Asian Journal of Chemistry; Vol. 29, No. 10 (2017), 2316-2320

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2017.20818

Estimation of Surface Water Quality Indices and Heavy Metals in Selected Polluted Areas of Riyadh City, Saudi Arabia

KHAIRIA M. AL-QAHTANI

Department of Chemistry, Princess Nourah bint Abdel-Rahman University, Riyadh, Saudi Arabia

Corresponding author: Fax: +966 114910132; Tel: +966 8248016; E-mail: dr_adalah@yahoo.com

Received: 26 May 2017; *Accepted*: 30 June 2017; *Published online*: 31 August 2017; AJC-18541

In this study, the quality of water was studied in three selected drainage water in Riyadh City of Saudi Arabia. Physico-chemical parameters (pH, temperature, electrical conductivity, total dissolved solids, chloride, total hardness (magnesium and calcium) and concentration of arsenic, mercury, copper and cobalt were studied. The heavy metal pollution index (HPI) and metal index (MI) were then calculated. The results revealed a fluctuating behaviour of different parameters throughout the study locations influenced by source of discharges. Except for cobalt, its concentration was found to be higher than the NEQS limit in L1 and L2. Based on the results obtained, heavy metals can be arranged in terms of their concentration in samples: Cu > Ar > Co > Hg in the area under investigation. The mean HPI values of surface water in L1, L2 and L3 were 95.35, 73.86 and 46.33, respectively (less than the critical pollution index value of 100). The mean MI values of surface water at different locations were 3.67, 5.93 and 2.67 for L1, L2 and L3, respectively. This revealed low quality water in L2 indicating that this plant was affected by the concentration of heavy metals.

Keywords: Water quality, Physico-chemical parameters, Heavy metals, Riyadh City.

INTRODUCTION

Water is an important component of urban and rural environments and arrangement of this patron is the key to ensuring a better and quality environment. But the production of different types of wastes such as scrap of cars, motor parts, cans tires, engines, *etc.*, are a result of globalization around the world, particularly in developing countries. Waste is often dumped in areas where hazardous materials can spread and thus cause chaos and damage to the ecosystem.

Development of industries and other activities in Riyadh City, Saudi Arabia, such as metal-working, electro-plating, refinishing, munitions manufacturing and mining produces metals contaminated with products responsible for polluting a large part of soil and surface water.

The most common contaminants are heavy metals and their source of diverse human activities that cause pollution of water and soil [1]. Their presence in and around urban areas with high concentrations is a source of concern and danger to the environment because of their long biological ages and long continuous nature in the human system. The study and control of heavy metals is necessary, because the small increase in their concentration above the threshold levels on human factors or biological factors, leading to subsequent health problems and serious environmental risks [2]. Recently, all studies have shown that heavy metals are dangerous environ-mental pollutants that have high toxicity, environmental sustainability and longevity [3-5]. Groundwater and surface water pollution with heavy metals has many adverse effects and is the most polluting water for chromium, manganese and zinc, causing chloros and neurotoxin while nickel, cobalt and cadmium reduce photosynthesis in plants and inhibit static activities [6,7]. It also causes both lead, manganese, Iron, nickel, cobalt, copper, zinc and aluminum have expected risks in water [8-10]. In general, the environmental system and pollution standards are monitored to assess the quality of the environment. This gives an idea of the amount of pollution in the environment and refers to the quality standards of the system. The study and development of quality indicators in the environment is useful in obtaining a specific composite effect from all factors and its relation to total pollution. There are many researches to implement several methods to develop quality indicators and to assess water quality in terms of water quality parameters [11]. Heavy metal pollution index (HPI) has been measured to study the ratio and trace concentration of heavy metals in the ecosystem [12]. Heavy metal pollution index (HPI) can be defined as a classification that reflects the combined effect of heavy metals dissolved in water [13]. Heavy metal pollution index (HPI) is a powerful factor to illustrate the effect of amalgam on individual heavy metals on the determination of overall water quality and the classification of surface and groundwater quality and suitability for human consumption [14]. The value of the water pollution index should be less than 100 and it is calculated to determine the suitability of groundwater and surface water for human consumption in relation to mineral pollution.

