ISSN-1996-918X

Pak. J. Anal. Environ. Chem. Vol. 19, No. 1 (2018) 79 – 85

http://doi.org/10.21743/pjaec/2018.06.08

Groundwater Quality and Health Risk Assessment in Rural Areas of District Jaffarabad, Baluchistan (Pakistan)

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Received 15 March 2017, Revised 01 January 2018, Accepted 19 March 2018

Abstract

Water quality has considerable impact on public health especially in areas where access to safe drinking water is very difficult. Keeping in view, drinking water quality in rural areas of district, Jaffarabad was assessed by evaluating 50 groundwater and 25 surface water samples for various physicochemical parameters (color, odour, taste, conductivity, pH, turbidity, alkalinity, hardness and TDS), metallic elements (Na, K, Ca, Mg, Fe and As) and microbiological organisms (*total coliform* and *faecal coliform*) employing standard methods. Analysis data revealed high level of microbial contamination as 62 and 84% water samples contained *total coliform* and 58 and 80% samples were having *faecal coliform* in groundwater and surface water samples, respectively. On the other hand 12, 36, 44, 14, 50 & 32% and 84, 32, 32, 20, 44 & 60% water samples were having higher turbidity, hardness, TDS, Cl^-, SO_4^{-2} and Fe in ground and surface water samples respectively. Health risk assessment data due to high content of Fe and As showed that mean chronic daily intake (CDI) and health risk index (HRI) for As was higher than Fe in both surface and groundwater samples, whereas calculated HRI for all water samples is less than 1. Other than this, CDI and HRI values for Fe in surface water samples are higher than groundwater samples.

Keywords: Contamination, Surface water, Drinking water, Risk assessment, Baluchistan.

Introduction

Water quality depends upon a number of things including minerals, sediments and various types of material on seepage routes as well as general human activities and sewerage or disposal system. Different natural and man-made sources like natural disasters, residues of pesticides, fertilizers and other domestic and industrial wastes having different organic and inorganic constituents pollute water [1]. Rain and flood water enter different kinds of contaminants like industrial, human and animal wastes into the water body through unprotected bore holes and surface water sources. Literature revealed that recent floods in different areas of Pakistan caused severe contamination of drinking water with various microorganisms like pathogenic bacteria which resulted occurrence of common waterborne diseases like diarrhea, typhoid fever, cholera, dysentery, food poisoning, gastroenteritis and other serious infections [2].

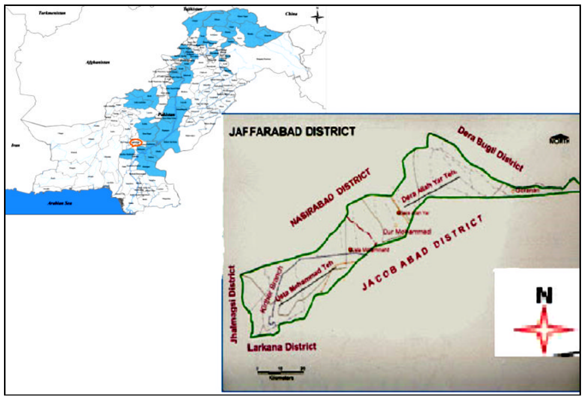
Waterborne diseases as a result of faecal pollution of drinking water are considered to be the major threat to the healthy life of the community [3]. In Pakistan, literature showed that over 71 and 58% water samples were contaminated with *total coliforms* and *fecal coliforms*, respectively and this contamination of drinking water accounted for 20 to 40% of all diseases prevailing in the country [4, 5]. A research study estimated that about 80% of total waterborne diseases including hepatitis, diarrhea, dysentery, anemia and tooth decay in children are due to intake of substandard water [6]. Another study conducted in district Charsadda, KPK highlighted that region was affected with waterborne diseases like diarrhea, gastroenteritis, viral hepatitis and dysentery due to consumption of drinking water polluted with *coliform* bacteria [7]. In Pakistan over 40% of urban deaths are attributed to the diseases caused by consumption of contaminated water [8].

