Hydrochemical assessment of groundwater in the Kert aquifer using a GIS application: an overview of the control factors for fluoride, arsenic and silica enrichment

Hicham Gueddari[1*], *Mustapha* Akodad[1], *Mourad* Baghour[1], *Abdelmajid* Moumen[1], *Yassine* El Yousfi[2], *Hanane* Ait Hmeid[1], *Mohamed* Chahban[1], *Ghizlane* Azizi[1], *Said* Benyoussef[2,3], *Abdennabi* Alitane[4, 5], *Ouassila* Riouchi[1] *Hamza* Ngadi[1]

[1]*Laboratory OLMAN-BPGE, Multidisciplinary Faculty of Nador, Mohamed First University – Oujda, 62700 Nador, Morroco,.*
[2] *Laboratory of Water and Environmental Management Unit, National School of Applied Sciences Al Hoceima, Abdelmalek Essaadi University- Tangier, 32003 Al Houceima, Morroco.*
[3]*Research team: Biology, Environment and Health, Department of Biology, Errachidia Faculty of Science and Technology, University of Moulay Ismaïl, 50000 Meknes, Morocco*
[4] *Geoengineering and Environment Laboratory, Research Group "Water Sciences and Environment Engineering", Geology Department, Faculty of Sciences, Moulay Ismail University, Presidency, Marjane 2, Meknes BP 298, Morocco*
[5] *Hydrology and Hydraulic Engineering Department, Vrije Universiteit Brussels (VUB), 1050 Brussels, Belgium*

Abstract. Our study was based on using a freshwater aquatic species to assess the short-and long-term toxicity of an organophosphate insecticide commonly adopted by the Moroccan agriculture sector. Recently, groundwater pollution has emerged as one of the most severe environmental challenges, with a particular emphasis on levels of heavy metal pollution. Conservation efforts and efficient management of groundwater resources are required to determine the full scope of this damage. The current research answers the physical-chemical evaluation of the middle Kert basin's water quality (Mediterranean area, Driouch province, Eastern Morocco) by collecting 42 samples and measuring pH, TDS that vary between 451 and 5841 mg/l, and EC that range from 0.72 to 9.41mS/cm^2 according to ISO 5665. The samples were analyzed by ICP-MS and flame atomic absorption spectrometry to detect fluoride and arsenic content. Whose fluoride in the survey area varied from 0.01 mg/l to 2.85 mg/l. The hydro-chemical classification resulting from the Geographic Information System (GIS) statistical data analysis was used to interpret the analytical data on the phenomena responsible for the mineralization. This quantity is considerably higher than the maximum allowable level of 1.5 mg/L, which is the regulation for drinking water in Morocco. It indicates that both natural and artificial factors have contributed to the effects. Most stations have a fluoride concentration in the water, which can be used to identify them. It is a significant amount less than the values that would be ideal; just four wells have concentrations higher than the values that are legally allowed to be. The fluoride levels in the region's water sources directly result from the natural elements that make up this particular geographic location.The same happened for arsenic, which exceeded 0.1 mg/l in just two samples. ***Keywords:*** *Kert basin; Fluoride; Arsenic, kert basin; ICP-MS; GIS.*

1 Introduction

In the western part of Morocco, there isn't a lot of water because the population is increasing and people are using more water. It is because the climate is constantly changing [1–3], which causes droughts.
Fast population growth and continuous climate change are the primary causes of the recurrence of insufficiency and the depletion of surface water bodies in recent years [4,5].
Other causes include the drying up of surface water bodies [6–8]. It is caused by several things, like fast population growth and constant climate change, which lead to frequent droughts and the drying up of surface water bodies [9–11].
Groundwater is one of the main ways that people get water for their homes, especially in the rural parts of the Rif, which use about 40% of the total amount of groundwater. It is because groundwater is one of the most accessible water sources. At the same time, 60% of the total groundwater is used for agricultural irrigation and cattle consumption [12,13]. Groundwater geochemistry determines the suitability of groundwater for household and water system objects as every groundwater framework has a unique hydrochemical composition and any change relies on a variety of factors, such as mineral disintegration, rock–water

* Corresponding author: hichamgueddari92@gmail.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

interaction, collaboration time, soil–water connection, human activities and temperature [14] Groundwater contamination has become one of the most important problems in the world today.

