

Bacterial contamination in drinking water of urban Peshawar: a comparative study at the sources and user points of tube wells

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ABSTRACT

Life needs clean drinking water free from contaminants including pathogenic bacteria. This study was conducted to assess the drinking water quality in urban areas of Peshawar District, Khyber Pakhtunkhwa, Pakistan. Water samples were collected at the source (tube wells) and the user points. These collected samples were analyzed for physicochemical parameters such as pH, turbidity, electrical conductivity (EC) and total dissolved solids (TDS), and bacterial contaminations. Results showed that physicochemical parameters were within the safe limits of drinking water guidelines set by the World Health Organization. However, drinking water was found severely contaminated with gastrointestinal flora (fecal coliforms and *Escherichia coli*) and infectious bacterial agents (*Salmonella* spp. *Shigella* spp. *Vibrio cholera*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*). High levels of bacterial contamination may pose potential threats to the local community and could result in waterborne diseases. Therefore, this study strongly recommends chlorination or boiling of the drinking water before use to avoid health risk in the inhabitants of the study area.

Keywords: Bacterial; Contamination; Drinking water; Groundwater

1. Introduction

Water is an essential substance to support life and the ecosystem. Water is a universal solvent, therefore, dissolve or suspend several life essential and non-essential materials [1–5] and may serve as a medium for the survival of numerous microorganisms [6–8]. The contaminants such as microorganisms in the water are considered key factors and associated with various types of diseases occurred in dependent living organisms [9,10]. Globally, deep groundwater

is considered a common and safe source of drinking water [11]. However, a number of studies have reported groundwater contamination with infectious microbial agents [6,7]. Studies on microbial contamination of drinking water had attracted global attention because of implied public health impacts [12,13].

Microbial quality of drinking water is a significant characteristic associated with waterborne diseases. Bacterial pathogens are the major source of waterborne diseases causing severe pathological conditions both in the public

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and veterinary sectors [14,15]. Many natural and anthropogenic sources cause microbial contamination in water [16]. The anthropogenic sources are linked directly or indirectly with human or animal excreta and hospital waste. The consumption of contaminated water with pathogenic microbes is known to contribute various kinds of diseases in consumers [17]. Especially in consumers with great risk of infection such as infants, immune-suppressed patients, and elders. These individuals are at high risk of infection with the consumption of contaminated water causing infectious diseases [18,19].

Like other developing countries, Pakistan is facing serious drinking water contamination problems [19,20]. Following national drinking water guidelines, only 56% population has access to safe drinking water [21]. However, according to international drinking water guidelines, only 25.6% (rural 23.5% and 30% urban) population in Pakistan has access to safe water [22]. Due to the lack of proper treatment and inappropriate delivery at the consumer spots, the drinking water of municipalities is mostly contaminated with infectious microbes or hazardous chemicals [23,24]. Studies have been conducted to evaluate the hazardous chemicals in drinking and wastewater of the study area [25,26]. However, studies are scant showing information about drinking water contamination with pathogenic bacterial contamination. Therefore, this study was aimed to investigate the bacterial contaminations in drinking water at source and user points in

densely populated Peshawar District, Khyber Pakhtunkhwa, Pakistan. This study also helps to find out the sources of bacterial contamination in drinking water.

2. Materials and methods

2.1. Study area description

Peshawar is provincial capital of Khyber Pakhtunkhwa Province, Pakistan and located at 33°–44' to 34°–15' N and 71°–22' to 71°–42' E. The district is bounded in the north by district Charsadda, east by district Nowshera, south by Orakzai and Khyber Agency, and west by Mohmand Agency. The district covers an approximately 1,257 km² area with 5.6 million population. The district hosts Hayatabad Industrial Estate located in the west of the city. Peshawar remains hot (46°C) during summer and cold (4°C) in winter receiving annual precipitation of 400 mm. The main supplier of drinking water is the district municipalities in the urban area to pump it from groundwater sources and supply to consumers through pipelines [25].