Although the major ions and minerals are an essential part of life cycle but excess of these minerals pose serious health hazards. Literature showed that high level of TDS, nitrate, fluoride, calcium and total hardness causes occurrence of renal gravels and renal stones [9]. It is thought that release of heavy metals from divergent anthropogenic and natural sources contaminate the ground and surface water that is used for industrial, agricultural and domestic purposes [10, 11]. Literature shows that malnourishment and various diseases including anorexia, abdominal pain, cardiovascular diseases, hypertension, immune dysfunction, cancers, liver and other kidney related disorders are caused by intake of excessive heavy metals as shown by different health risk assessment studies [12, 13].

Through a number of studies, it has been established that concentrations of different minerals, chemicals and substances in drinking water exceed WHO guideline values (GVs), as found in Cambodia [14], Zimbabwe [15], Ghana [16], Pakistan [6, 17, 18] and Bangladesh [19]. In Pakistan only 60% people have access to safe drinking water which is also diminishing day by day due to untreated industrial and sewerage wastes and natural disasters [20], therefore investigation of drinking water quality and associated health risk assessment is an important research area. Objective of the present study was to assess drinking water quality in flooded areas of district Jafarabad, Baluchistan after heavy raining in 2013. Keeping in view, physico-chemical and microbial investigation of surface and ground water samples collected from rural areas was undertaken to understand its suitability for human consumption.

Material and Methods

Study area: Jafarabad district lies in the South-East of the Baluchistan province of Pakistan and located at 12°41'23.7''N and 78°36'36.29''E.



Water sampling: From each site, three water samples were collected in clean poly propylene bottles (600mL) for physico-chemical, heavy metals and aesthetic parameters evaluation. Water sample for microbiological analysis were collected in sterilized bottles (250mL), stored in ice box and shifted to water quality laboratory for immediate analysis.

Physico-chemical and microbiological analysis: Aesthetic and physical parameters like color, odour, taste, turbidity, EC and pH were estimated by using field testing instruments at sampling site and analysis data was recorded. Chemical and microbiological analysis of other water quality constituents including potassium (K^+), sodium (Na^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), alkalinity, hardness, chloride (Cl^-), sulphate (SO_4^{-2}, nitrate (NO_3^-), TDS, iron (Fe), arsenic (As), total organic carbon (TOC), dissolved organic carbon (DOC), volatile organic carbon (VOC), total organic matter (TOM), *total coliform* and *faecal coliform* organisms was carried out at PCRWR water quality laboratory by applying APHA standard methods after proper calibration and standardization of instruments [21, 22].

Reagent and instrumentation: Analytical grade chemicals and reagent were employed for the study and calibration of all instruments was done prior to analysis. Instruments employed for evaluation of chemical parameters includes Louibond PC_H63739 Germany turbidity meter, Jenway, 350 pH meter EU, HANNA HI 99300 Italy EC meter, Flame Photometer Italy, Optizen 2120 UV Plus Spectrophotometer, Mecasy Co. Ltd. Korea, AAS Analytik Jena and Shimadzu TOC-5000A analyzer. Alkalinity of samples was performed by aqueous acid base titration. Ca, Mg and hardness by complexometric titration method using EDTA and Cl was determined by argentometric titration method. Analysis of *total coliform* and *faecal coliform* organisms was done by membrane filtration technique.

Health risk assessment: Health hazard due to intake of heavy metals through drinking water was studied by calculating both chronic daily intake (CDI) and health risk index (HRI) for adults and children by using following equation [13];

$$\text{Chronic Daily Intake (CDI)} = \frac{Mc \times Lw}{Wb}$$

where Mc (ppb) is the heavy metal concentration whereas Lw (L/day) denotes daily water intake that is assumed as 1L/day for child and 2 L/day for adult and Wb (kg) is body weight of consumer that is considered as 72 kg for adult and 32.7 kg for child [23].

