Shimod *et al.*
Bulletin of the National Research Centre (2022) 46:4
https://doi.org/10.1186/s42269-021-00691-y

Bulletin of the National Research Centre

RESEARCH

Open Access

Effect of urbanization on heavy metal contamination: a study on major townships of Kannur District in Kerala, India

K. P. Shimod[1*], V. Vineethkumar[2], T. K. Prasad[1] and G. Jayapal[1]

Abstract

Background: In the last few decades, the air, water, and soil are contaminated due to different anthropogenic activities and severely affect the environmental quality. Pollution is the harmful effect and creates undesirable changes in the land use and land cover pattern. The growth of urbanization leads to the degradation of the ecosystem and ultimately affects the living and non-living organisms. In view of these, the present investigation is carried out to assess the heavy metal pollution in major towns due to the impact of urbanization in Kannur district and desirable conclusions were drawn.

Results: The results shows that higher level of heavy metal pollution is observed in major towns of Kannur district.

Conclusion: The heavy metal contamination in the major towns of Kannur district is mainly due the anthropogenic activities. The discharge of domestic effluents and industrial waste is the major source of heavy metal pollution. In-depth studies and proper waste management plans are needed to decrease the level of heavy metal contamination prevailing in the study area.

Keywords: Urbanization, Heavy metals, Pollution, Kerala

Background

The process of urbanization is a dynamic and multifaceted progression. The relationship between land use change and environmental quality has been affected by the rapid rate of urbanization, industrialization, rural land conversion, and unexpected growth of population which can cause the degradation in the environmental quality. The fast phase of urbanization causes series environmental issues and diverse kinds of pollution with evolution of time and technology and is sensitive in the accumulation of heavy metal contamination in both spatial and temporal aspects. The urban and economic growth plays a massive impact in polluting the environment by discharging the wastewater which inputs pollutants particularly of toxic heavy metals (Sin et al. 2001; Feng Peng et al. 2009). Thus, the accumulation of contaminants in the sediments of the rivers and other water sources acts as the sink for pollutants (Harbison 1986; Hoch 2001; Nasehi et al. 2013; Rigaud et al. 2013).

The potential risk caused by environmental pollution and the degradation of different environmental matrices have turned out to be an issue of global significance. Overexploitation of natural resources to satisfy the demands of an unsustainable pattern of development across the world has rendered it more vulnerable to deficiencies. The elevated levels of heavy metals in the environment cause series health risks to the living and non-living organisms (Santos et al. 2005). Many researches like Bryan and Langston (1992), Tam and Wong (1996), Tam and Wong (1997), Khan et al. (2000), McGrath et al. (2001), Alam et al. (2003), Veeresh et al. (2003), Banerjee (2003), Sharma et al. (2004), Krishna and Govil (2004), Rattan et al. (2005), Ray et al. (2006), Abbas

*Correspondence: skp.orgin@gmail.com
[1] Department of Geography, Kannur University, Payyanur Campus, Edat, Kannur, Kerala 670327, India
Full list of author information is available at the end of the article

et al. (2007), Krishna and Govil (2008), Pandey and Pandey (2009), Sekabira et al. (2010), Prakash et al. (2011), Parth et al. (2011), Krishna et al. (2013), Chandrasekaran et al. (2015), Zhao et al. (2016), Feng et al. (2017), Islam et al. (2017), Ribeiro et al. (2018), Fletcher et al. (2019), Chai et al. (2019), EL Turk et al. (2019), Sayooj et al. (2020), Wang et al. (2020) and Alfaifi et al. (2021) have carried out studies on heavy metal contamination in different environmental matrices.

The sources of heavy metals can be classified as natural and manmade sources (Parth et al. 2011). The natural source of heavy metals is the result of paedogenic process of weathering of parental rock materials in the environment. The natural distribution of heavy metals depends on the environmental conditions and the bed rock type (igneous rock, sedimentary rock and metamorphic rock) present in the area. Soil formation from the lithogenic sources also contributes considerable amount of heavy metal concentration. Several studies state that natural disasters like forest fire and volcanic eruption will also contribute to the high concentration of heavy metals (Seaward and Richardson 1989; Ross 1994; Nagajyoti et al. 2010). Anthropogenic sources are found to be the major sources of heavy metals when compared with the natural sources (He et al. 2013). The environment is always subjected to different anthropogenic activities like use of fertilizers in the agricultural fields, industrial activities, mining activities, combustion processes, smelters, transportation, disposal of commercial waste products, construction residues, and demolition wastes (Tokman et al. 2004).

In view of the above, major towns of Kannur district have been selected for the present study. The main objective of the study is to find out the impact of urbanization in the heavy metal pollution of Kannur district, Kerala, and the results were discussed in detail.

Study area

Kannur district was taken as the study area for the present investigation. It lies between latitudes 11° 40′ to 12° 48′ N and longitude 74° 52′ to 76° 07′ E. The district is bound by the Western Ghats in the East (Coorg district of Karnataka state), Kozhikode and Wayanad district in the South, Lakshadweep Sea in the West, and Kasaragod, the northern most district of Kerala, in the North. The district has a total geographical area of 2966 sq. km. which accounts about 7.64% of the total area of Kerala state.

The urban growth of an area can be assessed with the urban population content. As per 2011 census, the total population of the district is about 25,23,003 persons in which 15,68,875 are treated as urban population. It ranks 8th in total population, and 4th in the urban population among the districts of Kerala. Among the total population in the district, 65.04% lives in the urban area. This shows that urbanization process is rather fast in the district. Figure 1 shows the location map of the study area. The latitude and longitude of the sampling stations are given in Table 1.

Methods

In the present study, X-ray Fluorescence Spectrometer (XRF), (Model: SPECTRO XEPOS) is used to measure the concentration of heavy metals in soil samples collected from the major towns of Kannur district. Latitude and longitude of the location points were noted using Trimble Juno SA handheld GNSS Receiver, and the location maps and interpolation maps were created using Arc GIS software version 10.8.

Land use/land cover

Land use/land cover (LULC) is defined as the physical composition, characteristics, and human activities in the surface of the earth (Cihlar 2000). The change in LULC is the rapid influence of human activities in the environment and followed by significant consequences. Anthropogenic activities play vital role in the land use and land cover changes which is commonly based on urban development. The accelerated growth of urban centres not only influences the socioeconomic changes, but also influences the biophysical environment (Li and Yeh 2000). It will lead to the problems associated with the urban centres like that of solid waste management and the wastewater disposal. To address these developmental issues, it is essential to have scientific analysis to understand the urban growth pattern and processes.

Figure 2 shows the land use/land cover classification of Kannur, prepared from LANDSAT 8 OLI TIRS satellite image. The land use/land cover in the district is categorized under twelve classes, and the percentage area under different land use classes is: mixed crops with 35.14%, followed by open scrub with 15.49%, forest with 14.16%, rubber plantation with 11.78%, built-up with 7.53%, cashew plantation with 3.66%, paddy with 3.63%, coconut plantation with 3.18% pepper plantation with 2.75%, waterbodies with 1.78%, marshy land with 0.62%, and rocky outcrops with 0.28%. The built-up is more prominent along the national high and coastal regions of the district, and more than half of the total population lives in these regions. The major towns in the district are also located in this region.

Sample collection and elemental analysis

Soil samples were collected from 20 different areas of major towns in Kannur district during the month of February 2019. Around 1 m^2 area was marked for the sample

