Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

DISTRIBUTION PATTERN OF HEAVY METALS IN ROADSIDE SOILS ALONG THE MAJOR HIGHWAYS PASSING THROUGH LUCKNOW DISTRICT, UTTAR PRADESH, INDIA

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Abstrat- *In present study spatial distribution and contamination assessment ofheavy metals in roadside soils along the three main highways of Lucknow disrict was conducted. A total of 270 surface soil samples were collected along the three main highwaysduring winter, summer and monsoon season at three different distances from the highways.The soil samples were digested by $HClO_4$, HF, HNO_3 followed by atomic absorption spectrophotometer for the analysis of heavy metals.Average concentrations of Fe, Mn, Pb, Ni, Zn, Cu &Cd in surface soils being 10253.24±2342.7, 72.10±14.09, 13.22±5.15, 4.80±1.82,64.78±21.60,12.27±5.35 and 0.16±0.07µg/g respectively.Results show that concentration of heavy metals tends to decrease with increasing distance from the highways.Correlation matrix analysis explains thatZn/Cu, Zn/Pb, Fe/Zn, Fe/Cu& Cd/Ni pair showssignificant positive correlation andimpliesthat major source for heavy metals in roadside environment arevehicular activities. Overall decreasing order for heavy metal contamination for all distances is as follows: Zn>Fe >Cu >Pb>Cd>Ni>Mn.Pollution load index is more than double for all three highways.Concentrations of metals in surface soils are in safe limits of Indian standard for agriculture soil but higher than the background values. Soil pH ranging from 7.12-8.82 shows alkaline dust depositions in surface soils. Organic carbon % values from 130.12-638.00 suggests that road side soils are important sink of nearby organic matter.*

Keywords-*Heavy metals, Spatial distribution, Contamination factor, Pollution Load Index, Background Values.*

I. INTRODUCTION

Highways are roads linking two cities and towns, encouraging trade, exchanging cultures between them and allowing people to travel from one place to another.National highwaysalways carry a hightraffic load so the adjacent surroundings along the highways receives large quantities of pollutants like particulate matter viz. PM_{10}, $PM_{2.5}$ & Ultrafine Particles, gaseous pollutants viz. oxides of nitrogen& sulphur, toxic organic hydrocarbons and inorganic pollutants like heavy metals etc. which can be accumulated nearby environment(1)(2)(3)(4). Among all these pollutant heavy metals are of particular concern because of having long persistence period and subsequent accumulation in soil which ultimately creates toxicity in to all the environment components.Heavy metals are naturally present in soils up to a certain level butanthropogenic sources like vehicular emission, industrial emission, incineration activities, construction & demolition activities, solid waste dumpingand domestic emission contribute various kinds of heavy metals in to the environment.Above all roadside soilsgreatly influence by vehicular generated heavy metalsin the form offuel emission, tire& brakepad wear particles, corrosion of metallic parts & paints and abrasion of road surface etc.(5)(6).Cu and Zn is mainly released from the brake linings& tyre wear. Brake dust and crushed brake pad analyses indicate high concentrations of Fe and Cu(7)(8)(9). Apart from the use of leaded gasoline in past, trace amount of Pbfound in engine & lubrication oil is responsible for Pb deposition in road side soil (10).Now–a-days nickel chrome scratch and rust proof painting all over the vehicular body is the main source of Ni, Cd, Crand Pb in the roadside soil environment (11).

The heavy metals transport into the soil environment mainly via dry &wet deposition (12).Several studies investigated the correlation between the metal depositionat roadside soils and different distances from the roads and various researches have shown thatmetal concentrations decrease as the distances increases from the road (13)(14).Accumulation of heavy metals in soils and plants determined byvarious other factorslike soil pH, organic matter and clay content (15). People, who live, work and walk near highways experiencesmore adverse effects which mainly include respiratory dysfunction, skin problems, nervous&cardiovascular system disorders, immune system suppression and the risk of cancer in later life (16)(17)(18).In particular , children are more vulnerable than adults because of their frequent hand – to-mouth activities (finger sucking) and their higher absorption rate from the digestion system, and haemoglobin sensitivity to toxic metals (19).

