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Research Article

SEASONAL VARIATION IN METAL CONCENTRATION OF ITHIKKARA AND KALLADA SPRING WATERS, SOUTHERN WESTERN GHATS, KERALA, INDIA

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ABSTRACT

The trace metals introduced into the environment by anthropogenic sources far outweigh natural sources. In the present study the trace metals such as As, Cd, Cu, Hg, Pb, Ni and Zn are estimated during pre-monsoon, monsoon and post-monsoon seasons (2011-12) in the spring water samples of two important river basins-the Ithikkara and Kallada river basins, Southern Western Ghats, Kerala, India. Heavy metal pollution Index (HPI), Heavy metal evaluation index (HEI) and Degree of contamination (C_d) are applied to assess the quality of water samples. All the spring samples during monsoon season falls in low pollution category. The spring water samples of highland are near neutral–low metal category and that in lowland region falls in acid-low metal zone. With the exception of nickel and lead in a few samples, the concentration of other metals detected in spring samples are below the standards set by WHO (2011) and BIS (2012).

INTRODUCTION

The importance of fresh water is unique since it cannot be replaced by any other substance. Despite impressive progress, half of the world's population still suffers with deplorable water services. A substantial volume of water now needs to be brought from far away sources. The burgeoning population will increase demands on water and land resources. Erosion salinization compaction and water logging deteriorates soil and water. Water contamination is showing a sharp upward trend world-wide. The four common types of groundwater contaminants are Nitrates, pathogens, trace metals and organic components. Trace metal migration is an important phenomenon in controlling the dynamics of contaminated groundwater.

Arsenic is present in waste waters of many industries such as ceramics, tanneries, chemicals, metal preparation and pesticides. It affects liver, heart and is reported to be carcinogenic. Copper in the natural waters results in higher concentration due to pollution. It is used with sulphate as pesticide and separately as an algaecide. Cadmium is present in waste water from electroplating, chemical industries etc. It causes a painful bone disease called *'itai-itai'*. The seepage of waste is the main source of contamination of groundwater. Mercury is a highly poisonous substance and increases in natural waters by the industrial waste. It affects central nervous system. Mercury caused *'minamata'* incident in Japan. Lead is a toxic element and it enters environment from industry, mining, plumbing, coal etc. Nickel occurs naturally in soils, groundwater and surface water. Zinc is present in high concentration in waste from pharmaceuticals, galvanizing, paint pigments, several insecticides, cosmetics etc., and their discharge increases its concentration in natural water.

Researches around the world have studied in detail the trace metal evaluation in spring water samples (Gutie´rrez *et al*., 2004; Al-Khashman 2007; Yalcin *et al*., 2007; Avdullahi *et al*., 2013). Trace metal contamination studies in spring water samples were also reported from India (Prasad and Bose 2001; Chandra and Ramaiah 2007). Very few studies has been carried out in Kerala state with respect to trace metal assessment in springs (Soorya *et al*., 2015). The present study is carried out to estimate the trace metal contamination of the springs in two important river basins of Southern Kerala, the Ithikkara and Kallada river basins of Southern Western Ghats, Kerala, India. Springs belonging to both flow types and pond types are subjected to study.

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Study Area

The study area consists of Ithikkara and Kallada river basins which is considered to be the life lines of Kollam district, Kerala, India. The area lies between North latitudes 8°45' - 9°15' and East longitudes 76°30' - 77°15'. The river length and catchment area are 56 km and 660 km^2 for the Ithikkara river and 121 km and 1699 km^2 for the Kallada river. The study area is located on the southwest part of Kerala State and extends from Lakshadweep Sea to the Western Ghats and is bordered by Trivandrum district on the South and Alleppey and Pathanamthitta districts in the North and Tirunelveli district of Tamil Nadu State in the East and Lakshadweep Sea in the west. Physiographically, the area can be divided into highland (>75 m), midland (75–8 m), and lowland (< 8 m); (CESS 1984). The study area has a tropical climate. The temperature is almost steady throughout the year. The average temperature ranges from 25 to 32 degrees Celsius. The average annual rainfall is 2468 mm. The area receives both southwest and northeast monsoons. The details about geology, soil, geomorphology and landuse pattern of the study area are detailed in our previous communication (Hema *et al*., 2015). The study area is very rich in mineral resources. The main minerals occurring in the district are bauxite, clay, chrysoberyl, graphite, heavy sand, mica and lime shell. Groundwater in the study area occurs in the porous granular formations such as alluvium, laterite, the tertiary sediments and weathered and decomposed crystalline rocks as well as in the fissures, joints and fractures in the fresh crystalline rocks. The aquifers in the area can be grouped into four distinct geological formations in which they occur viz alluvial aquifers, laterite aquifers, Tertiary sedimentary rock aquifers and crystalline rock aquifers (DMG, 2016). Although a large section of people locality depends on open wells for their fresh water needs, during summer season they depend on springs for meeting their water requirements. It is reported that spring water alone can meet the water requirements of 15.3% of the prevailing population of the spring located in the coastal belt of Kollam and Thiruvananthapuram districts in Kerala (Babu *et al*., 2010).