The amount and quality of groundwater are affected by rural activities, rural activities, urbanization, industrialization and farmin [15,16].

The most significant threats to the quality of groundwater are a high concentration of fluoride, contamination from domestic sewage caused by on-site sanitation, industrial effluents, leachates from solid waste dumps, leaking fuel and waste oils, and saltwater intrusion (also known as saltwater pollution) in coastal areas caused by over pumping of the aquifer. All of these threats come from human activities [17,18].

The theoretical underpinnings for regional groundwater safety were therefore developed by an examination of the diffusion of groundwater fluoride and also the variables that control it in shallow aquifers in this region.

These were the results of the study. Consequently, the following are the study's objectives:

(1) Get a deeper understanding of the Middle Kert Basin's hydrochemistry and (2) to identify the efective processes that control the fundamental hydrogeochemical mechanisms that govern the concentration of fluoride in groundwater. Both of these goals were intended to be achieved.

2 Material and methodes

2.1 F Research Area Description

The Kert Basin, which covers an area of around 450 km2, may be found in the northeastern part of Morocco (Fig. 1). The western Gareb mountain range acts as a barrier between it and the rest of the world, which is located to the east. The Temsamane metamorphic massif, which runs between latitudes 34°55'N and 35°54'N [19,20], borders the Plain to the North and northwest, may be found in the northeastern part of Morocco, which is situated between latitudes 34°55'N and 35°54'W.

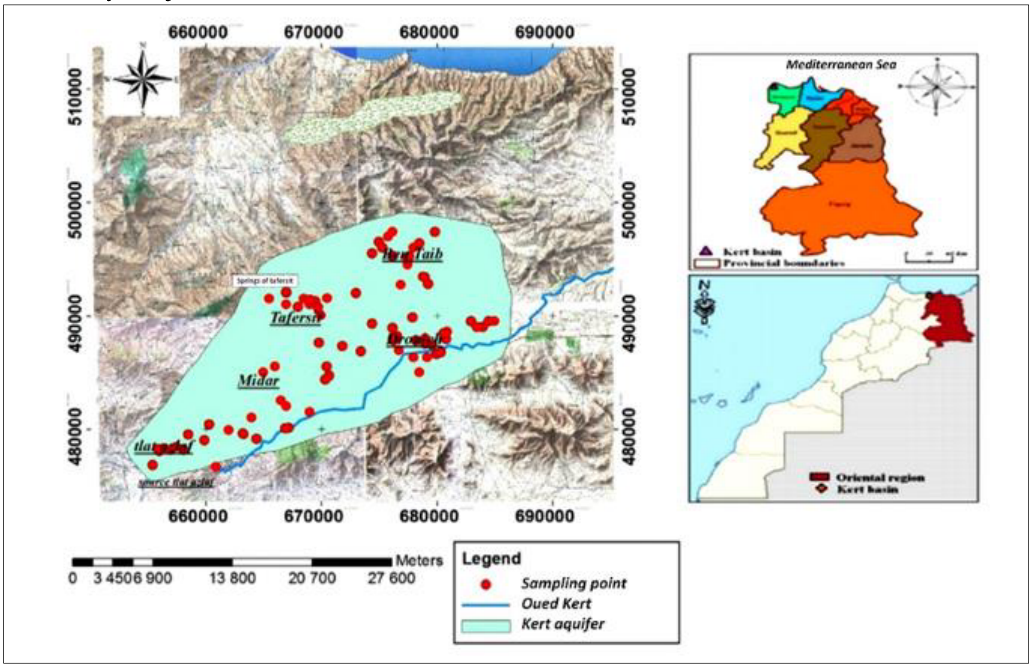

Fig. 1. Location of the Study Area

The Kert River, which has the majority of its flow during the summer months, may be found between the longitudes of 3°19' North and 3°34' West (Fig.1).