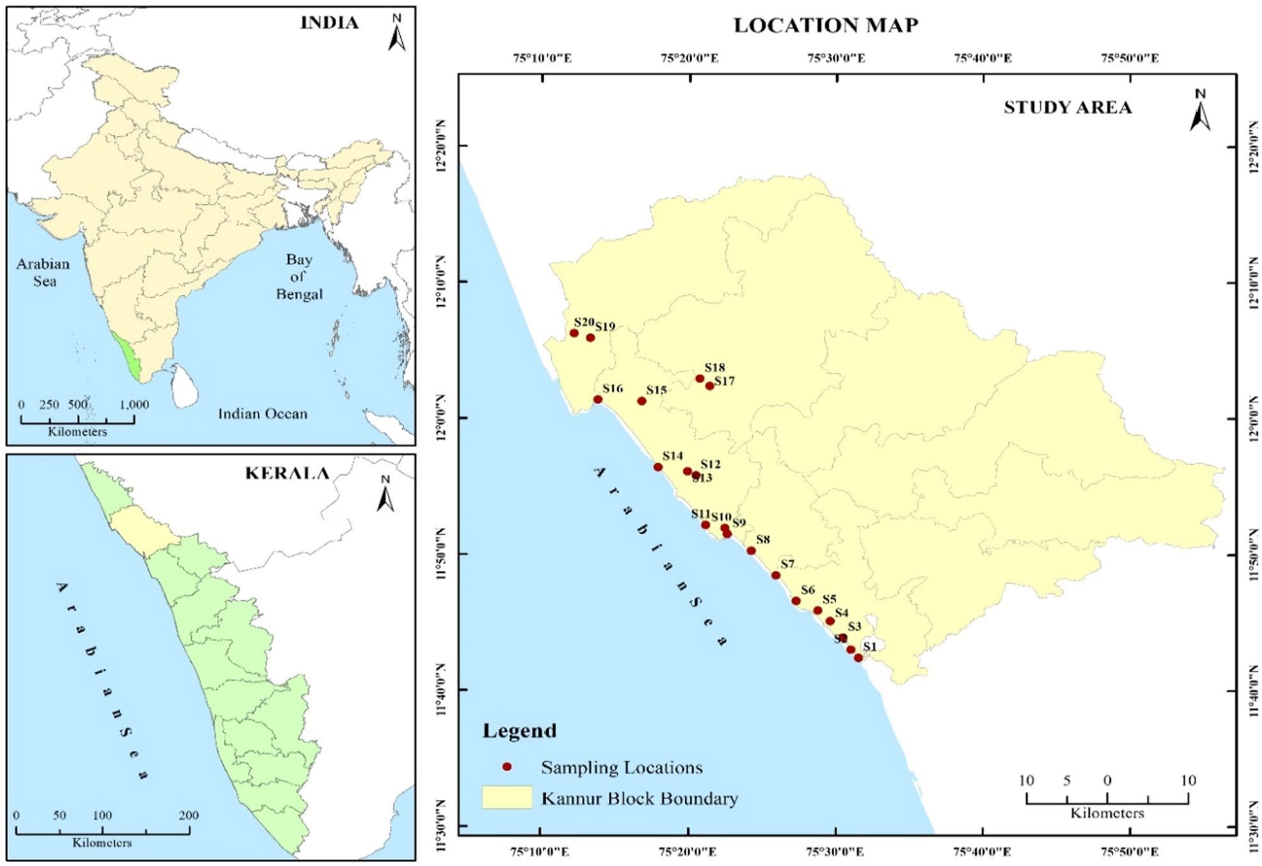

Fig. 1 Location map of the study area

collection with a depth of 30 cm and mixed thoroughly. The stones, pebbles, grass, and plant parts present on its surface were removed prior to the sample collection. Each sample collected was reduced to around 1 kg by quartering process. The thoroughly mixed samples were divided into four equal parts. By discarding the opposite ones, the remaining two parts were mixed again. This process was continued until 1 kg of soil sample was obtained and is taken as the representative sample. The samples were collected in polythene zip lock bags and brought to the laboratory for further analysis (Del Mastro et al. 2015 and Vineethkumar et al. 2020). The concentration of heavy metals such as lead (Pb), arsenic (As), mercury (Hg), cadmium (Cd), zinc (Zn), and iron (Fe) in the collected samples was analysed using X-ray fluorescence spectrometer (XRF).

Pollution indices

Pollution indices are analysed for the understanding of environmental quality matrices and the hazard effects of the enrichment of heavy metals. To measure the assessment of degree of contamination in the environment due to the accumulation of heavy metals, five parameters are used which are enrichment factor (EF), contamination factor (CF), geo-accumulation index (I_{geo}), pollution load index (PLI), and degree of contamination (C_d). These parameters are the major indicators of level of pollution in the environment and will provide a comprehensive way to analyse the pollution status, distribution, and accumulation of heavy metals in the environment. Apparently, the quantitative ranking of heavy metal contamination in different sampling sites with respect to natural environment can be studied by these pollution indices (Ganugapenta et al. 2018).

Enrichment factor (EF)

Enrichment factor is the parameter used to estimate the degree of contamination in the soil due to heavy metals. It is widely used as normalization technique to assess the degree of metal contamination in soil. Assessment of enrichment factor is helpful to examine separate naturally existing metal from those resulting from anthropogenic interventions in the soil. It will also help for the estimation of intensity of deposition of pollutants from

Table 1 The latitude and longitude of the sampling stations

Sample ID	Sampling stations	Latitude (decimal degree)	Longitude (decimal degree)
S1	New Mahe Beach	11.707222	75.525872
S2	Punnol Beach	11.71696	75.51733
S3	Thalassery Harbour	11.73176	75.508522
S4	Thalassery Market	11.751887	75.493728
S5	Co-operative Hospital, Thalassery	11.765137	75.479859
S6	Dharmadam	11.776638	75.455309
S7	Edakkad Beach	11.808048	75.432379
S8	Aadi Kadalayi Beach	11.838207	75.404228
S9	Mapila Bay Harbour	11.858546	75.376928
S10	Kannur New Bus Stand	11.865938	75.374405
S11	Payyambalam Beach	11.869632	75.352376
S12	Valapattanam	11.93025	75.341374
S13	Azhikkal Port Jetty	11.935248	75.331879
S14	Azhikkal	11.940422	75.298398
S15	Pazhayangadi	12.021101	75.27977
S16	Chootad Beach	12.022993	75.230058
S17	Thaliparamba	12.039966	75.356653
S18	Kuppam Bridge	12.048833	75.345656
S19	Perumba	12.098552	75.221173
S20	Payyanur Rly Road	12.104223	75.202829

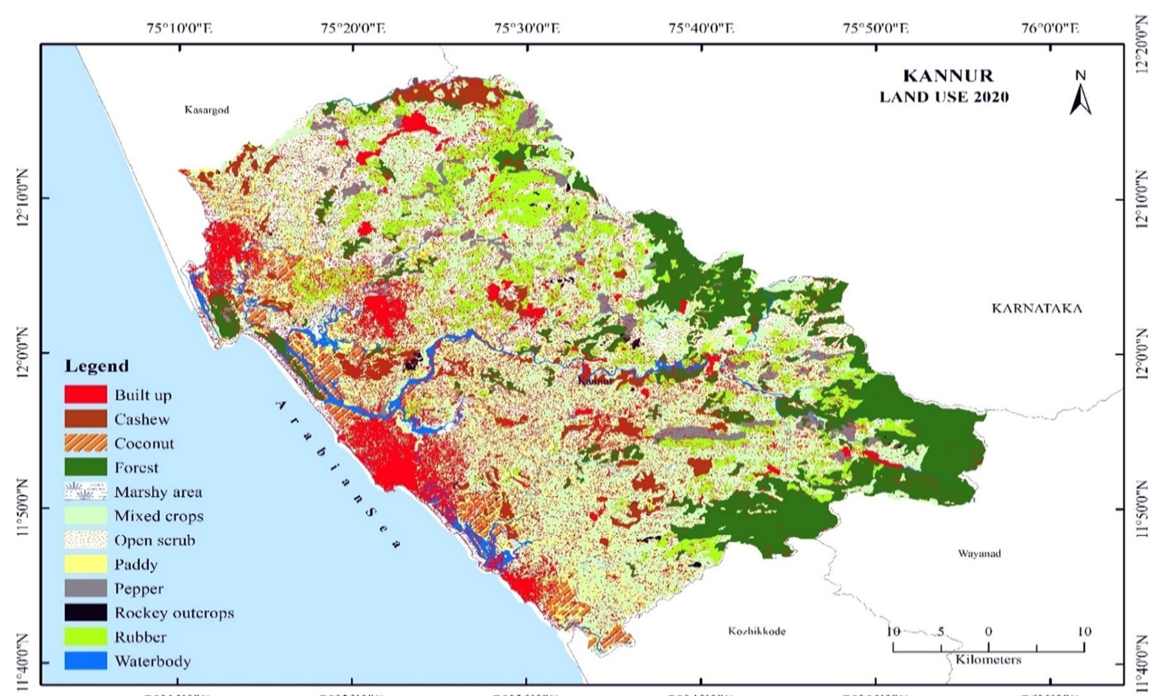

Fig. 2 Land use/land cover classification of Kannur

the anthropogenic activities. The enrichment factor is calculated based on a reference element concentration, which can be taken from local sites, where there is the deposition under similar conditions in the past without having any anthropogenic intrusion or from the composition of average in the regional or global level. In general, most of the studies use Fe or Al as the reference element. In the present study, Fe is taken as the reference element for the assessment of enrichment factor. The following equation is used to calculate the enrichment factor:

$$\mathrm{EF} = \frac{(C_x/C_{\mathrm{Fe}})_{\mathrm{sediment}}}{(C_x/C_{\mathrm{Fe}})_{\mathrm{reference\ value}}}$$

where $(C_x/C_{\mathrm{Fe}})_{\mathrm{sediment}}$ and $(C_x/C_{\mathrm{Fe}})_{\mathrm{reference\ value}}$ denote the concentration ratios of element 'x' to Fe in sediment sample and unpolluted reference baseline, respectively. The soil quality can be classified based on enrichment factor as shown in Table 2.

