Case-control study of drinking water quality in Yemen

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Abstract

Background: Water, sanitation and hygiene (WASH) activities collapsed in Yemen due to the 2015 war, causing acute safe water shortage, poor sanitation and hygiene, and degraded microbial water quality. The cholera outbreaks in 2016/2017 triggered emergency WASH interventions to improve water quality and reduce cholera and other water-borne disease incidence.

Aim: This study aimed to assess the microbial water quality in Sana'a, Yemen, following cessation of the WASH activities.

Methods: We collected and analysed water samples in 2022 from 64 out of the 381 mini water purification plants that benefitted from WASH interventions in Sana'a in 2018, 2019 and 2020. Face-to-face interviews with representatives of each mini water purification plant were conducted alongside observatory evaluations. We compared results of the 2022 analyses with those of 2018, 2019 and 2020. We analysed our data using Microsoft Excel 2010 and descriptive statistics and presented the results in tables and charts.

Results: By 2022, one year after suspending the WASH interventions, the purification system rating had decreased slightly from 87.4% to 84.1%, and the water safety requirements rating had decreased significantly from 78.1% to 62.1%, compared to the 2018–2020 values. This caused a nearly double value, from 15.1% to 31.3%, for the microbial pollution, confirming an inverse relationship between microbial pollution and both purification system and water safety requirements.

Conclusion: The microbial water quality of the plants was degraded due to the cessation of the WASH programme. It is important to consider sustainability issues when designing and implementing WASH programmes to ensure that they achieve their goals. It is also crucial to monitor WASH activities rigorously and invest in raising awareness of WASH benefits among operators and community members so they can become effective partners in preventing contamination and water pollution.

Keywords: Water quality, water pollution, water purification, water safety, WASH, Sana'a, Yemen

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Background

Water, sanitation and hygiene (WASH) attracts great global interest because of its importance for improving public services and health. Good quality water and adequate sanitation, along with proper hygiene practices, reduce risks of waterborne disease. Globally in 2012, 90% of diarrhoea-related mortality was due to poor water, sanitation and hygiene practices (*1,2*). In 2015, the world witnessed 1.3 million deaths due to diarrhoea, which is considered the fourth leading cause of deaths among under-5 children (*3,4*).

Globally in 2020, 5 years into implementation of the Sustainable Development Goals (SDGs) – including SDG 6 for water and sanitation – 2 billion people (mostly from developing countries) lacked safe drinking water services: 1.2 billion had basic services, 282 million had limited services, 367 million obtained drinking water from unimproved sources, and 122 million used surface water (*5*). For sanitation, 3.6 billion people lacked access to safe services: 1.9 billion had basic services, 580 million had limited services, 616 million used unimproved installations, and 494 million defecated in the open (*5*).

Several experts (*6–17*) agree that the United Nations water safety plans recommended by WHO can help identify hazards related to drinking water and facilitate evaluation of the severity of implementing them sustainably.

WASH interventions focus on strengthening infrastructure and public services in low-resource countries and fragile and humanitarian communities to ensure that services reach people equitably. WASH interventions are needed in almost all emergencies (e.g. natural disasters, conflict areas and disease outbreaks) to reduce disease risk and water contaminants and promote hygiene practices (*18*).

WASH services are deficient in Yemen, a developing country. The WASH interventions began in 2005 with modest improvements, although with a wide gap between urban and rural areas (*19*). In 2012, 45% of the Yemen population lacked access to safe water, and 47% lacked access to adequate sanitation (*20*). By 2016, due to the 2015 war, 72.4% of the population lacked access to clean water and sanitation (*19,21*). As a result of the declining trends in access to safe water and adequate sanitation and hygiene facilities, Yemen experienced 2 waves of acute watery diarrhoea and cholera. The first wave, from September 2016 to March 2017, had a relatively limited scale of 24 504 suspected cases (*22*). The second (large) wave began in late April 2017 and the number of cases increased rapidly to more than 1 million (*23,24*). During the first wave and early second wave, WASH strategy was not ready to move from non-specific to specific interventions (*25*). In the middle of the second wave (September 2017), specific WASH interventions began and initially focused on chlorination at all water supply chain points, then water quality monitoring at these points (*17*).