2.2. Water sample collection and preservation

Water samples were randomly collected from the urban area of district Peshawar during January 2016 (Fig. 1). Water samples were collected from tube wells ($n = 15$) and user

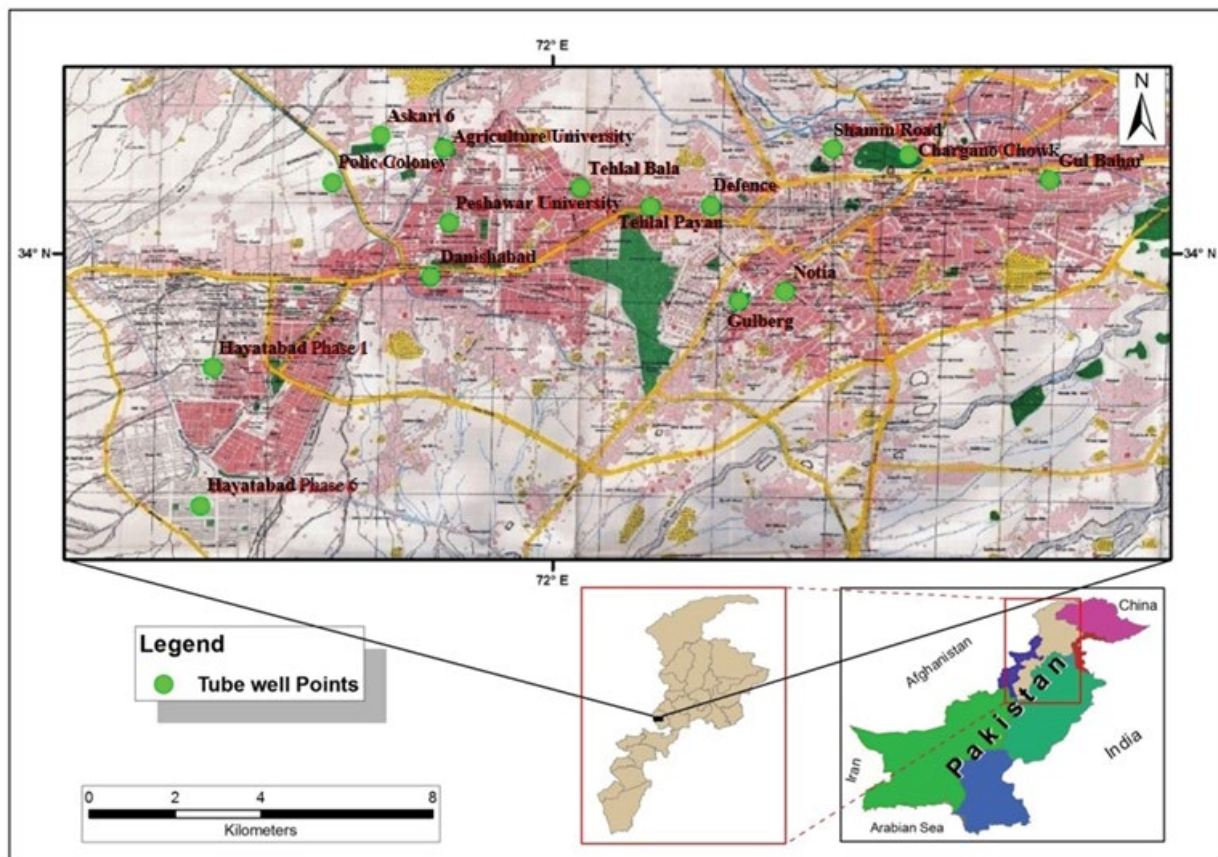


Fig. 1. Location map of the study area showing the tube wells sites.

points ($n = 60$). The outer and inner surface of the tap was cleaned with a sterilized cloth, followed by 70% alcohol and flame. Water (100 mL) was collected in a clean sampling bag avoiding any air bubbles. After the careful opening of the cap, sampling bags were immediately held under the water to fill without discarding the water from the tap. The second sample at the same user point was collected after discarding water for 5 min. The water sample was stored on ice or in cold storage (4°C) in the sampling box and transported to the laboratory. Basic parameters such as pH, temperature (T), electrical conductivity (EC), total dissolved solids (TDS) and turbidity were measured on the spot using a multi-water quality analyzer (CONSORT C6030, Belgium).