The objective of this study is to estimate the water quality indices of some selected areas in Riyadh City affected by different sources of pollution with respect to its physical and chemical parameters, heavy metal concentrations by estimating metal index (MI) and heavy metal pollution index (HPI).

Study area: Wastewater samples for physico-chemical analysis were collected from Al-Hair area in south of the city of Riyadh, Utaiqah in west of the city of Riyadh and Princess Nourah University (PNU) in north of the city of Riyadh. Riyadh is the capital city located in the center of Saudi Arabia. The climate of Riyadh city is classified as desert dry and very hot in summer, with variable temperatures throughout the year. However, the relative humidity is very low. The wastewater used in the analysis includes liquid waste from homes, commercial and industrial complexes and hospitals. Wastewater Al-Hair is the largest wastewater treatment plant in Saudi Arabia with a capacity of 600,000 m^3/day. Wastewater Utaiqah: flowing into Wadi Hanifa with a capacity of 400,000 m^3/day. Wastewater Princess Nourah University: the membrane bioreactor technology (MBR) is used in wastewater treatment with a capacity of 13,000 m^3/day.

EXPERIMENTAL

Sample collection and processing: Samples were collected from wastewater treatment plants, these samples are treated and pollution-free. A total number of nine surface samples were collected during the period from August 2016 to February 2017 and the average sample results were taken, across three distinct study locations [L1: wastewater Al-Hair (south of the city of Riyadh), L2: wastewater Utaiqah (west of the city of Riyadh) and L3: wastewater Princess Nourah University (north of the city of Riyadh)], representing different kinds of pollution sources. At each location, three stations were sampled using 1000 mL polyethylene bottles for the samples. Water samples were collected using a silicon/Teflon water pump. The water temperature, pH, electrical conductivity (EC) and Total dissolved solids (TDS) of the water samples were determined in the samples collection site by electrode method. Separately 100 mL of each water sample is collected and acidified with conc. HNO_3 for heavy metals analysis. Upon arriving laboratory, water samples were immediately filtered and the other physico-chemical parameters were determined.

Physico-chemical parameters of water samples: This requires analysis of the physical properties and chemical components of samples of treated wastewater. Total chloride was measured by silver nitrate titrimetric method (potassium chromate), total hardness was measured by (EDTA) titrimetric method (Erichrome black T), calcium and magnesium were measured by EDTA titrimetric method. Table-1 shows the results of the physical properties and chemical components of water samples.

Analysis of heavy metals in water samples: Quantitative method was used to determine concentrations of heavy metals in waters, heavy metals such as arsenic, mercury, copper and cobalt were determined by atomic absorption spectrophotometry. The concentration of heavy metals in the study area are presented in Table-1.

RESULTS AND DISCUSSION

Physical and chemical parameters: The average and standard deviation of physico-chemical parameters (temperature, pH, EC, TDS, chloride, hardness, calcium and magnesium) in all the samples of studied locations are summarized in Table-1. Water temperature is considered as main factor affecting ion and phase equilibria and influencing the rate of biochemical processes [15]. The temperature of the samples ranged between 30 and 35 °C. For the area under investigation, the temperature values range within the optimum range for growth of pathogenic bacteria. In previous studies have explained that temperature in the range of 20-45 °C is the appropriate range for the growth of pathogenic bacteria [16]. Based on the WHO, temperature is important in determining the microbiological characteristics of water through its effect on survival and growth of micro-organisms [17]. So warm water is good medium for micro-organisms growth.

