

EREM 82/3 Journal of Environmental Research, Engineering and Management Vol. 82 / No. 3 / 2026 pp. 96–102 10.5755/j01.erem.82.3.44455	Microbiological Contamination and Physicochemical Characteristics of Drinking Water in Secondary Schools, Al-Hilla City, Iraq	
	Received 2026/03	Accepted after revisions 2026/06
	https://doi.org/10.5755/j01.erem.82.3.44455	

Microbiological Contamination and Physicochemical Characteristics of Drinking Water in Secondary Schools, Al-Hilla City, Iraq

Sara Ahmed Ali Al-Husseini¹, Maytham Salim AL-Nasrawii^{2*}

- ¹ Community Health Department, College of Health and Medical Technologies/Kufa, Al-Furat Al-Awsat Technical University, Iraq
- ² Community Health Department, Polytechnic College/Karbala, Al-Furat Al-Awsat Technical University, Iraq

***Corresponding author:** maytham.alnasrawii@atu.edu.iq

Ensuring safe drinking water in schools is essential for protecting adolescent health and achieving Sustainable Development Goal 6. Evidence from Iraqi secondary schools remains limited. This study aims to assess the physicochemical and microbiological quality of drinking water in Al-Hilla City.

A cross-sectional study was conducted between September 2025 and February 2026 in 17 secondary schools in Al-Hilla City, Iraq. Drinking water samples were analyzed for physicochemical parameters (pH, turbidity, total dissolved solids, hardness, calcium, magnesium, nitrate, chloride) and microbiological indicators (total coliforms and *Escherichia coli*) using American Public Health Association standard methods. The results were compared with World Health Organization and Iraqi drinking water standards. The results of the study reveal that bacteriological contamination was detected in 35.3% of samples, indicating non-compliance with World Health Organization guidelines. Most physicochemical parameters were within permissible limits; however, total dissolved solids exceeded standards in 70.6% of samples, turbidity in 11.8%, and total hardness in 23.5% of water samples, and calcium exceeded the Iraqi standard in 17.6% of water samples. Although chemical safety was generally acceptable, the presence of microbial contamination and elevated dissolved solids in several schools suggests potential health risks. Routine monitoring, improved disinfection, and maintenance of school water systems are recommended to ensure sustained compliance with drinking water standards.

Keywords: Drinking water quality, microbiological contamination, physicochemical parameters, school WASH, total dissolved solids.

Introduction

Access to clean drinking water is essential for health, a basic human right, and a key component of effective health protection strategies. Poor water quality is linked to serious health risks, especially among school students. In Iraq, alongside the growing burden of non-communicable diseases such as kidney disease and neoplasms, controlling environmental and water-borne hazards remains essential for protecting public health (Merzah, 2025). Drinking water quality, defined by its chemical, physical, and biological characteristics, must meet World Health Organization (WHO) and national permissible limits to prevent acute and chronic infections (Atumo Ante et al., 2023; Ngcongco and Tekere, 2023).

Universal access to safe and affordable drinking water is a primary target of Sustainable Development Goal 6 (SDG6) (Hung et al., 2020), monitored through indicator 6.1.1 on safely managed drinking water services (WHO, 2023). Despite global efforts, approximately 2.5 billion people lack safe water, and millions die annually from waterborne diseases, including cholera (Abdulhussein, 2020). Water quality remains central to environmental safety and public health, serving as a major source and vehicle of infectious agents (Najeeb et al., 2024; Hameed et al., 2020; Sharma and Bhattacharya, 2017). Microbial indicators such as total coliforms, fecal coliforms, and *E. coli* are widely used to detect fecal contamination (AL-Dahmoshi, 2020). Evidence indicates that school drinking water supplies may contain significant microbial contamination, exposing children to diarrheal diseases, typhoid, cholera, and gastroenteritis (Kristanti et al., 2022), while chemical contaminants also pose health risks (WHO, 2017). Assessing school-based drinking water is critical, as students spend much of their time in school settings (WHO/UNICEF JMP, 2018).

