International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 7 Issue 12, December - 2023, Pages: 357-363

The Impacts of Seasonal Variations on Drinking Water Quality at the Northern State (Sudan)

Mona M. Fadul Abdalmotaleb[*1], Gibla Omer Adam[2], Mutasim Maknoon Hassan[3], Esraa Omer Adam[4]

[1, 2, 3, 4] Sudan University of Science and Technology, Chemistry Department, College of Science

Abstract: *The physicochemical parameters which determine the suitability of natural water sources for human consumption may significantly be affected by the seasonal climatic changes. This work was conducted to measure the different physicochemical parameters including, pH, TDS, EC, TH, T. alkalinity,* HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, NO_2^-, S^{2-} *and* F^- *during summer and winter. Forty-seven samples were collected in each season from the same sources covering the seven localities of the Northern State. The results were statistically analyzed using SPSS program and the mean values of the different parameters were correlated. The mean values showed significant seasonal variations in TDS, EC, T. alkalinity,* SO_4^{2-}, NO_3^- *and* F^- *which were all higher in summer. High bicarbonate means were observed in the two seasons. Sulfide ions showed almost similar means in the two seasons. The means of* Cl^- *and* NO_2^- *were higher in winter. The measured parameters in the two seasons were within the WHO guidelines.*

Keywords: Water bearing-rocks, Ground water, TDS, Bicarbonate, Correlation, SPSS.

Introduction

Global consumption of water is rapidly increasing due to, the high increase in population, rapid urbanization, changes in lifestyle and industrialization (Gajbhiye *et al*., 2014, Okimiji *et al.*, 2021). Water is one of the major resources that are under threat, from over exploitation and environmental pollution, due to extensive anthropogenic activities (Efe, 2002a, 2005).

Water as a liquid is the most essential component of life, in the sense, that, life without it is not possible but, natural water quality may be affected by the prolonged and continuous water-rock interaction (Gibla Omer A. and Esraa Omer., 2017). On global scale there is enough abundance of water, but water is not always available in the right place at the right time and the right form (V. M. Ahluwalia, 2008). Therefore an adequate, clean and safe drinking water supply is a basic human right (Kayser *et al.*, 2013, Enovwo O. *et al*., 2020). Today water quality has become one of the important issues for socioeconomic development in all countries (H. M. A. M. Omer, 2012). There are main three types of water resource problems, too little water, too much water and polluted water (Ayoade, J. O; 1988 and Adebola, 2001, Efe, 2005). Groundwater is an indispensable resource for drinking, irrigation, industrial production, urbanization and other activities related to social development (He and Wu 2019a, He. *et al*., 2019a, Li. *et al*., 2016a, Oişte, 2014, Velis *et al*., 2017; Zhang, *et al*., 2018, Y. Ji *et al.*, 2020). In the Northern State River Nile is the only permanent surface water source. Although some of the villages are situated near the eastern and western banks of the Nile, many royal communities use ground water sources.