Furthermore, chronic health problems associated with ingestion of heavy metals were addressed by calculating health risk index (HRI) using below mentioned equation [24].

$$\text{Health Risk Index (HRI)} = \frac{CDI}{RfD} \times 0.001$$

where HRI denotes measured health risk index, CDI and RfD represents chronic daily intake and reference dose for oral toxicity, respectively and 0.001 is the conversion factor used to downscale RfD from mg to µg. RfD is 0.0003, 0.7, 0.024, 0.037, 1.5, 0.02 and 0.3 $mgkg^{-1}day^{-1}$ for As, Fe, Mn, Cu, Cr, Ni and Zn, respectively. Water samples having HRI<1 will be safe for consumption.

Result and Discussion

Analysis data of major physicochemical parameters is presented in (Fig. 1,2) and (Table-1) whereas microbiological results are shown in (Fig. 3). Table-2, 3 shows health risk assessment data of heavy metals in surface and ground water samples, respectively.

Physico-chemical investigation: Analysis data revealed that physical and aesthetic parameters like taste and color of more than half of water samples were objectionable whereas turbidity of 84 and 12% samples was higher than GVs in surface and groundwater samples, respectively. pH of all water samples was in accordance with WHO GVs of 6.5-8.5 [3]. Electrical conductivity (EC) is an indicator of dissolved solids concentration and ions in a water sample. EC in groundwater varied from 290 µS/cm to 12820 µS/cm whereas in surface water samples it ranged from 281-17360 µS/cm.

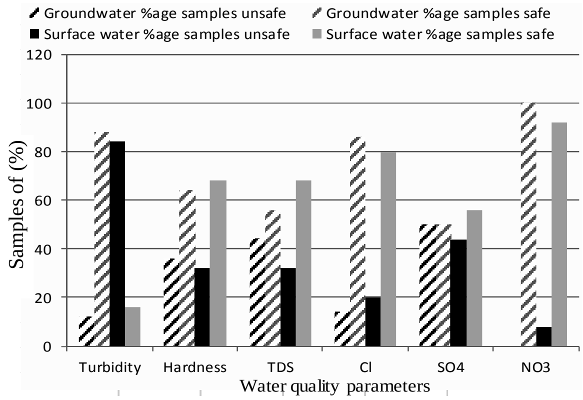


Figure 1. **Physico-chemical parameters in comparison with GVs**

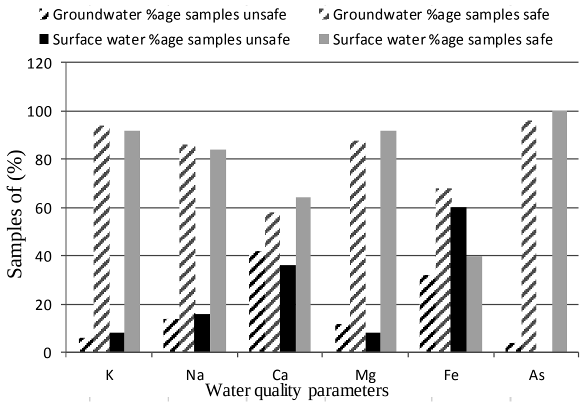


Figure 2. **Metal content in water samples as compared to GVs**

Alkalinity, an important water quality parameter, affects various chemical and biological reactions like hardness, gas trouble, kidney stone, damage of metallic pipes and severe irritation of skin, eyes and mucous membrane when found in higher concentration [25]. In present investigation, carbonate alkalinity in all of the samples analyzed was almost zero whereas bicarbonate alkalinity ranges from 80-1500 mg/L. In water, Cl is present in combination with Na, Ca and Mg and high concentration is associated with many digestive system problems along with saline taste and corrosion issue [26]. Presented study showed that

Cl in surface water (mean=316 mg/L) is higher than groundwater samples (194 mg/L) and overall 20 and 14% surface and groundwater samples, respectively have high content of Cl. Sulphate is another important water quality parameter, high level may cause respiratory illness, gastrointestinal disorder, diarrhea, dehydration and weight abatement [27]. Analysis data revealed that about half of the water samples carry SO_4 in high concentration which may be potential health hazard. Nitrate in groundwater samples were within GVs, whereas 8% surface water samples carry NO_3 content higher than GVs which may be due to fertilizers residue.