In Iraq, the United Nations Children's Fund reports that nearly half of schools lack access to safe drinking water and adequate sanitation facilities (UNICE/Iraq, 2023). Local studies in Al-Habbaniyah, Al-Muthanna, and Erbil have documented low residual chlorine levels, fecal contamination, and heavy-metal risks linked to water-borne infections (Hantoosh, 2023; Khalid et al., 2020). Ongoing drought and conflict have further affected water quality (Hantoosh, 2023). However, comprehensive

assessments in secondary schools, particularly in Al-Hilla City, remain limited. This study evaluates selected physicochemical and microbiological parameters of drinking water in secondary schools in Al-Hilla City and assesses compliance with WHO and Iraqi standards to inform public health and policy interventions.

Materials and methods

Study design and setting: A cross-sectional study was conducted from 1 September 2025 to 18 February 2026 to assess the physicochemical and microbiological quality of drinking water in secondary schools in Al-Hilla City, Iraq. A total of 17 schools were included, representing 30% of the 56 secondary schools operating in the city. Schools were selected using stratified random sampling by type (public and private) and by sex (boys and girls), and samples were collected from the main drinking water sources used by students.

Data collection: Water samples were collected from the main drinking water taps in schools. In most schools, the main source of drinking water was piped water, while only two schools used tanker-truck supplied water as an alternative source. Samples were collected using sterilized 250 ml polyethylene bottles. The bottles were pre-labeled with the sample ID, source, date, and time of collection. Two samples were obtained from each tap one for physicochemical analysis and one for microbiological analysis after allowing the water to run for 2–3 minutes to flush the line and avoid stagnant water. The bottle mouth was flamed or kept away from the tap to prevent external contamination, and the cap was closed immediately without touching the inner surface. Samples were stored in an icebox at 4–8°C and transported to the laboratory within 6 hours, where they were analyzed on the same day for physical, chemical, and microbiological parameters.

Analysis items and methods

Physical and chemical analysis: To assess water quality in secondary schools, the following parameters were measured: pH, turbidity, chloride, total dissolved solids (TDS), hardness, magnesium (Mg), calcium (Ca), and nitrate (NO₃). The analytical procedures and instruments used for each parameter are summarized in *Table 1*. All analyses were conducted according to the APHA (American Public Health Association) Standard Methods (2017) (Baird et al., 2017).

Table 1. Instruments and analytical methods used for physicochemical analysis

Parameters	Devices/methods	Unit
pH	pH meters	-
Turbidity	Turbidimeter	NTU
TDS	TDS meters	mg/l
Chloride	Silver nitrate method	mg/l
Total Hardness (TH)	EDTA complexometric titration with Eriochrome Black T	mg/l CaCO ₃
Ca	EDTA Titration	mg/l
Mg	Manual titration (total hardness-Ca hardness)	mg/l
Nitrate	Spectrophotometers	mg/l

Table 2. Water quality standards for physicochemical and microbiological parameters

Physicochemical and microbiological parameters	Iraq standard (Ali and Irzooki, 2025; WASH Cluster, 2022)	WHO guidelines (WHO, 2022)
pH	6.5–8.5	6.5–8.5
TDS	≤ 1000	≤ 1000
Turbidity	≤ 5 NTU	≤ 5 NTU
Chloride	< 350 mg/l	≤ 250 mg/l
Total hardness	< 500 mg/l	< 500 mg/l (Acceptable)
Ca	< 150 mg/l	Not specified
Mg	< 100mg/l	Not specified
Nitrate	< 50 mg/l	< 50 mg/l
Total coliform	0 MPN /100 ml	0 MPN /100 ml
E. coli	0 MPN/100 ml	0 MPN /100 ml

Microbiological analysis: The bacteriological quality of drinking water was assessed by detecting total coliforms and *E. coli* using the tube fermentation technique according to APHA standard methods. The Most Probable Number (MPN) method was applied, whereby serially diluted samples were inoculated into lactose broth. Coliform presence was indicated by acid production (color change) and gas formation in Durham tubes.

Positive tubes were counted and compared with standard MPN tables. Presumptive and confirmatory tests were conducted using Lauryl Tryptase Broth, Brilliant Green Broth, and EC Broth.

Standard for assessment: Measurements were done according to WHO guidelines and national standards for water testing. As results show in *Table (2)* they are compared to local and international guidelines (WASH Cluster, 2022; WHO, 2022).

