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Research Article
Evaluation of Health Risk after Nitrate Exposure in Drinking Water in the Al Duliel Area, Jordan

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Abstract
Background and Objective: Jordan's drinking water scarcity is desperately needed and it plays a critical role in improving safe drinking water quality, which is critical for nutritious and clean drinking water quality, which is a vital component of good public health. Recognize the potential risk of repeated exposure to high nitrate concentrations in drinking water in the A Duliel area and measure the impact on local communities' human health. **Materials and Methods:** In 2016, samples of groundwater were taken. With a mean value of 44.4 mg L^{-1}, nitrate concentrations ranged from 10-81.0 mg L^{-1}. **Results:** The findings showed that human activities, especially the extensive use of chemical fertilizers in agriculture, could be attributed to high NO_3 concentrations. To assess the possible risk to human health, Chronic Daily Intake (CDI) and Hazard Quotient (HQ) has been assessed. In the classes considered, infants tended to be at a greater risk than children and adults. Furthermore, the findings showed that in most of the groundwater considered, the health of people from nitrate contamination was not adequate and was also at risk from known concentrations of nitrate. **Conclusion:** Appropriate steps to improve groundwater protection and to better track and control stable sources of nitrate emissions are also important.

Key words: Drinking water, nitrate, health risk, evaluation, non-carcinogenic risk, groundwater protection, municipal wastewater

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The shortage of drinkable water in Jordan becoming increasingly in need and plays a vital role in improving the high quality of drinking water, which is important for healthy and safe drinking water quality, which is the cornerstone of good public health[1]. On the other hand, due to growing population groups, the greatly increased use of water globally had also led to the development of complicated demand difficulties besides clear water and resources[1]. Pointing to the Intergovernmental Panel on Climate Change (IPCC), approximately 2.2-2.4 billion people live in areas with stress conditions, these statistics are expected to grow strongly due to rapid population growth and the pushes of climate change[2-5]. For human communities, clean drinking water resources, clean and good water security are required[6-10].

Over time, in many arid and semi-arid areas, groundwater has been considered an important source of water, usually seen as a clean source of water, suitable for drinking without treatment [11]. In developed countries, on the other hand, rapid population growth, the use of exciting quantities of fertilizers to boost and raise crop productivity, the drainage of pollutants into the atmosphere and collective industrial development are all facing, impacting the availability of safe freshwater and have become a severe and dynamic environmental issue[3-5,12-14]. Because of this, a significant correlation between irrigation and the increase of nitrate contamination in groundwater has been identified in several studies[12,15]. Inside this agricultural area as well as the municipal wastewater-flowing area, a high nitrate rate was found[16,17]. On the other hand, Zhang *et al.*[18] worked on the spread of nitrate in various aquifers in southern China's municipal area and noted that municipal regions were mainly followed by a domestic sewage outflow, which was the central strong strength to increase the amount of nitrate in groundwater[18]. Furthermore, the manufacturing region groundwater is also governed by high nitrate pollution[18].

All research in this area has suggested that continuing drinking contaminated drinking water with nitrates poses significant health risks. Therefore, nitrate exposure-related health risk assessment studies are widely conducted in different regions such as Iran[7,9,19], Pakistan[20], China[13,21], India[14], Mexico[8], which have focused on non-carcinogenesis. The real energy source for drinking water is groundwater and vast numbers of Jordanians depending on groundwater for drinking purposes. The authoritative study has since been conducted to Rehman *et al.*[20] determine whether nitrate levels are beyond the range of recommended and agreed levels in drinking water to prevent health problems. There is a lack of studies in the literature on nitrate levels in drinking water to our knowledge, except for the research conducted by Foster and Chilton[1], which focused on the risk of groundwater contamination in Jordan, especially in the Duliel region[1].

Therefore, the purpose of the present work was to examine the accumulation of nitrates in groundwater in country areas of Al Duliel, Jordan and their probable effects on the health of locals. This research may be useful in preventing the risks of nitrate toxicity to human health and for the potential protection of local groundwater resources in the region under consideration.