Table 1.**Physico-chemical parameters of surface and groundwater samples.**

Parameter	Groundwater		Surface water	
	Range	*Mean ± SD*	*Range*	*Mean ± SD*
Turbidity (NTU)	0.2-15	4.2 ± 3	0.6-291	37± 61
TDS (ppm)	186-8204	1189± 1495.8	180-11110	1374± 2284.5
Total Alkalinity (ppm)	40-1220	228± 4.3	40-1050	202± 4
Carbonate (ppm)	Nil	Nil	0-4	2± 2.6
Total Hardness (ppm)	85-5150	624± 940	90-7400	761± 1509.8
K (ppm)	0.5-12.4	3.9± 3.0	1.0-38	6.2± 7.5
Na (ppm)	20-637	134.5± 118	20-528	135± 142.5
Ca (ppm)	22-600	97± 100.1	20-2280	183± 443.9
Mg (ppm)	1.2-921	92± 175.2	2.4-549	74.1± 130.2
Cl (ppm)	30-1520	194± 262.7	28-3823	316± 772.6
SO_4 (ppm)	56-8416	578± 1282.9	54-3093	441± 655
Fe (ppm)	0.0-0.4	0.2± 0.11	0.10-0.52	0.31± 0.11
As (ppb)	0.0-11	1.3± 2.3	0.01-1.49	0.55± 0.34
NO_3 (ppm)	0.1-7.4	1.8± 1.6	0.50-15.40	2.23± 3.44
TOC (ppm)	0.0-0.14	0.04± 0.04	0.1-1.2	0.35± 0.12
IC (ppm)	40-1220	228± 4.3	40-1054	203± 4.1
TOM (ppm)	0.0-0.25	0.06± 0.06	0.1-2.5	0.70± 0.45

Hardness is combination of carbonates, sulphates and chlorides of Ca and Mg. High value of hardness may impart clothes cleaning problem and other stomach and digestive disorder [28]. Hardness of surface and groundwater samples in 32 and 36% sampling sites respectively was higher than permissible limit. TDS measure the concentration of all soluble salts and its value beyond the permissible limit can cause taste variation, cardiac disease and toxemia in women [29]. Findings in the present study envisaged that 32 and 44% water samples have higher TDS than permissible limit of WHO (1000 mg/L). Presence of high concentration of Na, K, Ca, Cl, SO_4 and many more minerals contribute towards high level of TDS that may cause gastrointestinal exasperation [30].

Metals content estimation: Metals, including essential metals and trace metals play a vital role in various biological and physiological functions in human body, but an unsuitable intake may lead towards health implications. Metal content data indicated that K, Na, Ca, Mg, Fe and As in 8, 16, 36, 08, 0.0 & 60% and 6, 14, 42, 12, 4 & 32 % samples collected from surface and groundwater sources, respectively were higher than GVs. Presence of high concentration of Na, K, Ca, Cl, SO_4 and many more minerals contribute towards high level of TDS [31]. High concentration of Mg in drinking water is associated with laxative effect [19]. High level of Na is responsible for increase in blood pressure in children, male and female of all ages [32]. Potassium, a macronutrient, plays an important role in keeping electrolytic balance of our body [33].

Trace metals are considered to induce serious health hazards if ingested in excess as is evident from various studies conducted to evaluate heavy metal concentration and possible health risks assessments [5, 34]. Literature shows that as a result of natural disasters like floods, earthquakes or rains, presence of natural organic matter (NOM) in water increases due to the interactions between the hydrological cycle and the biosphere and geosphere. NOM present in water inhibit oxidation of iron by reducing it from Fe^{+3} to Fe^{+2}, and as a result iron content in water is increased. The excess amount of iron may accelerate the formation of free radicals resulting in instigation of mutagenicity, nephrotoxicity and renal carcinoma [9].