Drinking water of high-quality is essential to improve human health and decrease the spread of water borne diseases (Benjamin, 2003). 80% of the common diseases were reported to be transmitted by contaminated water including, diarrhoea, dysentery, schistosomiases and urinary tract infections (Bharti *et al*., 2003, Schafera, 2009). In several developing countries the WHO drinking water standards are not satisfied (Khan N. *et al*., 2013). The water bearing rocks play a major role in the formation of ground water sources and their chemical constituents (Gibla Omer A. M. *et al.,* 2016). Water as a good polar solvent, dissolves many inorganic and organic materials, so that, it's taste, color, smell and many other properties can become environmentally polluted (Trivedi, *et al*, 2010). Therefore TDS, EC, TH, T. Alkalinity as well as, the specific anions HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, NO_2^-, S^{2-} and F^- are considered to be the main drinking water quality determining parameters (University of California, 2003 publication 8048). Some water-soluble pollutants cannot easily be identified (WHO, 1996, Chan, M, and A, 2007). High availability of some minerals can cause morphological abnormalities, reduce growth, increase mortality and mutagenic effects (Nkono, *et al.,* 1998, Asaolu, 2002; Adeyeye, 2000). The Physico-chemical properties are very vital water quality monitoring characteristics because of their significant seasonal variations that, may affect water sources suitability for human use (Efe *et al*., 2005). The seasonal variations of drinking water quality over different geological locations and climatic regions may help researchers to understand water quality management (Iqbal M. M. *et al*., 2022). The climatic changes have significant influence on human health via different pathways (IEDCR, 2016). In Southern Kordofan State, Madena K. KoKo, *et al.,* (2019, 2022) reported clear seasonal variations in, pH, TDS, EC, F^-, Cl^-, SO_4^{2-} and NO_3^-. In some areas of Nigeria seasonality showed significant variations on drinking water quality where, water samples were highly polluted during the dry season (Okimiji *et al.*, 2021). Evaporation is one of the main factors which are responsible from the seasonal variation effects on ground water quality (Y. Ji *et al.*, 2020).

The study area

International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 7 Issue 12, December - 2023, Pages: 357-363

The study area lies within Sudan in arid desert climatic region, in which rainfall is very low or negligible. The Northern State covers an area of 348,765 km^2, with estimated population as 833,743 (Census 2006). The highest and lowest temperatures in Sudan were recorded at Wadi-Halfa as 52 and 2^{o}C. Throughout the country the maximum temperature ranges from 34 to 40^{o}C and the minimum from 16 to 44^{o}C (H.G. Roddis, 1963, UN, 1988). Figure (1) shows the location of the Northern State and it's administrative localities (Halfa, Dalgo, Alburgag, Dongola, Marawai, Algolid and Aldaba).

Figure 1 : Northern State (sample collection areas).

Methodology

Forty seven samples were collected during winter and summer from the same sources. pH, EC, TDS, TH, total alkalinity, CO_3^{2-}, $HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, NO_2^-, S^{2-}$ and F^- ions were determined by the appropriate standard methods. Analytical grade chemicals were used. The results were statistically analyzed using SPSS.

Results and Discussion

pH value

The pH values were within the accepted drinking water quality guidelines (WHO, 2008). In summer the range was from (7.35 to 8.5) with a mean value of (7.74), whereas the range in winter was from (6.65 to 8.15), with a mean value as (7.57). The lower and higher pH values were greater in summer than those of winter (Fig. 2).