MATERIALS AND METHODS

Study area and sampling site: The field research in this study was focused on 6 rural areas around A Duliel which are located in the Northwest of Al Zarqa city in Northeast Jordan, the area is approximately 220 km^2, has a desert climate, population of about 76703. This study was carried out at the Department of Biology and Biotechnology, The Hashemite University, Jordan from February-July 2016, by using 500 mL capacity of polyethylene bottles washed by Hydrochloric acid (HCl). In this area, all the people are working in agriculture. The industrial sector also rapidly developed as many factories' production is based on agricultural output. The agricultural activities in this area include irrigation, livestock and dairy farming. The research areas are not too far removed from large manufacturing facilities.

Nitrate analysis: Between February and July, 2016, triplicate groundwater samples were taken from each of the six areas in Duliel per month. Samples were obtained from local wells and collecting locations were chosen according to the requirements of the World Health Organization (WHO)[17]. Finally, using the Lambda35 UV/VIS Spectrometer (PerkinElmer, USA, www.perkinelmer.com) the nitrate concentrations of the samples were analyzed. The data of nitrate concentration used for the health risk assessments were average of triplicate groundwater samples from each sampling area. Analytical techniques were tested using successive criteria such as instrument calibration, accuracy, linearity, the limit of detection, blank reagents for quality control. The error was tested for the quality of the analyzed data before determining the non-carcinogenic health risk due to groundwater nitrate.

Nitrate exposure assessment of public health risk: Contamination of groundwater could have serious health effects on humans through mainly two pathways, i.e. (oral) ingestion as well as physical contact (dermal). To identify the possibility of adverse health effects on humans who are subjected to all of it, risk analysis of chemical components in polluted groundwater is beneficial. Health risk assessment, based on literature and scientific research, is indeed an important issue used in predicting this impact[3,22]. Keramati *et al.*[23] classified the health risk into non-carcinogenic and carcinogenic[22]. A selection of input parameters is being used by health risk assessment models to accurately predict contamination levels[7,21,24,25]. Contaminant and Hazard Quotient (HQ) Chronic Daily Intake (CDI) is approximately the key indices used for health risk estimation, the method used to conduct a health risk evaluation is according to the non-carcinogenic hazard quotient model advocated by the United States Environmental Protection Agency[26]. The Chronic Daily Intake (CDI) value of a given factor (mg/kg/day) can be determined using the following equation[6,14,19,22,27]:

$$CDI = \frac{C_w \times DI \times EF \times EP}{B.W \times AT}$$

where, CDI is the chronic normal water consumption (mg/kg/day), where C is the concentration of contaminant in water in mg L^{-1}, where IR is the amount of intake, where EF is the signalled level of exposure (day/year), where ED is the period of exposure in years (40 years for adults 10 years for children and 1 year for infants), where B.W is the mean body weight (70 kg for adults, 20 kg for children and 1 year for infants), where CDI is the average body weight (70 kg for adults, 20 kg for children and 20 kg for infants)[28].

As a Hazard Quotient (HQ) that can be calculated using the following equation, the non-carcinogenic effect of each contaminant can be confirmed[29,30]:

$$HQ = \frac{CDI}{RfD}$$

where, RfD is the reference dosage for oral exposure, which is 1.6 mg/kg/day nitrate[26]. If the HQ value is greater than 1, the Non-carcinogenic Human Health Risk (NHHR) in drinking water exceeds the appropriate contaminant level[31,32].

RESULTS AND DISCUSSION

Concentrations of nitrate in wells: The data of Fig. 1 indicates the findings for nitrate concentrations in the groundwater tests of the wells tested. In groundwater tests, nitrate concentrations ranged from 10±1.3-81.0±1.4 mg L^{-1} (Mean±Std) with a mean value of 44.4 mg L^{-1}. It also showed that 4% of groundwater samples were found to be around 10.0 mg L^{-1} NO_3, followed by 21% of samples varying from 14-41 mg L^{-1} NO_3 and 45% of groundwater samples displaying a value between 50-67 mg L^{-1} NO_3 and 30% of groundwater samples >75 mg L^{-1} NO_3.