2.2 Methodology

T This research aims to identify practical means of expanding the perception of risk to include the precise locations of wells in the study region. This objective is motivated by the need to manage water supplies efficiently. We conducted a single sampling campaign in the summer of 2019 to collect water samples from all 42 wells and springs included in the study. The provisions of ISO 5665 performed sampling [21]. After collecting the samples, they were placed in plastic bottles, given labels, and then placed in a refrigerator. To conduct a chemical analysis on the models, they were stored at a temperature ranging from 2 to 4 degrees Celsius in plastic bottles with legible labels. The parameters of electrical conductivity (EC) and pH were measured on-site. Inductively coupled plasma mass spectrometry (ICP-MS) was used to analyze minor element concentrations following ISO 17294-2:2016. The features that are investigated include electrical conductivity (EC) and pH. The measurements are carried out per EN-ISO 12677 using a method referred to as fluorescence X. The methodology in question is a method for determining and quantifying the amount of silica dioxide present. Plasma mass spectroscopy with inductively coupled chromatography ionique IC6200 by the NF EN ISO 14911 standard for identifying trace elements F is used to carry out the analyses, and a computer analyses the results. The National Institute of Standards and Technology (NIST) developed the standard for identifying trace elements F.

2.3 Data processing

First, the findings from the physicochemical inquiry were analyzed statistically using the data gathered. After then, the hydrochemical processes were carried out in parallel. The statistical approach known as descriptive statistics will be used to research the occurrences of water mineralization and water pooling and determine the factors contributing to these water groups' formation. Excel is used in the carrying out of the statistical analyses that were performed. The values of the parameters are analyzed in light of the guidelines that the World Health Organization established for the amount of water that should be consumed. A Geographic Information System will generate graphical depictions of the results on several map types (GIS).

3 Results and discussion

In 2021, an investigation into the Kert aquifer's physical characteristics was carried out. They focus primarily on the water's temperature, pH, and conductivity. Temperature is important to consider when researching well water because it tells you where the wells are. The processes in water, both chemical and microbiological, are heavily influenced by temperature [22–24]. According to the data obtained, the temperature values range from 20°C to 24°C (Table.1).

Table 1. Physical-chemicalelement descriptive statistics Variable

Variable	Mean	Min	Max	WHO Standard
PH	7.26	6.80	8.20	6.50-8
T (C)	22.5	20	24	
EC (mS/cm^2)	4.00	0.70	9.50	2.5
TDS (mg/L)	2847	451	584	300-1000
Fluoride (mg/L)	0.47	3	2.85	1.5
Arsenic (mg/L)	0.006	0.00	0.01	
Silicate	20.31	13	34	0.01

3.1 Hydrogen potential (pH)

The water's point of origin and the characteristics of the terrain it travels over may affect the pH. It risks the delicate physicochemical equilibrium of the water and develops in tandem with the mineral dissolution and precipitation processes [25–27].

The pH levels of the investigated wells fall within the acceptable range for drinking water [28], Which is between 6.8 and 8.2 (Fig. 2) compared to studies carried out in the region of the Ghiss Nekour aquifer, which is practically similar to the basicity of the groundwater in the current aquifer [29].