WHO and UNICEF led the rapid response in health and WASH and outbreak rates continued to fluctuate throughout 2018 and 2019 on a relatively limited scale, and decreased in 2020 as specific WASH interventions continued in tandem with non-specific activities. We believe that the precautions taken, including hygiene education due to the COVID-19 outbreak, helped reduce and minimize acute watery diarrhoea and cholera diseases.

Specific WASH programmes are typically adapted from general development settings that may not be adequate for the timeframe, scope and approach required during emergencies (*15*). WASH strategy during emergencies has a limited evidence base, as priority is often given to research, which has traditionally led to best practices rather than evidence-based programming (*15,26*).

In this context, assessing specific WASH programmes in an emergency context is essential to understand the effectiveness of the interventions on water quality, identify gaps and improve service quality. Hence, this study aimed to assess water quality, including water microbial quality, based on WASH interventions in Sana'a, Yemen.

Methodology

Study design and setting

A case-control study, using a combined quantitative and qualitative approach, was conducted in 2022 on mini water purification plants (MWPPs) operating in Sana'a, the capital of Yemen, where specific WASH interventions were implemented in 2018–2020. Water samples from 64 MWPPs were collected and microbiologically analysed in 2022, with follow-up activities on the purification system and water safety requirements in the MWPPs using the National Water Resource Authority (NWRA) standard checklists. Face-to-face interviews with representatives of each MWPP were conducted alongside observatory evaluations.

Due to the difficulties in tracking and evaluating WASH programmes in Sana'a City, we selected the water quality monitoring programme executed on MWPPs, an important part of the drinking water supply chain in the region, for careful study and evaluation. The intervention focused on improving purification systems and water safety requirements of the MWPP facilities to ensure that drinking water was free of contaminants, including microbial contamination (Figure 1).

Study sample size

According to NWRA, in 2020, the 381 MWPPs distributed across 10 districts of Sana'a were a major source of drinking water for 70–80% of the population. These facilities are commercial and provided a platform-mounted packaged system comprising filtration and disinfection units. They are supplied in different sizes, shapes and production capacities upon request. The production capacity varies from 1500 to 6000 litres per hour or more.

A purposive sampling method was used to set the sample size at 20% of the 381 MWPPs, ensuring equal distribution between districts and data availability across the evaluation years. Accordingly, 76 MWPPs were selected as the sample size (Table 1).