Similarly, excess concentration of As may result heart attack, skin damage, Nephritis, Emphysema or circulatory system problems and its carcinogenic nature may cause various types of cancer [35]. Present investigation showed that 60 and 32% samples contained high content of Fe in surface and groundwater samples, respectively. Whereas As in only 4% groundwater samples was higher than GVs (Fig. 2). Presence of organic molecules or contaminants in drinking water can be assessed by measuring TOC. Most of these organic contaminants or materials are introduced into the ground or surface water from the water sources, or from other natural products of living systems or synthetic materials. Present study showed that TOC, DOC, VOC and TOM in groundwater samples was not the major concern, however 40% surface water samples were having higher TOC than the recommended value of 0.5 ppm. TOM in surface water samples was also higher than groundwater samples.

Health risk assessment: CDI and HRI for surface and groundwater samples are shown in Table 2 & 3 which indicated that mean CDI & HRI for Fe in surface water samples was higher than groundwater samples. Whereas, mean CDI & HRI for As in surface water samples was less than groundwater samples in both children and adults respectively. Calculated As HRI>1 for only 2 and 1 groundwater samples for children and adults respectively. Whereas mean HRI for both Fe and As is less than one which shows that there was no risk associated with most of the water samples. Literature shows very high carcinogenic and non-carcinogenic health risk associated with elevated concentration of As in drinking water and its correlation with Fe and other heavy metals [36].

***Table 2*. Health risk assessment data of surface water samples.**

		CDI		HRI	
		Children	*Adults*	*Children*	*Adults*
Fe	Min.	0.003	0.003	4.37E-06	3.97E-06
	Max.	0.016	0.014	2.27E-05	2.06E-05
	Mean	0.009	0.009	1.35E-05	1.23E-05
As	Min.	0.000	0.000	0.001	0.001
	Max.	0.046	0.041	0.152	0.138
	Mean	0.017	0.015	0.056	0.051

***Table 3*. Health risk assessment data of groundwater samples.**

		CDI		HRI	
		Children	*Adults*	*Children*	*Adults*
Fe	Min.	0.000	0.000	4.37E-07	3.97E-07
	Max.	0.012	0.011	1.70E-05	1.55E-05
	Mean	0.007	0.006	9.45E-06	8.58E-06
As	Min.	0.000	0.000	0.001	0.001
	Max.	0.336	0.306	1.121	1.019
	Mean	0.039	0.036	0.131	0.119

Microbiological monitoring: Present study showed high level of microbial contamination as 80 and 58% sites were contaminated with *faecal coliform* bacteria in surface and groundwater sources, respectively as shown in Fig. 3. Literature reports that flood and rain water carry human and animal's faecal wastes along with it and contaminate the water bodies with pathogenic organisms and ultimately direct consumption from these sources may cause infectious diseases [37, 38]. Studies conducted in Badin, Thatta and Thar districts of Southern Sindh, Pakistan revealed that common diseases like vomiting, diarrhea, dysentery, gastroenteritis and kidney problems are linked with consumption of contaminated drinking water [6].