2.3. Bacterial characteristics

The total plate count (TPC) of bacteria was determined using a plate counting technique. Serial dilutions (10^{-1} to 10^{-4}) of the product were made and aliquots of 1 mL were added to each Petri dish. Total plates count, coliform bacteria, fecal coliform, *Escherichia coli* (*E. coli*) and *Pseudomonas aeruginosa* (*P. aeruginosa*) were measured according to the standard methods augar, membrane filtration, membrane filtration with coli-blue and 2% inoculum in Mueller-Hinton broth [27], respectively. *Salmonella* spp. *Shigella* spp. *Vibrio cholera* (*V. cholera*) and *Staphylococcus aureus* (*S. aureus*) were measured according to the procedure of *Salmonella-Shigella* (SS) medium, fluorescent-antibody direct viable count, Chapman mannited medium (Difco) and incubated aerobically for 24 h at 37°C adopted from the [28–31].

Drinking water analyses were conducted in triplicate. The reproducibility of results was found to be at a $90\% \pm 5\%$ confidence level. Therefore, the mean values of each sample were used for interpretation of further results. The reliability and reproducibility of analyses were checked by analyzing

blank and known standards. Chemicals used for water analyses were of analytical grade purchased from MERCK (Germany). For bacterial analyses, the required materials such as cultural media was autoclaved properly.

3. Results and discussion

3.1. Physicochemical parameters

Results of physicochemical parameters in urban areas of district Peshawar are summarized in Table 1. The turbidity of drinking water was noted less than 5 NTU, while pH values were ranged from 6–8.2. pH values ranging between 3–10.5 can support pathogenic bacterial growth [32]. Likewise, pH also effect the growth of bacteria, at extreme pH (<4.5 or >8.2). Cell die-off can be predictable but the standard pH range for most drinking water sources is near to 7 and this pH value doesn't affect the bacterial growth [33]. The pH of drinking water most commonly ranges from 6.0–8.5 of World Health Organization (WHO) [34]. When the pH of drinking water is less than 7, it contributes to the corrosion of water pipes resulting in the release of metals into the drinking water.

In drinking water samples, EC values were ranged from 387–1,320 $\mu\text{S}/\text{Cm}$. The Higher EC value indicates the existence of a high amount of dissolved inorganic substances [20]. Similarly, the TDS values in drinking water samples ranged from 232–688 mg/L. The TDS and EC values of the study areas were found within the safe drinking water guidelines set by WHO [34].

3.2. Bacterial parameters

Water may serve as a medium for the survival of various microorganisms' species. For human use and consumption, the most important microorganisms are pathogens that

Table 1
Physicochemical properties of drinking water at sources and user points in the study area