TABLE-1
DRAINAGE FLOW RATE, PHYSICO-CHEMICAL PARAMETERS AND HEAVY METALS OF SELECTED LOCATIONS IN THE AREA UNDER INVESTIGATION

Parameters	NEQS value (mg/L)	Mean concentrations		
		L1	L2	L3
Drainage water flow rate (× 10^3 m^3/day)		400-640	260	10400
Temperature (°C)		30	34	35
pH	6-9	8.7	7.9	8.5
Electrical conductivity (µS/cm)	–	1980	521	1106
TDS (mg/L)	3500	1000	273	606
Chloride (mg/L)	1000	850	295	4
Hardness (mg/L)	500	38	23	15
Calcium (mg/L)	NGVS	448	180	7
Magnesium (mg/L)	NGVS	116.8	41.4	1.4
Arsenic (mg/L)	1.0	0.357	0.380	0.429
Mercury (mg/L)	0.01	0.008	0.001	0.004
Copper (mg/L)	1.0	0.583	0.871	1.057
Cobalt (mg/L)	0.06	0.116	0.275	0.047

NGVS = No guideline value suggested

Mean pH values of the locations under investigation for all water samples were (7.9-8.7), these values are within the range of 6-9 defined by the World Health Organization [18]. According to the pH values are in the alkaline range, they do not cause health problems as in acidic water [19]. Variations of pH of sea water and fresh water are controlled by several factors and the main are water temperature, dissolved oxygen respiration of aquatic organisms, land runoff, decomposing of organic matter as well as precipitation and oxidation reduction reactions occurring in the environment [20]. The different results in pH values from station to another and reported in (Table-1) show that these values are consistent with the values allowed the National Environmental Quality Standards (NEQS).

The amount of dissolved solids in water gives a high electrical conductivity to the water samples. The amount of dissolved solids in water indicates the amount of inorganic salts in the water including nitrogen, bicarbonate, calcium, magnesium and others [21]. The National Environmental Quality Standards (NEQS) has not given a standard value for the amount of electrical conductivity. The electrical conductivity values of the selected stations are: 1980, 521 and 1106 for stations L1, L2 and L3, respectively. Some of these values are above the standard values of WHO and NAFDAC (1000 μS/cm). The observed data of electrical conductivity followed similar style as pH. It was observed that the electrical conductivity values increased with increasing flow rate of drainage water to Al Hair drain and this showed the positive effect of prevailing wind and rate of discharges from sewage and industrial wastewater on water electrical conductivity as the effect of runoff seemed to be restricted to the surface water. Moreover, the dilution effect of this discharge was responsible for the difference in values between different locations.

The amount of total dissolved salts (TDS) are an important factor in the quality of agricultural water. Total dissolved salts are of great importance in plant growth, product quality and yield of crop [21]. Total dissolved salts (TDS) was found to range from 273 to 1000 for L_2 and L_1, respectively recorded acceptable values accor-ding to NEQS (which are 3,500 mg/L). A direct correlation can be established between TDS and EC. It is worth noting that TDS and chloride ions follow the same pattern in case of L_1 and L_2. However in L_3, chloride ions recorded the minimum value of 4 mg/L which may be attributed to further treatment of its removal from water to be suitable for using in irrigation system of University.

Hardness values show a relationship with the concentration of calcium, chloride and magnesium for the whole area under investigation (Table-1). Results showed that strong relationship was presented in the values of hardness and chloride in locations 1 and 2 (values were below the permissible levels given by WHO guidelines). Calcium and magnesium were also found to be higher in the same two locations. Chloride, magnesium and calcium ions are not cumulative toxins, but if a person intake large quantities of them are considered dangerous to health. Previous research has shown that high chloride concentrations cause taste problems [22].

Calcium and magnesium are alkaline elements found in water bodies [23]. Surface and ground water contain high concentrations of magnesium salts naturally, it also contains abundant amounts of calcium and sodium cations. The concentration of calcium and magnesium cation is increased in surface and groundwater as these cations are washed [24]. The current study showed that the calcium content were within the range of 448.7 mg/L for L1 and L3, respectively while the magnesium content varied from 116.8 mg/L in L1-1.4 mg/L in L3. In this case, the calcium and magnesium levels in surface water could be greatly affected by organic compounds provide with the wastewater discharged directly to Al Hair drainage received water of growing human activity and farmland. Relatively low Ca and Mg concentrations in overflow from princess Nourah bint-Abdel Rahman University related to sufficient processing capacity of treatment plant.