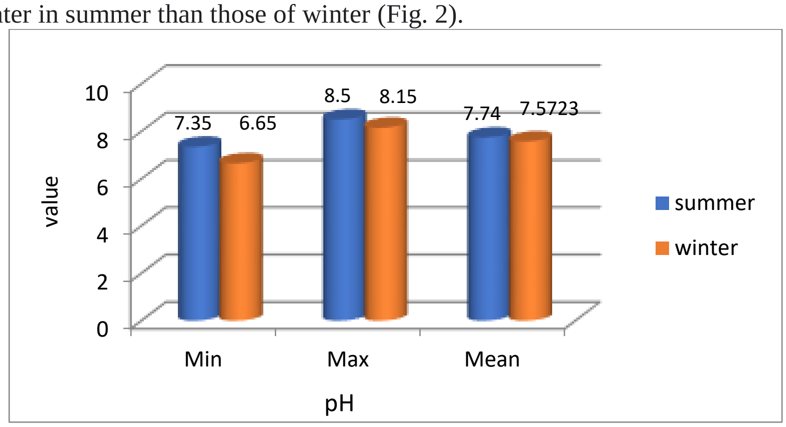

Fig. 2: Minimum, maximum and mean pH values

EC, TDS and Total alkalinity

The EC range was from (150.4 to 889µs/cm) with a mean value of (316.6 µs/cm) in summer and from (128.8 to 548µs/cm) in winter with a mean value of (253.8µs/cm). The two seasons showed maximum EC reading higher than the permissible guideline (WHO, 2008). The TDS range was from (60.4 to 367 mg/l) in summer with a mean value as (218.5mg/l) and from (61.4 to 254 mg/l) in winter with a mean value of (157.7 mg/l). As reported by WHO (1984, 1993), the admissible TDS range for drinking water is (500- 1500mg/l). The total hardness varied from (28 to 220mg/l) in summer with a mean value as (122.8mg/l), whereas in winter it was from (74 to 200mg/l) with a mean value of (137.8mg/l). Few samples showed total hardness higher than the permissible guideline values. The total alkalinity range was (100 to 530mg/l) in summer with a mean value of (179.8mg/L). In winter the mean value was from (0.00 to 152) with a mean value of (38.23mg/l). The obtained results of EC, TDS, TH and total alkalinity may indicate the suitability of surface and ground water sources throughout the sampling areas for human drink.

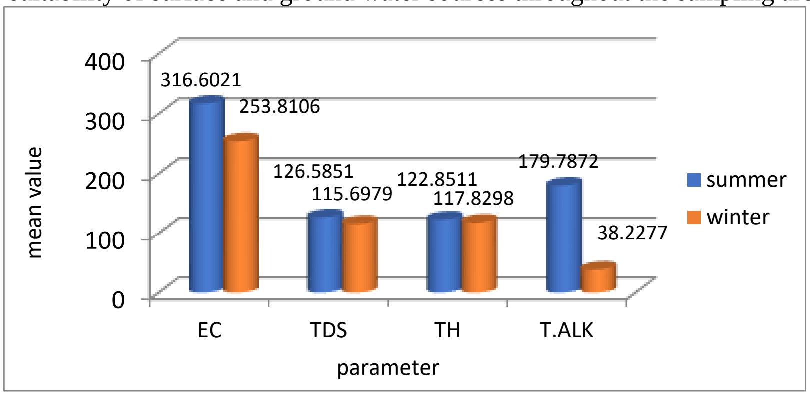

Fig. 3: EC, TDS, TH and total alkalinity mean values

HCO_3^-, Cl^- and SO_4^{2-} content

The two seasons showed high (HCO_3^-) content, but it is relatively low in winter (Fig. 4). This may reflect the geological background of the area since, high bicarbonate is normally expected when the water bearing rocks are dominated by limestone and/or dolomite formations (Mona, *et al.*, 2023). According to, Mawia H. Elsaim and Omer A., (2019) the alkalinity of drinking water samples from Argo is caused by the presence of hydrogen carbonate only. Omer Gibla and Esraa, (2020) reported strong positive correlation of Mg^{2+} ions with HCO_3^-, SO_4^{2-} and Cl^- in drinking water. Hamdia M. A. (2022, 2023) reported high Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^- and CO_3^{2-} in ground water samples from Gedarif State. The mean chloride content was within the permissible guideline values in the two seasons, but it is significantly high in winter (152.66mg/l) when compared with that of summer (18.77mg/l). Low availability mean was shown by sulfate as (13.51mg/l) in summer and (6.30mg/l) in winter. Therefore the Northern State drinking water can be classified as bicarbonate and chloride water. The main salinity constituents in Bara basin were reported as bicarbonate, sulfate and chloride (Gibla Omer A. and Esraa Omer., 2017).