Data collection and water sampling/analysis

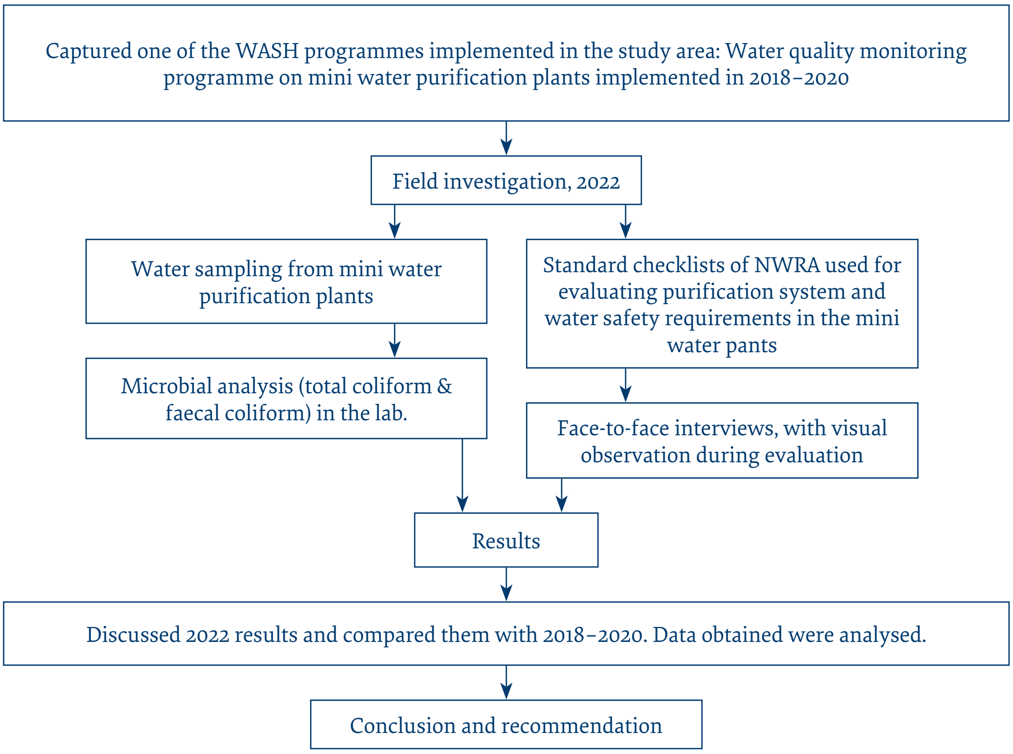
Data on the 76 MWPPs was gathered for the 2018, 2019 and 2020 UNICEF-led WASH programmes implemented by NWRA. It included frequent (monthly, plus additional evaluations when needed) evaluations of the purification systems and WSR, as well as monthly results of microbial tests (total coliform and faecal coliform). No data was available for 2021 due to suspension of the WASH programme.

A field investigation was conducted in January 2022 jointly with the NWRA to gather the 2022 data. Standard 2-section NWRA checklists were used to follow-up on purification systems and WSR at these MWPPs. Section 1, with a total score of 100, evaluated filtration and disinfection systems. Section 2, also with a total score of 100, assessed health and environmental requirements. In addition to visual observation during evaluations, face-to-face interviews were conducted with a representative of each MWPP.

Water samples were taken in sterile 500 ml glass bottles from each MWPP for bacterial analysis (total coliform and faecal coliform), using the American Public Health Association (APHA) (2017) standard procedure. The procedure recommends that at sampling bottles should not be completely filled with water and should be kept between ice in a cooler and transported directly to the laboratory for microbial analysis.

In the laboratory, for enumeration of total coliform and faecal coliform, the M-Endo broth environment for testing total coliform and membrane faecal coliform (mFC) broth environment for testing faecal coliform were prepared according to a standard filtration method

Figure 1 Methodology for assessing water quality based on WASH programmes



(membrane filter technique) and incubated for 24 hours at 37°C and 44°C, respectively (27).

Data processing and presentation

Microsoft Excel 2010 and descriptive statistics were used to process and analyse the data, which were then presented in tables and charts. First, the quantitative data for 2018–2020 were processed and then the 2022 data using Microsoft Excel 2010. The tables obtained were processed and analysed using Microsoft Excel 2010 and descriptive statistics for display finally in tables and charts that included the final average values for purification systems, WSR and microbial tests for 2018, 2019, 2020 and 2022 (Tables 2 & 3 and Figures 2 & 3).

Table 1 Specified sample size based on total MWPPs, using purposive sampling method, 2018–2020, 2022

District	No. of MWPPs	Sample size at 20%
Al Sabeen-A	46	10
Al Sabeen-B	41	8
Al Tahreer	30	6
Al Thworah	37	7
Al Safeah	18	4
Al Whdah	31	6
Azal	22	4
Bni Harith-A	22	4
Bni Harith-B	27	5
Meen	50	10
Old Sana'a	9	2
Sho'op	48	10
Total	381	76

Ethical approval

This research was part of a PhD thesis at the Higher Institute of Water Sciences and Techniques, University of Gabes, Tunisia. No human or animal subjects were used, therefore, no ethical approval was needed. Verbal consent was obtained from the owner of each mini water purification plant before interviewing them or their staff and collecting water samples.