METHODOLOGY

Sampling and Analytical method

A total of 19 spring water samples from the Ithikkara (nine) and the Kallada (ten) river basins during pre-monsoon, monsoon, and post-monsoon seasons of 2011–2012 were subjected to the study of metal ion concentration (57 samples in total). Figure 1 shows the spatial distribution of spring water samples (Source: Hema *et al*., 2015). The trace metals such as Arsenic (As), Cadmium (Cd), Copper (Cu), Mercury (Hg), Lead (Pb), Nickel (Ni) and Zinc (Zn) were estimated in spring water samples using ICP AES (Inductively Coupled Plasma and Atomic Emission Spectroscope Model: Thermo Electron IRIS Intrepid II XSP Duo).

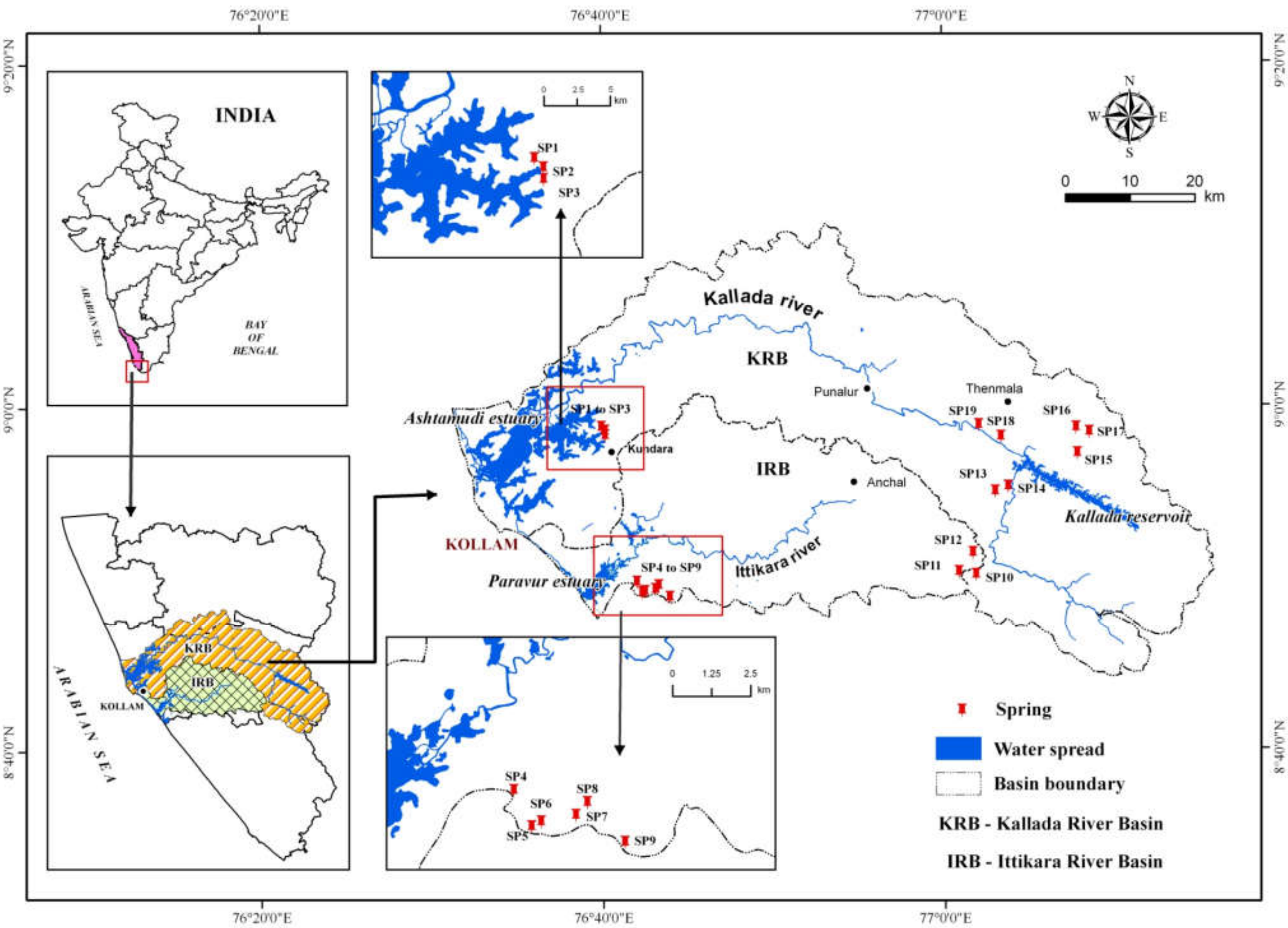

Fig 1 Study area of spring water sampling locations. (Source: - Hema *et al*., 2015)

Non–breakable high density polyethylene plastic containers were used for the sample collection for metal analysis. The containers were soaked in 10% HNO_3 for 48 hours and then pre-rinsed with deionised water several times. The samples were subjected to analysis after filtering the water samples using 0.45µm cellulose nitrate filter paper and preserved by adding ultra-pure HNO_3 to a pH < 2. The method used in determination of the metal pollution indices is illustrated in Table 1.

Table 1 Methods adopted for determining metal pollution indices

Method	Formula	Reference
Heavy metal pollution index (HPI)	$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$ $Q_i = \sum_{i=1}^{n} \frac{\{M_i(-)I_i\}}{S_i - I_i} \times 100$	Horton, 1965; Reddy, 1995; Mohan *et al.*, 1996
Heavy metal evaluation index (HEI)	$HEI = \sum_{i=1}^{n} \frac{H_c}{H_{mac}}$	Edet and Offiong, 2002
Degree of contamination (Cd)	$Cd = \sum_{i=1}^{n} C_{fi}$ with $C_{fi} = \frac{C_{Ai}}{C_{Ni}} - 1$	Backman *et al.*, 1997

Mi, Ii, and Si - monitored, ideal, and standard values of the i^{th} parameter, respectively.
Wi - Rating or weightage (Wi) for each selected parameter
Qi-Sub index of the parameter
n-The number of parameters considered

