEDDI M. (2020). Simulation and Analysis of Infiltration Phenomenon In Earth Dams: Case of Fontaine Des Gazelles Dam.Biskra. PhD Thesis. ENSH Blida.

TOUMI A., REMINI B. (2004). Foum EL Gherza Dam Water Leak Problem, Larhyss Journal, No 3, pp. 25-38.

TOUMI A., REMINI B. (2006). The problem of water leaks from the Hammam-Grouz Dam. Larhyss Journal, No 5, pp.41-48

TORAN C. (1970). Preliminary detailed project of the Ouizert Dam. (Madrid Design Office), National Agency for Dams and Transfers (ANBT), Algiers.