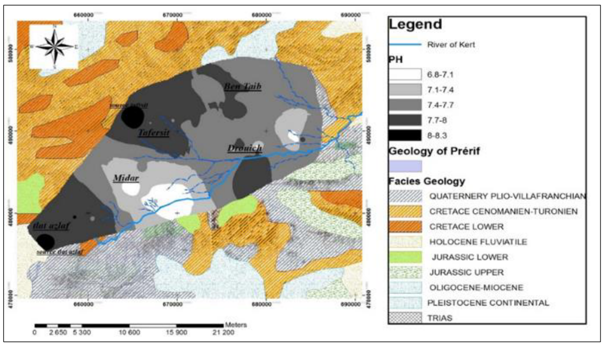

Fig. 2. pH distribution in Kert groundwater.

3.2 Conductivity

It reveals the quantity of charge dissolved in the water and the degree to which it has been mineralized. In addition, moving ions are in the medium and are enclosed by an electric field [30–32]. There is a range of values accessible, which goes from 0.736 to 9.400 ms.cm-2, The bulk of the aquifer has a conductivity higher than the WHO's recommendation of 2.5 mS/cm-2, except for northeastern and southeastern portions (Fig. 3).

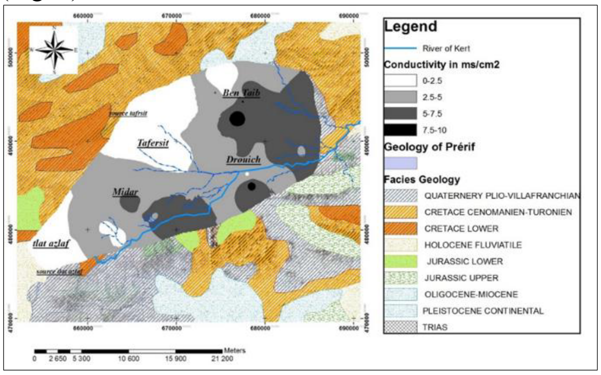

Fig. 3. Conductivity distribution in Kert groundwater.

3.3 TDS

The Total Dissolved Solids (TDS) may vary between 451.00 (W42) and 5841.00 (W17), although a value of 2859.94 mg/L acts as the average for this particular parameter (Fig.4).It is established that such total dissolved solids (TDS) in water is a suitable method for determining where the water originates and may reveal information about the elements in the water [33–35].

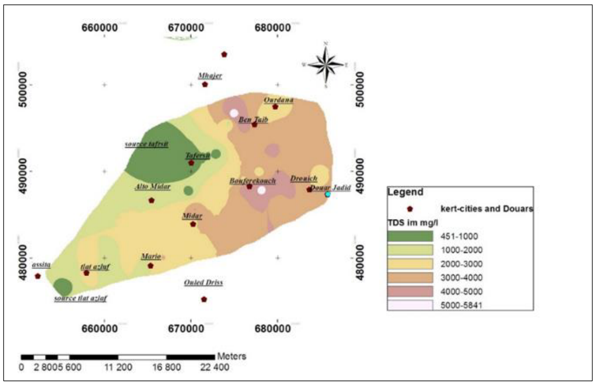

Fig. 4. TDS distribution in Kert groundwater.

3.4 Fluoride

We found that the amount of fluoride in the area they were looking into ranged from 0.01 mg/L to 2.85 mg/L. Except for five wells surpassing the norm of 1.5 mg/l (Fig.5), all 42 samples in our research will have an F-value below the guideline established by the WHO. The only exception to this will be the one with an F-grade higher than the international standard (Edition, 2011). The amount of fluoride in the groundwater is influenced by the particular land formations that may be found in each region. May and June, the beginning and end of summer,the natural presence of groundwater fluoride is mostly attributable to the weathering of rocks that are rich in fluoride [15,36,37].

Fluoride-rich water is most often discovered in sediments with a marine provenance and at the base of mountainous regions [36,38].

Fluorite may be found in sedimentary as well as igneous rocks. The presence of fluoride in each of these kinds of rocks has been found to be almost the same. Fluoride exists form sellaite [MgF2], fluorite or fluorspar [CaF2], cryolite [Na3AlF6], fluorapatite [3Ca3(PO4)2 Ca(F,Cl2)] [36,39].