Statistical analysis: The collected data were analyzed by using the IBM SPSS-29 (Statistical Packages for Social Sciences, version 29, Chicago, IL, USA). Descriptive statistics, including frequency, percentage, mean, standard deviation, and range (minimum-maximum values), were calculated. The results were evaluated by comparison with the WHO guidelines and Iraqi drinking water standards.

Results

Bacteriological quality of drinking water samples: Indicated a majority of schools were free from bacterial contamination, with zero counts of total coliform and *E. coli*. However, a limited number of schools showed a detectable level of bacteriological contamination. The table reveals that the highest level of coliform in water samples was 6 cells/100 mL, while the highest level of **E. coli** was 8 cells/100 ml.

Also, as in *Fig. (1)*, the results show that 64.7% of water samples met the standard, whereas 35.3% of samples were classified as sub-standard.

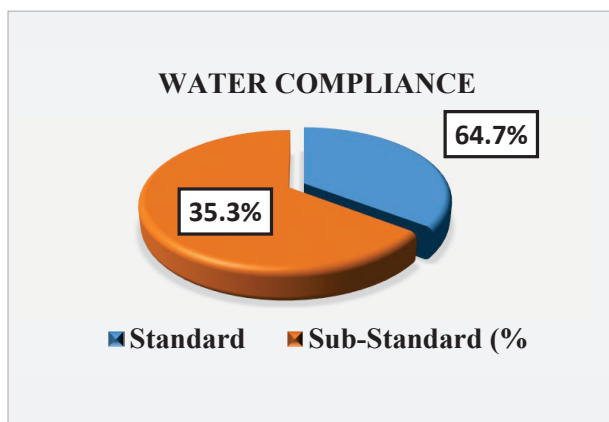
Fig. 1. Overall compliance bacteriological parameters of drinking water samples

Table 4. *Physicochemical parameters of water samples*

Parameters	Iraq standard (Ali and Irzooki, 2025; WASH Cluster, 2022)	WHO guidelines WHO, 2022)	Min-Max	Mean $\pm$ SD
Turbidity	≤ 5	≤ 5	1–6	4.00 ± 1.54
TDS	≤ 1000	≤ 1000	36–1077	826.00 ± 380.38
pH	6.5–8.5	6.5–8.5	7–7.93	7.49 ± 0.33
Chloride	< 350	≤ 250	30–224	132.65 ± 57.07
Ca	< 150	-	24–200	106.47 ± 50.46
Hardness	< 500	< 500	162–684	427.76 ± 123.51
Mg	< 100	-	9.6–76.8	43.52 ± 17.70
Nitrate	< 50	< 50	0.03–1.52	0.88 ± 0.48

Table 3. *MPN of coliforms and E. coli in water samples*

Code	School name	Total coliform / MPN/100 ml	E. coli MPN/ 100 ml
1	Al-Nujoom	0	0
2	Al-Shaheed Al-Sadr	0	0
3	Halab	4	4
4	Al-Baqir	4	4
5	Al-Dustour	0	0
6	Al-Nasr	0	0
7	Zahret Al-Furat	0	0
8	Qasim Al-Sabbak	0	0
9	Al-Mutafawwiqat	0	0
10	Al-Shaheed Abdul-Sahib	6	6
11	Al-Warith	0	0
12	Al-Mazaya	0	0
13	Babel	4	2
14	Al-Mawahib	8	4
15	Babrosh	0	0
16	Al-Sadiq	0	0
17	Al-Mustansiriya	6	6
Minimum-Maximum		0.0–6.0	0.0–8.0

Physicochemical quality of drinking water samples: Table 4 shows the physicochemical parameters of the water. Turbidity ranged from 1–6 NTU (mean 4.00 ± 1.54). Total dissolved solids varied widely (36–1077; mean 826.00 ± 380.38). pH values were within standard

Table 5. *Compliance with WHO guidelines and Iraq standards*

Parameters	Standard (%)	Sub-Standard (%)
Turbidity	88.2%	11.8%
TDS	29.4%	70.6%
Ph	100%	0%
Chloride	100%	0%
Ca	82.4%	17.6%
Hardness	76.5%	23.5%
Mg	100%	0%
Nitrate	100%	0%

limits (7–7.93). Chloride ranged from 30–224 (mean 132.65 ± 57.07). Calcium levels ranged from 24–200 (mean 106.47 ± 50.46). Total hardness was slightly elevated (162–684; mean 427.76 ± 123.51). Magnesium ranged from 9.6–76.8 (mean 43.52 ± 17.70). Nitrate levels were low (0.03–1.52; mean 0.88 ± 0.48).