RESULTS AND DISCUSSION

Trace elements in spring waters

The contamination of water resources by heavy metals is of major concern to mankind. Heavy metals particularly those metals which are in the toxic category even in trace quantities in water may create unnatural physical responses in human beings and animals. A total of 19 samples (lowland-9 and highland-10) were subjected to heavy metal estimation. The samples were studied for Arsenic (As), Copper (Cu), Cadmium (Cd), Mercury (Hg), Lead (Pb), Nickel (Ni) and Zinc (Zn).

The results of the metal analysis for lowland and highland regions in three seasons are given in Tables 2 and 3. The concentration of cadmium and mercury were found to be below detection limit (0.01 mg/L and 0.05 mg/L) in all the samples of lowland and highland region. In the case of copper, two samples in highland (SP15 and SP16) registered its presence in monsoon season within the permissible limit of 1.5 mg/L (BIS, 2012), but none of the samples in lowland region detected its presence. Arsenic was detected only in one sample (SP1) in lowland and two pre-monsoon samples (SP15 and SP18) in highland and the value is 0.05 mg/L. Arsenic are found to be associated with sediments with high organic matter like peat, lignite. High arsenic is reported in formations rich in pyrite, bituminous deposit and organic rich shale or organic rich clay (Bhumbla and Keefer 1994) and it can be responsible for greater arsenic release into groundwater (McArthur *et al.*, 2004). Lead was detected in a few samples of the lowlands (SP2, SP3 and SP5) and the highlands (SP16, SP17, SP18, SP19) during pre-monsoon season and its concentration was above the permissible limit (0.01 mg/L). Unlike the case of other heavy metals, the presence of nickel and zinc were noticed in many of the spring water samples. In 33.3% of lowland and 43.3% of highland samples nickel was detected whereas 48% of lowland and 63% of highland samples registered the presence of zinc.