Overall, the findings revealed that nitrate concentrations were above 50 mg L^{-1} in 50% of the areas in Al Duliel, which was the WHO guidelines' maximum limit and the Jordanian

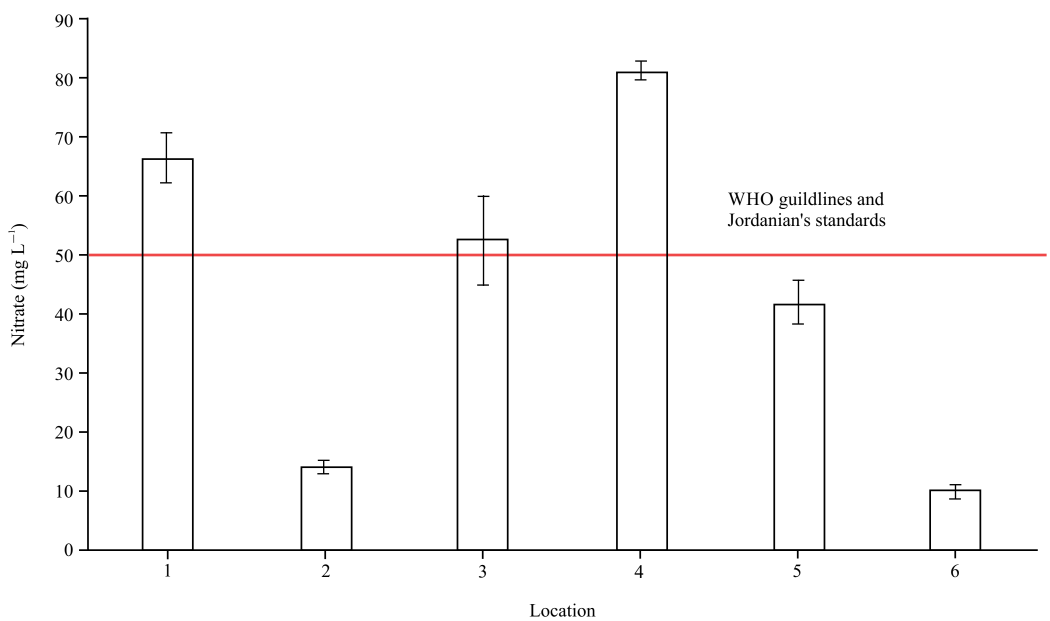

Fig. 1: Nitrate concentrations (mg L^{-1}) in groundwater samples (wells) collected from Al Duliel
(Mean±Std)

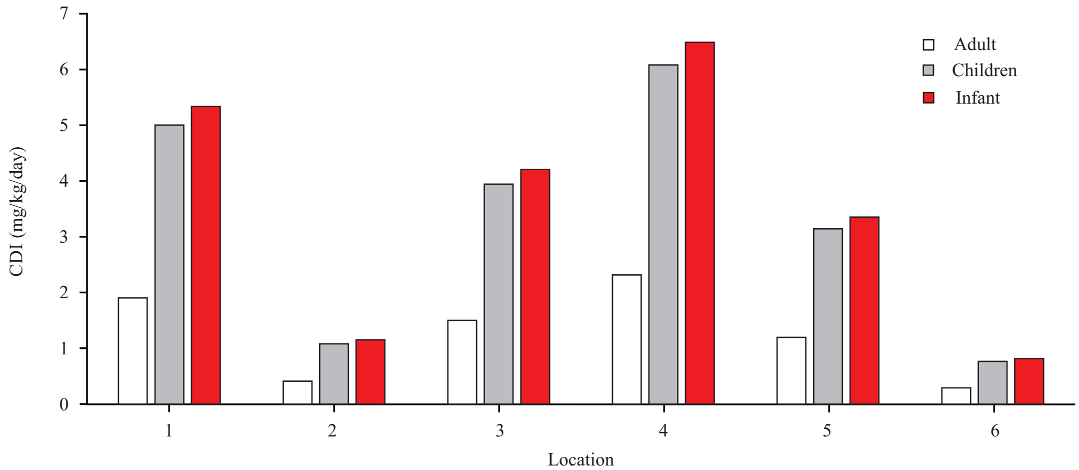

Fig. 2: Estimation of chronic daily intake (CDI, mg/kg/day) values for three studied age groups