Contamination factor (CF)

The contamination factor is the ratio of metal concentration in the sediment sample to the reference value of that metal. This calculation is used to identify the pollution levels in the soil by the presence of heavy metals. This soil sample contamination can be measured using the contamination factor. This can be calculated using the following relation.

$$\mathrm{CF} = \frac{(C_x)_{\mathrm{sediment}}}{(C_x)_{\mathrm{reference}}}$$

where $(C_x)_{\mathrm{sediment}}$ refers to the concentration of element 'x' and $(C_x)_{\mathrm{reference}}$ is the concentration of reference element. The level of contamination can be classified on the basis of CF as shown in Table 3.

Geo-accumulation index (I_{geo})

The geo-accumulation index was proposed by Muller, a German scientist in the year 1979, to determine the concentration of accumulation of metal in the sediments by comparing the present with pre-industrial levels. This can be used to determine the contamination of aquatic sediments by organic and inorganic substances. The geo-accumulation index can be calculated by the following relation.

$$I_{\mathrm{geo}} = \log_2\left(\frac{Cx}{1.5 \times Bx}\right)$$

where Cx is the concentration of metal '*x*' in the sediment and Bx is the geo-chemical background value of metal '*x*'. The factor 1.5 is used in the equation to compensate the variations in background data due to lithogenic effects. The pollution intensity can be classified on the basis of I_{geo} as shown in Table 4.

Pollution load index (PLI)

Pollution load index (PLI) is used to determine the integrated pollution level of combined toxicant pollutants present in the soil samples and provide the extend of pollution by heavy metals in the soil. It is also used to assess the overall soil toxicity. The following equation is used to calculate pollution load index.

$$\mathrm{PLI} = [\mathrm{CF}_1 \times \mathrm{CF}_2 \times \mathrm{CF}_3 \times \cdots \times \mathrm{CF}_n]^{1/n}$$

where CF_n is the value of contamination factor for metal '*n*' and '*n*' is the number of metals present in the analysis. The classification of pollution level on the basis of PLI is shown in Table 5.

Table 2 Classification of enrichment factor

Enrichment factor	Soil quality
EF < 2	Deficiency to minimal enrichment
2 < EF < 5	Moderate enrichment
5 < EF < 20	Significant enrichment
20 < EF < 40	Very high enrichment
EF > 40	Extremely high enrichment

Veerasingam et al. (2012) and Petrelli et al. (2016)

Table 3 Classification of contamination factor

Contamination factor	Contamination level
CF < 1	Low contamination
1 ≤ CF < 3	Moderate contamination
3 ≤ CF < 6	Considerable contamination
CF > 6	Very high contamination

Vineethkumar et al. (2020) and Sheela et al. (2012)

Table 4 Classification of geo-accumulation index

Geo-accumulation index	I_{geo} class	Pollution intensity
> 5	6	Very strongly polluted
> 4–5	5	Strong to very strongly polluted
> 3–4	4	Strongly polluted
> 2–3	3	Moderately to strongly polluted
> 1–2	2	Moderately polluted
> 0–1	1	Unpolluted to moderate polluted
< 0	0	Practically unpolluted

Asa et al. (2013) and Vineethkumar et al. (2020)

Table 5 Classification of pollution load index

Pollution load index	Pollution level
≤ 1	No metal pollution
> 1	Metal pollution exist

(Vineethkumar et al. 2020; Tholkappian et al. 2018)

Table 6 Classification of degree of contamination

C_d levels	Degree of contamination
$C_d < 8$	Low degree of contamination
$8 \le C_d < 16$	Moderate degree of contamination
$16 \le C_d < 32$	Considerable degree of contamination
$C_d \ge 32$	Very high degree of contamination indicating serious anthropogenic pollution

Bramha et al. (2014) and Sivakumar et al. (2016)

Degree of contamination (C_d)

Degree of contamination (C_d) is the sum of all the contamination factors (CF) for a given set of samples. It is calculated using the following relation.

$$C_d = \sum \mathrm{CF}$$

where CF is the contamination factor. The classification of contamination status on the basis of modified degree of contamination is shown in Table 6.

Results

The concentration of heavy metals in the soil samples collected from different locations of Kannur district is given in Table 7. The pollution indices such as enrichment factor, contamination factor, geo-accumulation index, pollution load index, and degree of contamination are summarized in Tables 8, 9, 10 and 11, respectively. The spatial distribution of heavy metals in the soil samples collected from different parts of Kannur district is shown in Fig. 3. The spatial distribution of enrichment factor, contamination factor, geo-accumulation index, pollution load index and degree of contamination is given in Figs. 4, 5, 6 and 7, respectively.

Discussion

The concentration of Pb in soil samples collected from different environs of Kannur district ranges from 7.3 ppm (Chootad Beach) to 725.1 ppm (Kannur New Bus Stand)

Table 7 Concentration of heavy metals in soil samples of Kannur district

Sample ID	Sampling location	Pb (ppm)	As (ppm)	Hg (ppm)	Cd (ppm)	Zn (ppm)	Fe (ppm)
S1	New Mahe Beach	17.1	3.4	0.9	0.4	12.4	23,876.6
S2	Punnol Beach	11.2	0.8	0.7	0.4	2.1	18,954.8
S3	Thalassery Harbour	327.3	11.2	8.6	0.7	112.3	65,798.3
S4	Thalassery Market	647.3	17.8	11.7	6.4	189.3	86,574.5
S5	Co-operative Hospital, Thalassery	478.4	19.3	9.1	2.3	134.2	78,564.2
S6	Dharmadam Beach	45.3	1.8	1.6	0.8	14.3	13,897.3
S7	Edakkad Beach	8.4	0.7	0.7	0.5	1.5	16,457.1
S8	Aadi Kadalayi Beach	19.8	0.8	0.6	0.6	6.5	13,478.4
S9	Mapila Bay Harbour	234.7	13.2	1.1	1.3	75.6	58,724.2
S10	Kannur New Bus Stand	725.1	21.3	12.4	7.3	210.4	97,874.3
S11	Payyambalam Beach	16.3	0.9	0.7	0.4	7.5	14,657.1
S12	Valapattanam	456.5	4.5	6.4	1.4	124.3	42,664.2
S13	Azhikkal Port Jetty	513.8	16.8	8.7	4.6	98.4	84,235.3
S14	Azhikkal	478.3	14.3	6.5	4.3	112.4	65,427.6
S15	Pazhayangadi	98.3	1.2	1.1	0.8	12.3	24,983.3
S16	Chootad Beach	7.3	0.8	0.8	0.3	4.3	11,564.2
S17	Thaliparamba	398.9	14.8	7.3	1.9	126.7	65,124.5
S18	Kuppam Bridge	75.4	2.7	4.1	0.9	90.2	58,463.4
S19	Perumba	24.8	12.4	2.3	0.8	64.2	47,569.3
S20	Payyanur Rly Road	156.3	8.7	4.3	1.4	63.5	34,785.6
Minimum		7.3	0.7	0.6	0.3	1.5	11,564.2
Maximum		725.1	21.3	12.4	7.3	210.4	97,874.3
Mean		237.025	8.37	4.48	1.875	73.12	46,183.71
Standard Deviation		242.373	7.341	4.020	2.084	64.990	28,323.77