Heavy metals results: The concentration of cobalt, copper, mercury and arsenic was studied and the results of this study are recorded in Table-1. The results of concentration of elements were different according to different study stations. The concentrations of cobalt in L1 and L2 (0.116 and 0.275 mg/L) were found to be higher than the allowable value (0.06 mg/L) in NQES guideline. However, the mean concentrations of other elements were present in all locations of below the highest permissible values with regional average values of 0.388, 0.0043, 0.837 and 0.146 mg/L for Ar, Hg, Cu and Co, respectively (Table-1). Based on the results obtained, heavy metals can be arranged in terms of their concentration in samples: Cu > Ar > Co > Hg in the area under investigation.

Copper is widely found in nature and has great industrial significance. Copper is also found in water in the form of ions or complexes. Copper enters the process of food metabolism in photosynthesis in plants [25]. The concentration of copper allowed in drinking water does not exceed 1.0 mg/L. The highest concentration of copper at the stations under study was recorded in sample collected from L3 (1.057 mg/L) which is slightly exceeded the permissible value (Table-1). The regular wastewater discharges from laboratories of Princess Nourah University may be the main reason responsible for its higher concentrations and a heavy growing automobile traffic close to this area. Moreover, in the artificial wetland received this runoff, the portion of copper ions interacts with organic materials (coming from laboratories) that have a possibility complexion ability to precipitate out as in soluble copper [26]. Although the other two locations are surrounded by reclaimed cultivated land using Cu in the manufacturing of fertilizers and algaecide, the Cu concentrations were notably low (< 1.0 mg/L). This may be attributed to the neutral and alkaline conditions of collected water (Table-1). The solubility of anionic and cationic forms of Cu decreases in pH range from 7 to 8 [27].

Arsenic is widely spread in the environment due to increased human activities and natural resources [28]. There is an arsenic in surface water and groundwater in the form of inorganic form (arsenic, arsenite) and organic form (dimethylarsinic acid acid, DMA and monomethylarsonic acid, MMA). As is known, inorganic arsenic has high toxicity, the permissible limits of arsenic in drinking water and water with human use should not exceed 1 mg/L [29,30]. Obtained concentrations of arsenic in analyzed waters of studied locations were ranged within limited range from 0.357 to 0.429 mg/L for L1 and L3, respectively (below acceptable limits).

The existence of cobalt on the earth's surface is different from the rest of the elements, where there is only free form in the meteorites. The high quality iron alloy industry and metal fabrication are the main source of environmental pollution of the cobalt element. Cobalt is also, used in the bio-industries, the food industry and the manufacture of batteries and paints, in phosphate fertilizers and animal feed, in petroleum refining, in the electroplating industry as well as atmospheric deposition from various activities such as the smelting and refining of metals and the burning of fossil fuel [31]. Cobalt is found in different oxidation states from -1 to +4, but in nature it is usually found as Co^{2+}. Cobalt cation is relatively easy to carry in acidic environments, but does not have complete migration in the aquatic media because it binds with manganese and iron hydroxides as well as glacial minerals [32]. The highest co concentration is recorded at L2 with value: 0.275 mg/L followed by L1 with value: 0.116 mg/L (> acceptable range of NEQS, 0.06 mg/L). This highest value is related to the surrounding agricultural area. Through previous research, In EU (European Union) agricultural soils, the ratio of heavy metals was 4.5 % of the samples, cobalt in samples of agricultural land was above the allowable limit [33].

The concentration of mercury in the samples was 0.008, 0.001 and 0.004 mg/L for L1, L2 and L3, respectively. Results of treated wastewater samples under study showed that the concentration of mercury in the samples was below the limit set by NEQS (< 0.01 mg/L). This indicates that no direct pollution source of mercury in the area under investigation.

Heavy metal pollution index (HPI): The study of heavy metal pollution index (HPI) is an important determinate of water quality. In other word, it is also a way to classify water quality by the effect of heavy metals concentration [34,35]. To calculate heavy metal pollution index (HPI), follow the steps:

(a) First, calculate the weightage of i^{th} parameter by the following equation:

$$W_i = \frac{k}{S_i} \quad (1)$$

where W_i = unit weightage, k = constant of proportionality and S_i = allowed values for i^{th} parameter.