The results showed that most physicochemical parameters of the analyzed water samples were within the WHO and Iraqi standards. However, turbidity, total dissolved solids (TDS), and total hardness exceeded the permissible limits in some samples, and calcium exceeded the Iraqi standard. Elevated turbidity was detected in 11.8% of samples, TDS in 70.6%, and total hardness in 23.5%.

Figs. (2, 3,4 and 5) illustrate the distribution and variability of turbidity, TDS, Hardness, across the studied schools in comparison with WHO guideline limits and Iraq standard, emphasizing parameters that showed noncompliance.

Fig. 2. Total dissolved solids value

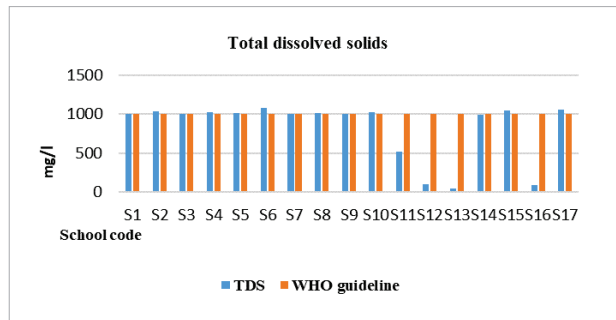


Fig. 4. Hardness value

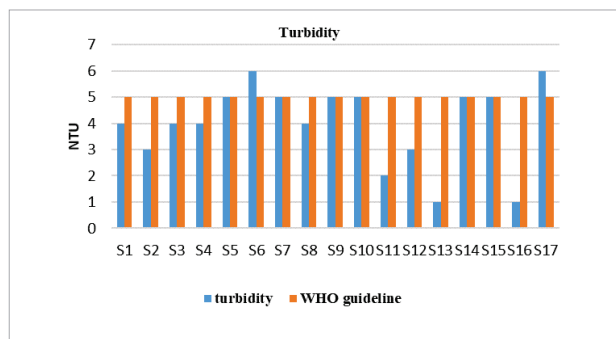


Fig. 3. Turbidity values

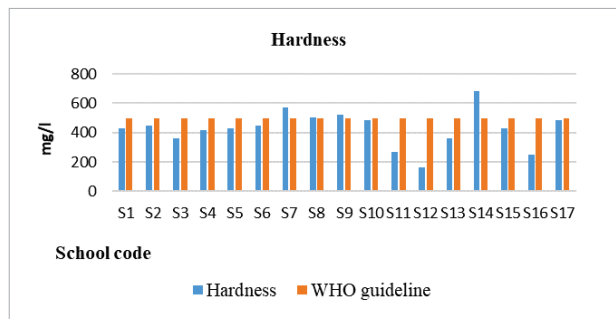
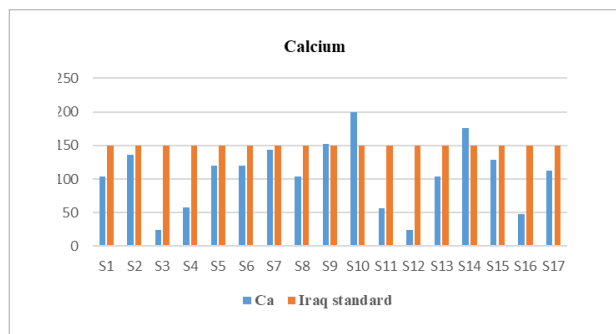