Table 8 Enrichment factor

Sample ID	Sampling location	Pb (ppm)	As (ppm)	Hg (ppm)	Cd (ppm)	Zn (ppm)
S1	New Mahe Beach	1.69	0.517	4.448	2.636	0.258
S2	Punnol Beach	1.394	0.153	4.358	3.32	0.055
S3	Thalassery Harbour	11.739	0.618	15.423	1.674	0.848
S4	Thalassery Market	17.645	0.746	15.947	11.631	1.086
S5	Co-operative Hospital, Thalassery	14.371	0.892	13.668	4.606	0.849
S6	Dharmadam Beach	7.693	0.47	13.585	9.057	0.511
S7	Edakkad Beach	1.205	0.154	4.302	4.78	0.045
S8	Aadi Kadalayi Beach	3.467	0.189	5.253	7.004	0.24
S9	Mapila Bay Harbour	9.432	0.816	2.21	3.483	0.64
S10	Kannur New Bus Stand	17.484	0.79	14.95	11.735	1.068
S11	Payyambalam Beach	2.625	0.223	5.635	4.294	0.254
S12	Valapattanam	25.252	0.383	17.701	5.163	1.448
S13	Azhikkal Port Jetty	14.395	0.724	12.187	8.592	0.58
S14	Azhikkal	17.252	0.794	11.723	10.34	0.854
S15	Pazhayangadi	9.286	0.174	5.195	5.038	0.245
S16	Chootad Beach	1.49	0.251	8.163	4.082	0.185
S17	Thaliparamba	14.455	0.825	13.227	4.59	0.967
S18	Kuppam Bridge	3.044	0.168	8.275	2.422	0.767
S19	Perumba	1.23	0.946	5.705	2.646	0.671
S20	Payyanur Rly Road	10.604	0.908	14.586	6.332	0.907
Minimum		1.205	0.153	2.21	1.674	0.045
Maximum		17.645	0.946	17.701	11.735	1.448
Mean		9.288	0.537	9.827	5.671	0.624
Standard deviation		7.155	0.299	4.914	3.076	0.390

Table 9 Contamination factor

Sample ID	Sampling location	Pb (ppm)	As (ppm)	Hg (ppm)	Cd (ppm)	Zn (ppm)	Fe (ppm)
S1	New Mahe Beach	0.855	0.262	2.25	1.333	0.131	0.506
S2	Punnol Beach	0.56	0.062	1.75	1.333	0.022	0.402
S3	Thalassery Harbour	16.365	0.862	21.5	2.333	1.182	1.394
S4	Thalassery Market	32.365	1.369	29.25	21.333	1.993	1.834
S5	Co-operative Hospital, Thalassery	23.92	1.485	22.75	7.667	1.413	1.664
S6	Dharmadam Beach	2.265	0.138	4.0	2.667	0.151	0.294
S7	Edakkad Beach	0.42	0.054	1.5	1.667	0.016	0.349
S8	Aadi Kadalayi Beach	0.99	0.054	1.5	2.0	0.068	0.286
S9	Mapila Bay Harbour	11.735	1.015	2.75	4.333	0.796	1.244
S10	Kannur New Bus Stand	36.255	1.638	31.0	24.333	2.215	2.074
S11	Payyambalam Beach	0.815	0.069	1.75	1.333	0.079	0.311
S12	Valapattanam	22.825	0.346	16.0	4.667	1.308	0.904
S13	Azhikkal Port Jetty	25.69	1.292	21.75	15.333	1.036	1.785
S14	Azhikkal	23.915	1.1	16.25	14.333	1.183	1.386
S15	Pazhayangadi	4.915	0.092	2.75	2.667	0.129	0.529
S16	Chootad Beach	0.365	0.062	2.0	1.0	0.045	0.245
S17	Thaliparamba	19.945	1.138	18.25	6.333	1.334	1.38
S18	Kuppam Bridge	3.77	0.208	10.25	3.0	0.949	1.239
S19	Perumba	1.24	0.954	5.75	2.667	0.676	1.008
S20	Payyanur Rly Road	7.815	0.669	10.75	4.667	0.668	0.737
Minimum		0.365	0.054	1.5	1.0	0.016	0.245
Maximum		36.255	1.638	29.25	24.333	2.215	1.834
Mean		11.851	0.643	11.188	6.250	0.770	0.979
Standard deviation		12.119	0.565	10.063	6.946	0.684	0.600

Table 10 Geo-accumulation index

Sample ID	Sampling location	Pb (ppm)	As (ppm)	Hg (ppm)	Cd (ppm)	Zn (ppm)	Fe (ppm)
S1	New Mahe Beach	−4.15	−2.52	0.585	−0.17	−3.523	−1.568
S2	Punnol Beach	−4.427	−4.607	0.222	−0.17	−6.084	−1.901
S3	Thalassery Harbour	−1.354	−0.8	3.841	0.637	−0.344	−0.106
S4	Thalassery Market	−0.766	−0.132	4.285	3.83	0.41	0.29
S5	Co-operative Hospital, Thalassery	−1.062	−0.015	3.923	2.354	−0.087	0.15
S6	Dharmadam Beach	−1.963	−3.437	1.415	0.83	−3.317	−2.349
S7	Edakkad Beach	−4.638	−4.8	0	0.152	−6.57	−2.105
S8	Aadi Kadalayi Beach	−3.113	−4.8	0	0.415	−4.454	−2.393
S9	Mapila Bay Harbour	−1.669	−0.563	0.874	1.531	−0.915	−0.27
S10	Kannur New Bus Stand	−0.779	0.127	4.369	4.02	0.562	0.467
S11	Payyambalam Beach	−3.515	−4.437	0.222	−0.17	−4.248	−2.272
S12	Valapattanam	−0.249	−2.115	3.415	1.637	−0.197	−0.731
S13	Azhikkal Port Jetty	−1.059	−0.215	3.858	3.354	−0.534	0.251
S14	Azhikkal	−0.798	−0.447	3.437	3.256	−0.342	−0.114
S15	Pazhayangadi	−1.692	−4.022	0.874	0.83	−3.534	−1.503
S16	Chootad Beach	−4.332	−4.607	0.415	−0.585	−5.05	−2.614
S17	Thaliparamba	−1.053	−0.398	3.605	2.078	−0.17	−0.121
S18	Kuppam Bridge	−3.301	−2.852	2.773	1.0	−0.66	−0.276
S19	Perumba	−4.608	−0.653	1.939	0.83	−1.15	−0.574
S20	Payyanur Rly Road	−1.5	−1.164	2.841	1.637	−1.166	−1.025
Minimum		−4.638	−4.8	0	−0.585	−6.57	−2.614
Maximum		−0.249	0.127	4.369	4.02	0.562	0.467
Mean		−2.301	−2.123	2.145	1.365	−2.069	−0.938
Standard deviation		1.525	1.895	1.632	1.397	2.282	1.048

with a mean value of 237.03 ppm. The mean value of the concentration of Pb exceeds the crustal average value of 20 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). The enrichment factor of Pb varies in the range 1.21 (Edakkad Beach) to 17.65 (Thalassery Market) with a mean value of 9.29. Significant enrichment of Pb is observed in most of the sampling stations. The contamination factor of Pb varies from 0.37 (Chootad Beach) to 36.26 (Kannur New Bus Stand) with a mean value of 11.85. The results indicate that a very high contamination of Pb is observed in most of the sampling points. Geo-accumulation index of Pb ranges from −4.638 (Edakkad Beach) to −0.249 (Valapattanam) with a mean value of −2.301. The study area is practically unpolluted due to the presence of Pb.

The concentration of As in the collected soil samples varies in the range 0.7 ppm (Edakkad Beach) to 21.3 ppm (Kannur New Bus Stand) with a mean value of 8.37 ppm. The mean value concentration of As is lower than the crustal average value of 13 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). The enrichment factor of As varies from 0.153 (Punnol Beach) to 0.946 (Perumba) with a mean value of 0.537. Deficiency to minimal enrichment of As is observed in all the sampling stations. The contamination factor of As ranges from 0.054 (Edakkad Beach) to 1.638 (Kannur New Bus Stand) with

Table 11 Pollution load index and degree of contamination

Sample ID	Sampling location	PLI	C_d
S1	New Mahe Beach	0.595	5.336
S2	Punnol Beach	0.299	4.129
S3	Thalassery Harbour	3.244	43.636
S4	Thalassery Market	6.825	88.144
S5	Co-operative Hospital, Thalassery	4.942	58.898
S6	Dharmadam Beach	0.728	9.515
S7	Edakkad Beach	0.26	4.005
S8	Aadi Kadalayi Beach	0.382	4.898
S9	Mapila Bay Harbour	2.28	21.874
S10	Kannur New Bus Stand	7.684	97.515
S11	Payyambalam Beach	0.384	4.357
S12	Valapattanam	2.978	46.05
S13	Azhikkal Port Jetty	5.23	66.886
S14	Azhikkal	4.645	58.168
S15	Pazhayangadi	0.782	11.083
S16	Chootad Beach	0.282	3.717
S17	Thaliparamba	4.111	48.38
S18	Kuppam Bridge	1.746	19.416
S19	Perumba	1.52	12.294
S20	Payyanur Rly Road	2.249	25.306
Minimum		0.26	3.717
Maximum		7.684	97.515
Mean		2.558	31.680
Standard deviation		2.317	29.803