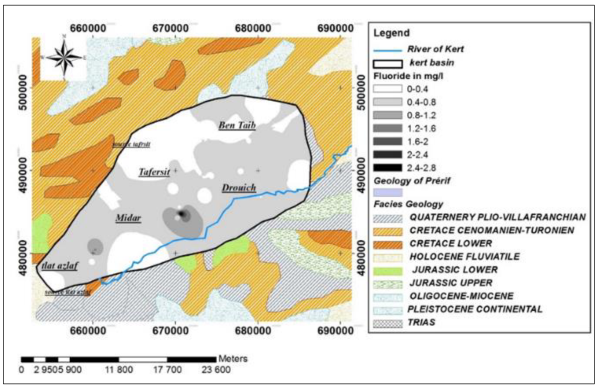

Fig. 5. Fluoride distribution in Kert groundwater.

3.5 Arsenic

The World Health Organization has set a guideline for the amount of arsenic that should be present in groundwater at 0.01 mg/l (Fig.6).

This guideline is similar in the Kert Basin, except for two wells that exceed the norm of 0.1 mg/l and can be found in the southeast part of the aquifer. It is possible to find arsenic in groundwater that is located in the Holocene, as well as in alluvial and deltaic sands and silts, grey and unconsolidated sands, and river systems that are related to those areas.[40,41].

The presence of arsenic may also be the consequence of anthropogenic pollution owing to the use of septic tanks and the existence of uncontrolled landfills, together with the excessive use of pesticides.[40,42,43] Skin diseases and tumors of the internal organs are two examples of well-known health issues[44]

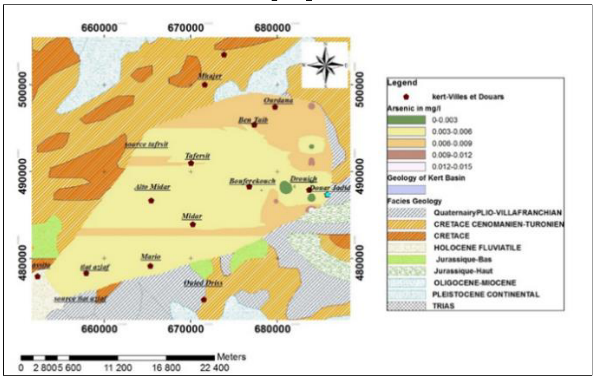

Fig. 6. Arsenic distribution in Kert groundwater.

3.6 Silicate

Depending on where you are in Kert Plain, the quantity of silicate present in groundwater may vary anywhere from 34.00 mg/l to 0.50 mg/l.(Fig. 7). The amount of silicate may be found in the groundwater of the aquifer. The average silicate content is much greater than Japan, reaching 6.60 mg/l [32], coming in at 17.85 mg/l.Cation exchange reactions and the dissolution of silicate minerals from lithological divides in the groundwater are examples of these processes [14,32], the extensive path that groundwater takes affects the outcomes along the fluid flow. It enhanced the contact between the water and the sediment, leading to a considerable reduction in silicate minerals [45,46].

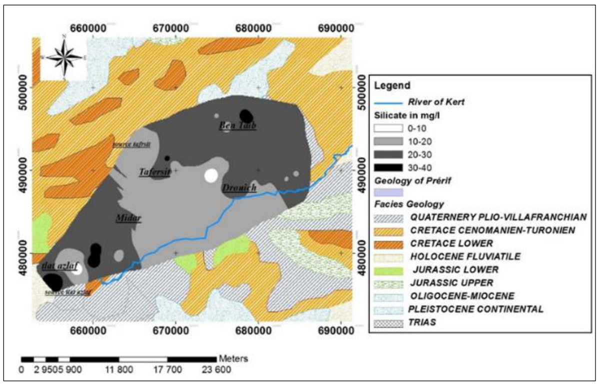

Fig. 6 Silicate distribution in Kert groundwater.