The population and number of vehiclesare increasing day by day; therefore,the concentration of heavy metals inroadside environment is also increasing.Moreover,now-a-daysconstruction of small scale industries, residentialbuildings & commercial centres near highwaysare very common practice in Lucknow District due to easy connectivity. Thus roadside soils are act as an indicator of urban pollution.The main aim of this research is to find outthe concentration and contamination level of heavy metals in theroadside surface soil along the highways of the Lucknow district. Statistical parameters like average, standard deviation and Correlation matrix is applied to different variables. Furthermore, in thefuture, this study willalso help to make plan and policies for the remediation and pollution free environment.

II. MATERIALS AND METHODS

Lucknow district is located along the Gomati River which a part of Central Ganga Plain. The district lies at 26°30' and 27°10'N and 80°30'and 81°13'E latitudes and occupies an area of 2,528 sq. km with total population of 34 lakhs as per 2011 census. General elevation of the district varies between 103 and 130 metres above mean sea level. Lucknow district has a well connected system of roads and five national highways pass through the district.

2.1 Sample collection

Three main national highways (NH-24, NH-28 &NH-25) were chosen for the surface soil sampling. On each highway five sampling points were chosen for the collection of surface soils.From each sampling points samples were collected from both sides of the highway road. A total of 90 surface soil samples were collected from each highway in all three seasons. The soil sampling was avoided from places of disturbances like places where soils were burrowed by animals and places used for landfills, dumping sites etc. For surface soil sampling, firstly the dirt and other residues at the surface were removed then soil was collected from 0-10 cm depth. To determine spatial distribution surface soil sample were collected at three different distances perpendicular to the highway i.e. 0-2 m, 5-6m and 15-20 m. The soil was digged by a shovel to collect the samples. For comparative study between highways and city centre roads, we collected the roadside dust from the five areas of Lucknow city having high traffic density. The road side dusts were collected with a clean plastic pan and a brush. The soil and dust samples were transferred to self sealing polybags and processed for heavy metals and other physiochemical analysis. For assessing seasonal difference samples were collected in winter (Jan-Fab), summer (May-June) and monsoon season (July- Aug) in the year 2014. For background data (control) Surface soil samples were collected from an unpolluted site in mall area of Lucknow district where there were minimum influence of anthropogenic activities like high traffic emission, industrial activity and solid waste dumping influence. The mean metal concentrations of these samples were taken as local natural background data.

2.2Analysis of samples

The collected soil samples were air-dried and sieved through a 2-mm polyethylene sieve. Soil pH and EC was measured in a soil:water (1:2) suspentionby glass electrode and conductivity electrode respectively (Hanna potable pH/EC/TDS/Temp meter, model no. HI 9813-6). Organic carbon (OC) in the soil samples was determined by Walkley and Black's rapid titration method.For heavy metal analysis, 1gm soil sample were digested using a concentrate acid mixture i.e. HNO_3, $HClO_4$ and HF. The soil digest were filtered and diluted to 50 ml with distilled water. These filtrates were then assessed by atomic absorption spectrophotometer (AAS; Varian Spectra AA-250 Plus). The AAS value of blank (without sample) of each metal was deducted from the sample value for final calculations (20).

2.3Contamination assessment

To assess the extent of contamination of heavy metals in roadside surface soils anddegree of overall contamination for a particular highway and distance, contamination factor (CF) and pollution load index (PLI) has been applied. The calculation ofCF is as follows:

$$\mathbf{CF = Cmetal / Cbackground}$$

Where CF is the contamination factor, C_{metal} is the concentration of pollutant in sediment $C_{background}$ is the background value for the heavy metal. The CF reflects the heavy metal enrichment in the sediment. The CF was classified into four groups i.e. contamination factor CF < 1 refers to low contamination; 1 ≤ CF < 3 means moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination (21).Each land type is evaluated for the extent of heavy metal pollution by calculating the pollution load index (22) as follows:

$$\mathbf{PLI = \sqrt[n]{(CF_1 \times CF_2 \times CF_3 \times .... CF_n)}}$$

Where n is the number of heavy metals studied (seven in this study) and CF is contamination factor of each heavy metal at a particular site. The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denote perfection; PLI = 1 present that only baseline levels of pollutants are present and PLI >1 would indicate deterioration of site quality. Distributionmap of different heavy metals in surface soils along the highway is prepared by using raster interpolation technique in Arc GIS 10software.