(b) Second, the quality rating is calculated for each of the heavy metals by the following equation:

$$Q_i = \frac{100 \times V_i}{S_i} \quad (2)$$

where Q_i = sub index of i^{th} parameter, S_i = allowed values for the i^{th} parameter and V_i = observed value of i^{th} parameter.

(c) Third, the general index is then calculated from the total number of sub-indices (heavy metal pollution index) by the following equation:

$$HPI = \frac{Q_i \times W_i}{W_i} \quad (3)$$

where HPI = heavy metal pollution index, Q_i = sub index of i^{th} parameter and W_i = unit weightage for i^{th} parameter.

The value of the critical pollution indicator is 100. The S_i value was taken from NEQS in the present study. The results of HPI are shown in the Table-2.

TABLE-2
HEAVY METAL POLLUTION INDEX (HPI) CALCULATION FOR L1-L3 SAMPLES

Heavy metal	Mean value (mg/L) (M_i)	Standard permissible value (mg/L) (S_i)	Unit weighted value (W_i)	Sub index (Q_i)	$W_i \times Q_i$
L1					
Co	0.116	0.06	16.67	193.33	3222
As	0.357	1.0	1.0	35.70	35.7
Cu	0.583	1.0	1.0	58.30	58.3
Hg	0.008	0.01	100	80.00	8000
			ΣW_i = 118.67		ΣW_iQ_i = 11316
Heavy metal pollution index (HPI) = 11316/118.67 = 95.35					
L2					
Co	0.275	0.06	16.67	458.33	7640
As	0.380	1.0	1.0	38.00	38
Cu	0.871	1.0	1.0	87.10	87.1
Hg	0.001	0.01	100	10	1000
			ΣW_i = 118.67		ΣW_iQ_i = 8765
Heavy metal pollution index (HPI) = 8765/118.67 = 73.86					
L3					
Co	0.047	0.06	16.67	78.33	1305
As	0.429	1.0	1.0	42.90	42.9
Cu	1.057	1.0	1.0	105.70	105.7
Hg	0.004	0.01	100	40.00	4000
			ΣW_i = 118.67		ΣW_iQ_i = 5498
Heavy metal pollution index (HPI) = 5498/118.67 = 46.33					

Metal index (MI): Water is classified according to the metal index (MI) values as shown in Table-3. If the value of MI < 0.3, the water quality is marked as very pure, if MI = 0.3-1.0, the water quality is pure, if MI = 1.0-2.0, the water quality is slightly affected, if MI = 2.0-4.0, the water quality is moderately affected, if MI = 4.6, the water quality is strongly affected and if MI > 6.0, the water quality is seriously affected [36].

TABLE-3
WATER QUALITY CLASSIFICATION USING MI

MI	Characteristics	Class
< 0.3	Very pure	I
0.3-1.0	Pure	II
1.0-2.0	Slightly affected	III
2.0-4.0	Moderately affected	IV
4.6	Strongly affected	V
> 6.0	Seriously affected	VI

The metal index (MI) was calculated using the following equation [37]:

$$MI = \sum_{I=1}^{N} \frac{M_i}{S_i} \quad (4)$$

where M_i is the concentration of each metal, S_i is the standard limit for each metal was taken from NEQS and the subscript i is the ith sample. Calculations are shown in Table-4.

The HPI values for 9 water samples (three in each location) were calculated and the results were tabulated in Table-2 and used to estimate the quality of surface water samples. The mean heavy metal pollution indexes (HPI) of different locations (wastewater Al-Hair 95.35, wastewater Utaiqah 73.86 and wastewater Princess Nourah University 46.33), respectively, are found below the critical index value 100.

TABLE-4
HPI AND MI VALUES RECORDED AT DIFFERENT LOCATIONS

Locations	HPI	MI
L1	95.35	3.67
L2	73.86	5.93
L3	46.33	2.67

It is worth noting that a noticeable higher HPI value in L1 compared with others indicated the presence of Co, As, Cu and Hg in this location. These were attributed from anthropogenic origin which includes traffic sources, industrial activities, domestic wastes, atmospheric depositions and municipal sewage affect this area. The results of this research were consistent with previous research, that notarized that metal from chemical weathering of minerals, industrial discharges and scrap yard increase heavy metals concentration in water [38]. The lower HPI value calculated on L3 indicate a slightly best quality in terms of concentration of heavy metals as a result of treatment of wastewater discharged from Princess Nourah University.