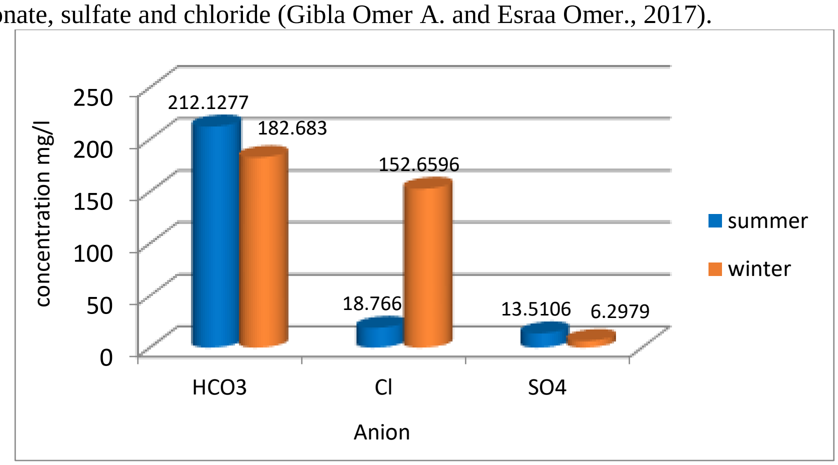

Fig 4: Mean concentration of HCO_3^-, Cl^- and SO_4^{2-}

NO_3^-, NO_2^- F^- and H_2S

The mean concentrations of NO_3^-, NO_2^-, F^- and H_2S were low in the two seasons (Fig. 5). They are all below the lower permissible limits of drinking water guidelines (WHO, 1993, SSMO, 2002). The lower permissible limit for NO_3^- is 10mg/l (USEPA, 1991e, Gibla Omer A. 2007) and 3mg/l for NO_2^- (WHO., 1993). The SSMO (2002) considered the lower admissible limit for NO_2^- as 2mg/l. Relatively high NO_3^- mean was shown in summer (5.33mg/l) compared with that of winter (2.384 mg/l).

The mean concentration of NO_2^- was lower in summer (0.061mg/l) than that of winter (0.24mg/l). The two seasons showed almost similar mean content of F^-as (0.38mg/l) in summer and (0.32mg/l) in winter.
The WHO (1984; 1993) and SSMO, (2002) recommended the maximum guideline value of F^-as (1.5mg/l). The geological and climatic factors were suggested to be the main reasons that cause the significant seasonal variations in ground water fluoride (Asgeir Bardsen, *et al.*, 1999). This may agree with the findings reported by (Mawia H. Elsaim and Omer A., 2019) for availability of Sulfate, Chloride, Nitrate and Fluoride. The mean concentrations of H_2S were (0.0394 mg/l) in summer and (0.0385mg/l) in winter. No health guideline value is proposed for sulfide in drinking water, but it should not be detectable by taste or odor (WHO, 1993). The level of H_2S in drinking water is usually low, because sulfides are readily oxidized in the well aerated water (Gibla Omer A. 2007). The suitability of drinking water sources in the study area for human consumption may be enhanced by the findings reported by (Mawia H. Elsaim and Omer Abdelrham, 2019).