Results

For 2022, 64 of the target sample of 76 MWPPs were evaluated because the remaining 12 were either out of service or were rejected by their owners, giving us a response rate of 84.2%.

Table 3 and Figure 2 show that in 2018, purification systems accounted for 75.3%, WSR for 73.6% and microbial pollution for 26.1% of the 64 MWPPs evaluated. For the purification systems and WSR values, microbial pollution was relatively high. For 2019, when the purification systems and WSR evaluation values improved slightly from 75.3% to 76.9% and 73.6% to 75.5%, respectively, microbial water pollution decreased from 26.1% to 18%. For 2020, more improvement was observed in the purification systems and WSR evaluation values, offset by a further decrease in the microbial contamination value, as the purification systems and WSR ratings reached 87.4% and 78.1%, respectively, and microbial contamination decreased to 15.1%.

Table 2 **Evaluation of purification system, water safety requirements and microbial pollution with total coliform and faecal coliform in each of the 64 MWPPs, 2018–2020, 2022**

MWPP No.	Evaluation year											
	2018			2019			2020			2022		
	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP
1	91	73	25	86	77	7.7	86	90	0.0	93	83	Unpolluted *
2	84	81	25	84	87	8.3	84	93	33.3	93	70	Unpolluted
3	68	83	0.0	63	85	0.0	59	87	14.3	57	68	Unpolluted
4	58	72	25	66	80	8.3	69	84	25	66	80	Polluted **
5	84	72	20	82	78	7.7	89	88	0.0	90	65	Unpolluted
6	64	86	20	77	91	21.4	83	91	14.3	96	95	Polluted
7	66	57	50	66	73	21.4	80	81	0.0	81	81	Polluted
8	86	78	16.7	86	73	27.3	86	86	11.1	93	63	Unpolluted
9	67	81	16.7	80	72	9.1	90	79	0.0	90	71	Unpolluted
10	90	80	40	84	85	40	94	78	0.0	94	75	Unpolluted
11	50	71	20	74	67	40	91	69	60	53	63	Polluted
12	83	69	40	77	63	16.7	93	69	50	89	57	Polluted
13	64	62	37.5	75	61	15.4	94	68	44.4	62	58	Polluted
14	60	73	33.3	74	74	7.7	91	77	0.0	80	73	Unpolluted
15	70	67	37.5	78	68	0.0	78	76	0.0	75	46	Unpolluted
16	84	81	28.6	81	82	18.8	92	81	0.0	88	51	Polluted
17	84	75	20	84	76	10	92	69	0.0	90	76	Unpolluted
18	71	68	16.7	71	69	8.3	88	69	0.0	97	63	Unpolluted
19	80	82	0.0	81	72	15.4	91	69	33.3	94	49	Unpolluted
20	85	86	20.0	86	87	0.0	94	87	0.0	78	73	Unpolluted
21	89	74	42.9	83	70	27.3	95	75	0.0	84	52	Polluted
22	80	68	40.0	82	68	21.4	82	69	18.2	84	53	Unpolluted
23	90	90	0.0	86	90	11.1	84	86	0.0	72	68	Unpolluted
24	83	63	16.7	87	75	0.0	96	83	0.0	96	69	Unpolluted
25	92	82	0.0	86	83	11.1	89	80	0.0	93	67	Unpolluted
26	62	65	55.6	72	65	14.3	99	70	0.0	93	72	Unpolluted
27	86	82	16.7	80	77	9.1	83	72	11.1	81	72	Unpolluted
28	53	60	33.3	59	70	25.0	57	70	42.9	59	45	Polluted
29	77	84	20.0	82	83	0.0	89	85	0.0	85	71	Unpolluted
30	72	74	14.3	68	75	21.4	71	73	0.0	63	48	Unpolluted
31	73	82	14.3	85	77	21.4	92	77	10.0	90	67	Polluted
32	82	82	28.6	85	81	14.3	96	82	10.0	96	57	Polluted
33	62	63	28.6	66	59	30.8	63	58	25.0	45	43	Unpolluted
34	82	76	28.6	84	75	25.0	91	81	27.3	93	54	Polluted