Fig. 5. Calcium value



Discussion

Bacteriological parameters

The present study evaluated the bacteriological quality of drinking water in secondary schools in Al-Hilla City in accordance with WHO and Iraqi standards, which require zero detectable (0 CFU/100 mL) total coliform and *Escherichia coli*. Microbial contamination represents a major public health concern due to its association with waterborne diseases. Overall, 35.3% of samples were contaminated with total coliform and *E. coli*, indicating noncompliance with WHO guidelines and a potential health risk for students. International contamination rates vary widely, ranging from 7.8% in Vietnam (Hung et al., 2020) to 73.68% in Bangladesh and Ghana (Karim et al., 2024; Kuffour, 2020). Reported rates were 55% in Pakistan (Talpur et al., 2024), 18.87% in Thailand (Precha et al., 2022), 17% in Uganda and 29% in Mozambique (Morgan et al., 2021), 59% in South Africa, and 20.7% in Palestine. In contrast, studies in Nigeria and India reported no contamination (Effiong et al., 2022; Jeyasekhar, 2022). In Iraq, contamination rates range from 12% to 64% (Hantoosh, 2023; Najeeb et al., 2024), likely reflecting variations in water treatment, infrastructure, storage maintenance, and monitoring systems.

Physicochemical parameters

The present study assessed the physicochemical quality of drinking water in secondary schools in Al-Hilla City, including pH, total dissolved solids (TDS), turbidity, chloride, total hardness, magnesium, calcium, and nitrate. Overall, most parameters were within permissible limits, indicating generally acceptable chemical quality. Similar findings were reported in Pakistan, Nigeria, and Ghana (Effiong et al., 2022; Kuffour, 2020; Talpur et al., 2024). However, TDS, turbidity, and total hardness exceeded WHO recommendations and calcium exceeded Iraq's standard in a proportion of samples.

Elevated turbidity was observed in 11.8% of samples and may compromise disinfection efficiency, possibly due to suspended particles from aging distribution systems or inadequately maintained storage tanks, and may correlate with microbial presence (Hung et al., 2020). Comparable findings were reported in Al-Muthana Governorate, Iraq (Hantoosh, 2023), whereas

other studies documented turbidity within WHO limits (Atumo Ante et al., 2023; Khalil and Mahmoud, 2022).

TDS, representing dissolved organic matter and electrolytes from sources such as industrial, agricultural, or sewage inputs (Fatima Ali, 2020), exceeded permissible limits in 70.6% of samples (range: 36–1077 mg/L). Similar exceedances were reported in Iraq (Najeeb et al., 2024) and in India and Bangladesh, where values reached 1148 mg/L (Jeyasekhar, 2022; Karim et al., 2024). Although TDS primarily affects taste rather than health at moderate levels, persistently high concentrations may reduce water acceptability. Total hardness, reflecting calcium and magnesium content (WHO, 2017), exceeded limits in 23.5% of samples, and calcium in 17.6% exceeded limits of Iraq standard, consistent with findings of approximately 20% exceedance in other studies (Jeyasekhar, 2022; Khalil and Mahmoud, 2022), but differing from reports in Babylon, Iraq, and Lebanon (Diab et al., 2024; Nehaba et al., 2020). In general, school drinking water demonstrated acceptable chemical safety with localized exceedances in turbidity, TDS, and hardness, highlighting the need for routine monitoring, proper storage tank maintenance, and appropriate treatment interventions to ensure compliance with standards and alignment with WASH requirements and SDG 6 targets.

Limitations: include the absence of residual chlorine measurement, the cross-sectional design limiting causal inference, the relatively small number of schools, and single-point sampling that may not capture temporal variation in water quality.

References

- Abdulhussein F.A. (2020) Bacteriological and physicochemical properties of some types of drinking water in Holy Najaf, Iraq. Master's thesis. University of Kufa, Iraq. Available at: https://drive.google.com/file/d/1wm_2sjMiVbqzYlc7BplZlFq0LFaOXV-VS/view?usp=drive_link
- Al-Dahmoshi A. O. M. (2020). *Isolation and identification of some bacteria and their use for environmental monitoring of pollution in Kufa River*. Master's thesis, University of Kufa, Iraq. Available at: <https://drive.google.com/file/d/1wwy5ri3tHlHB0JndVJQZbD-BUA2JB9rys/view?usp=sharing>
- Ali O. N., Irzooki R. H. (2025) Assessing the influence of Samarra Barrage Lake on the water quality of the Tigris River, Iraq, using the Canadian Water Quality Index. *International Journal of De-*

Conclusions

Most physical and chemical parameters were within WHO and Iraqi permissible limits; however, turbidity, total hardness, and total dissolved solids exceeded the standards in some cases, with 70.6% of samples surpassing the limit for TDS. Bacterial contamination was detected in 35.3% of samples, indicating a potential health risk to students. The study recommends regular water quality monitoring, enhanced disinfection or treatment processes, and proper maintenance of storage and distribution systems to safeguard students' health.