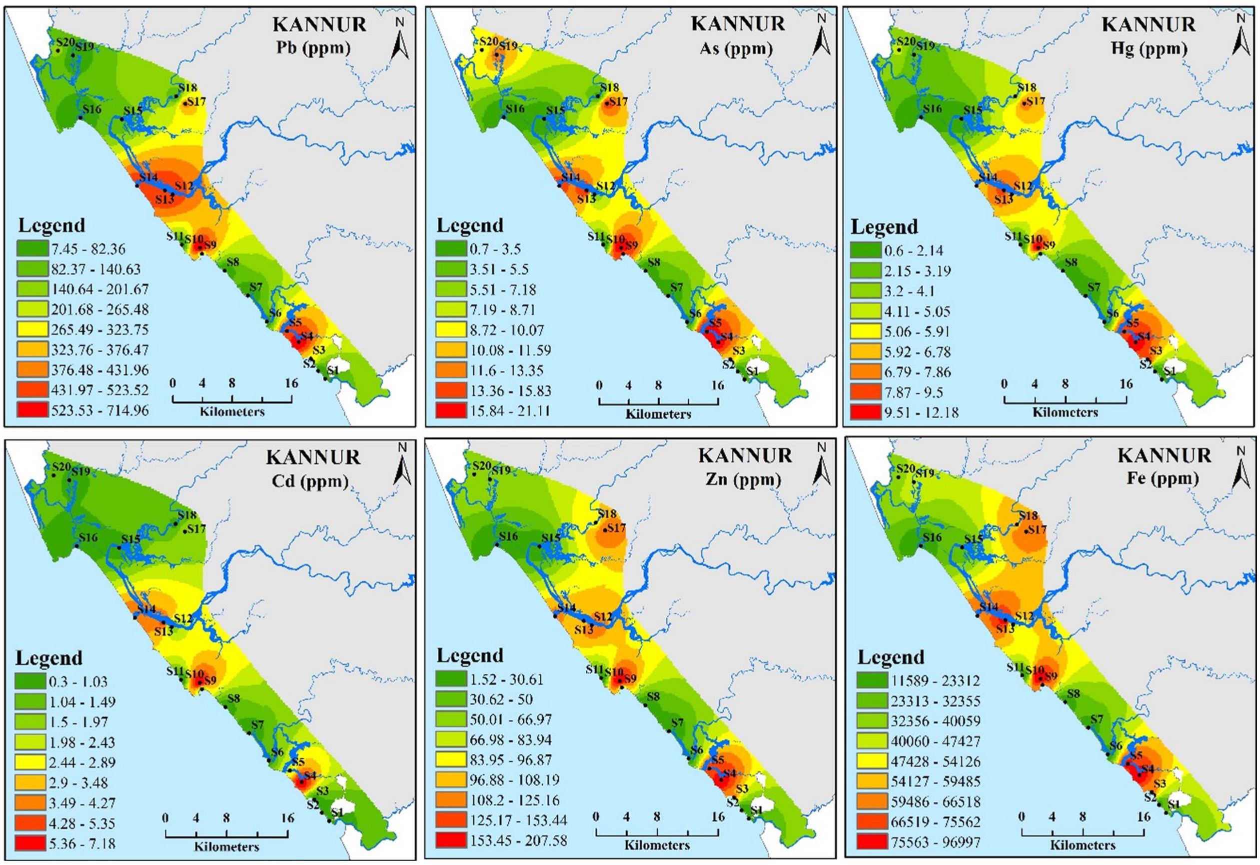

Fig. 3 Spatial distribution of heavy metals in soil samples of Kannur district

a mean value 0.643. From the results, it is clear that the study area is less contaminated by the presence of As. Geo-accumulation index of As ranges from − 4.8 (Edakkad Beach and Aadi Kadalayi Beach) to 0.127 (Kannur New Bus Stand) with a mean value of − 2.123. The major towns of Kannur district are practically unpolluted due to the presence of As except Kannur New Bus Stand region. This area comes under the classification of unpolluted to moderately polluted by the presence of As.

The concentration of Hg in the soil samples varies from 0.6 ppm (Aadi Kadalayi Beach) to 12.4 ppm (Kannur New Bus Stand) with a mean value of 4.48 ppm. The mean value of the concentration of Hg is higher than the suggested crustal average value of 0.4 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). The enrichment factor of Hg ranges from 2.21 (Mapila Bay Harbour) to 17.70 (Valapattanam) with a mean value of 9.83. Significant enrichment of Hg is observed in most of the sampling stations. The contamination factor of Hg varies in the range 1.5 (Edakkad Beach and Aadi Kadalayi Beach) to 29.25 (Thalassery Market) with a mean value of 11.19. Very high contamination of Hg is observed in most of the sampling stations. Geo-accumulation index of Hg varies from zero (Edakkad Beach and Aadi Kadalayi Beach) to 4.369 (Kannur New Bus Stand) with a mean value of 2.145. Most of the sampling locations are strongly polluted due the presence of Hg.

The concentration of Cd in the collected soil samples ranges from 0.3 ppm (Chootad Beach) to 6.4 ppm (Kannur New Bus Stand) with a mean value of 1.88 ppm. The mean value of the concentration of Cd is higher than the crustal average value of 0.3 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). The enrichment factor of Cd varies in the range 1.67 (Thalassery Harbour) to 11.74 (Kannur New Bus Stand) with a mean value of 5.67. Moderate enrichment of Cd is observed in most of the sampling stations. The contamination factor of Cd varies from 1.0 (Chootad Beach) to 24.33 (Kannur New Bus Stand) with a mean value of 6.25. Moderate contamination of Cd is observed in most of the sampling stations. Geo-accumulation index of Cd ranges from − 0.585 (Chootad Beach) to 4.02 (Kannur New Bus Stand) with a mean value of 1.365. Major portion of the study area falls

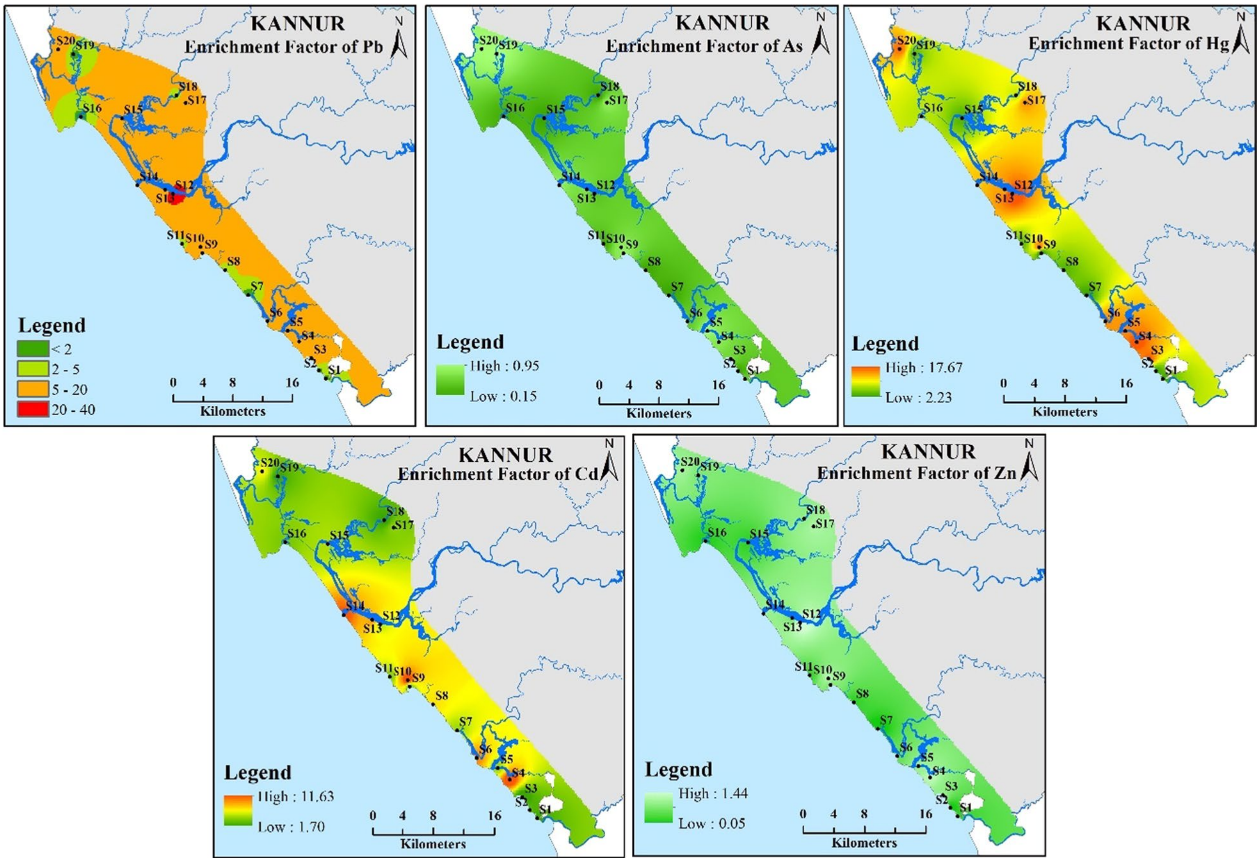

Fig. 4 Spatial distribution of enrichment factor of heavy metals

under practically unpolluted category with the presence of Cd.