Table 2 Evaluation of purification system, water safety requirements and microbial pollution with total coliform and faecal coliform in each of the 64 MWPPs, 2018–2020, 2022

MWPP No.	Evaluation year											
	2018			2019			2020			2022		
	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP (%)	PS (%)	WSR (%)	MP
35	86	93	20.0	86	94	0.0	99	91	0.0	92	75	Unpolluted
36	77	63	0.0	77	74	33.3	92	58	0.0	94	43	Polluted
37	56	59	0.0	65	69	35.7	68	74	46.2	59	41	Polluted
38	66	58	60.0	59	70	31.3	68	82	27.3	75	55	Polluted
39	80	82	0.0	80	85	21.4	99	85	16.7	100	87	Unpolluted
40	90	76	0.0	77	82	7.7	93	77	30.0	87	66	Unpolluted
41	75	76	0.0	64	67	0.0	90	64	11.1	96	70	Unpolluted
42	64	85	28.6	73	85	0.0	96	83	28.6	87	63	Unpolluted
43	90	85	16.7	72	81	8.3	86	79	0.0	94	57	Unpolluted
44	80	74	57.1	79	83	25.0	87	85	14.3	87	80	Unpolluted
45	81	71	25.0	75	70	20.0	84	73	33.3	84	45	Unpolluted
46	76	71	16.7	76	75	15.4	84	81	9.1	93	46	Unpolluted
47	35	83	33.3	65	86	33.3	94	83	0.0	97	75	Unpolluted
48	73	70	16.7	74	81	15.4	94	85	0.0	43	72	Unpolluted
49	95	79	60.0	77	77	20.0	87	84	25.0	93	64	Polluted
50	84	64	50.0	76	60	46.7	87	77	28.6	90	80	Unpolluted
51	75	76	20.0	79	79	25.0	97	87	11.1	93	56	Unpolluted
52	60	59	66.7	70	65	33.3	75	73	28.6	84	55	Polluted
53	88	80	0.0	77	80	16.7	94	81	12.5	100	73	Polluted
54	86	83	25.0	81	71	23.1	90	68	10.0	96	51	Unpolluted
55	85	83	28.6	83	92	7.7	90	87	25.0	87	66	Unpolluted
56	83	92	0.0	83	92	15.4	99	93	0.0	100	87	Unpolluted
57	83	72	0.0	80	75	9.1	96	75	33.3	91	53	Unpolluted
58	58	61	50.0	77	64	28.6	92	73	22.2	96	43	Unpolluted
59	61	39	75.0	70	41	45.5	92	62	42.9	35	27	Polluted
60	60	52	57.1	71	62	25.0	85	70	33.3	84	28	Unpolluted
61	70	77	20.0	80	82	14.3	92	81	0.0	90	63	Unpolluted
62	80	69	37.5	80	79	10.0	89	78	0.0	88	42	Unpolluted
63	77	70	33.3	78	73	16.7	88	84	12.5	93	65	Polluted
64	75	70	40.0	78	70	50.0	96	72	33.3	81	52	Unpolluted