Acknowledgement

The authors gratefully acknowledge the Babylon Education Directorate and the Babylon Health Directorate for granting permission and facilitating access to the selected schools and the Public Health Laboratory. The cooperation of school administrations during sample collection is appreciated. Technical assistance provided by the laboratory staff and the support of the Scientific Research Council at the College of Health and Medical Technologies/Kufa are also acknowledged.

Ethical approval and official permissions were obtained from the Babylon Education Directorate and the Babylon Health Directorate prior to data collection and laboratory analysis. All procedures were conducted in accordance with institutional and national regulations governing research activities.

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

sign and Nature and Ecodynamics 20(8): 1865–1874. Available at: <https://doi.org/10.18280/ij dne.200816>

Atumo Ante A., Asefa Bogale G., Mohammed Adem B. (2023) Bacteriological and physicochemical quality of drinking water and associated risk factors in Ethiopia. *Cogent Food and Agriculture* 9(1): 2219473. Available at: <https://doi.org/10.1080/23311932.2023.2219473>

Baird R., Eaton A. D., Rice E. W., Bridgewater L. (2017) *Standard methods for the examination of water and wastewater*. 23rd ed. American Public Health Association. Available at: <https://www.standardmethods.org>

Diab W., Farhat M., Rammal M., Haidar C. M., Yaacoub A., Hamzeh A. (2024) Drinking-water quality assessment in selective schools

from Mount Lebanon. *Annals of Civil and Environmental Engineering* 8(1): 018–024. Available at: <https://doi.org/10.29328/journal.acee.1001061>

Effiong E. E., Ngah S. A., Abam T. K. S., Ubong I. U. (2022) Water quality assessment for drinking and sanitation purposes in secondary schools in Port Harcourt Metropolis, Rivers State, Nigeria. *Journal CleanWAS* 6(2): 78–85. Available at: <https://doi.org/10.26480/jcleanwas.02.2022.78.85>

Hantoosh S. M. (2023) Hand hygiene and water quality assessment in schools of Muthanna Province, Southern Iraq. *Journal of Infection in Developing Countries* 17(4): 518–524. Available at: <https://doi.org/10.3855/jidc.17264>

Hung D. T., Thi Cuc V., Thi Bich Phuong V., Thi Thanh Diu D., Thi Huyen Trang N., Phuong Thoa N., Thi Tuyet Chinh D., Manh Hung T., Manh Linh C., Van Long N. (2020) Evaluation of drinking water quality in schools in a district area in Hanoi, Vietnam. *Environmental Health Insights* 14: 1178630220959672. Available at: <https://doi.org/10.1177/1178630220959672>

Jeyasekhar M. P. (2022) Assessment of drinking water quality in government schools in Virudhunagar District, Tamil Nadu, India. *International Journal of Health Sciences* 6(S5): 9534–9543. Available at: <https://doi.org/10.53730/ijhs.v6ns5.10070>

Karim M. R., Shariar S., Rahadujjaman M., Hasan R., Islam M. T., Faysal A., Khan M. H., Khan M. H. R. B. (2024) Evaluating water, sanitation, and hygiene in schools of Bangladesh: progress toward SDG compliance. *Journal of Water and Health* 22(10): 1942–1955. Available at: <https://doi.org/10.2166/wh.2024.223>

Khalid H. S., Ali H. S., Almashhadany D. A. (2020) Metalliferous content of drinking water and sediments in storage tanks of some schools in Erbil City, Iraq. *Italian Journal of Food Safety* 9(3): 181–188. Available at: <https://doi.org/10.4081/ijfs.2020.8862>