Sampling sites	Turbidity (NTU)		pH		TDS (mg/L)		EC ($\mu\text{S}/\text{Cm}$)	
	Source	User points	Source	User points	Source	User points	Source	User points
Agriculture University	<5 \pm 0.0	<5 \pm 0.0	6.9 \pm 0.10	6.90 \pm 0.32	245 \pm 21	280 \pm 16	409 \pm 23	467 \pm 27
Hayatabad Phase 1	<5 \pm 0.0	<5 \pm 0.0	7.4 \pm 0.13	7.00 \pm 0.29	232 \pm 18	300 \pm 9.2	387 \pm 12	501 \pm 16
Hayatabad Phase 6	<5 \pm 0.0	<5 \pm 0.0	6.2 \pm 0.07	6.20 \pm 0.18	235 \pm 32	293 \pm 27	392 \pm 17	489 \pm 45
Nasir Bagh/Police Colony	<5 \pm 0.0	<5 \pm 0.0	8.7 \pm 0.06	7.63 \pm 0.34	405 \pm 19	562 \pm 39	676 \pm 25	937 \pm 66
Regi/Askari 6	<5 \pm 0.0	<5 \pm 0.0	7.5 \pm 0.21	6.75 \pm 0.44	361 \pm 24	425 \pm 12	603 \pm 29	707 \pm 20
Danishabad	<5 \pm 0.0	<5 \pm 0.0	7.6 \pm 0.04	7.38 \pm 0.13	372 \pm 20	421 \pm 51	621 \pm 31	702 \pm 86
Peshawar University	<5 \pm 0.0	<5 \pm 0.0	8.2 \pm 0.13	7.88 \pm 0.22	326 \pm 15	315 \pm 9.4	542 \pm 24	525 \pm 16
Tehkal Bala	<5 \pm 0.0	<5 \pm 0.0	7.9 \pm 0.51	7.20 \pm 0.52	379 \pm 14	545 \pm 25	632 \pm 33	1,100 \pm 198
Tehkal Payan	<5 \pm 0.0	<5 \pm 0.0	7.5 \pm 0.11	7.60 \pm 0.22	667 \pm 37	598 \pm 68	946 \pm 102	998 \pm 114
Defense Colony	<5 \pm 0.0	<5 \pm 0.0	7.3 \pm 0.10	6.78 \pm 0.30	431 \pm 16	429 \pm 56	719 \pm 27	702 \pm 89
Shami Road	<5 \pm 0.0	<5 \pm 0.0	8.0 \pm 0.22	7.78 \pm 0.22	358 \pm 23	470 \pm 96	589 \pm 30	773 \pm 157
Bacha Khan Chowk	<5 \pm 0.0	<5 \pm 0.0	7.1 \pm 0.12	6.88 \pm 0.22	346 \pm 28	326 \pm 42	578 \pm 26	544 \pm 71
Noutia	<5 \pm 0.0	<5 \pm 0.0	6.2 \pm 0.08	6.73 \pm 0.17	439 \pm 35	563 \pm 35	732 \pm 41	939 \pm 58
Gulberg	<5 \pm 0.0	<5 \pm 0.0	7.9 \pm 0.31	7.48 \pm 0.31	325 \pm 21	355 \pm 11	543 \pm 23	591 \pm 18
Gul Bahar	<5 \pm 0.0	<5 \pm 0.0	7.5 \pm 0.21	7.38 \pm 0.15	338 \pm 15	381 \pm 40	564 \pm 21	622 \pm 38

are capable of causing diseases. The waterborne pathogens include bacteria species such as *V. cholera*, *Salmonella*, *Shigella*, and *S. aureus* mostly occurred in sewage, human feces, wildlife and wildfowl contaminated water. In addition, some of the group may survive in drinking water biofilms and regrow during high temperature [6,19].

Table 2 summarizes the bacterial contamination of drinking water samples collected from urban areas of district Peshawar. The current research provided a picture of bacterial contamination in the drinking water of the study area.

3.2.1. Total plate count

TPC is useful for representing the general drinking water quality and the existence of pathogens or opportunistic pathogens. Standard plate count is used as an indicator of bacterial population in drinking water collected from various sources. Microbial load in these water samples ranged from 48–1,600 CFU/mL (Table 2). Results of the study area showed that the bacterial contamination in 88% of water samples was found above the safe drinking water permissible limit. The rest of the samples (12%) collected from tube wells of Agriculture University, University of Peshawar and residential areas (Askari 6, Hayatabad Phase-1 and Gulbahar) were found within the range of WHO [34] standard set for TPC in water. In addition, results revealed that drinking water contamination level was high (91.7%) at user points as compared to source at the tube wells (73.3%) (Fig. 2).

The bacterial contamination of drinking water samples may be due to the failure of source water disinfection, infiltration of contaminated water through cross-connection and at leakage points. Although, TPC bacteria are naturally present in all saturated environment, however, a rapid increase in TPC levels might sometimes be linked with fecal and wildlife contamination.

3.2.2. Coliform bacteria

Coliform bacteria in drinking water samples were found in a range between <1.1 to 16 MPN/100 mL (Table 2). The highest value (16) of total coliform bacteria was found at user point TP2 (a), while the sampling points where the concentration of coliform bacteria found within the safe limit of drinking water guidelines set by WHO [34] (<1.1 MPN/100 mL). Some sampling points were observed with bacterial contamination (Table 2). Coliform bacteria contamination was found maximum (65%) for user points as compared to source at the tube wells (40%) (Fig. 2).