4 Conclusion

It was determined how much F and the SiO2 index were present in the groundwater aquifers in the Kert basin's lowland region. We investigated the distribution of groundwater temperatures that are considered normal, as well as factors that have an impact on their distribution. The following is a list of the most important conclusions that may be attracted: (1) The plain of the Kert Basin has fluoride concentrations in its groundwater that averaged 1.26 mg/L, although these concentrations varied from 0.18 to 2.5 mg/L. A rise of twelve percentage points was seen in the standard rate. The central regions were home to most places that included groundwater rich in high levels of dissolved fluoride.

Combined biological cycles (such as late runoff and heavy evaporation) and artificial activities (such as irrigated agriculture) in the area contribute considerably to significantly enhanced concentrations of fluoride ions in the groundwater. Natural processes include:

(2) The silicate minerals make up the majority of the natural sediment, whereas the Fe–Mn oxyhydroxides make up the minority of the natural sediment. In spite of this, the significance of aluminosilicates and the oxyhydroxides of iron and manganese cannot be emphasised. In terms of storing minerals, silicate mineral reserves store 75% of the whole amount of arsenic, whereas iron-manganese oxyhydroxides retain 16% of the total amount of arsenic.

Analyzing samples from wells of Kert indicated that almost all hydrochemical parameters of a good sample in the following research remain within the limits of tafersit and tlat azlaf.

Acknowledgments

The authors apprecieate the Laboratory OLMAN-BPGE, Multidisciplinary Faculty of Nador, Mohamed First University – Oujda, 62700 Nador, Morroco for facilitation during the research work.