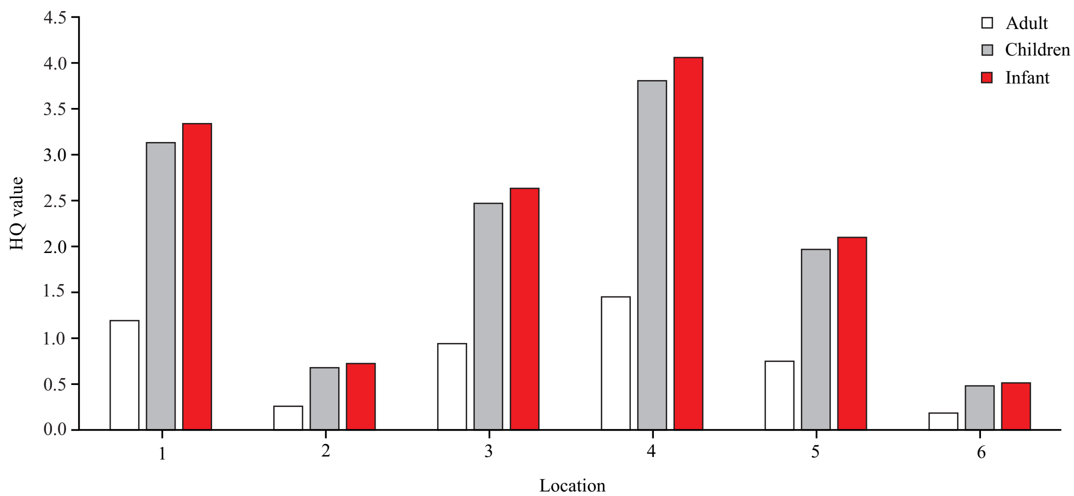

Fig. 3: Hazard Quotient (HQ) values for nitrate in samples from Al Duliel area

drinking water nitrate level. The groundwater nitrate concentration study of Prince Edward Island, Canada, was also estimated to demonstrate that 6% of domestic wells used for drinking had concentrations of nitrate above the WHO guideline[33]. That may be due to human actions, including the improper use in agriculture for artificial fertilizers and the disposal of domestic waste instead of the normal effects of contact between groundwater and rock. Besides, no substantial change in nitrate concentration during the dry and rainy seasons was observed in this analysis, suggesting that nitrate concentration did not change over time and remained relatively stable. Some studies have shown that there is a correlation between high nitrate intake and thyroid dysfunction, gastrointestinal cancer and[34,35]. Little information on the effects of nitrates on adult health is available in Jordan.

Risk evaluation on human health by estimating the Daily Chronic Intake (CDI): Exposure and contact with pollutants by polluted drinking water is commonly accepted as causative of public quality changes for rural areas in Jordan. To our knowledge, no clear research has measured the non-carcinogenic effects of nitrate in al-Duliel groundwater and little evidence is available on the toxicity effects of water pollutants. To assess the health risk in the groundwater tests, nitrate concentrations were taken to assess the non-carcinogenic risk in the region's groundwater during 2017.

The CDI data and the estimated nitrate HQ of groundwater from the sample area are shown in Fig. 2. For groundwater well tests, the ranges of CDI values were 0.29-2.31 (mean 1.27), 0.76-6.07 (mean 3.33) and 0.82-6.488 (mean 3.65) mg/kg/day for adults, children and infants, respectively. The most important exposure path for nitrate in groundwater occurs through the ingestion contact route. According to Fig. 2, the health risk of infants was greater than that of children and adults.

