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

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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

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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 pedogenic process of weathering of parental rock materials in the environment. The natural distribution of heavy metals depends on the environmental conditions and the bedrock 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). Anthropicogenic 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 ArcGIS 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 m² area was marked for the sample
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       | Kuppm 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:

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

where \((C_x/C_{Fe})_{sediment}\) and \((C_x/C_{Fe})_{reference\ value}\) 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.

\[ CF = \frac{(C_x)_{sediment}}{(C_x)_{reference}} \]

where \((C_x)_{sediment}\) refers to the concentration of element ‘x’ and \((C_x)_{reference}\) 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.

\[ I_{geo} = \log_2 \left( \frac{C_x}{1.5 \times B_x} \right) \]

where \(C_x\) is the concentration of metal ‘x’ in the sediment and \(B_x\) 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.

\[ PLI = [CF_1 \times CF_2 \times CF_3 \times \cdots \times CF_n]^{1/n} \]

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)
Degree of contamination ($Cd$)

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

$$Cd = \sum CF$$

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) indicating serious anthropogenic pollution.

### 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

| $Cd$ levels | Degree of contamination      |
|-------------|------------------------------|
| $Cd < 8$    | Low degree of contamination  |
| 8 ≤ $Cd$ < 16 | Moderate degree of contamination |
| 16 ≤ $Cd$ < 32 | Considerable degree of contamination |
| $Cd$ ≥ 32  | Very high degree of contamination indicating serious anthropogenic pollution |

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

### 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        | Ponnol 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    | 163.5    | 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       | Perumbra              | 24.8     | 12.4     | 2.3      | 0.8      | 64.2     | 47,589.3 |
| 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       | Pazhuyangadi              | 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       | Pazhuyangadi              | 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    |
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 soils 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 (Perumamba) 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 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   | −0.016   |
| 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            | −6.638   | −4.8     | 0        | 0.152    | −6.57    | −2.105   |
| S8        | Aadi Kadalayi Beach      | −3.113   | −4.8     | 0        | 0.415    | −4.454   | −2.933   |
| 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       | Thalparamba              | −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                   | 1.213    | 2.145    | 1.365    | −2.069   | −0.938   |
| Standard deviation | 1.525 | 1.895 | 1.632 | 1.397 | 2.282 | 1.048 |

### Table 11 Pollution load index and degree of contamination

| Sample ID | Sampling location        | PLI | $C_a$ |
|-----------|--------------------------|-----|-------|
| 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 | 4.988 |
| 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       | Thalparamba              | 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 |       |
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 to 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 1.0 (Chootad Beach) to 24.33 (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...
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
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; Cgeo: Geo-accumulation index; PLI: Pollution load index; Ceq: Degree of contamination; ppm: Parts per million.

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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.

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Not applicable.

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Competing interests
The authors declare that they have no competing interests.

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