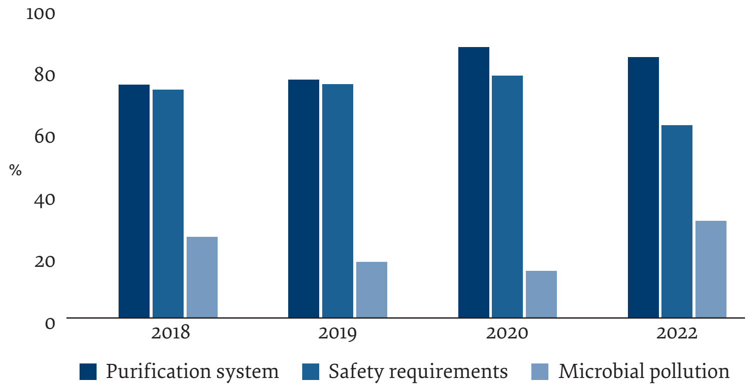
PS = purification system; WSR = water safety requirements; MP = microbial pollution

**The water is bacterially unpolluted as the result of total coliform and faecal coliform test showed 0 colonies/100 ml. **Water is bacterially polluted because the test result (total coliform and faecal coliform) showed several colonies/100 ml.*

Table 3 **General evaluation of 64 MWPPs, 2018–2020, 2022 (%)**

Evaluation item	2018	2019	2020	2022
Purification system	75.3	76.9	87.4	84.1
Safety requirements	73.6	75.5	78.1	62.1
Microbial pollution	26.1	18.0	15.1	31.3

Figure 2 **Overall evaluation of 64 MWPPs operating in Sana'a, 2018–2020 and 2022**



A strong correlation between purification systems, WSR and microbial contamination can be inferred since, when the purification systems and WSP ratings increased, microbial pollution decreased (i.e. water quality improved). This improvement was caused by specific WASH interventions implemented in 2018–2020.

By 2022, one year after suspending the WASH intervention, results showed that the purification systems rating decreased slightly from 87.4% to 84.1% and the WSR rating decreased significantly from 78.1% to 62.1%, leading to nearly double value, from 15.1% to 31.3%, for microbial pollution. Results from 2022 confirm the inverse relationship between microbial pollution and both purification systems and WSR.

The lines chart for these 3 variables (Figure 3) shows that when purification systems and WSR increased, microbial pollution decreased, whereas when they reduced, microbial pollution increased. This degraded microbial water quality was a consequence of stopping the specific WASH programme before achieving sustainability.

Discussion

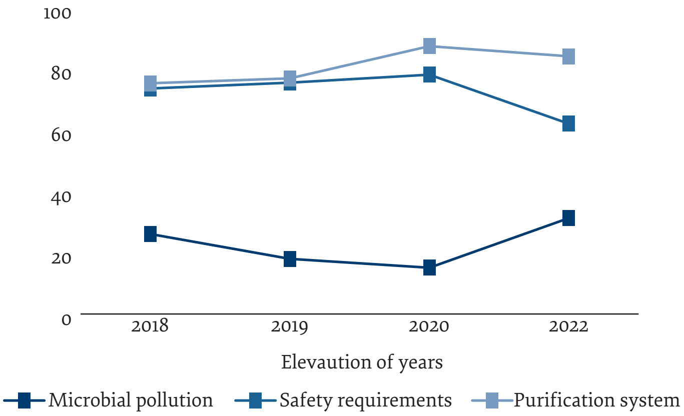
Our study showed a decrease in microbial water pollution in 2018–2020 as a result of the WASH interventions in Sana'a, while cessation of the interventions in 2021 led to an increase in microbial water pollution. The WASH interventions focused on 2 goals, improving purification systems and WSR at MWPPs facilities producing potable water in Sana'a.

More specifically, in 2018–2020, there was an upward trend for the purification systems rating from 75.3% to 76.9% to 87.4%, and an upward trend for WSR rating from 73.6% to 75.5% to 78.1%, resulting in a decrease in bacterial pollution from 26.1% to 18% to 15.1% for the same years. Thereafter, because of the suspension of WASH interventions in 2021, the purification systems rating decreased to 84.1% and WSR rating decreased to 62.1% in 2022, causing bacterial pollution to double (31.3%).