III. RESULTS AND DISCUSSION

Average concentration and range for heavy metals and other physiochemical in winter summer & monsoon seasons at 0-2, 5-6 & 15-20 m is represented in Table 1. In this study for surface soil at 0-2m, concentration of iron ranges from 7125.45-15489.15 with an average of 10783.70, concentration of lead ranges from 6.12-28.30 with an average 15.32, concentration of zinc ranges from 40.85-135.63 with an average 73.62, concentration of cadmium ranges from 0.10-

0.355 with an average 0.21, concentration of nickel ranges from 3.12-9.98 with an average 5.75, concentration of copper ranges from 3.36-35.15 with an average 15.10, concentration of manganese ranges from 50.12-125.25 with an average 78.90, concentration of pH ranges from 7.12-8.82 with an average 7.88, concentration of EC ranges from 170.69-638.00 µS with an average 300.50 µS and concentration of organic carbon ranges from 0.0.21-1.53 % with an average 0.80 %.

In this study for surface soil at 5-6m concentration of iron ranges from 7140.56-14969.33 with an average of 10422.40, concentration of lead ranges from 7.02-25.36 with an average 14.27, concentration of zinc ranges from 40.15-130.60 with an average 67.68, concentration of cadmium ranges from 0.08-0.35 with an average 0.17, concentration of nickel ranges from 2.15-9.36 with an average 4.95, concentration of copper ranges from 5.85-22.56 with an average 12.85, concentration of manganese ranges from 45.23-100.15 with an average 70.27, concentration of pH ranges from 7.20-8.55 with an average 7.81 concentration of EC ranges from 150.15-550.12 µS with an average 303.05 µS and concentration of organic carbon ranges from 0.13-1.21 % with an average 0.64 %.

For surface soil at 15-20m, concentration of iron ranges from 6032.15-13256.45 with an average 9553.64, concentration of lead ranges from 4.45-20.16 with an average 10.08, concentration of zinc ranges from 35.12-110.65 with an average 53.03, concentration of cadmium ranges from 0.05-0.20 with an average 0.11, concentration of nickel ranges from 2.02-6.23 with an average 3.71, concentration of copper ranges from 3.52-18.63 with an average 8.87, concentration of manganese ranges from 40.15-92.10 with an average 67.13, concentration of pH ranges from 7.12-8.71 with an average 7.60, concentration of EC ranges from 130.12-521.14 µS with an average 251.01 µS and concentration of organic carbon ranges from 0.02-1.23 % with an average 0.52 %.

For road dusts at city centre of iron ranges from 14555.69-25854.55 with an average 15766.69 concentration of lead ranges from 50.36-65.36 with an average 56.12, concentration of zinc ranges from 170.63-195.85 with an average 181.77, concentration of cadmium ranges from 0.35-0.55 with an average 0.45, concentration of nickel ranges from 15.50-20.45 with an average 17.17, concentration of copper ranges from 35.69-55.85 with an average 45.70, concentration of manganese ranges from 125.69-162.55 with an average 147.48, concentration of pH ranges from 8.12-8.42 with an average 8.32, concentration of EC ranges from 1405.96-550.69 µS with an average 467.43 µS and concentration of organic carbon ranges from 0.65-0.88 % with an average 0.77 %.

High concentration of zinc, copper and iron supposed to be come from tyre and brake pad wear(23)(24) whereas nickel, cadmium and lead may be come from corrosion of metal body of vehicles and nearby industrial deposition on road side surface soil. Inspite the use of unleaded petrol the lead is found in surface soil and road dust in significant amount because of the past deposition and from the lubrication and engine oil in which lead is present in trace amounts. Metals like Cr, Cd, Ni & Mn also comes from industrial emission near highways like NH-25 & NH-28. Iron and manganese is also contributed by geological consequences. It is found that concentration of heavy metals found in road dusts of city center is higher than the soils along the all highway. It is probably because of high traffic volumes, frequent breaking & start-stop patterns, congestions, traffic jams and poor conditions of roads inside the city. Close proximity of Market area, shops and other buildings near the roads decreases the dispersal rate of the pollutants hence increases the concentration of heavy metals in road dust.