Estimating non-carcinogenic nitrate exposure levels: The non-carcinogenic risk was assessed in the groundwater wells of the sample area using the Hazard Quotient (HQ) model based on the US Environmental Protection Agency process[26]. This research examined the potential for health risks from exposure by ingesting nitrate-containing water from wells in three age categories, including adults, children and infants in the Al Duliel district. The mean distribution of nitrate concentration was calculated and estimated for the HQ values in the groundwater supplies of the Al Duliel district (Fig. 3).

The findings revealed that the HQ values in Al Duliel were for adults, children and infants by the intake of nitrate-containing drinking water ranges of 0.18-1.45, 0.48-3.79 and 0.51-4.05 with means of 0.79, 2.08 and 2.22, respectively. Normally, where the HQ value is greater than1, the frequency of adverse health effects is observed and when the HQ value is less than1, it is assumed to be healthy. Total 86% of HQ levels for children and infants were above the protection limit, meaning that nitrate from groundwater would have major health consequences on these age ranges. This indicates that certain age ranges (children and infants) are more likely to be affected by exposure to nitrates in drinking water due to distinctive physiological characteristics and behavioural habits and their gastrointestinal intake of such constituents increases when their bodies are in a developmental phase, rendering them more susceptible to external pollutants[36].

Indirectly, owing to the consumption of nitrate-contaminated freshwater, children and infants in the study area are more vulnerable to non-carcinogenic human health sensitivity compared with adults. The results of this research are consistent with similar studies undertaken by numerous researchers in other areas of the world[37-40,12,19].

It was also estimated that the nitrate content in the study area ranged from not available to 82.8 mg L^{-1} and about 50% of the groundwater samples exceeded the nitrate drinking water level in research into the human health risk of groundwater nitrogen contamination in the Jinghui canal irrigation field of the Loess area of northwest China[18,41]. The results found that across about 40% of the areas analyzed, the ideal level was overhead for potential health risks of adult males and females. In the areas surveyed, 41 and 63% of children and infants were also a health risk. The findings also revealed that high amounts of nitrate could be due to human activities, in particular the widespread use of nitrogen fertilizers in agriculture[24].

The present research focuses primarily on the measurement of nitrate in the groundwater as a non-carcinogenic human health concern. In certain areas of Jordan, nitrate contamination of the drinking water supply is normal and correctly considered. The first move in the path of protecting groundwater from contamination is the recording of nitrate-susceptible areas. For three groups, including adults, children and infants, the examination of groundwater nitrate exposure in rural areas of Al Duliel is of unusual significance in quantifying the non-carcinogenic health risk associated with nitrate pollution in those regions. Nitrate values ranged from 10 ± 1.3-81.0 ± 1.4 mg L^{-1} (Mean$\pm$Stdev) with just three wells above the WHO guideline value of 50 mg L^{-1} as indicated above. Nonetheless, the ingestion of high nitrate-containing water may have a major impact on individual health. In the present analysis, the non-carcinogenic risk evaluation showed that the CDI and HQ values were flocculated. The non-carcinogenic risk assessment was determined for the classes evaluated as follows: Infants>children>adults. This will clearly warn consumers that groundwater is not safe, particularly for infants under 1 year of age. These findings also suggest that nitrate amounts should be routinely checked in the groundwater of the study area to ensure they are within appropriate levels. In these areas, a wide-ranging hygiene improvement strategy is expected that will have an optimistic effect on the reduction of nitrate levels in groundwater supplies. The last recommendation is to limit the intake of water from any well which is found to be polluted with nitrates greater than the 50 mg L^{-1} WHO guideline. As a final step, it is important to help complete the transition from anthropogenic activities that add nitrate to groundwater, including animal operations, field fertilization, wastewater discharge, septic well absorption systems, etc. as nitrate is expensive to be removed from drinking water sources.