The concentration of Zn in the collected soil samples varies in the range 1.5 ppm (Edakkad Beach) to 210.4 ppm (Kannur New Bus Stand) with a mean value of 73.12 ppm. The mean value of the concentration of Zn is lower than the suggested crustal average value of 95 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). The enrichment factor of Zn ranges from 0.05 (Edakkad Beach) to 1.45 (Valapattanam) with a mean value 0.62. Deficiency to minimal enrichment of Zn is observed in most of the sampling stations. The contamination factor of Zn varies from 0.016 (Edakkad Beach) to 2.215 (Kannur New Bus Stand) with a mean value of 0.77. Low contamination of Zn is noticed in most of the sampling points in the study area. Geo-accumulation index of Zn ranges from −6.57 (Edakkad Beach) to 0.562 (Kannur New Bus Stand) with a mean value of −2.069. All the area under present study is practically unpolluted except Kannur New Bus Stand and Thalassery Market region.

The concentration of Fe in the collected soil samples varies from 11,564.2 ppm (Chootad Beach) to 97,874.3 ppm (Kannur New Bus Stand) with a mean value of 46,183.71 ppm. The mean value of the concentration of Fe is lower than the crustal average value of 47,200 ppm (Turkian and Wedpohl 1961; Vineethkumar et al. 2020). Contamination factor of Fe ranges from 0.245 (Chootad Beach) to 1.834 (Thalassery Market), with a mean value of 0.979. The contamination of Fe is low in most of the sampling locations. Geo-accumulation index of Fe varies from −2.614 (Chootad Beach) to 0.467 (Kannur New Bus Stand) with a mean value of −0.938. Most of the study area is practically unpolluted due the presence of Fe.

The pollution load index and degree of contamination are shown in Table 11. The pollution load index varies from 0.26 (Edakkad Beach) to 7.684 (Kannur New Bus Stand) with a mean value of 2.558. The results indicate that severe heavy metal pollution exists in the sampling locations such as Thalassery Harbour, Thalassery Market, Co-operative Hospital Thalassery, Mapila Bay Harbour, Kannur New Bus Stand, Valapattanam, Azhikkal Port Jetty, Azhikkal, Thaliparamba, Kuppam Bridge, Perumba, and Payyanur Railway Station Road. The degree of

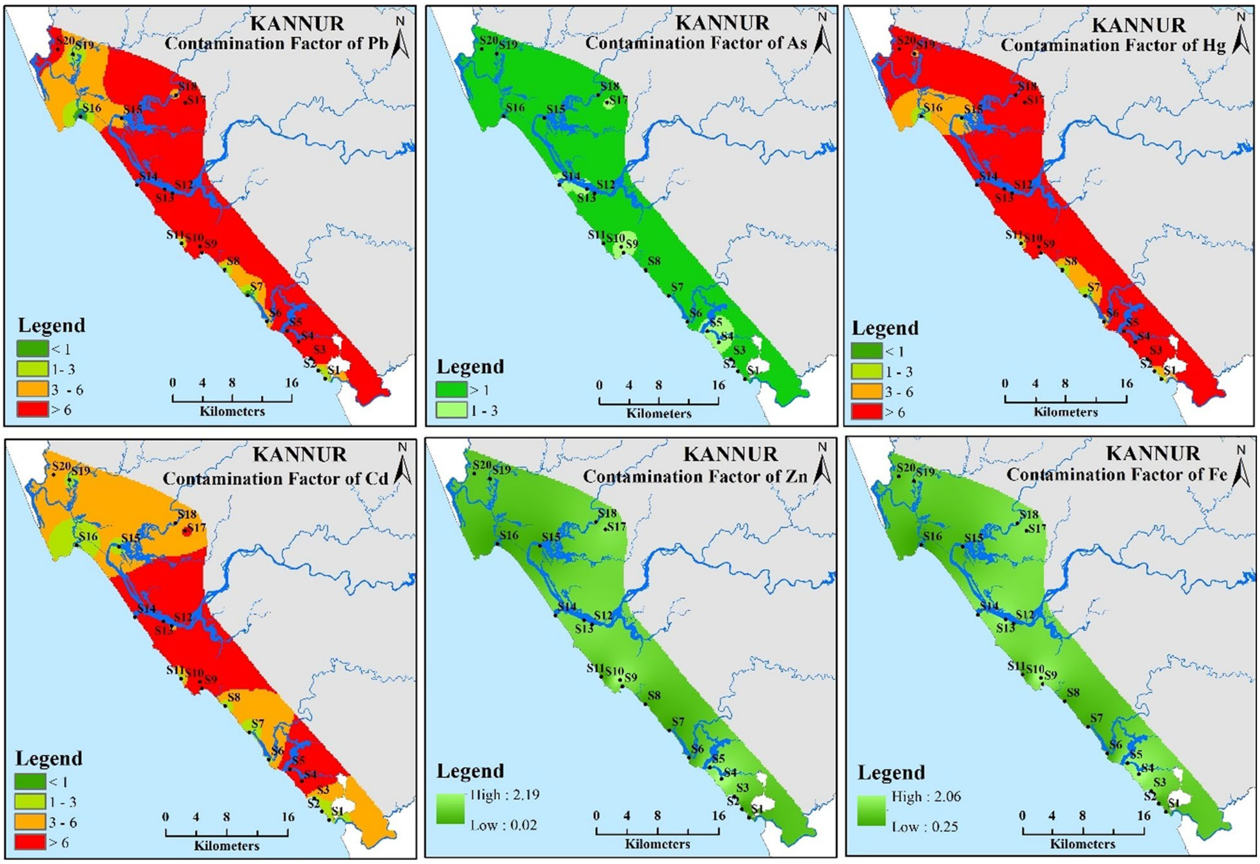

Fig. 5 Spatial distribution of contamination factor of heavy metals

contamination ranges from 3.717 (Chootad Beach) to 97.515 (Kannur New Bus Stand) with a mean value of 31.68. A very high degree of contamination due to heavy metals is observed in the sampling locations such as Thalassery Market, Co-operative Hospital Thalassery, Kannur New Bus Stand, Valapattanam, Azhikkal Port Jetty, Azhikkal, and Thaliparamba, and it indicates that a serious anthropogenic pollution is present in these regions.

Conclusions

The study shows that the primary source of heavy metal contamination in the study area is mostly by the anthropogenic activities due to the rapid increase of urbanization in Kannur district. The enhanced level of heavy metal concentration in the major towns of Kannur district shows how far the process of urbanization has made an impact of contaminating the environment. The improper solid waste management and untreated wastewater disposal in and around the study area influence the heavy metal contamination. The wastewater treated in treatment plants before discharging to the nearby waterbodies will improve the water quality in that region. With further development in the process of urbanization in the district, greater attention should be paid to decrease the contamination of heavy metals due to the anthropogenic activities. A detailed masterplan for solid waste management and wastewater treatment for each city and periodical evaluation of pollutant origins and development of practical strategies for remediating pollutants discharge is needed to reduce the heavy metal contamination in the study area.