Among all three seasons, winter season have highest and monsoon season shows lowest values of heavy metals concentration in surface soil samples. It is because winters have stagnant condition and low dispersal rate of pollutants and in monsoon season rain events washed and leached out heavy metals from surface soil. Results for spatial distribution of heavy metals showed that concentration of heavy metal decreases with increasing distance from highway.Increasing distance increases the dilution of heavy metal concentration because soils nearer to highway continuouslyexposed tovehicular emission, corrosion of highway surface and due to construction &maintenance activities. In monsoon season speed of raining, slope and runoff water carry pollutants away from the highway so that concentration of some heavy metals i.e. iron and lead found maximum in 5-6 m distance instead of 0-2 m.

pH of soil samples found alkaline in nature and ranging from 7.12-8.82. pH is decreases with the increasing distance from highway, this is may be due to the richness of rearranged bituminous portion and carbonates salt coming from road surface abrasion and typical building materials respectively (25)(26).The percentage of organic carbonin soil samples ranged from 0.06-1.53 basically comes from decomposed organic material and hydrocarbon emitted from vehicular emission which eventually sink in road side dusts& soilsand subsequently transported by wind or runoff water and accumulated along the road section of the highway.

Correlation between various variables resented in Table 3. According to the Tablethere is a strong correlation between Fe and Zn ($r = 0.806$), Fe and Cu ($r = 0.790$), Fe and pH ($r = 0.719$), Fe and EC ($r = 0.853$) Pb and Zn ($r = 0.852$), Pb and Cu ($r = 0.734$), Zn and Cu ($r = 0.832$), Zn and pH ($r = 0.716$), Zn and EC ($r = 0.781$), Cd and Ni ($r = 0.711$ The strong correlation between these heavy metals indicate that most of the heavy metals are vehicular generated i.e. Zn, Cu, & Fe from tire and brake pad wear, Mn, Cd & Ni are come in to the soil from vehicular corrosion as well as nearby industrial emission.

The contamination factor (CF) for each heavy metal shown in Table 4 and calculated according to the equation previously described. Tableindicate that at 0-2 & 5-6 m distance Fe, Zn & Cu are in considerable contamination category whereas Pb, Cd, Ni & Mn are in moderate contamination category and at 15-20 m distance Zn falls in considerable contamination category and Fe, Pb, Cd, Ni Cu & Mn are in moderately contamination category. Zn, Fe and Cu have highest value of contamination factor than other metals because these three metals are primarily emitted from the abrasion and corrosion of brake pads and tyres. Table 4 shows that for NH-24 all metals falls in moderate contamination category except Zn which is falls in considerable contamination category. For NH-28 Fe & Cu comes under considerable contamination category and Pb, Cd, Ni & Cu comes under moderate contamination category. For NH-25 Fe, Zn and Cu comes under considerable contamination category and Pb, Cd, Ni, Mn comes under moderate contamination category. Overall average decreasing order for heavy metal contamination factor for all highways is as follows: Zn>Fe >Cu >Pb>Cd>Ni>Mn>Ni.

For effective comparison of contamination Pollution load index (PLI) was applied which provide a degree of contamination along the various land use types. According to Table 4Pollution load is more than double at 0-2 & 5-6 m and almost double at 15-20 m distances PLI found highest at 0-2 m distance it shows that distance nearer the highway experience more contamination and deposition of heavy metal because of the close proximity towards highway and pollution load decreases as distance increases because of the dilution and dispersal of pollutants. According to results the overall pollution load is of the order NH-25> NH-28> NH-24. Surface soils along NH-25 is highly deteriorated because of many reasons like NH-25 connects the Lucknow district to Kanpur which is an industrial city which increases the density the heavy duty vehicles on the highway. Main railway station Charbagh and amausi airport a number of commercial centres and shops creating heavy vehicular density, frequent stop start pattern, congestion, traffic jams which are also responsible for heavy pollution along NH-25. Industrial areas like Amausi and Mohanlalganj also residing along the NH-25 which also gives its inputs towards heavy metal contamination in soils. PLI value of NH-28 is closer to NH-25 because NH-28 is also having Chinhat industrial area, many road side institutional centres, markets, storage houses, motor/ vehicle repairing workshops etc which enhances the traffic pollution and contributed towards heavy metal pollution.

III. CONCLUSION

The present study revealed heavy metal contamination pattern in surface soils along the highways passing through rapidly growing Lucknow district, Uttar Pradesh, India. Results show that soil quality near highways has deteriorated up to some extent.Though the heavy metals concentration in surface soils were within the safe limits of India, but higher than the control values. Concentration of heavy metals decreases by increasing distance from the highways. Pollution load found maximum in close proximity towards highway and pollution load decreases as distance increases because of the dilution and dispersal of pollutants. The concentration of heavy metals in surface soil found higher in winter season and lowest in monsoon season. surface soil is contaminated highest with Zn, Fe, Cu because these metals are comes directly from tyre and brakepad wear where as Pb in soil comes from past use of leaded gasoline and Cd, Ni & Mn comes in soil from various corroded metallic parts, corroded road surface, construction and demolition activity and nearby industrial deposition in the soil. The findings of the present study suggest that the regular monitoring of heavy metals in roadside soils and dusts should be performed. Preventive measures like green belt development along the highways should be promoted and construction of residential buildings in the close proximity towards highways should be stopped. Crops and vegetables grown in the agricultural fields along the highways links human in food chain so a more detailed study is recommended for human health and ecological risk assessment.