CONCLUSION

The findings of the current work would help to decide more definitively the levels of nitrate pollution in the groundwater of the Al Duliel area, thus recommending and choosing the most suitable substitutions for remediation and prevention. Furthermore, the results of this study provide valuable advice for future work planning and are important for assessing the potential health effects of nitrate toxicity.

SIGNIFICANCE STATEMENT

This research indicated that the concentration of nitrate in al Duliel well water is within the unacceptable limit and that the health risk of respondents in this area was considered to be high. Although the level of nitrate in this study was high, efforts should be made to minimize any further exposure of nitrate to humans as well as to ecosystems and the environment.

REFERENCES

1. Foster, S.S.D. and P.J. Chilton, 2004. Downstream of downtown: Urban wastewater as groundwater recharge. Hydrogeol. J., 12: 115-120.
2. Chaudhry, A.K. and P. Sachdeva, 2020. Groundwater quality and non-carcinogenic health risk assessment of nitrate in the semi-arid region of Punjab, India. J. Water Health, 18: 1073-1083.
3. Ghaderpoori, M., M. Paydar, A. Zarei, H. Alidadi, A.A. Najafpoor, A.H. Gohary and M. Shams, 2019. Health risk assessment of fluoride in water distribution network of Mashhad, Iran. Hum. Ecol. Risk Assess.: Int. J., 25: 851-862.
4. Li, P., R. Tian, C. Xue and J. Wu, 2017. Progress, opportunities, and key fields for groundwater quality research under the impacts of human activities in China with a special focus on western China. Environ. Sci. Pollut. Res., 24: 13224-13234.
5. Wheater, H., S. Sorooshian and K.D. Sharma, 2007. Hydrological Modelling in Arid and Semi-Arid Areas. Cambridge University Press, United Kingdom, ISBN-13: 9780511535734.
6. Qasemi, M., M. Farhang, H. Biglari, M. Afsharnia and A. Ojrati *et al*., 2018. Health risk assessments due to nitrate levels in drinking water in villages of Azadshahr, Northeastern Iran. Environ. Earth Sci., Vol. 77. 10.1007/s12665-018-7973-6.
7. Qasemi, M., M. Afsharnia, M. Farhang, A. Bakhshizadeh, M. Allahdadi and A. Zarei, 2018. Health risk assessment of nitrate exposure in groundwater of rural areas of Gonabad and Bajestan, Iran. Environ. Earth Sci., Vol. 77. 10.1007/s12665-018-7732-8.
8. Qasemi, M., M. Afsharnia, M. Farhang, M. Ghaderpoori, A. Karimi, H. Abbasi and A. Zarei, 2019. Spatial distribution of fluoride and nitrate in groundwater and its associated human health risk assessment in residents living in western Khorasan Razavi, Iran. Desalin. Water Treat., 170: 176-186.
9. Qasemi, M., M. Afsharnia, A. Zarei, M. Farhang and M. Allahdadi, 2019. Non-carcinogenic risk assessment to human health due to intake of fluoride in the groundwater in rural areas of Gonabad and Bajestan, Iran: A case study. Hum. Ecol. Risk Assess.: Int. J., 25: 1222-1233.