Table 2 Trace metal concentration (mg/L), pH and metal load in the lowland springs of the study area

Season	Spring Code	pH (Hema et al 2015)	As	Cd	Cu	Hg	Pb	Ni	Zn	Metal load
Pre-monsoon	SP1	4.5	0.05	BDL	BDL	BDL	BDL	BDL	BDL	0.1
	SP2	4.2	BDL	BDL	BDL	BDL	0.03	BDL	BDL	0.0
	SP3	3.8	BDL	BDL	BDL	BDL	0.04	BDL	BDL	0.0
	SP4	4.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP5	4.5	BDL	BDL	BDL	BDL	0.05	BDL	0.01	0.1
	SP6	4.2	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP7	6	BDL	BDL	BDL	BDL	BDL	BDL	0.06	0.1
	SP8	4.1	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP9	4.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
Monsoon	SP1	4.4	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP2	4.4	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP3	4.4	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP4	4.7	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP5	4.8	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP6	4.2	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP7	6.5	BDL	BDL	BDL	BDL	BDL	0.01	0.01	0.0
	SP8	4.8	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP9	4.8	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
Post-monsoon	SP1	4.7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP2	4.7	BDL	BDL	BDL	BDL	BDL	0.01	BDL	0.0
	SP3	4.6	BDL	BDL	BDL	BDL	BDL	0.12	BDL	0.1
	SP4	5	BDL	BDL	BDL	BDL	BDL	0.03	BDL	0.0
	SP5	4.6	BDL	BDL	BDL	BDL	BDL	0.012	BDL	0.0
	SP6	4.8	BDL	BDL	BDL	BDL	BDL	0.013	BDL	0.0
	SP7	6.4	BDL	BDL	BDL	BDL	BDL	0.013	BDL	0.0
	SP8	4.7	BDL	BDL	BDL	BDL	BDL	0.011	BDL	0.0
	SP9	5.3	BDL	BDL	BDL	BDL	BDL	0.01	BDL	0.0

BDL : Below Detection Limit.
Detection Limit: As:0.05mg/L; Cd: 0.01 mg/L, Cu: 0.01 mg/L, Hg: 0.05 mg/L, Pb: 0.03 mg/L, Ni: 0.01 mg/L, Zn: 0.01 mg/L.

Table 3 Trace metal concentration (mg/L), pH and metal load in the highland springs of the study area

Season	Spring code	pH (Hema et al 2015)	As	Cd	Cu	Hg	Pb	Ni	Zn	Metal load
Pre-monsoon	SP10	6.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP11	6.2	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
	SP12	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP13	5.8	BDL	BDL	BDL	BDL	BDL	0.02	0.05	0.1
	SP14	5.5	BDL	BDL	BDL	BDL	BDL	1.02	0.02	1.0
	SP15	5.9	0.05	BDL	BDL	BDL	BDL	BDL	0.01	0.1
	SP16	5.6	BDL	BDL	BDL	BDL	0.03	BDL	BDL	0.0
	SP17	5.6	BDL	BDL	BDL	BDL	0.03	BDL	BDL	0.0
	SP18	6.2	0.05	BDL	BDL	BDL	0.03	BDL	0.01	0.1
	SP19	5.8	BDL	BDL	BDL	BDL	0.06	BDL	0.01	0.1
Monsoon	SP10	6.2	BDL	BDL	BDL	BDL	BDL	BDL	0.02	0.0
	SP11	6.2	BDL	BDL	BDL	BDL	BDL	BDL	0.02	0.0
	SP12	5.3	BDL	BDL	BDL	BDL	BDL	0.01	0.02	0.0
	SP13	6	BDL	BDL	BDL	BDL	BDL	0.01	0.03	0.0
	SP14	5.7	BDL	BDL	BDL	BDL	BDL	BDL	0.03	0.0
	SP15	6.2	BDL	BDL	1.004	BDL	BDL	0.01	0.01	1.0
	SP16	5.7	BDL	BDL	1.002	BDL	BDL	BDL	0.01	1.0
	SP17	5.7	BDL	BDL	BDL	BDL	BDL	0.01	0.02	0.0
	SP18	6.1	BDL	BDL	BDL	BDL	BDL	0.01	0.02	0.0
	SP19	5.9	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0
Post-monsoon	SP10	6.2	BDL	BDL	BDL	BDL	BDL	0.34	BDL	0.3
	SP11	6.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP12	5.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP13	6	BDL	BDL	BDL	BDL	BDL	BDL	0.19	0.2
	SP14	5.7	BDL	BDL	BDL	BDL	BDL	0.014	0.16	0.2
	SP15	6.2	BDL	BDL	BDL	BDL	BDL	0.01	0.01	0.0
	SP16	5.7	BDL	BDL	BDL	BDL	BDL	0.01	BDL	0.0
	SP17	5.7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	SP18	6.1	BDL	BDL	BDL	BDL	BDL	0.01	BDL	0.0
	SP19	5.9	BDL	BDL	BDL	BDL	BDL	0.01	BDL	0.0