References

1. Y. El Yousfi, M. Himi, H. El Ouarghi, M. Aqnouy, S. Benyoussef, H. Gueddari, H. Ait Hmeid, A. Alitane, M. Chaibi, and M. Zahid, *Sustainability* 15, 402 (2023).
2. A. Azdimousa, J. Bourgois, G. Poupeau, and R. Montigny, Comptes Rendus de l'Académie Des Sciences-Series IIA-Earth and Planetary Science **326**, 847 (1998)
3. M. Ramdani, A. F. Taybi, Y. Mabrouki, B. Haloui, O. El Asri, H. Elmsellem, N. El Khiati, and M. Mostareh, Moroccan Journal of Chemistry **5**, 5 (2017), http://revues.imist.ma/?journal=morjchem&page=login
4. A. Alitane, A. Essahlaoui, M. El Hafyani, A. El Hmaidi, A. El Ouali, A. Kassou, Y. El Yousfi, A. van Griensven, C. J. Chawanda, and A. Van Rompaey, Land **11**, 93 (2022)
5. A. Alitane, A. Essahlaoui, A. Van Griensven, E. A. Yimer, N. Essahlaoui, M. Mohajane, C. J. Chawanda, and A. Van Rompaey, Sustainability **14**, 10848 (2022)
6. A. Chalouan, A. Michard, K. Kadiri, F. Negro, D. Lamotte, J. I. Soto, and O. Saddiqi, in *Continental Evolution: The Geology of Morocco* (Springer, 2008), pp. 203–302
7. D. Belghyti, H. Daifi, A. Alemad, K. Elkharrim, M. Elmarkhi, Y. Souidi, F. Benelharkati, B. Joti, Z. Elmoukrifi, and A. Ibeda, WIT Transactions on Ecology and the Environment **178**, 241 (2013), https://doi.org/10.2495/WS130201.
8. K. Saravanan, K. Srinivasamoorthy, S. Gopinath, R. Prakash, and C. S. Suma, Arabian Journal of Geosciences **9**, 1 (2016), https://doi.org/10.1007/s12517-016-2369-y.
9. J.-J. Barathon, Méditerranée **17**, 21 (1974), https://doi.org/10.3406/medit.1974.1534.
10. H. Besser, N. Mokadem, B. Redhouania, N. Rhimi, F. Khlifi, Y. Ayadi, Z. Omar, A. Bouajila, and Y. Hamed, Arabian Journal of Geosciences **10**, 1 (2017), https://doi.org/10.1007/s12517-017-3148-0.
11. G. Krishan, G. Prasad, C. P. Kumar, N. Patidar, B. K. Yadav, M. L. Kansal, S. Singh, L. M. Sharma, A. Bradley, and S. K. Verma, Journal of Hydrology: Regional Studies **31**, 100724 (2020), https://doi.org/10.1016/j.ejrh.2020.100724.
12. P. Huang, Z. Yang, X. Wang, and F. Ding, Arabian Journal of Geosciences **12**, 1 (2019), https://doi.org/10.1007/s12517-019-4500-3.
13. H. Gueddari, M. Akodad, M. Baghour, A. Moumen, A. Skalli, Y. El Yousfi, A. Ismail, M. Chahban, G. Azizi, and H. A. Hmeid, Scientific African **16**, e01226 (2022), https://doi.org/10.1016/j.sciaf.2022.e01226
14. F. Vinnarasi, K. Srinivasamoorthy, K. Saravanan, S. Gopinath, R. Prakash, G. Ponnumani, and C. Babu, Environmental Geochemistry and Health **43**, 771 (2021), https://doi.org/10.1007/s10653-020-00540-3.
15. J. N. Jannat, M. S. I. Khan, H. T. Islam, M. S. Islam, R. Khan, M. A. B. Siddique, M. Varol, C. Tokatli, S. C. Pal, A. Islam, *J. Clean. Prod.* **372**, 133675 (2022).
16. N. Nouayti, E. K. Cherif, M. Algarra, M. L. Pola, S. Fernández, A. Nouayti, J. C. Esteves da Silva, K. Driss, N. Samlani, H. Mohamed, *Water* **14**, 606 (2022).
17. G. Singh and R. K. Kamal, Applied Water Science **7**, 1479 (2017), https://doi.org/10.1007/s13201-016-0430-3.
18. G. Hicham, A. Mustapha, B. Mourad, M. Abdelmajid, S. Ali, E. Y. Yassine, A. H. Hanane, C. Mohamed, A. Ghizlane, and R. Abderahmane, *Environ. Quality Manag.* **32**, 53 (2022).
19. H. Gueddari, M. Akodad, M. Baghour, A. Moumen, A. Skalli, Y. El Yousfi, H. A. Hmeid, M. Chahban, G. Azizi, and M. Chaibi, *Nat. Environ. Pollut. Technol.* (2023).
20. M. Elgettafi, A. Elmandour, M. Himi, and A. Casas, *Int. J. Environ. Sci. Technol.* **10**, 719 (2013).
21. G. Hicham, A. Mustapha, B. Mourad, M. Abdelmajid, S. Ali, E. Y. Yassine, A. H. Hanane, C. Mohamed, A. Ghizlane, and R. Abderahmane, *Environ. Quality Manag.* (2021).