The coliform group of bacteria has always been used to assess the drinking water quality and indicate water pollution. On the other hand, high levels of coliforms in drinking water supply may point out contamination from the surface or shallow subsurface sources such as soil, wildlife, septic or open-drain leakage and treatment failures [35]. The presence of coliform bacteria in the water samples collected from the sources and user points indicating the quality of pipes used in tube wells were either of poor quality or corroded rapidly with time. Similarly, the pipes used for distribution lines were mostly cemented material that was observed leaked or broken at several points causing seepage from sewage line into the water.

3.2.3. Fecal coliform

Results of drinking water showed that 34.7% of samples had fecal coliform bacteria contamination and rest (64.3%) of sampling points were clear (Table 2). The contamination level in the samples of tube wells and user points was greatly varied. The highest (38.3%) of samples showed fecal coliform bacterial contaminations at the user points, while the lowest (20%) in the samples collected at the source.

The presence of fecal coliform in the water indicates the presence of fecal contamination. The presence of coliform group bacteria always indicates sewage contamination of drinking. The presence of fecal coliform in drinking water poses a threat to human life. Therefore, regular use of chlorine or boiling water may help to irradiate these pathogens from water reservoirs [35].

3.2.4. Escherichia coli

E. coli was found in 20% of drinking water samples collected from the study area (Table 2). *E. coli* contaminations were found highest (28.3%) of water samples at user points as compared to the source, that is, at tube wells (13.3%). Previous studies mostly focused on arsenic and another toxic element contamination in drinking water [36] and very little attention is given water contamination with pathogenic organisms in this study area.

3.2.5. Salmonella

The data indicated that 9.3% of drinking water samples were found positive for the presence of *Salmonella* spp. Only at the user point (Table 2). The sources that showed positive results for *Salmonella* were both tube wells and user points. In most of the sites, all samples were found negative and thus showed the absence of *Salmonella* spp. The contamination level of water with *Salmonella* spp. was higher at the user point (8.3%).

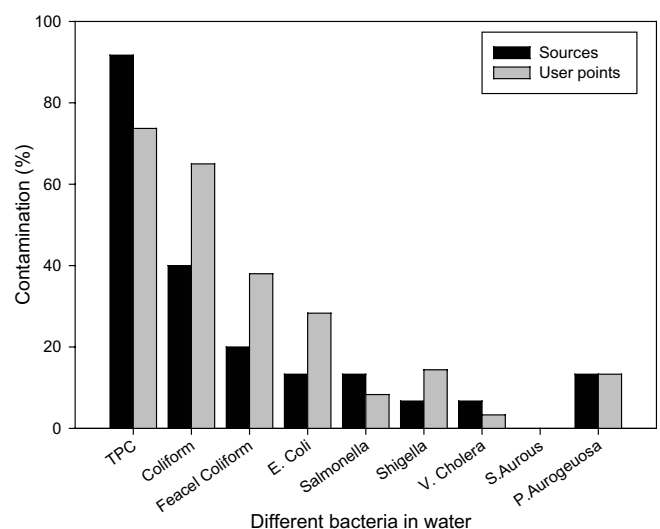


Fig. 2. Comparison (%) of bacterial contamination at the sources and user points.

3.2.6. *Shigella*

In the study area, 14.7% of drinking water samples were found positive for the presence of *Shigella* spp. (Table 2). The level of contamination caused by *Shigella* spp. was greatly varied at the user point. The contamination of samples with *Shigella* spp. at user points (14.4%) was observed higher as compared to the source tube wells (6.7%).

3.2.7. *Vibrio cholera*

Drinking water (3) samples were found positive for the presence of *V. cholera*, whereas *S. aureus* was not determined in any water sample (Table 2). Out of 3 water samples, two samples were from user points, while only one sample was at source (Table 2). The water that contained microorganisms if ingested, may cause health problems such as cholera, acute diarrheal diseases, and other severe infections [37].