BDL: Below Detection Limit
Detection Limit: As:0.05mg/L; Cd: 0.01 mg/L, Cu: 0.01 mg/L, Hg: 0.05 mg/L, Pb: 0.03 mg/L, Ni: 0.01 mg/L, Zn: 0.01 mg/L.

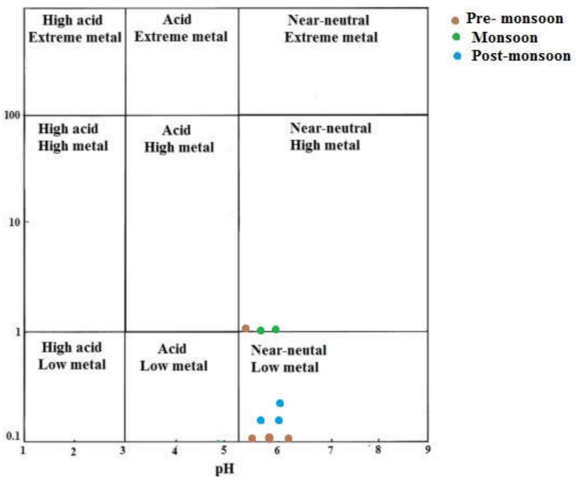

Fig 2 Calculation of spring water samples in highland region based on the plot of metal load and pH

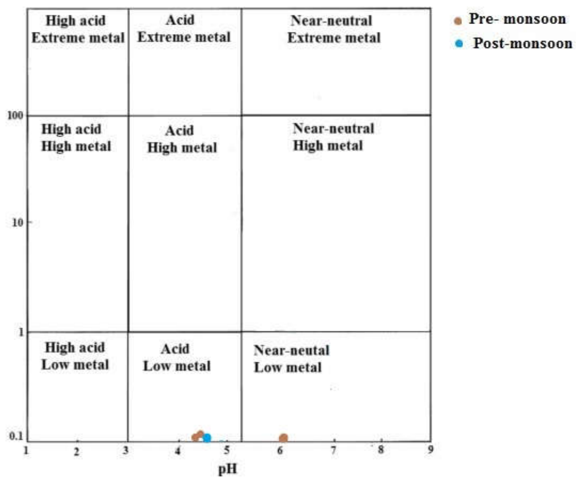

Fig 3 Calculation of spring water samples in lowland region based on the plot of metal load and pH

The ranges of nickel and zinc were respectively BDL to 0.12 mg/L and BDL to 0.06 mg/L in lowland and BDL to 1.02 mg/L and BDL to 0.19 mg/L in highland. The highland sample SP14 (pre-monsoon and sample SP10 (post-monsoon) registered nickel values above the permissible limit. The metal zinc is below detection limit i.e., < 0.01mg/L in all the spring water samples of the lowlands during post-monsoon season. Metals tend to dissolve more in low pH water. Comparative evaluation of the dissolved heavy metal values reveals that with the exception of nickel and lead in a few samples, the concentration of other metals detected in spring samples are below the standards set by WHO (2011) and BIS (2012) which is given in Table 4.