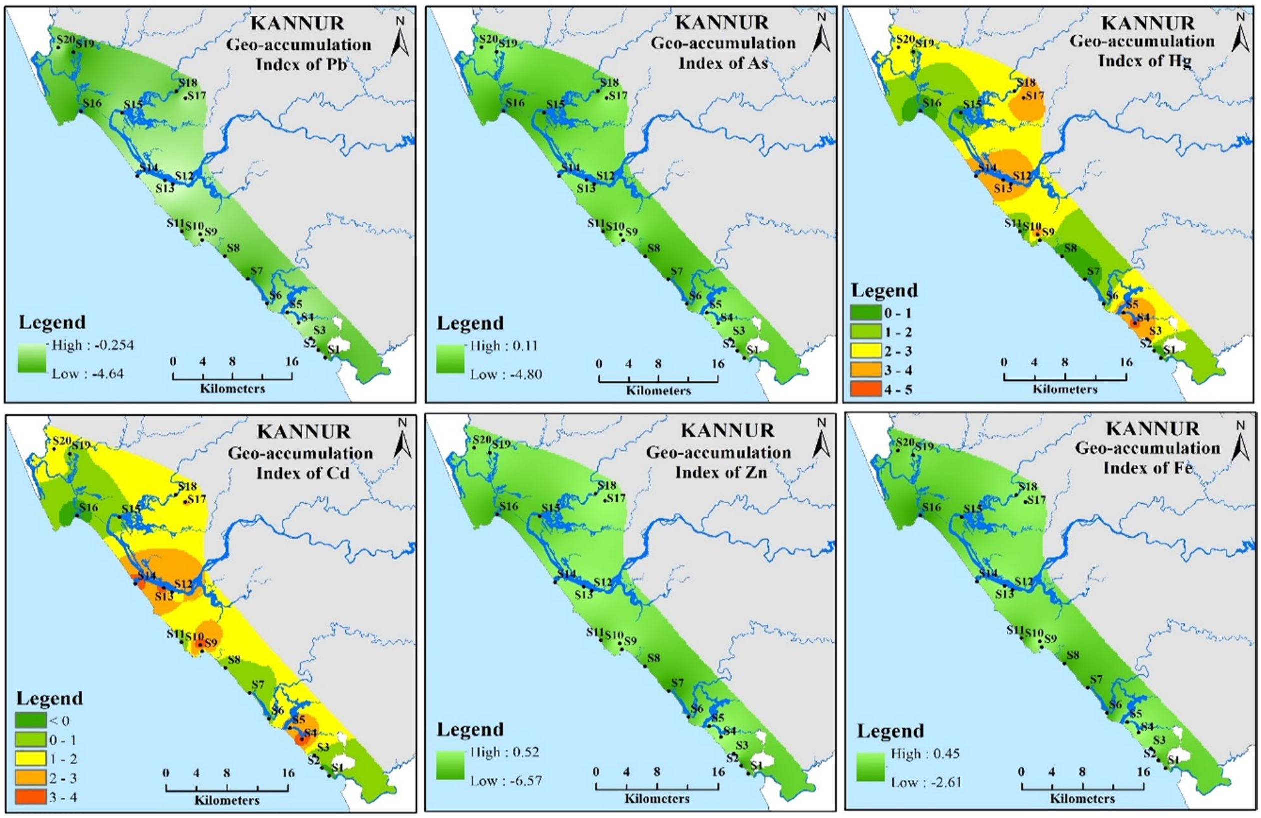

Fig. 6 Spatial distribution of geo-accumulation index of heavy metals

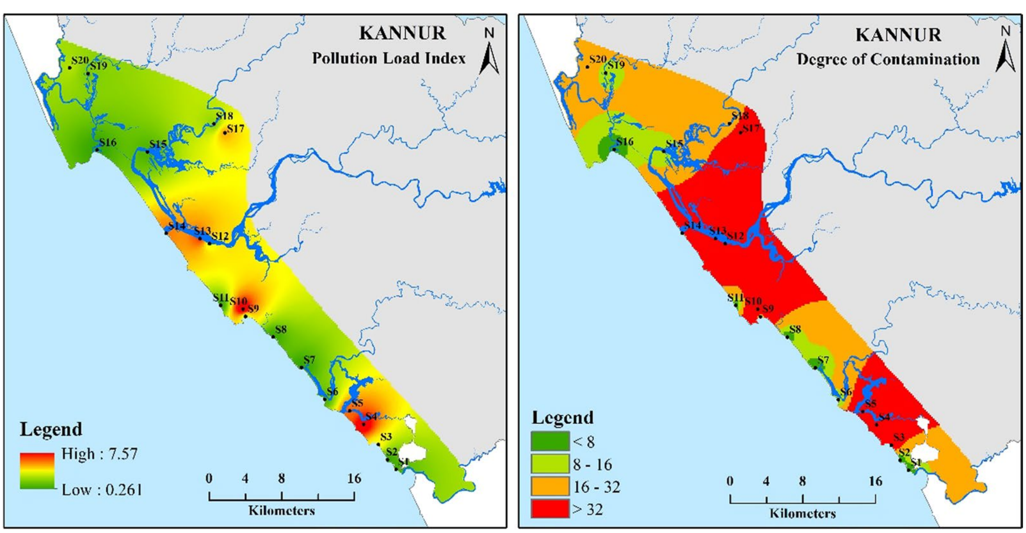

Fig. 7 Spatial distribution of pollution load index and degree of contamination

Abbreviations

XRF: X-ray fluorescence spectrometer; GNSS: Global Navigation Satellite System; Arc GIS: Area coded geographic information system; LULC: Land use/land cover; kg: Kilogram; EF: Enrichment factor; CF: Contamination factor; I_{geo}: Geo-accumulation index; PLI: Pollution load index; C_d: Degree of contamination; ppm: Parts per million.

Acknowledgements

The technical help received from Mr. Mithun Raj P. R. is gratefully acknowledged.

Authors' contributions

The sample collection and mineral analysis have carried out by the authors KPS and VV. Analysis and interpretation of the data were done by KPS, TKP, and GJ. The cartographic analysis of the study was executed by KPS and TKP. The major contributors in writing manuscript were KPS and VV. All authors read and approved the final manuscript.

Funding

The work was self-funded by the authors.

Availability of data and materials

All data generated or analysed during the present investigation are included in this published article.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Geography, Kannur University, Payyanur Campus, Edat, Kannur, Kerala 670327, India. [2]Department of Studies and Research in Physics, Payyanur College, Edat, Kannur, Kerala 670327, India.

Received: 7 October 2021 Accepted: 19 December 2021
Published online: 04 January 2022

References

Abbas ST, Sarfraz M, Mehdi SM, Hassan G (2007) Trace elements accumulation in soil and rice plants irrigated with the contaminated water. Soil Tillage Res 94:503–509

Alam MGM, Snow ET, Tanaka A (2003) Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Total Environ 308:83–96

Alfaifi H, El-Sorogy AS, Qaysi S, Kahal A, Almadani S, Alshehri F, Zaidi FK (2021) Evaluation of heavy metal contamination and groundwater quality along the Red Sea coast, southern Saudi Arabia. Mar Pollut Bull 163:111975

Asa SC, Rath P, Panda UC, Parhi PK, Bramha S (2013) Application of sequential leaching, risk indices and multivariate statistics to evaluate heavy metal contamination of estuarine sediments: Dhamara Estuary, East Coast of India. Environ Monit Assess 185(8):6719–6737

Banerjee ADK (2003) Heavy metal levels and solid phase speciation in street dusts of Delhi, Delhi. Environ Pollut 123:95–105

Bramha SN, Mohanty AK, Satpathy KK, Kanagasabapathy KV, Panigrahi S, Samantara MK, Prasad MVR (2014) Heavy metal content in the beach sediment with respect to contamination levels and sediment quality guidelines: a study at Kalpakkam coast, southeast coast of India. Environ Earth Sci 72(11):4463–4472

Bryan GW, Langston WJ (1992) Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ Pollut 76(2):89–131

Chai M, Li R, Tam NFY, Zan Q (2019) Effects of mangrove plant species on accumulation of heavy metals in sediment in a heavily polluted mangrove swamp in Pearl River Estuary, China. Environ Geochem Health 41(1):175–189

Chandrasekaran A, Rajalakshmi A, Ravisankar R, Vijayagopal P, Venkatraman B (2015) Measurements of natural gamma radiations and effects of physico-chemical properties in soils of Yelagiri hills, Tamilnadu India with statistical approach. Procedia Earth Planet Sci 11:531–538

Cihlar J (2000) Land cover mapping of large areas from satellites: status and research priorities. Int J Remote Sens 21(6–7):1093–1114

Del Mastro AM, Londonio A, Rebagliati RJ, Pereyra M, Dawidowski L, Gómez D, Smichowski P (2015) Plasma-based techniques applied to the determination of 17 elements in partitioned top soils. Microchem J 123:224–229

ELTurk M, Abdullah R, Zakaria RM, Bakar NKA (2019) Heavy metal contamination in mangrove sediments in Klang estuary, Malaysia: implication of risk assessment. Estuar Coast Shelf Sci 226:106266

Feng Peng F, Song YH, Yuan P, Cui X, Qiu G (2009) The remediation of heavy metals contaminated sediment. Hazard Mater 161:633–640

Feng J, Zhu X, Wu H, Ning C, Lin G (2017) Distribution and ecological risk assessment of heavy metals in surface sediments of a typical restored mangrove–aquaculture wetland in Shenzhen, China. Mar Pollut Bull 124(2):1033–1039