Khalil R., Mahmoud N. (2022) Assessment of drinking water quality at public schools at Jenin Directorate of Education, Palestine. *Desalination and Water Treatment* 275: 196–206. Available at: <https://doi.org/10.5004/dwt.2022.28874>

Kristanti R. A., Hadibarata T., Syafrudin M., Yilmaz M., Abdullah S. (2022) Microbiological contaminants in drinking water: current status and challenges. *Water, Air, and Soil Pollution* 233(8): 299. Available at: <https://doi.org/10.1007/s11270-022-05698-3>

Kuffour R. A. (2020) Assessment of water used in basic schools and its impact on school feeding programme: a case study in Mampong Municipality. *East African Scholars Journal of Agriculture and Life Sciences* 3(9): 295–303. Available at: <https://doi.org/10.36349/easjals.2020.v03i09.001>

Merzah M. (2025) Trends in incidence, prevalence, and mortality of non-communicable diseases in Iraq (2003–2021). *BMC Public Health* 25(1): 374. Available at: <https://doi.org/10.1186/s12889-024-21080-w>

Morgan C. E., Bowling J. M., Bartram J., Kayser G. L. (2021) Attributes of drinking water, sanitation, and hygiene associated with microbiological water quality of stored drinking water in rural schools in Mozambique and Uganda. *International Journal of Hygiene and Environmental Health* 236: 113804. Available at: <https://doi.org/10.1016/j.ijheh.2021.113804>

Najeeb L. M., Shartooh S. M., Yaqob H. K. (2024) Detection of bacterial pollution from school drinking water tanks in the Habbaniyah District, west of Iraq. *Iraqi Journal of Science* 65(11): 6392–6404. Available at: <https://doi.org/10.24996/ijhs.2024.65.11.16>

Hameed Z. B., Nehaba S. S., Obayes A. A., Khlaif A. T. (2020) Evaluation of physicochemical parameters of bottled water marketed in Babel Governorate, Iraq. *Plant Archives* 20(1): 201–206. Available at: <https://www.researchgate.net/publication/329375093>

Ngcongong M. T., Tekere M. (2023) WASH and drinking water quality considerations in schools in reflection of the sustainable development goals: a review. *Journal of Water, Sanitation and Hygiene for Development* 13(8): 566–583. Available at: <https://doi.org/10.2166/washdev.2023.028>

Precha N., Rattanaphan C., Galiga T., Makkaew P., Narom N., Jawjit S. (2022) Bacteriological quality of drinking water and hygienic assessment of water cooler dispensers in higher education institution. *International Journal of Preventive Medicine* 13(1): 77. Available at: https://doi.org/10.4103/ijpvm.IJPVM_644_20

Sharma S., Bhattacharya A. (2017) Drinking water contamination and treatment techniques. *Applied Water Science* 7(3): 1043–1067. Available at: <https://doi.org/10.1007/s13201-016-0455-7>

Talpur H. A., Talpur S. A., Mahar A., Rosatelli G., Baloch M. Y. J., Ahmed A., Khan A. H. A. (2024) Investigating drinking water quality, microbial pollution, and potential health risks in selected schools of Badin City, Pakistan. *HydroResearch* 7: 248–256. Available at: <https://doi.org/10.1016/j.hydres.2024.04.004>

UNICEF. (2023). Annual Report 2022: UNICEF in Iraq – For Every Child. UNICEF Iraq. Available at: <https://www.unicef.org/iraq/media/2411/file/Annual%20Report%202022%20-%20Eng.pdf>

WASH Cluster (2022) WASH Cluster minimum technical standards Iraq-2022: post-emergency phase. Available at: <https://reliefweb.int/report/iraq/wash-cluster-minimum-technical-standards-iraq-2022-post-emergency-phase>

WHO (World Health Organization) (2017) Guidelines for drinking-water quality: *first addendum to the fourth edition*. Available at: <https://iris.who.int/bitstream/handle/10665/254636/9789241550017-eng.pdf>

WHO (World Health Organization) (2022) Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. Available at: <https://iris.who.int/bitstream/handle/10665/352532/9789240045064-eng.pdf?sequence=1>