Among the results obtained, it was found that water index (MI) from the sampling sites falls within the range of the average of severely affected effect. The lowest value of MI (2.67) in sample location L3 indicates that this water can be used for agricultural purposes and domestic.

Conclusion

The results in this study showed that the physical and chemical parameters and mean concentrations of metals (except for cobalt) in surface wastewater of sampling locations, recorded values less than permissible limits set by NEQS. Limited difference in concentrations of these parameters and heavy metals in wastewater sampled are a result of different activities in the neighbourhood areas. Based on the average concentration of heavy metals was calculated heavy metal pollution index (HPI) for three locations (L1, L2 and L3) was computed to be 95.35, 73.86 and 46.33 and were less than the critical pollution value of 100. The result of the MI also computed to be 3.67, 5.93 and 2.67 for L1, L2 and L3, respectively propose that the selected wastewater samples were found to fall in range between moderately affected to strongly affected water with heavy metals. The results also showed that the effect of human activities on carrying pollution in water in the scrap yard neighborhood. The HPI seems to be useful and can be used to assess the level of total contamination of groundwater and surface water in terms of heavy metals. The metal index (MI) is an another index used to evaluate the surface water samples with respect to heavy metals. This index study showed that L2 was polluted when compared to L1 and L3.

REFERENCES

1. O. Akoto, J.H. Ephraim and G. Darko, *Int. J. Environ. Res.*, **2**, 359 (2008).
2. M.I. Yahaya, S. Mohammad and B.K. Abdullahi, *J. Appl. Sci. Environ. Manag.*, **13**, 9 (2009).
3. M. Klavins, A. Briede, V. Rodinov, I. Kokorite, E. Parele and I. Klavina, *Sci. Total Environ.*, **262**, 175 (2000); https://doi.org/10.1016/S0048-9697(00)00597-0.
4. B.Z. Yuan, A.M. Jefferson, K.T. Baldwin, S.S. Thorgeirsson, N.C. Popescu and S.H. Reynolds, *Oncogene*, **23**, 1405 (2004); https://doi.org/10.1038/sj.onc.1207291.
5. H. Pekey, *Mar. Pollut. Bull.*, **52**, 1197 (2006); https://doi.org/10.1016/j.marpolbul.2006.02.012.
6. A. Tumuklu, M.G. Yalcin and M. Sonmez, *Pol. J. Environ. Stud.*, **16**, 651 (2007).
7. M.N. Prasad, *Environ. Exp. Bot.*, **35**, 525 (1995); https://doi.org/10.1016/0098-8472(95)00024-0.
8. I. Grigalaviciene, V. Rutkoviene and V. Marozas, *Pol. J. Environ. Stud.*, **14**, 109 (2005).
9. O.A. Al-Khashman and R.A. Shawabkeh, *Environ. Geochem. Health*, **31**, 717 (2009); https://doi.org/10.1007/s10653-009-9250-9.
10. B.N. Lohani and G. Todino, *J. Environ. Eng.*, **110**, 1163 (1984); https://doi.org/10.1061/(ASCE)0733-9372(1984)110:6(1163).
11. S.V. Mohan, P. Nithila and S.J. Reddy, *J. Environ. Sci. Health A*, **31**, 283 (1996); https://doi.org/10.1080/10934529609376357.
12. S. Sirajudeen, V. Arulmanikandan and A. Manivel, *J. Pharm. Pharm. Sci.*, **4**, 967 (2014).
13. R. Reza and G. Singh, *World Appl. Sci. J.*, **9**, 1392 (2010).
14. R. Rizwan, S. Gurdeep and J.M. Kumar, *Int. J. Res. Chem. Environ.*, **1**, 118 (2011).