Fletcher DE, Lindell AH, Seaman JC, Stankus PT, Fletcher ND, Barton CD, Biemiller RA, McArthur JV (2019) Sediment and biota trace element distribution in streams disturbed by upland industrial activity. Environ Toxicol Chem 38:115–131

Ganugapenta S, Nadimikeri J, Chinnapolla SRRB, Ballari L, Madiga R, Nirmala K, Tella LP (2018) Assessment of heavy metal pollution from the sediment of Tupilipalem Coast, southeast coast of India. Int J Sedim Res 33(3):294–302

Harbison PAT (1986) Mangrove muds—a sink and a source for trace metals. Mar Pollut Bull 17(6):246–250

He B, Yun Z, Shi J, Jiang G (2013) Research progress of heavy metal pollution in China: Sources, analytical methods, status, and toxicity. Chin Sci Bull 58(2):134–140

Hoch M (2001) Organotin compounds in the environment—an overview. Appl Geochem 16(7–8):719–743

Islam MA, Al-Mamun A, Hossain F, Quraishi SB, Naher K, Khan R, Das S, Tamim U, Hossain SM, Nahid F (2017) Contamination and ecological risk assessment of trace elements in sediments of the rivers of Sundarban mangrove forest, Bangladesh. Mar Pollut Bull 124:356–366

Khan AG, Kuek C, Chaudhry TM, Khoo CS, Hayes WJ (2000) Role of plants, mycorrhizae and phytochelators in heavy metal contaminated land remediation. Chemosphere 41(1–2):197–207

Krishna AK, Govil PK (2004) Heavy metal contamination of soil around Pali industrial area, Rajasthan, India. Environ Geol 47:38–44

Krishna AK, Govil PK (2008) Assessment of heavy metal contamination in soils around Manali industrial area, Chennai, Southern India. Environ Geol 54:1465–1472

Krishna AK, Mohan KR, Murthy NN, Periasamy V, Bipinkumar G, Manohar K, Rao SS (2013) Assessment of heavy metal contamination in soils around chromite mining areas, Nuggihalli, Karnataka, India. Environ Earth Sci 70:699–708

Li X, Yeh AG-O (2000) Modelling sustainable urban development by the integration of constrained cellular automata and GIS. Int J Geogr Inf Sci 14(2):131–152

McGrath SP, Zhao FJ, Lombi E (2001) Plant and rhizosphere processes involved in phytoremediation of metal-contaminated soils. Plant Soil 232:207–214

Nagajyoti PC, Lee KD, Sreekanth TVM (2010) Heavy metals, occurrence and toxicity for plants: a review. Environ Chem Lett 8(3):199–216

Nasehi F, Hassani AH, Monavvari M, Karbassi AR, Khorasani N (2013) Evaluating the metallic pollution of riverine water and sediments: a case study of Aras River. Environ Monit Assess 185(1):197–203

Pandey J, Pandey U (2009) Accumulation of heavy metals in dietary vegetables and cultivated soil horizon in organic farming system in relation to atmospheric deposition in a seasonally dry tropical region of India. Environ Monit Assess 148:61–74

Parth V, Murthy NN, Saxena PR (2011) Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city (India): natural and anthropogenic implications. J Environ Res Manag 2(2):027–034

Petrelli M, Laeger K, Perugini D (2016) High spatial resolution trace element determination of geological samples by laser ablation quadrupole plasma mass spectrometry: Implications for glass analysis in volcanic products. Geosci J 20(6):851–863. https://doi.org/10.1007/s12303-016-0007-z
Prakash V, Narayana Y, Saxena M, Deb S, Nagar B, Ramakumar K (2011) Study of transfer of trace elements from soil to medicinal plants in the environment of Mangalore. J Radioanal Nucl Chem 290:103–107
Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK (2005) Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. Agric Ecosyst Environ 109:310–322
Ray AK, Tripathy SC, Patra S, Sarma VV (2006) Assessment of Godavari estuarine mangrove ecosystem through trace metal studies. Environ Int 32(2):219–223
Ribeiro C, Couto C, Ribeiro AR, Maia AS, Santos M, Tiritan ME, Pinto E, Almeida AA (2018) Distribution and environmental assessment of trace elements contamination of water, sediments and flora from Douro River estuary, Portugal. Sci Total Environ 639:1381–1393
Rigaud S, Radakovitch O, Couture R-M, Deflandre B, Cossa D, Garnier C, Garnier J-M (2013) Mobility and fluxes of trace elements and nutrients at the sediment–water interface of a lagoon under contrasting water column oxygenation conditions. Appl Geochem 31:35–51
Ross SM (1994) Toxic metals in soil-plant systems. Wiley, Chichester
Santos IR, Silva-Filho EV, Schaefer CE, Albuquerque-Filho MR, Campos LS (2005) Heavy metal contamination in coastal sediments and soils near the Brazilian Antarctic Station, King George Island. Mar Pollut Bull 50(2):185–194
Sayooj VV, Vineethkumar V, Ramesh S, Prakash V (2020) Dynamics of heavy metal accumulation in an endosulfan affected area of Kasaragod district, southwest coast of India. Radiat Prot Environ 43:44
Seaward MRD, Richardson DHS (1989) Atmospheric sources of metal pollution and effects on vegetation. In: Heavy metal tolerance in plants: evolutionary aspects, pp 75–92
Sekabira K, Origa HO, Basamba TA, Mutumba G, Kakudidi E (2010) Assessment of heavy metal pollution in the urban stream sediments and its tributaries. Int J Environ Sci Technol 7(3):435–446
Sharma OP, Bangar KS, Jain R, Sharma PK (2004) Heavy metals accumulation in soils irrigated by municipal and industrial effluent. J Environ Sci Eng 46:65–73
Sheela AM, Letha J, Joseph S, Thomas J (2012) Assessment of heavy metal contamination in coastal lake sediments associated with urbanization: Southern Kerala, India. Lakes Reserv Res Manag 17(2):97–112
Sin SN, Chua H, Lo W, Ng LM (2001) Assessment of heavy metal cations in sediments of Shing Mun River, Hong Kong. Environ Int 26(5–6):297–301
Sivakumar S, Chandrasekaran A, Balaji G, Ravisankar R (2016) Assessment of heavy metal enrichment and the degree of contamination in coastal sediment from South East Coast of Tamilnadu, India. J Heavy Met Toxic Dis 1(2):1–8
Tam NFY, Wong YS (1996) Retention and distribution of heavy metals in mangrove soils receiving wastewater. Environ Pollut 94(3):283–291
Tam NF, Wong Y-S (1997) Accumulation and distribution of heavy metals in a simulated mangrove system treated with sewage. In: Asia-Pacific conference on science and management of coastal environment, pp 67–75
Tholkappian M, Ravisankar R, Chandrasekaran A, Jebakumar JPP, Kanagasabapathy KV, Prasad MVR, Satapathy KK (2018) Assessing heavy metal toxicity in sediments of Chennai Coast of Tamil Nadu using Energy Dispersive X-Ray Fluorescence Spectroscopy (EDXRF) with statistical approach. Toxicol Rep 5:173–182
Tokman N, Akman S, Ozeroglu C (2004) Determination of lead, copper and manganese by graphite furnace atomic absorption spectrometry after separation/concentration using a water-soluble polymer. Talanta 63(3):699–703
Turkian KK, Wedpohl KH (1961) World geochemical background value in average shale for metals in stream sediments. Geol Soc Am Bull 72:175–191
Veerasingam S, Venkatachalapathy R, Ramkumar T (2012) Heavy metals and ecological risk assessment in marine sediments of Chennai, India. Carpathian J Earth Environ Sci 7(2):111–124
Veeresh H, Tripathy S, Chaudhuri D, Hart BR, Powell MA (2003) Competitive adsorption behavior of selected heavy metals in three soil types of India amended with fly ash and sewage sludge. Environ Geol 44:363–370
Vineethkumar V, Sayooj VV, Shimod KP, Prakash V (2020) Estimation of pollution indices and hazard evaluation from trace elements concentration in coastal sediments of Kerala, Southwest Coast of India. Bull Natl Res Centre 44(1):198. https://doi.org/10.1186/s42269-020-00455-0
Wang Q, Hong H, Yang D, Li J, Chen S, Pan C, Lu H, Liu J, Yan C (2020) Health risk assessment of heavy metal and its mitigation by glomalin-related soil protein in sediments along the South China coast. Environ Pollut 263:114565
Zhao G, Lu Q, Ye S, Yuan H, Ding X, Wang J (2016) Assessment of heavy metal contamination in surface sediments of the west Guangdong coastal region, China. Mar Pollut Bull 108:268–274. https://doi.org/10.1016/j.marpolbul.2016.04.057

Publisher's Note