10. Derakhshani, E., A. Naghizadeh, A.R. Yari, M.J. Mohammadi, M. Kamranifar and M. Farhang, 2018. Association of toxicochemical and microbiological quality of bottled mineral water in Birjand city, Iran. Toxin Rev., 37: 138-143.
11. Dehghani, M.H., M. Farhang, M. Alimohammadi, M. Afsharnia and G. Mckay, 2018. Adsorptive removal of fluoride from water by activated carbon derived from $CaCl_2$-modified *Crocus sativus* leaves: Equilibrium adsorption isotherms, optimization, and influence of anions. Chem. Eng. Commun., 205: 955-965.
12. Kumar, D., A. Singh, R.K. Jha, B.B. Sahoo, S.K. Sahoo and V. Jha, 2019. Source characterization and human health risk assessment of nitrate in groundwater of middle Gangetic plain, India. Arabian J. Geosci., Vol. 12. 10.1007/s12517-019-4519-5.
13. Gao, S., C. Li, C. Jia, H. Zhang and Q. Guan *et al*., 2020. Health risk assessment of groundwater nitrate contamination: A case study of a typical karst hydrogeological unit in East China. Environ. Sci. Pollut. Res., 27: 9274-9287.
14. Adimalla, N., 2020. Spatial distribution, exposure, and potential health risk assessment from nitrate in drinking water from semi-arid region of South India. Hum. Ecol. Risk Assess.: Int. J., 26: 310-334.
15. Mas-Pla, J. and A. Mencio, 2018. Groundwater nitrate pollution and climate change: Learnings from a water balance-based analysis of several aquifers in a Western Mediterranean region (catalonia). Environ. Sci. Pollut. Res., 26: 2184-2202.
16. Qasemi, M., M. Farhang, M. Morovati, M. Mahmoudi and S. Ebrahimi *et al*., 2020. Investigation of potential human health risks from fluoride and nitrate via water consumption in Sabzevar, Iran. Int. J. Environ. Anal. Chem., Vol. 99. 10.1080/03067319.2020.1720668.
17. Villarreal, J.P., J.A.A. Olivera, I.I. Alcántara and O.B. Delgado, 2019. Nitrate as a parameter for differentiating groundwater flow systems in urban and agricultural areas: The case of Morelia-Capula area, Mexico. Hydrogeol. J., 27: 1767-1778.
18. Zhang, M., G. Huang, C. Liu, Y. Zhang, Z. Chen and J. Wang, 2020. Distributions and origins of nitrate, nitrite, and ammonium in various aquifers in an urbanized coastal area, South China. J. Hydrol., Vol. 582. 10.1016/j.jhydrol.2019.124528.
19. Yousefi, M., M. Ghoochani and A.H. Mahvi, 2018. Health risk assessment to fluoride in drinking water of rural residents living in the Poldasht city, Northwest of Iran. Ecotoxicol. Environ. Saf., 148: 426-430.
20. Rehman, J.U., N. Ahmad, N. Ullah, I. Alam and H. Ullah, 2020. Health risks in different age group of nitrate in spring water used for drinking in Harnai, Balochistan, Pakistan. Ecol. Food Nutr., 59: 462-471.
21. Su, X., H. Wang and Y. Zhang, 2013. Health risk assessment of nitrate contamination in groundwater: A case study of an agricultural area in Northeast China. Water Resour. Manage., 27: 3025-3034.