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Table 1:The range and average values of heavy metals &other physiochemical parameters in surface soil at different distancesin different seasons.

	Metal	Winter		Summer		Monsoon	
		Avg ± SD	Range	Avg ± SD	Range	Avg ± SD	Range
0-2 m	Fe	13141.33± 2108.98	8064.45- 15489.15	11242.96± 2042.39	8278.55- 13624.48	7966.80± 659.73	7125.45- 9123.56
	Pb	18.30±5.20	10.23-25.69	17.16±5.04	10.29-28.30	10.49±2.77	6.12-15.55
	Zn	85.98±23.63	52.69-135.63	73.10±21.37	48.12-120.53	61.79±15.54	40.85-95.65
	Cd	0.26±0.07	0.15-0.35	0.20±0.05	0.12-0.28	0.17±0.06	0.10-0.30
	Ni	7.48±1.33	5.02-9.98	5.65±1.08	3.45-7.15	4.11±0.98	3.12-6.12
	Cu	20.44±5.68	15.26-35.15	15.61±2.98	12.12-20.25	9.25±2.93	3.36-12.89
	Mn	89.85±18.41	65.59-125.25	77.25±11.28	55.26-98.12	69.61±12.14	50.12-91.12
	pH	8.28±0.31	7.75-8.82	7.88±0.38	7.35-8.82	7.47±0.24	7.12-7.85
	EC	344.26±97.04	237.50-638.00	285.40±73.88	170.69-410.25	271.84±71.41	185.22-492.15
	OC	0.92±0.40	0.21-1.53	0.81±0.25	0.50-1.25	0.68±0.15	0.45-0.90
5-6m	Fe	1191.57± 1701.64	8534.95- 14896.45	10562.57± 2269.28	7210.92- 14969.33	8803.06± 1100.89	7140.56- 10552.23
	Pb	16.39±3.17	10.56-25.36	15.00±3.62	8.85-22.02	11.42±4.02	7.02-18.65
	Zn	79.85±23.59	40.23-130.60	65.78±21.80	40.15-115.22	57.41±11.13	45.12-90.26
	Cd	0.21±0.06	0.12-0.35	0.17±0.05	0.10-0.25	0.14±0.06	0.08-0.30
	Ni	6.52±1.77	3.14-9.36	5.02±1.12	3.35-6.94	3.30±1.15	2.15-5.25
	Cu	16.75±2.83	12.23-22.56	12.99±2.59	10.12-17.88	8.82±3.49	5.85-17.95
	Mn	76.76±14.87	55.92-100.15	72.11±10.06	45.23-85.56	61.93±5.15	55.12-70.45
	pH	8.01±0.27	7.58-8.40	7.79v0.37	7.20-8.55	7.63±0.21	7.25-8.12
	EC	303.45±62.50	214.00-412.20	330.43±101.92	195.23-550.12	275.27±70.18	150.15-402.12
	OC	0.66±0.28	0.13-1.21	0.62±0.18	0.35-0.99	0.64±0.13	0.40-0.88
15-20m	Fe	11193.95± 1181.0.2	8975.18- 13256.45	9853.23± 1476.57	7123.69 -12232.12	7613.72± 1098.16	6032.15- 9582.45
	Pb	12.63±3.03	9.56-18.55	11.03±4.12	6.23-20.16	6.57±1.27	4.45-9.12
	Zn	58.14±11.91	42.36-82.12	57.93±19.63	36.69-110.65	43.04±7.49	35.12-65.56
	Cd	0.13±0.04	0.08-0.20	0.11±0.03	0.08-0.15	0.09±0.02	0.05-0.12
	Ni	4.42±0.99	2.45-6.23	3.67±0.95	2.02-4.95	3.06±0.99	2.08-5.15
	Cu	11.93±2.55	8.23-18.63	8.78±2.12	6.10-14.12	5.89±1.38	3.52-9.02
	Mn	69.4±13.02	50.25-90.12	69.26±7.98	58.85-92.10	62.68±9.26	40.15-78.85
	pH	7.83±0.42	7.25-8.71	7.62±0.19	7.35-7.90	7.34±0.16	7.12-7.70
	EC	262.99±58.26	165.30-375.56	261.24±101.25	130.12-521.14	228.78±45.78	150.36-305.15
	OC	0.56±0.28	0.20-1.23	0.49±0.18	0.20-0.85	0.50±0.14	0.30-0.70