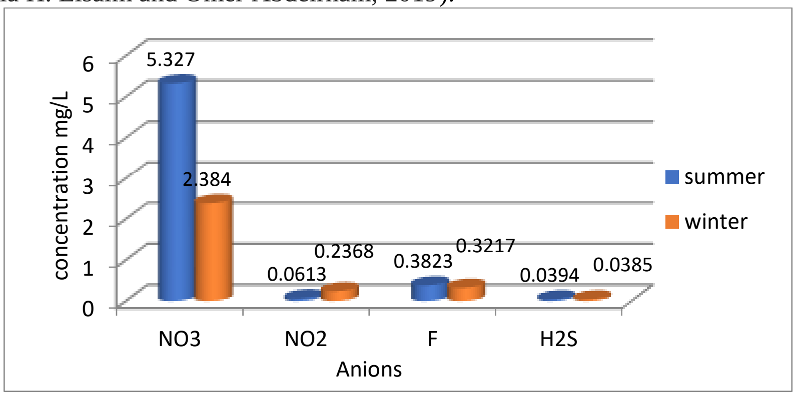

Fig 5: Mean concentration of NO_3^-, NO_2^-, F^- and H_2S

Correlation

The specific ions HCO_3^-, Cl^- and SO_4^{2-} showed significantly strong positive correlation with TDS, EC and total alkalinity in the two seasons. Since the EC and total alkalinity depend mainly on TDS of the natural water, the seasonal variations in HCO_3^-, Cl^- and SO_4^{2-} were expressed in the form of their correlation with TDS mean values (Fig. 6).
The correlation of chloride and TDS was almost similar in the two seasons whereas, low fluctuation was shown by sulfate. Bicarbonate correlation coefficient was significantly high in winter (0.77) compared with that of summer (0.37). Therefore it may be concluded that, the Northern State drinking water is dominated by the ions HCO_3^-, Cl^- and SO_4^{2-} during winter and by Cl^- and SO_4^{2-} in summer**.** H. M. A. M. Omer (2012), reported that, the western bank of River Nile water samples were of bicarbonate, sulfate and chloride type while, that of the eastern bank was of bicarbonate type. Iqbal M. M. *et al.*, (2022) reported relatively good correlation between water quality variables and vegetation indices on the annual scale for T-N, BOD and DO.

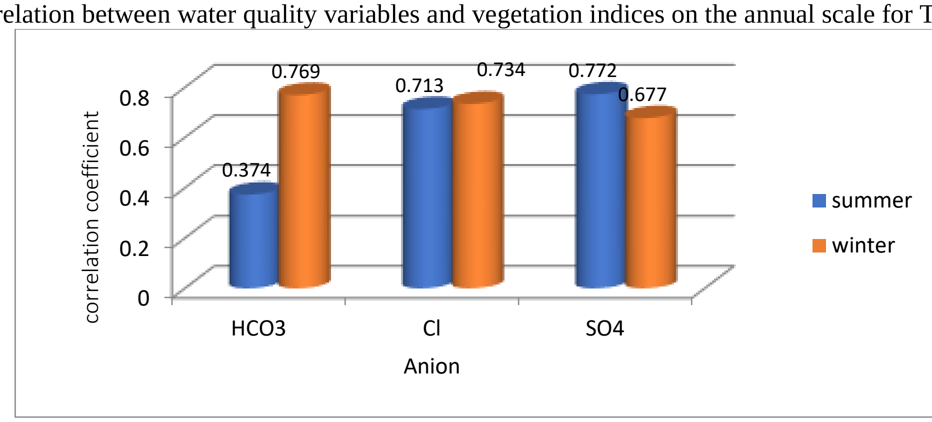

Figure 6: Seasonal correlation of TDS with HCO_3^-, Cl^- and SO_4^{2-} ions

Conclusion

The measured physicochemical parameters showed clear seasonal variations throughout the sampling areas. The EC, TDS, TH, Total alkalinity, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, NO_2^-, F^- and H_2S contents were within the WHO guidelines for drinking water quality. The correlation coefficients indicate that, the drinking water of the State is dominated by HCO_3^-, Cl^- and SO_4^{2-} during winter and by Cl^- and SO_4^{2-} in summer.

Refernces

1- Alrumman S A, El-kott A F, Kehsk M A, (2016), Water pollution: Source and treatment. *American journal of Environmental Engineering*, **6**(3):88-98.

2- Adeyeye, E. I. (2000). Bio-concentration of macro and trace minerals in prawns living in Lagos lagoon . *Pakistan Journal of Scientific and Industrial* Research, **43**: 367-373.

3- Asaolu, S. S, (2002), Asaolu, S.S. 2002. Determination of some heavy metals is Orechromis nicoticus,Clarias gariepinus and Synontis spp from the coastal water of Ondo state Nigeria. *Pakistan Journal of Scientific and Industrial* Research, **45**: 17-19.