Since no similar studies had been conducted in Yemen, it was difficult to link findings with any previous national, even internationally, studies; this indicates a disconnect between academic research and field assessments of WASH packages (*15*). However, some studies have been conducted to evaluate the effects of WASH interventions on water quality and health. For example, a study in Ethiopia (*28*) that used primary household survey data and *E. coli* microbiological water test reported that uncontaminated household storage water and safe disposal of infant faeces decreased the incidence of childhood diarrhoea by 16% and 23%, respectively.

A systematic review of published and grey literature (*16*) assessing the impact of emergency WASH interventions in 19 countries focused on the cholera response. The study reported that WASH interventions – water source treatment, household water treatment, sanitation, hygiene promotion, and environmental hygiene – consistently reduced the risk of disease transmission, and noted that improvements are needed to ensure the effectiveness of WASH interventions. The study recommended that interventions should be effective, simple, timely, and community-driven, and should link relief and development and address barriers and facilitators for use with communities. This conclusion is consistent with our findings that WASH interventions improve water quality for human consumption, but the challenge lies in sustainable implementation, particularly in emergency contexts.

Figure 3 Relationship between microbial contamination and both purification system and water safety requirements in MWPPs, 2018–2020, 2022



Conclusion

This study assessed water quality in Sana'a, Yemen, and how it was affected by specific WASH programmes implemented in the study area following a cholera outbreak. In 2018, 2019 and 2020, specific WASH interventions implemented on MWPPs helped improve the quality of drinking water produced in these facilities, but this improvement was not sustained, based on the 2022 results. Thus, for emergency WASH interventions like this one, the design and implementation should be well-planned to achieve sustainability so that the effort would not be wasted. Achieving sustainability in MWPP facilities requires more rigorous monitoring and awareness-raising among facility staff and community members so they can become effective partners in monitoring and correcting wrong behaviours and malpractices.

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Étude cas-témoin de la qualité de l'eau potable au Yémen

Résumé

Contexte : Les activités relatives à l'eau, l'assainissement et l'hygiène (WASH) ont été interrompues au Yémen en raison de la guerre de 2015, provoquant une grave pénurie d'eau salubre, des conditions d'assainissement et d'hygiène médiocres, ainsi qu'une dégradation de la qualité microbienne de l'eau. Suite aux épidémies de choléra survenues au cours des années 2016 et 2017, des interventions WASH d'urgence ont été mises en place afin d'améliorer la qualité de l'eau et de réduire l'incidence du choléra et d'autres maladies à transmission hydrique.

Objectif : La présente étude visait à évaluer la qualité microbienne de l'eau à Sanaa (Yémen), après l'arrêt des activités relatives à l'eau, l'assainissement et l'hygiène.

Méthodes : Au cours de l'année 2022, nous avons prélevé et analysé des échantillons d'eau provenant de 64 des 381 mini stations d'épuration qui ont tiré bénéfice des interventions WASH à Sanaa en 2018, 2019 et 2020. Des entretiens en présentiel avec des représentants de chaque mini station ont été menés parallèlement aux évaluations observatoires. Nous avons comparé les résultats des analyses réalisées en 2022 avec ceux des analyses menées en 2018, 2019 et 2020. Nos données ont été analysées à l'aide de Microsoft Excel 2010 et de statistiques descriptives et nous avons présenté les résultats sous forme de tableaux et de graphiques.

Résultats : En 2022, un an après la suspension des interventions WASH, la note attribuée aux systèmes d'épuration avait légèrement diminué, passant de 87,4 % à 84,1 %, et la note relative aux exigences en matière de sécurité de l'eau avait considérablement diminué, passant de 78,1 % à 62,1 %, par rapport aux valeurs enregistrées entre 2018 et 2020. La valeur de la pollution microbienne a donc presque doublé, passant de 15,1 % à 31,3 %. Cela confirme l'existence d'une relation inverse entre la pollution microbienne et les exigences des systèmes d'épuration et de sécurité de l'eau.