Concentration of all metals found in µg/g
Concentration of OC (Organic carbon) found in %
Unit of EC (Electrical conductivity) micro Siemens (µS)

Table 2:The range and average values of heavy metals & other physiochemical parameters in surface soil (control site) and road dust (city centre sites).

Metal	City centre (Road dust)		Control site (Surface soil)	
	Avg ± SD	Range	Avg ± SD	Range
Fe	15766.69±125.69	14555.30-25854.55	3259.68±215.33	3098.23-3485.86
Pb	56.12±12.26	50.36-65.36	5.68±0.73	5.29-6.65
Zn	181.77±25.62	170.63-195.85	15.3±1.57	12.12-15.18
Cd	0.45±0.05	0.35-0.55	0.09±0.02	0.08-0.11
Ni	17.17±2.63	15.50-20.45	3.03±0.67	2.46-3.70
Cu	45.70±12.86	35.69-55.85	4.12±0.62	3.25-4.48
Mn	147.48±25.26	125.69-162.55	44.45±2.05	38.09-45.54
pH	8.32±0.08	8.12-8.42	7.40±0.10	7.30-7.50
EC	467.43±12.25	405.96-550.69	176.85±5.15	175.45-182.56
OC	0.77±0.07	0.65-0.88	0.81±0.05	0.75-0.85

Concentration of all metals found in µg/g
Concentration of OC (Organic carbon) found in %
Unit of EC (Electrical conductivity) micro Siemens (µS)

Table 3: Pearson correlation matrix between various physico-chemical characteristics of surface soil.

Metal	Fe	Pb	Zn	Cd	Ni	Cu	Mn	pH	EC	OC
Fe	1	.603**	.806**	.646**	.404	.790**	.646*	.719**	.853**	.438*
Pb		1	.852**	.558**	.578	.734**	.663**	.659**	.648*	.687**
Zn			1	.692**	.562	.832**	.360	.716**	.781**	.694*
Cd				1	.711**	.612*	.437	.135	.221	.185
Ni					1	.328	.274	.378	.052	.644**
Cu						1	.254	.524**	.617*	.546**
Mn							1	.321	.244	-.089
pH								1	.538*	.445**
EC									1	.685**
OC										1

** Correlation is significant at the 0.01 level (2-tailed
* Correlation is significant at the 0.05 level (2-tailed)

Table 4:Overall Contamination factor (CF) and pollution load index (PLI) at different distances and at different highways from the highway.

		Fe	Pb	Zn	Cd	Ni	Cu	Mn	Pollution load index
Highway	NH-24	2.73	1.99	3.89	1.79	1.36	2.71	1.46	2.134
	NH-28	3.37	2.28	3.66	1.86	1.79	2.92	1.75	2.414
	NH-25	3.34	2.72	5.19	1.83	1.60	3.31	1.65	2.578
Distance from the Highway	0-2 m	3.31	2.70	4.83	2.33	1.90	3.67	1.78	2.765
	5-6 m	3.20	2.51	4.44	1.89	1.63	3.12	1.58	2.458
	15-20 m	2.93	1.77	3.48	1.25	1.23	2.15	1.51	1.901

CF<1 Low contamination, $1 \leq CF < 3$ Moderate contamination, $3 \leq CF \leq 6$ Considerable contamination, CF > 6 Very high contamination

Table 5: Comparisons of mean concentrations (µg/g) of metals of soils/road dusts in different areas