4- Asgeir Bardsen, Kjell Bjorvatn, Kari Sand And David Banks, (1999), Seasonal variations of fluoride content in groundwater from wells drilled in bedrock, *Norges geologiske undersekelse Bulletin*, 435: 53-58.

5- Adeyeye, E. L and Abulude, F. O, (2004), Analytical assessments of some surface and ground water resources in Ile–Ife, Nigeria, *J. Chem. Soc.Nig,* **9**(2): 98-103.

6- Ayoade, J. O. (1988), Tropical Hydrology and Water Resources. London and Basingstoke, Macmillan.

7- Adebola, K. D. (2001) Groundwater Quality in Ilorin Township: An Environmental Review African Journal of Environmental Studies. **2**(2) 4-6.

8- Bharti, A. R., Nally, J. E., Ricaldi, J. N., Matthias, M. A., Diaz, M. M., Lovett, M. A., Levett, P. N., Gilman, R. H., Willig, M. R., Gotuzzo, E. and Vinetz, J. M. (2003). Leptospirosis: azoonotic diseases of global importance. *Lancet. Infect. Dis*. 3:757-571.

9- Bartram, J. K. (2005). Focusing on improved water and sanitation for the Physico-Chemical Properties of Drinking Water Available in Educational institutes of Karachi City. ResearchGate, [Lancet], **365**(9461): 810-812.

10- Benjamin, C, (2003), Encyclopedia of Food science and Nutrition 10. San Diego, Calif. ; London: Academic.

11- Briggs D, (2003), Environmental pollution and the global burden of disease. *British medical bulletin*, **68**:1-24.

12- Bibi S, Khan R. L, Nazir R, et al.(2016) Heavy metals in drinking water of Lakki Marwat District, KPK, Pakistan. *World applied sciences journal*, **34**(1):15-19.

13- Chan, C. L., M, K. Z., and A, S. N. (2007). Microbiological and physicochemical quality of drinking water. *Malaysian Journal of Analytical Sciences*, **11**(2):414-420.

14- Enovwo Odjegba, Grace Oluwasanya , Olufemi Idowu, Olufunke Shittu and Gail Brion, 2020, Sustainability indices and risk analysis of drinking water systems in Southwest Nigeria, Journal of Water Supply: Research and Technology-AQUA, **69**(6):591-603.

15- Efe, S I, Ogban, F E, Horsfall, M Jnr, Akporhonor, E E, (2005), Seasonal Variations of Physico-chemical Characteristics in Water Resources Quality in Western Niger Delta Region, Nigeria, *J. Appl. Sci. Environ. Mgt* **9**(1):191- 195.

16- Efe, S. T. (2002a), Urban Warming in Nigerian cities: The case of Warri metropolis, *African Journal of Environmental Studies*, **2**(2). 162-168.

17- Gajbhiye, M.K. Awasthi, S.K. Sharma. (2014). Assessment of Ground Water Quality, LAMBERT Academic Publishing, Germany.

18- Gibla Omer A. M, Mohammed Ahmed Hassan El-Tayeb, Abd El-Salam Abdalla Dafa Alla, Esraa Omer Adam Mohammed, (2016), Investigation of the Relationship between Top Soil, Bedrocks (Parent rocks) and Groundwater Salinity at Sharshar and Algaa'h Areas, European Academic Research 7(4): 6071- 6080.

19- Hamdia M. Abdallah, Gibla O. Adam, M. Maknoon H, (2022), Drinking Water Quality of Surface and Ground Water Samples from Gedarif State (Sudan), *International Journal of Academic and Applied Research*, **10**(6):103-108.

20- Hamdia M. Abdallah, Gibla O. Adam, M. Maknoon H, (2022), Availability of Macro and Trace Minerals in Drinking water from El-Gedarif State (Sudan), *International Journal of Academic multidisciplinary Research*, **12**(6): 11-15.