3.2.8. *Pseudomonas aeruginosa*

Drinking water showed contamination with *P. aeruginosa*, (13.3%) as given in Table 2. The existence of *P. aeruginosa* in drinking water is associated with a decline in water quality such as color, turbidity, taste, and odor. It is useful to check whirlpools, Spa pools, and swimming pools for *P. aeruginosa* because they can cause ear infection, which always linked with these recreational sources and the existence of *P. aeruginosa*. The *P. aeruginosa* is considered as an indicator of a disinfection process due to their increased resistance as compared to other microorganisms against chemicals used. In some cases, it may be the cause of some opportunistic diseases in man particularly debilitated patients [38]. *P. aeruginosa* is one of the most common causes of nosocomial infections, including urinary tract infection, pneumonia, and maybe acted as life-threatening organisms [39,40].

4. Conclusions

Physicochemical parameters including turbidity, pH, TDS, and EC in drinking water of the study area were found within the drinking water guidelines set by WHO. However, the TPC revealed that 88% of samples violated the safe drinking water guidelines and showed contamination of fecal coliform, *E. coli*, *Salmonella* spp. *Shigella* spp. *V. cholera* and *P. aeruginosa*. Results revealed that drinking water had bacterial contamination both at source and user points. Drinking water contamination was observed higher at consumer point as compared to the source. Higher bacterial contaminations at consumer point could be attributed to pipelines leakage, biofilm, and growth in pipes, improper handling, and storage of drinking water. In summary, we recommend the replacement of leaking pipes, washing and chlorination of water tanks at intervals and awareness for proper handling. Moreover, drinking water should be boiled or chlorinated before use to avoid microbial contamination.