The pre-monsoon spring water samples record the lowest pH (av. 4.5; range 3.8–6.0) than monsoon (4.8; 4.2–6.5) and post-monsoon (5.0; 4.6–6.4) samples; (Refer Table 2 and Table 3). The relationship between the water pH and metal load (As + Cd + Cu + Hg + Pb + Ni + Zn mg/L) computed (Ficklin *et al.* 1992; Caboi *et al.* 1999) is given in Fig. 2 & Fig. 3. The relationship shows that all the spring water samples in highland are classified as near neutral–low metal category whereas that in lowland region falls in acid-low metal zone. Soorya *et al*., 2015 studied the hydro-geochemical and trace metal analysis of coastal springs of Varkala cliff, Kerala, South India which has a similar terrain characteristics of present study area and reported that all the samples showed a comparatively low heavy metal concentrations.

Table 4 Summary of table showing trace element concentration (mg/L) in the spring water samples of the study area, with that of BIS (2012) and WHO (2011)

Parameters	Lowland	Highland	BIS (2012)		WHO 2011
			AL	MPL	
As	(BDL – 0.05)	(BDL – 0.05)	0.01	0.05	0.05
Cu	BDL	(BDL – 1.004)	0.05	1.5	2
Pb	(BDL – 0.04)	(BDL – 0.06)	0.01	NR	0.01
Ni	(BDL – 0.12)	(BDL – 1.02)	0.02	NR	0.07
Zn	(BDL – 0. 6)	(BDL – 0.19)	5	15	-
Cd	BDL	BDL	-	-	-
Hg	BDL	BDL	-	-	-

Ranges are given in parenthesis; BDL: Below Detection Level; AL: Acceptable Limit; MPL: Maximum Permissible Limit; NR: No relaxation.

Table 5 Standard values for the indices computation (Aghazadeh *et al.,* 2016; Herojeet e*t al.,* 2015)

Parameter	W	S_i	I_i	MAC
As	0.02	50	10	50
Cu	0.001	1000	50	1000
Pb	0.70	100	10	1.5
Ni	0.05	70	20	20
Zn	0.0002	5000	3000	5000

W: Weightage (1/MAC) (adopted from Edet and Offiong 2002); Si: standard permissible in µg/L, Ii: highest permissible in µg/L, MAC: maximum admissible concentration/upper permissible.

Table 6 Results of integrated pollution indices of spring water samples collected from lowland and highland regions of the study area.

Season	Lowland				Highland			
	Sample	HPI	HEI	Cd	Sample	HPI	HEI	Cd
Pre-monsoon	SP1	2.59	1	0	SP10	BDL	BDL	BDL
	SP2	20.2	20	19	SP11	0.03	0.002	-0.998
	SP3	30.3	26.7	25.7	SP12	BDL	BDL	BDL
	SP4	BDL	BDL	BDL	SP13	0.04	1.01	0.01
	SP5	40.43	33.3	32.3	SP14	129.87	51.00	50.00
	SP6	0.03	0.002	-0.998	SP15	2.62	1.00	0.00
	SP7	0.03	0.012	-0.988	SP16	20.20	20.00	19.00
	SP8	0.03	0.002	-0.998	SP17	20.20	20.00	19.00
	SP9	BDL	BDL	BDL	SP18	20.24	20.00	19.00
					SP19	50.53	40.00	39.00
Monsoon	SP1	0.03	0.002	-0.998	SP10	0.04	0.002	-0.998
	SP2	0.03	0.002	-0.998	SP11	0.04	0.002	-0.998
	SP3	0.03	0.002	-0.998	SP12	1.33	0.5	-0.50
	SP4	0.03	0.002	-0.998	SP13	1.33	0.50	-0.50
	SP5	0.03	0.002	-0.998	SP14	0.03	0.01	-0.99
	SP6	0.03	0.002	-0.998	SP15	0.12	1.00	0.00
	SP7	1.33	0.5	-0.5	SP16	0.12	1.00	0.00
	SP8	0.03	0.002	-0.998	SP17	1.33	0.50	-0.50
	SP9	0.03	0.002	-0.998	SP18	1.33	0.50	-0.50
					SP19	0.04	0.002	-0.998
Post - Monsoon	SP1	BDL	BDL	BDL	SP10	41.55	17.00	16.00
	SP2	1.3	0.5	-0.5	SP11	BDL	BDL	BDL
	SP3	12.98	6	5	SP12	BDL	BDL	BDL
	SP4	1.3	1.5	0.5	SP13	0.023	0.038	-0.96
	SP5	1.04	0.6	-0.4	SP14	0.81	0.732	-0.27
	SP6	0.91	0.65	-0.35	SP15	1.33	0.5	-0.50
	SP7	0.91	0.65	-0.35	SP16	1.3	0.5	-0.50
	SP8	1.17	0.55	-0.45	SP17	BDL	BDL	BDL
	SP9	1.3	0.5	-0.5	SP18	1.3	0.5	-0.50
					SP19	1.3	0.5	-0.50