21- He S, Wu J (2019a) Hydrogeochemical characteristics, groundwater quality and health risks from hexavalent chromium and nitrate in groundwater of Huanhe Formation in Wuqi County, northwest Chin,. *Expo Health,* **11**(2): 125–137.

22- H. M. A. M. Omer, (2012), Evaluation of groundwater quality in Dongula basin: the Northern state of Sudan, *Water Pollution*, **164**(11): 67-76.

23- Iqbal, M.M.; Li, L.; Hussain, S.; Lee, J.L.; Mumtaz, F.; Elbeltagi, A.; Waqas, M.S.; Dilawar, A., (**2022**), Analysis of Seasonal Variations in Surface Water Quality Over Wet and Dry Regions. *Water*, 1058(14):1-13.

24- IEDCR, (2006), The Effects of Climate Variability, Seasonal Variations and Environmental Events on Drinking Water Quality, Diarrhea Prevalence and Wash Behaviour in Bangladesh: Standard Operating Procedures and Data Collection Tools.

25- Jena, P. K., Mohanty, M, (2005), Processing of liquid effluents of mineral processing industries, Intl Symposium Environ Manag Mining Metallurgical Industries, 11-14, *Bhubaneshwar*, 193-212.

26- Khan N, Hussain S. T, Saboor A, Jamila N, Kim K. S, (2013), Physiochemical investigation of the drinking water sources from Mardan, Khyber Pakhtunkhwa, Pakistan, *International journal of physical sciences,* **8**(33):1661-71.

27- Li P, Wu J, Qian H, Zhang Y, Yang N, Jing L, Yu P, (2016a), Hydrogeochemical characterization of groundwater in and around a wastewater irrigated forest in the southeastern edge of the Tengger Desert, Northwest China. Expo Health 8(3):331–348.

28- Madena K. KoKo, Mohammed E. Osman, Gibla Omer A., (2019), Determination of Physicochemical Properties and some trace metals of Ground and Surface Drinking Water in Southern Kordofan State, (Sudan), *Albutana Journal of Applied Science* **8**(7): 73-83.

29- Madena K. KoKo, Mohammed E. Osman, Gibla Omer Adam, (2022), The Influence of Seasonal Variations on Ground and Surface Water Quality at Southern Kordofan State, Sudan, *International Journal of Academic and Applied Research*, **6**(7): 8-14.

30- Md. Galal Uddin, Md. Moniruzzaman, Muhammad Al-Amin Hoque, Md.Abu Hasan and Mala Khan, (2016), Seasonal Variation of Physicochemical Properties of Water in the Buriganga River, Bangladesh, *World Applied Sciences Journal*, 34(1): 24- 43.

31- Mona M. Fadul Abdalmotaleb, Gibla Omer Adam, Mutasim Maknoon Hassan, (2023), The Seasonal Availability of Some Minerals in Drinking Water Samples from the Northern State (Sudan), European Academic Research, 11(1):207-212.

32- Mawia H. Elsaim, Omer A., (2019), Physico-Chemical Properties of Drinking Water of Argo City, Northern Sudan, Abdulatif Alhamad Journal 4: 60-73.

33- N Kono, N., and Asubiojo, O. I, (1998), Elemental composition of drinking water supplies in three states in Southern Nigeria, Journal of Radioanalytical and Nuclear Chemistry, 227:117-119.

34- Omer Adam M Gibla, Mohammed Ahmed Hassan El-Tayeb, Abd EL-Salam Abdalla Dafa Alla, Esraa Omer Adam Mohammed, (2016), Ground water salinity in Bara basin, International Journal of Multidisciplinary Research and Development, 3(6): 57-64.

35- Omer Adam M. Gibla, Esraa Omer Adam Mohammed, (2017), Spectrophotometric Measurements of Some Inorganic Contaminants in Ground Water Samples, European Academic Research, 11(4):9608-9620.

36- Organization W. H. (1996), Guidelines for drinking water Health Criteria and other Supporting Information 2nd ED Geneva, Switzerland, WHO, Geneva, Switzerland.