15. M.A.H. Saad, M.A. Abdel-Moati, A.A. Abdel-Wahed and N.B. Badr, Environmental Characyeristics of the Eastern Harbour of Alexandria, Egypt, Proceeding of the 9 th International Conference of Environmental Protection is a Must, 4-6 May, Alexandria, Egypt (1999).
16. L.M. Prescott, J.P. Harley and D.A. Klein, The Influence of Environmental Factors on Growth, In: Microbiology, McGraw-Hill Companies, Inc., USA, edn 4, pp 123 (1999).
17. IPCS, Inorganic Lead, Geneva, World Health Organization, International Programme on Chemical Safety, Environmental Health Criteria 165 (1995); http://www.inchem.org/documents/ehc/ehc/ehc165.htm.
18. WHO, Guidelines for Drinking-Water Quality, World Health Organisation, Geneva (2011).
19. D.N. Asamoah and R. Amorin, *Res. J. Appl. Sci. Eng. Technol.*, **3**, 377 (2011).
20. M.A.H. Saad, A.A. Abdel-Wahed and N.B. Badr, Hydrographic Investigation in Abu-Kir Bay, Egypt, Fifth International Water Conference IWTC, Alexandria, Egypt (2000).
21. SFWF, TDS and pH, Organization of Safe Drinking Water, Canada, pp. 1-6 (2002).
22. APHA, Standard Methods for the Examination of Water and Wastewater, American Public Health Association,Washington, DC, edn 20 (2005).
23. J. Grochowska and R. Tandyrak, *Limnol. Review*, **9**, 9 (2009).
24. M. Galczyñska, R. Gamrat, P. Burczyk, A. Horak and M. Kot, *Water-Environm.-Rural Areas*, **3**, 41 (2013).
25. A. Serra, N. Corcoll and H. Guasch, *Chemosphere*, **74**, 633 (2009); https://doi.org/10.1016/j.chemosphere.2008.10.036.
26. C. Prabhahar, K. Saleshrani, D. Dhanasekaran, K. Tharmaraj and K. Baskaran, *Int. J. Curr. Life Sci.*, **1**, 41 (2011).
27. A. Kabata-Pendias and H. Pendias, Trace Elements in Soils and Plants. CRC Press, Boca Raton FL. USA, pp 406 (2001).
28. J.A. Baig, T.G. Kazi, A.Q. Shah, G.A. Kandhro, H.I. Afridi, M.B. Arain, M.K. Jamali and N. Jalbani, *Ecotoxicol. Environ. Saf.*, **73**, 914 (2010); https://doi.org/10.1016/j.ecoenv.2010.01.002.
29. DIRECTIVE 40/CE DE LA COMMISSION du 16 mai 2003, Journal officiel de l'Union européenne, L 126/34 (2003).
30. The Drinking Water Directive (Council Directive 98/83/EC of 3 November 1998) on the Quality of Water Intended for Human Consumption.
31. D.R. Lide, CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, FL, USA (2006).
32. K.K. Turekian and M. Scott, *Environ. Sci. Technol.*, **1**, 940 (1967); https://doi.org/10.1021/es60011a001.
33. G. Tóth, T. Hermann, M.R. Da Silva and L. Montanarella, *Environ. Int.*, **88**, 299 (2016); https://doi.org/10.1016/j.envint.2015.12.017.
34. R. Reza and G. Singh, *Int. J. Environ. Sci. Technol.*, **7**, 785 (2010); https://doi.org/10.1007/BF03326187.
35. B. Prasad and K. Sangita, *Mine Water Environ.*, **27**, 265 (2008); https://doi.org/10.1007/s10230-008-0050-8.
36. S. Caerio, M.H. Costa, T.B. Ramos, F. Fernandes, N. Silveira, A. Coimbra and M. Painho, *Ecol. Indic.*, **5**, 155 (2005).
37. G. Tamasi and R. Cini, *Sci. Total Environ.*, **327**, 41 (2004); https://doi.org/10.1016/j.scitotenv.2003.10.011.
38. K. Manoj, P. Kumar and S. Chaudhury, *Bull. Environ. Pharmacol. Life Sci.*, **1**, 7 (2012).