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References

- [1] E. Alemayehu, F. Melak, S.K. Sharma, B. Van der Bruggen, B. Lennartz, Use of porous volcanic rocks for the adsorptive removal of copper, *Water Environ. J.*, 31 (2017) 194–201.
- [2] M. Garvey, J. Hayes, E. Clifford, N. Rowan, Ecotoxicological assessment of pulsed ultraviolet light-treated water containing microbial species and *Cryptosporidium parvum* using a microbiotest test battery, *Water Environ. J.*, 29 (2015) 27–35.
- [3] M. Nola, M.E. Nougang, O.V. Noah Ewoti, L.M. Mounang, F. Krier, N.-E. Chihib, Detection of pathogenic *Escherichia coli* strains in groundwater in the Yaoundé region (Cameroon, Central Africa), *Water Environ. J.*, 27 (2013) 328–337.
- [4] S.A. Khan, N. Abeer, S.Z. Hussain, S. Muhammad, F. Jawad, T. Khan, Potentially toxic elements contamination in water and their evaluation for risk assessment in the Rawalpindi, Pakistan, *Desal. Wat. Treat.*, 159 (2019) 327–337.
- [5] S. Jadoon, Z. Hilal, M. Ali, S. Muhammad, Potentially toxic elements in drinking water and associated health risk assessment in Abbottabad city, northern Pakistan, *Desal. Wat. Treat.*, 151 (2019) 392–402.
- [6] B.L. Coleman, M. Louie, M.I. Salvadori, S.A. McEwen, N. Neumann, K. Sibley, R.J. Irwin, F.B. Jamieson, D. Daignault, A. Majury, Contamination of Canadian private drinking water sources with antimicrobial resistant *Escherichia coli*, *Water Res.*, 47 (2013) 3026–3036.
- [7] C.L. Richards, S.C. Broadaway, M.J. Eggers, J. Doyle, B.H. Pyle, A.K. Camper, T.E. Ford, Detection of pathogenic and non-pathogenic bacteria in drinking water and associated biofilms on the crow reservation, Montana, USA, *Microb. Ecol.*, 76 (2018) 52–63.
- [8] T. Odamaki, F. Bottacini, E. Mitsuyama, K. Yoshida, K. Kato, J.-z. Xiao, D. van Sinderen, Impact of a bathing tradition on shared gut microbe among Japanese families, *Sci. Rep.*, 9 (2019) 4380.
- [9] S. O'Neill, A.R. Adhikari, M.R. Gautam, K. Acharya, Bacterial contamination due to point and nonpoint source pollution in a rapidly growing urban center in an arid region, *Urban Water J.*, 10 (2013) 411–421.
- [10] J.P. Stokdyk, S.K. Spencer, J.F. Walsh, J.R. de Lambert, A.D. Firnstahl, A.C. Anderson, L.-i.W. Rezanian, M.A. Borchardt, *Cryptosporidium* incidence and surface water influence of groundwater supplying public water systems in Minnesota, USA, *Environ. Sci. Technol.*, 53 (2019) 3391–3398.
- [11] S.A. Khan, H. Khan, M. Ishtiaq, U. Saddique, S. Muhammad, M. Farooq, Shallow water proved higher levels of potentially harmful elements and human health risk along the Sadkal oil exploration and production, *Desal. Wat. Treat.*, 114 (2018) 146–154.
- [12] D.S. Thaler, M.G. Head, A. Horsley, Precision public health to inhibit the contagion of disease and move toward a future in which microbes spread health, *BMC Infect. Dis.*, 19 (2019) 120.
- [13] E. Sanganyado, W. Gwenzi, Antibiotic resistance in drinking water systems: occurrence, removal, and human health risks, *Sci. Total Environ.*, 669 (2019) 785–797.
- [14] N.J. Ashbolt, Microbial contamination of drinking water and disease outcomes in developing regions, *Toxicology*, 198 (2004) 229–238.
- [15] J.O. Falkinham III, E.D. Hilborn, M.J. Arduino, A. Pruden, M.A. Edwards, Epidemiology and ecology of opportunistic premise plumbing pathogens: *Legionella pneumophila*, *Mycobacterium avium*, and *Pseudomonas aeruginosa*, *Environ. Health Perspect.*, 123 (2015) 749.
- [16] S. Lewerin, E. Sokolova, H. Wahlström, G. Lindström, C. Pers, J. Strömqvist, K. Sörén, Potential infection of grazing cattle via contaminated water: a theoretical modelling approach, *Animal*, 13 (2019) 2052–2059.
- [17] S. Water, Emerging Issues in Water and Infectious Disease, World Health Organization, Geneva, 2002.
- [18] World Health Organization (WHO), Guidelines for Drinking-water Quality, 4th ed., Geneva, Switzerland, 2011.
- [19] A. Azizullah, M.N.K. Khattak, P. Richter, D.-P. Häder, Water pollution in Pakistan and its impact on public health—a review, *Environ. Int.*, 37 (2011) 479–497.