37- Oişte AM (2014) Groundwater quality assessment in urban environment, Int J Environ Sci Technol, 11(7):2095–2102.

38- Okimiji, O.P., Okafor, A.T., Adedeji, O.H., Oguntoke, O. And Shittu, O.B., (2021), Seasonal Variation In Physico-Chemical Properties Of Drinking Water Quality Around Slum Settlements In Lagos Metropolis, Nigeria, Ethiopian Journal of Environmental Studies and Management, 14(1): 84-97.

39- Pawari MJ, Gawande S.(2015), Ground water pollution & its consequence. International journal of engineering research and general science, 3(4):773-76.

40- Rizak, S., Cunliffe, D., Sinclair, M., Vulcano., Howard, J., Hrudey, S., and Callan, P. (2003), Drinking water quality management, a holistic approach. Water Science and Technology, 47(9):31-36.

41- Roddis H. G., and Abdalla Hassan lutfi Wahadan, (1963) US. Geological Survey Availability of Ground Water in Kordofan Province, Sudan, Geological Survey Department of Sudan, Buletin No. 12.

42- Schsfera, A. H. (2009), Physico-chemical water quality in Ghana: prospects for water supply technology implementation. Science Direct, 248: 193- 203.

43- Schafera, Al., Rossitera, H M A.,Owusub, P A., Richards, B S and Awuah, E. 2009, Physicochemical Water Quality in Ghana: Prospects for Water Supply Technology Implementation, Desalination, 248: 193-203.

44- SSMO (Sudanese Standards and Metrology Organization), (2002), Unbottled Drinking Water: Standard NO.044-First edition.

45- Trivedi, P, Bajpai, and Thareja S, (2010), Comparative Study of Seasonal Varition in Physico-Chemical characteristics in Drinking Water Quality of Kanpur, Nature and Science, 8(4):1-11.

46- Tihansky, D. P, (1974), Economic damage from residential use of mineralized water supply. Water Resources Research, 10(2):145-154.

47- United Nations, (1988) Ground Water in North and West Africa. Natural Resources, Water Series No. 18, New York.

48- Velis M, Conti KI, Biermann F, (2017), Groundwater and human development: synergies and trade-offs within the context of the sustainable development goals, Sustain Sci, 12(6):1007–1017.
49- V. K. Ahluwalia; Lalita. S. Kumar, (2008), Environmental chemistry, First Edition, Ane Books. India.
50- Wu J, Zhou H, He S, Zhang Y (2019) Comprehensive understanding of groundwater quality for domestic and agricultural purposes in terms of health risks in a coal mine area of the Ordos basin, north of the Chinese Loess Plateau. Environ Earth Sci 78:446.
51- WHO, (2008), Guidelines for drinking-water quality, third edition incorporating the first and second addenda- Volume 1: Recommendations. Geneva: World Health Organization.
52- WHO, (2006), Guidelines for the Safe Use of Wastewater, Excreta and Greywater- volume 2: Waste Water Use in Agriculture, Geneva: World Health Organization.
53- WHO, (1993) Guidelines for Drinking Water Quality, Geneva, World Health Organization.
54- WHO, (1984). Guidelines for Drinking Water, Water Quality, Vol.1, 2, 3. Health Criteria and other Supporting Information, Geneva.
55- Yujie Ji, Jianhua Wu, Yuanhang Wang, Vetrimurugan Elumalai, Thirumalaisamy Subramani, (2020), Seasonal Variation of Drinking Water Quality and Human Health Risk Assessment in Hancheng City of Guanzhong Plain, China, Exposure and Health,12: 469-485.
56- Zhang Y, Wu J, Xu B, (2018), Human health risk assessment of groundwater nitrogen pollution in Jinghui canal irrigation area of the loess region, northwest China, Environ Earth Sci, 77(7):273.