22. Bantin, A.B., X. Jun and H. Wang, 2020. Monitoring the bacteriological quality of manual drilling water in the tandjile region in chad. Preprints, 10.20944/preprints202009.0667.v1.
23. Keramati, H., R. Ghorbani, Y. Fakhri, A.M. Khaneghah and G.O. Conti *et al*., 2018. Radon 222 in drinking water resources of Iran: a systematic review, meta-analysis and probabilistic risk assessment (*Monte carlo* simulation). Food Chem. Toxicol., 115: 460-469.
24. Zhai, Y., X. Zhao, Y. Teng, X. Li, J. Zhang, J. Wu and R. Zuo, 2017. Groundwater nitrate pollution and human health risk assessment by using HHRA model in an agricultural area, NE China. Ecotoxicol. Environ. Saf., 137: 130-142.
25. Oh, K.S., J.Y.C. Leong, P.E. Poh, M.N. Chong and E.V. Lau, 2018. A review of greywater recycling related issues: Challenges and future prospects in Malaysia. J. Cleaner Prod., 171: 17-29.
26. National Research Council, 2013. Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic: Interim Report. The National Academies Press, United States, ISBN: 13 978-0-309-29706-6, Pages: 127.
27. Kaur, L., M.S. Rishi and A.U. Siddiqui, 2020. Deterministic and probabilistic health risk assessment techniques to evaluate non-carcinogenic human health risk (NHHR) due to fluoride and nitrate in groundwater of Panipat, Haryana, India. Environ. Pollut., Vol. 259. 10.1016/j.envpol.2019.113711.
28. Ravindra, K., P.S. Thind, S. Mor, T. Singh and S. Mor, 2019. Evaluation of groundwater contamination in chandigarh: Source identification and health risk assessment. Environ. Pollut., Vol. 255. 10.1016/j.envpol.2019.113062.
29. Mohammadi, M.J., A.R. Yari, M. Saghazadeh, S. Sobhanardakani and S. Geravandi *et al*., 2018. A health risk assessment of heavy metals in people consuming Sohan in Qom, Iran. Toxin Rev., 37: 278-286.
30. Radfard, M., M. Yunesian, R. Nabizadeh, H. Biglari and S. Nazmara *et al*., 2019. Drinking water quality and arsenic health risk assessment in Sistan and Baluchestan, Southeastern province, Iran. Hum. Ecol. Risk Assess.: Int. J., 25: 949-965.
31. Jafari, A., B. Kamarehie, M. Ghaderpoori, N. Khoshnamvand and M. Birjandi, 2018. The concentration data of heavy metals in Iranian grown and imported rice and human health hazard assessment. Data Brief, 16: 453-459.
32. Huang, Y., Y. Teng, N. Zhang, Z. Fu and W. Ren, 2018. Human health risk assessment of heavy metals in the soil-panax notoginseng system in Yunnan province, China. Hum. Ecol. Risk Assess.: Int. J., 24: 1312-1326.
33. Paradis, D., H. Vigneault, R. Lefebvre, M.M. Savard, J.M. Ballard and B. Qian, 2016. Groundwater nitrate concentration evolution under climate change and agricultural adaptation scenarios: Prince Edward island, Canada. Earth Syst. Dyn., 7: 183-202.
34. Yu, G., J. Wang, L. Liu, Y. Li, Y. Zhang and S. Wang, 2020. The analysis of groundwater nitrate pollution and health risk assessment in rural areas of Yantai, China. BMC Public Health, Vol. 20. 10.1186/s12889-020-08583-y.
35. Achadi, E., M.J. Hansell, N.L. Sloan and M.A. Anderson, 1995. Women`s nutritional status, iron consumption and weight gain during pregnancy in relation to neonatal weight and length in West Java, Indonesia. Int. J. Gynecol. Obstet., 48: S103-S119.
36. Chen, H., Y. Teng, S. Lu, Y. Wang, J. Wu and J. Wang, 2016. Source apportionment and health risk assessment of trace metals in surface soils of Beijing metropolitan, China. Chemosphere, 144: 1002-1011.
37. He, S. and J. Wu, 2018. Hydrogeochemical characteristics, groundwater quality, and health risks from hexavalent chromium and nitrate in groundwater of huanhe formation in Wuqi county, Northwest China. Exposure Health, 11: 125-137.
38. He, X., J. Wu and S. He, 2019. Hydrochemical characteristics and quality evaluation of groundwater in terms of health risks in luohe aquifer in Wuqi county of the Chinese loess plateau, Northwest China. Hum. Ecol. Risk Assess.: Int. J., 25: 32-51.
39. Wu, J., J. Bian, H. Wan, Y. Ma and X. Sun, 2021. Health risk assessment of groundwater nitrogen pollution in Songnen Plain. Ecotoxicol. Environ. Saf., Vol. 207. 10.1016/j.ecoenv.2020.111245.
40. Singh, G., M.S. Rishi, R. Herojeet, L. Kaur and K. Sharma, 2020. Evaluation of groundwater quality and human health risks from fluoride and nitrate in semi-arid region of Northern India. Environ. Geochem. Health, 42: 1833-1862.
41. Zhang, Y., J. Wu and B. Xu, 2018. Human health risk assessment of groundwater nitrogen pollution in Jinghui canal irrigation area of the Loess region, Northwest China. Environ. Earth Sci., Vol. 77. 10.1007/s12665-018-7456-9.