Conclusion : L'arrêt des programmes dans le domaine de l'eau, de l'assainissement et de l'hygiène a provoqué une dégradation de la qualité microbienne de l'eau des stations d'épuration. Il est important de prendre en compte les questions de pérennité lors de la conception et de la mise en place de ce type de programmes afin de s'assurer qu'ils réalisent leurs objectifs. La surveillance rigoureuse des activités relatives à l'eau, l'assainissement et l'hygiène ainsi que la sensibilisation des opérateurs et des membres de la communauté quant aux avantages des programmes WASH sont également essentielles afin qu'ils puissent devenir des partenaires efficaces dans la lutte contre la contamination et la pollution des eaux.

دراسة حالات وشواهد بشأن جودة مياه الشرب في اليمن

أحمد الحماني، نجيب بن جامع، عادل خروبي، بلقاسم يعقوبي، جواد محمد عبده الوبر

الخلاصة

الخلفية: انهارت أنشطة المياه والصرف الصحي والنظافة العامة في اليمن بسبب حرب عام 2015، وهو ما تسبب في نقص حاد في المياه المأمونة، وسوء خدمات الصرف الصحي والنظافة العامة، وتدهور جودة المياه الميكروبية. وأدت فاشيات الكوليرا في المدة 2016–2017 إلى تدخلات طارئة في مجال المياه والصرف الصحي والنظافة العامة لتحسين جودة المياه والحد من الإصابة بالكوليرا، وغيرها من الأمراض المنقولة عن طريق المياه.

الهدف: هدفت هذه الدراسة إلى تقييم جودة المياه الميكروبية في صنعاء باليمن بعد توقف أنشطة المياه والصرف الصحي والنظافة العامة.

طرق البحث: جمعنا وحللنا عينات من المياه في عام 2022 من 64 من أصل 381 محطة صغيرة لتنقية المياه استفادت من تدخلات المياه والصرف الصحي والنظافة العامة في صنعاء في الأعوام 2018 و2019 و2020. وأجريت مقابلات مباشرة مع ممثلي كل محطة صغيرة لتنقية المياه إلى جانب إجراء تقييمات رصدية. وقارنًا نتائج تحليلات عام 2022 بنتائج تحليلات الأعوام 2018 و2019 و2020. وحللنا البيانات ببرنامج مايكروسوفت إكسل 2010، وأجرينا إحصاءات وصفية، وعرضنا النتائج في جداول ورسوم بيانية.

النتائج: بحلول عام 2022، أي بعد مرور عام واحد على تعليق تدخلات المياه والصرف الصحي والنظافة العامة، انخفض تصنيف نظام التنقية انخفاضًا طفيفًا من 87.4٪ إلى 84.1٪، وانخفض تصنيف متطلبات مأمونية المياه انخفاضًا كبيرًا من 78.1٪ إلى 62.1٪، مقارنة بقيم المدة 2018–2020. وتسبب ذلك في ارتفاع تصنيف التلوث الميكروبي إلى ما يقرب من الضعف، من 15.1٪ إلى 31.3٪، وهو ما يؤكد وجود علاقة عكسية بين التلوث الميكروبي وكل من نظام التنقية ومتطلبات مأمونية المياه.

الاستنتاجات: تدهورت جودة المياه الميكروبية في محطات التنقية بسبب توقُّف برنامج المياه والصرف الصحي والنظافة العامة. ومن المهم النظر في قضايا الاستدامة عند تصميم برامج المياه والصرف الصحي والنظافة العامة وتنفيذها لضمان تحقيقها لأهدافها. ومن المهم أيضًا رصد أنشطة المياه والصرف الصحي والنظافة الصحية رصدًا دقيقًا، والاستثمار في إذكاء الوعي بفوائد تدخلات المياه والصرف الصحي والنظافة الصحية لدى مقدمي الخدمات وأفراد المجتمع المحلي، لكي يصبحوا شركاء فعَّالين في منع تلوث المياه.

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