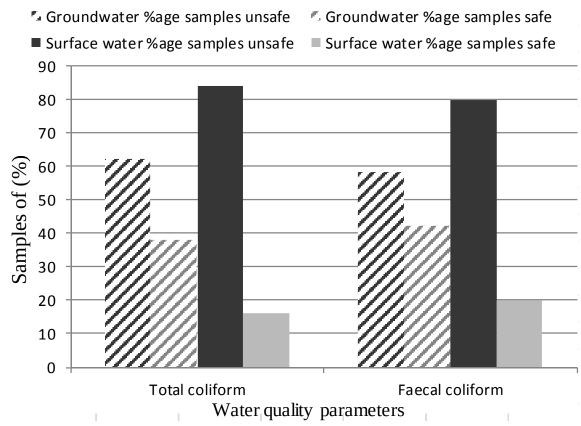


Figure 3. **Microbiological parameters in comparison with GVs**

Conclusion

Surface and groundwater quality assessment in flood affected areas of district, Jaffarabad, Baluchistan, Pakistan showed that there was high level of microbial contamination as 62 and 84% water samples were contaminated with *total coliform* organisms and 58 and 80% samples were having *faecal coliform* in groundwater and surface water samples, respectively. On the other hand, chemical constituents like turbidity, hardness, TDS, Cl^-, SO_4^{-2} and Fe in groundwater was higher in 12, 36, 44, 14, 50 & 32% samples and in surface water in 84, 32, 32, 20, 44 & 60% samples, respectively. Health risk assessment data showed that CDI and HRI values for Fe in surface water samples are higher than groundwater samples and mean HRI for As and Fe is less than 1 for both children and adults.

References

1. O. Phiri, P. Mumba, B. Moyo and W. Kadewa, *Int. J. Environ. Sci. Technol.*, 2 (2005) 237. https://doi.org/10.1007/BF03325882
2. S. Baig, X. Xu and R. Khan, Rural Remote Health, 12 (2012) 3. https://doi.org/10.1111/j.1440-1584.2004.00545.x
3. World Health Organization, (1996). http://apps.who.int/iris/bitstream/10665/63024/1/TDR_Gen_96.1_pp1-34.pdf
4. F. Nabeela, A. Azizullah, R. Bibi, S. Uzma, W. Murad, S. K. Shakir, W. Ullah, M. Qasim and D.-P. Häder, *Environ. Sci. Pollut. Res.*, 21 (2014) 13929. https://doi.org/10.1007/s11356-014-3348-z
5. A. Adepoju-Bello and O. Alabi, *The Nigerian J. Pharm.*, 37 (2005) 41.
6. M. Memon, M. S. Soomro, M. S. Akhtar and K. S. Memon, *Environ. Monit. Assess.*, 177 (2011) 39. https://doi.org/10.1007/s10661-010-1616-z
7. S. Khan, M. Shahnaz, N. Jehan, S. Rehman, M. T. Shah and I. Din, *J. Cleaner Prod.*, 60 (2013) 931. https://doi.org/10.1016/j.jclepro.2012.02.016
8. D. S. Asia, water vision 2025, Country Report, Pakistan, Maharashtra, India, Global Water Partnership, South Asia Technical Advisory Committee Regional Office, (2000). http://fics.seecs.edu.pk/Vision/Vision-2025/Pakistan-Vision-2025.pdf
9. I. A. Al-Saleh, *Sci. the Total Environ.*, 181 (1996) 215. https://doi.org/10.1016/0048-9697(95)05014-0
10. S. Khan, Q. Cao, Y. Zheng, Y. Huang and Y. Zhu, *Environ. Pollut.*, 152 (2008) 686. https://doi.org/10.1016/j.envpol.2007.06.056
11. A. K. Krishna, M. Satyanarayanan and P. K. Govil, *J. Hazd. Mat.*, 167 (2009) 366. https://doi.org/10.1016/j.jhazmat.2008.12.131
12. S. Muhammad, M. T. Shah and S. Khan, *Microchem. J.*, 98 (2011) 334. https://doi.org/10.1016/j.microc.2011.03.003
13. M. Shah, J. Ara, S. Muhammad, S. Khan and S. Tariq, *J. Geochem. Explor.*, 118 (2012) 60. https://doi.org/10.1016/j.gexplo.2012.04.008
14. C. Laluraj and G. Gopinath, *Environ. Monit. Assess.*, 117 (2006) 45. https://doi.org/10.1007/s10661-006-7675-5
15. World Health Organization. Guidelines for drinking-water quality: recommendations, (2004).
16. F. T. Wakida and D. N. Lerner, *Water Res.*, 39 (2005) 3. https://doi.org/10.1016/j.watres.2004.07.026
17. G. Akhter, Z. Ahmad, J. Iqbal, N. Shaheen and M. H. Shah, *J. Chem. Soc. Pak.*, 32 (2010) 306. https://www.jcsp.org.pk/ArticleUpload/749-3221-1-CE.pdf
18. N. Imitiaz, T. Aftab, Z. Iqbal, M. Asi and A. Hussain, *J. Chem Soc. Pak.*, 26 (2004) 450. https://www.jcsp.org.pk/ArticleUpload/1375-6201-1-CE.pdf
19. World Health Organization (2010). http://www.who.int/healthsystems/topics/financing/healthreport/whr_background/en/
20. J. Aziz, Country report prepared for WHO regional work shop on "Introducing environmental health manual". Amman, Jordan, (1998).
21. APHA, Standard methods for the examination of water and wastewater, 21 (2005) 258. https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/scienti