- [20] M.T. Shah, J. Ara, S. Muhammad, S. Khan, S. Tariq, Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan, *J. Geochem. Explor.*, 118 (2012) 60–67.
- [21] S. Farooq, I. Hashmi, I.A. Qazi, S. Qaiser, S. Rasheed, Monitoring of coliforms and chlorine residual in water distribution network of Rawalpindi, Pakistan, *Environ. Monit. Assess.*, 140 (2008) 339–347.
- [22] N. Rosemann, Drinking Water Crisis in Pakistan and the Issue of Bottled Water: The Case of Nestlé's 'Pure Life', Actionaid Pakistan, IRC, Asia, 2005.
- [23] F. Nabeela, A. Azizullah, R. Bibi, S. Uzma, W. Murad, S.K. Shakir, W. Ullah, M. Qasim, D.-P. Häder, Microbial contamination of drinking water in Pakistan—a review, *Environ. Sci. Pollut. Res.*, 21 (2014) 13929–13942.
- [24] F.A. Yousuf, R. Siddiqui, N.A. Khan, Survey of gram negative and gram positive bacteria in drinking water supplies in Karachi, Pakistan, *Br. Microbiol. Res. J.*, 4 (2014) 592.
- [25] S. Khan, R. Rauf, S. Muhammad, M. Qasim, I. Din, Arsenic and heavy metals health risk assessment through drinking water consumption in the Peshawar District, Pakistan, *Hum. Ecol. Risk Assess.*, 22 (2015) 581–596.
- [26] F.A. Jan, M. Ishaq, I. Ihsanullah, S. Asim, Multivariate statistical analysis of heavy metals pollution in industrial area and its comparison with relatively less polluted area: a case study from the City of Peshawar and district Dir Lower, *J. Hazard. Mater.*, 176 (2010) 609–616.
- [27] J.C. Young, L.S. Clesceri, S.M. Kamhawy, Changes in the Biochemical Oxygen Demand Procedure in the 21st Edition of Standard Methods for the Examination of Water and Wastewater, *Water Environ. Res.*, 2005, pp. 404–410.
- [28] E. Scallan, R.M. Hoekstra, F.J. Angulo, R.V. Tauxe, M.-A. Widdowson, S.L. Roy, J.L. Jones, P.M. Griffin, Foodborne illness acquired in the United States—major pathogens, *Emerging Infect. Dis.*, 17 (2011) 1–15.
- [29] A.A. Mihdhdhir, Evaluation of bacteriological and sanitary quality of drinking water stations and water tankers in Makkah Al-Mokarama, Pakistan, *J. Biol. Sci.*, 12 (2009) 401.
- [30] V. Manchanda, N.P. Singh, Occurrence and detection of AmpC β -lactamases among Gram-negative clinical isolates using a modified three-dimensional test at Guru Tegh Bahadur Hospital, Delhi, India, *J. Antimicrob. Chemother.*, 51 (2003) 415–418.
- [31] N. Barro, A.R. Bello, A. Savadogo, C.A.T. Ouattara, A. Iiboudo, A.S. Traore, Hygienic status assessment of dish washing waters, utensils, hands and pieces of money from street food processing sites in Ouagadougou (Burkina Faso), *Afr. J. Biotechnol.*, 5 (2006) 1107–1112.
- [32] A. Aydin, The microbiological and physico-chemical quality of groundwater in West Thrace, Turkey, *Pol. J. Environ. Stud.*, 16 (2007) 377.
- [33] B. Million, Assessment of the Contamination Level of Water at Collection Points and Determination of the Major Sources of Contaminants in the Central Highlands of Ethiopia, Yubdo Legabatu PA, 2008.
- [34] WHO, (World Health Organization), Guidelines for Drinking Water Quality, 4th ed., Recommendations, Geneva, Switzerland, 2011.
- [35] C.K. Uejio, S.H. Yale, K. Malecki, M.A. Borchardt, H.A. Anderson, J.A. Patz, Drinking water systems, hydrology, and childhood gastrointestinal illness in Central and Northern Wisconsin, *Am. J. Public Health*, 104 (2014) 639–646.
- [36] N. Gul, M. Shah, S. Khan, N. Khattak, S. Muhammad, Arsenic and heavy metals contamination, risk assessment and their source in drinking water of the Mardan district, Khyber Pakhtunkhwa, Pakistan, *J. Water Health*, 13 (2015) 1073–1084.
- [37] P. Rajendran, S. Murugan, S. Raju, T. Sundararaj, B. Kanthesh, E. Reddy, Bacterial analysis of water samples from Tsunami hit coastal areas of Kanyakumari District, Tamil Nadu, *Indian J. Med. Microbiol.*, 24 (2006) 114.
- [38] F. Rasheed, A. Khan, S. Kazmi, Bacterial analysis, antimicrobial susceptibility and detection of 16S rRNA gene of *Helicobacter pylori* by PCR in drinking water samples of earthquake affected areas and other parts of Pakistan, *Malaysian J. Microbiol.*, 5 (2009) 123–127.
- [39] F. Arancibia, S. Ewig, J.A. Martinez, M. Ruiz, T. Bauer, M.A. Marcos, J. Mensa, A. Torres, Antimicrobial treatment failures in patients with community-acquired pneumonia: causes and prognostic implications, *Am. J. Respir. Crit. Care Med.*, 162 (2000) 154–160.
- [40] N.M. Moore, M.L. Flaws, Epidemiology and pathogenesis of *Pseudomonas aeruginosa* infections, *Clin. Lab. Sci.*, 24 (2011) 43.