22. A. Michard, F. Negro, O. Saddiqi, M. L. Bouybaouene, A. Chalouan, R. Montigny, and B. Goffé, C. R. Geosci. **338**, 92 (2006).
23. K. Wick, C. Heumesser, and E. Schmid, *J. Environ. Manag.* **111**, 178 (2012), https://doi.org/10.1016/j.jenvman.2012.06.030.
24. H. Gueddari, M. Akodad, M. Baghour, A. Moumen, A. Skalli, M. Chahban, G. Azizi, H. A. Hmeid, M. Maach, and R. Riouchi, *Int. J. Health Sci.* 4121 (2022.).
25. C. B. Pande, K. N. Moharir, S. K. Singh, and B. Dzwairo, *Environ. Dev. Sustain.* **22**, 7453 (2020), https://doi.org/10.1007/s10668-019-00531-0.
26. M. Gheboulis, Utilisation des A.C.P et des rapports caractéristiques dans l'explication du chimisme des eaux souterraines cas de la plaine de Bir Haddada de Setif) (2010).
27. S. Gopinath, K. Srinivasamoorthy, K. Saravanan, and R. Prakash, *Chemosphere* **236**, (2019).
28. F. Edition, WHO Chronicle **38**, 104 (2011)
29. N. AL Nouayti, E. K. Cherif, M. Algarra, M. L. Pola, S. Fern, A. Nouayti, J. C. G. Esteves, K. Driss, N. Samlani, H. Mohamed, E. M. Azzirgue, D. A. Krawczyk, A. Rodero, (2022)
30. J. Rodier, B. Legube, and N. Merlet, *L'analyse de l'eau-10e Éd.* (Dunod, 2016).
31. M. Saber, M. Abdelshafy, M. E.-A. A. Faragallah, and M. H. Abd-Alla, Arabian Journal of Geosciences **7**, 4593 (2014), https://doi.org/10.1007/s12517-013-1103-2.
32. S. Gopinath, K. Srinivasamoorthy, K. Saravanan, and R. Prakash, *Environ. Dev. Sustain.* **21**, 2443 (2019).
33. S. Gopinath, K. Srinivasamoorthy, K. Saravanan, R. Prakash, D. Karunanidhi, *Hum Ecol Risk Assess.* **25**, 314 (2019),
34. A. Salinization, A. C. Study, G. Krishan, P. Sejwal, A. Bhagwat, G. Prasad, B. K. Yadav, L. M. Sharma, M. Muste, **1** (2021).
35. Y. El Yousfi, M. Himi, H. El Ouarghi, M. Elgettafi, S. Benyoussef, H. Gueddari, M. Aqnouy, A. Salhi, and A. Alitane, *Groundw. Sustain. Dev.* **19**, 100818 (2022).
36. S. Ali, Y. Fakhri, M. Golbini, S. K. Thakur, A. Alinejad, I. Parseh, S. Shekhar, and P. Bhattacharya, *Groundw. Sustain. Dev.* **9**, 100224 (2019).
37. M. Egor and G. Birungi, *Scientific African* **7**, e00241 (2020), https://doi.org/10.1016/j.sciaf.2019.e00241
38. A. Toolabi, Z. Bonyadi, M. Paydar, A. A. Najafpoor, and B. Ramavandi, *Groundw. Sustain. Dev.* **12**, 100543 (2021), https://doi.org/10.1016/j.gsd.2020.100543.
39. E. Shaji, J. J. Gómez-Alday, S. Hussein, T. R. Deepu, and Y. Anilkumar, *J. Geol. Soc. India.* **92**, 337 (2018).
40. C. K. Jain, S. K. Sharma, and S. Singh, *Environ. Monit. Assess.* **190**, 1 (2018).
41. A. Toolabi, Z. Bonyadi, M. Paydar, A. Asghar, and B. Ramavandi, Groundwater for Sustainable Development **12**, 100543 (2021).
42. H. Neidhardt, Z. A. Berner, D. Freikowski, A. Biswas, S. Majumder, J. Winter, C. Gallert, D. Chatterjee, and S. Norra, *Chem. Geol.* **367**, 51 (2014).
43. N. Nouayti, D. Khattach, M. Hilali, A. Brahimi, and S. Baki, J. Mater. Environ. Sci. **7**, 1495 (2016).
44. V. Rashmi and D. Pratima, *Rec. Res. Sci.Technol.* **5**, 98 (2013).
45. V. Rajendiran, *Jpn. Geotech. Soc. spec. publ.* **2**, 2138 (2016).
46. F. Khan, S. Krishnaraj, P. Raja, G. Selvaraj, and R. Cheelil, *Environ. Sci. Pollut. Res.* **28**, 18567 (2021), https://doi.org/10.1007/s11356-020-10912-y.