fic/technical-documents/white-papers/apha-nitrate-ise-standard-methods-white-paper.pdf

22. P. dll Version, Method 1603: Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified membrane-Thermotolerant Escherichia coli Agar (Modified mTEC), (2003). https://www.epa.gov/sites/production/files/2015-08/documents/method_1603_2009.pdf
23. F. A. Jan, M. Ishaq, S. Khan, I. Ihsanullah, I. Ahmad and M. Shakirullah, *J. Hazard. Mat.*, 179 (2010) 612. https://doi.org/10.1016/j.jhazmat.2010.03.047
24. S. Muhammad, M. T. Shah and S. Khan, *Food Chem. Toxicol*., 48 (2010) 2855. https://doi.org/10.1016/j.fct.2010.07.018
25. S. Alam, *J. Chem. Soc. Pak.*, 30 (2008) 521. http://www.jcsp.org.pk/ArticleUpload/544-2663-1-CE.pdf
26. A. Khan, I. Haq, W. Khan, M. Akif, M. Khan and M. Riaz, *J. Chem. Soc. Pak.*, 22 (2000) 87. http://www.jcsp.org.pk/ArticleUpload/2643-11935-1-RV.pdf
27. S. Mazloomi, M. H. Dehghani, M. Norouzi, M. F. Davil, A. Amarluie, A. Tardast and Y. Karamitabar, *World Appl. Sci. J.*, 6 (2009) 1660. http://idosi.org/wasj/wasj6(12)/13.pdf
28. A. Khan, F. Hussain, M. Khan and M. Riaz, *J. Chem. Soc. Pak.*, 21.2 (1999) 106. http://www.jcsp.org.pk/ArticleUpload/1779-7863-1-RV.pdf
29. A. Smith, *Analyst*, 98 (1973) 65. https://doi.org/10.1039/an9739800065
30. N. J. Ashbolt, *Toxicology*, 198 (2004) 229. https://doi.org/10.1016/j.tox.2004.01.030
31. M. K. Kindhauser, Communicable diseases 2002. Global defence against the infectious disease threat, (2003). http://apps.who.int/iris/bitstream/10665/42572/1/9241590297.pdf
32. H. Mobley, M. D. Island and R. P. Hausinger, *Microbiol. Rev.*, 59 (1995) 451.
33. G. M. Arain, M. Aslam and S. A. Majidano, *J. Chem. Soc. Pak.*, 29 (2007) 463.
34. S. Venkatramanan, S. Chung, T. Kim, M. Prasanna and S. Hamm, *Water Quality, Exposure Health*, 7 (2015) 219. https://doi.org/10.1007/s12403-014-0142-6
35. M. R. Karagas, T. A. Stukel and T. D. Tosteson, *Intern. J. Hygiene Environ. Health*, 205 (2002) 85. https://doi.org/10.1078/1438-4639-00133
36. D. Van Halem, S. Olivero, W. de Vet, J. Verberk, G. Amy and J. van Dijk, *Water Res.*, 44 (2010) 5761. https://doi.org/10.1016/j.watres.2010.05.049
37. World Health Organization. Calcium and Magnesium in Drinking-water: Public health significance. World Health Organization (2009).
38. S. A. Bablani and S. A. Soomro. Evaluation of seawater intrusions in left bank sediments of coastal district Thatta, Sindh, Pakistan. 1st SWIM-SWICA Joint Saltwater Intrusion Conference. (2006) 24. http://www.swim-site.nl/pdf/swim19/pages_205_212.pdf