BDL: Below Detection Limit; HPI Heavy metal Pollution Index.; HEI: Heavy metal evaluation Index; Cd: Contamination Index

Integrated pollution indices

Drinking water suitability of spring samples are further assessed applying pollution indices taking into account the concentration of dissolved heavy metals in µg/L. Pollution indices were computed based on WHO (1993) water standard. The standard values for indices computation are detailed in Table 5. Pollution indices such as Heavy metal evaluation Index (HEI), Heavy metal Pollution Index (HPI) and degree of contamination index (C_d) were calculated individually using international methods (Edet and Offiong 2002) for the spring samples belonging to the lowland and highland regions and are presented in Table 6. As per modified categories of pollution indices (Selvam *et al.,* 2015) HEI, are classified as low (< 10), medium (10-20) and high (> 20).The results drawn from pollution indices with respect to HEI , it is observed that the samples SP3 and SP5 of the lowland region during pre-monsoon season belongs to high and the sample SP2 in medium pollution category. All the other samples in lowland region fall in low pollution zone. In the case of HPI, which is categorised as low (< 90), medium (90-180) and high (> 180); no samples of lowland region are found to exceed the lower limit. Cd may be classified into three categories (Backman *et al.* 1997; Edet and Offiong 2002) as follows: low (C_d <1), medium (C_d = 1 - 3), and high (C_d >3). According to C_d distribution three samples SP2 (pre-monsoon), SP3 (pre-monsoon and post monsoon) and SP5 (pre-monsoon) belongs to the high pollution sector. All the other samples fall in a low pollution category.

In the highland region, as per HEI values, and C_d distribution, the samples SP14, SP16, SP17, SP18 and SP19 (pre-monsoon), fall in high pollution zone. SP10 (post monsoon) fall in medium pollution zone with respect to HEI and in high contamination category when Cd is considered. With respect to HPI values computed, except sample SP14 of pre-monsoon season, all the other samples of highland belong to low pollution region. During pre-monsoon, the area where the polluted samples located experiences acute scarcity of water. People of this area depend more on these springs. Anthropogenic activities may have lead to the possible pollution of water due to heavy metals such as lead and nickel. All the spring samples during monsoon season are found to be safe with respect to metal indices studies due to dilution effect. Influx of surplus quantity of water from monsoon rainfall causes the dilution effect (Golekar *et al*., 2013). Proper maintenance and preservation is urgently required for the restoration of spring water quality and quantity.

CONCLUSION

In Kerala conventional water resources are facing maximum strain in the present scenario. Several springs exist in the highlands as well as coastal lands of Kerala. Many of them are seasonal. The perennial springs in the area have been used by the settlers as their source of water for drinking, bathing and other domestic needs. The ecosystem supplying spring water are constantly changing due to direct or indirect human interference and massive human encroachments to virgin areas. This may lead to change in quality and quantity of these precious natural gift. The present study 19 spring samples falling in lowland and highland region of Ithikkara and Kallada river basins are identified and mapped. The seasonal variation of trace metal concentration of these samples were estimated. Majority of the spring show acidic to near neutral characteristics with respect to pH values. Metals tend to dissolve more in low pH water. The pH-metal load relationship shows that highland samples belongs to near neutral-low metal class and lowland samples falls in acid-low metal category. From the integrated pollution indices study it is assessed that 85% of lowland spring water samples are safe to drink with respect to metal ion concentration where as in highland region 74% of pre-monsoon and 95% of post-monsoon samples fall in low polluted category. All the samples of monsoon season are found to be safe to as per the metal indices study due to the dilution effect.

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