Location	Highway	Fe	Pb	Zn	Cd	Ni	Cu	Mn	References
Lucknow district major highways	NH-24	8887.15	11.30	59.32	0.16	4.11	13.64	64.90	Present study
	NH-28	10989.27	12.94	55.82	0.17	5.43	11.15	77.89	
	NH-25	10883.32	15.43	79.20	0.16	4.86	12.02	73.52	
Luck now district background soil		3259.68	5.68	15.25	0.09	3.03	4.12	44.45	
Safe Limit*		**-**	**250-500**	**300-600**	**-**	**75-150**	**135-270**	**-**	**(27)**
Delhi road dust		27047.0	128.7	263.70	-	37.2	168.70	699.20	(23)
Istanbul	E-5	-	185.84	447.72	2.32	30.0	122.37	395	(28)
Pakistan	N-5	3970	36.46	56.72	0.84	8.82	12.98	174	(24)
Dhaka (Bangladesh)		-	74	154	-	26	46	-	(5)
French Major highway		15000	93	57	0.30	14	14	277	(13)
Beijing		27900	61	214			42	552	(29)
Birmingham		-	48	534	-	41.1	466.9	-	(30)
China soil guidelines[a]		-	300	250	-	50	100	-	(31)
Canada soil guidelines[b]		-	140	200	-	50	63	-	(32)
Canada soil guidelines[c]		-	600	360	-	50	91	-	(32)
poland soil guidelines[d]		-	100	300	-	100	150	-	(33)
poland soil guidelines[e]		-	600	1000	-	300	600	-	(33)

* IS Indian standard of potential toxic element for agricultural soils

a Class II. Metal levels in class II are threshold values established to protect agricultural production and maintain human health

b Residential/parkland landuse

c Industrial landuse

d Residential landuse

e Transportation and industrial landuse

Figure 1: Map of study area

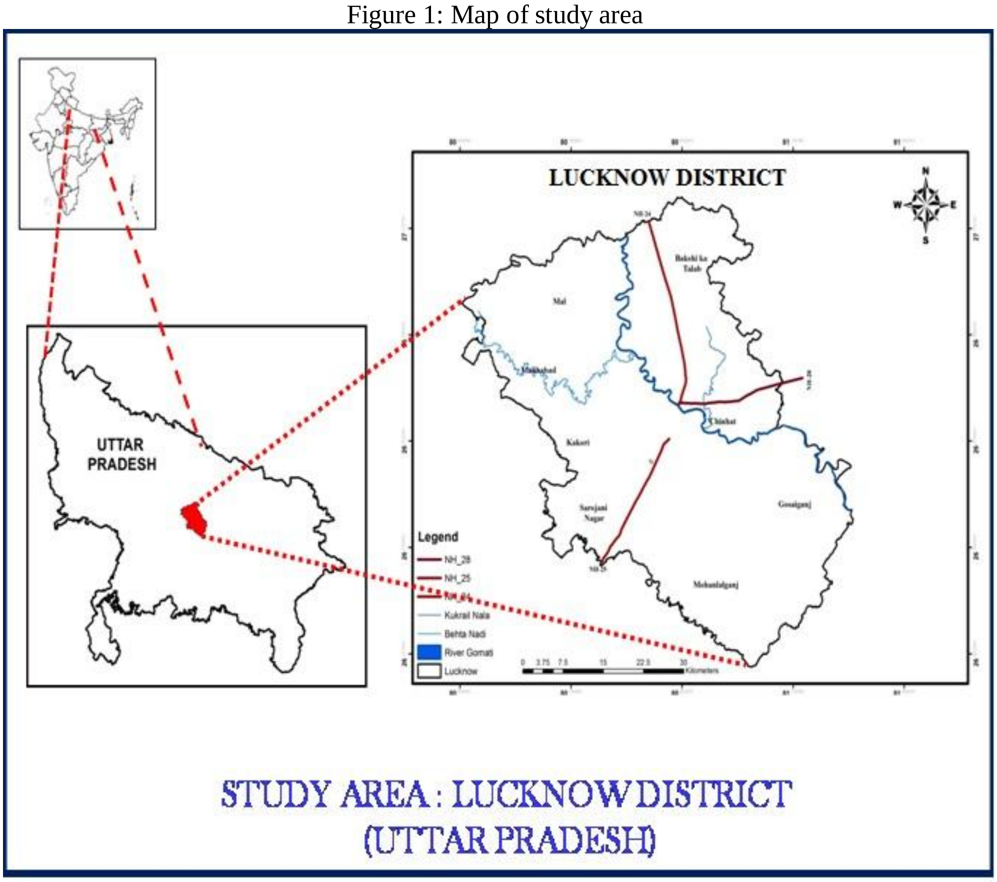

Figure 2: Map of sampling locations

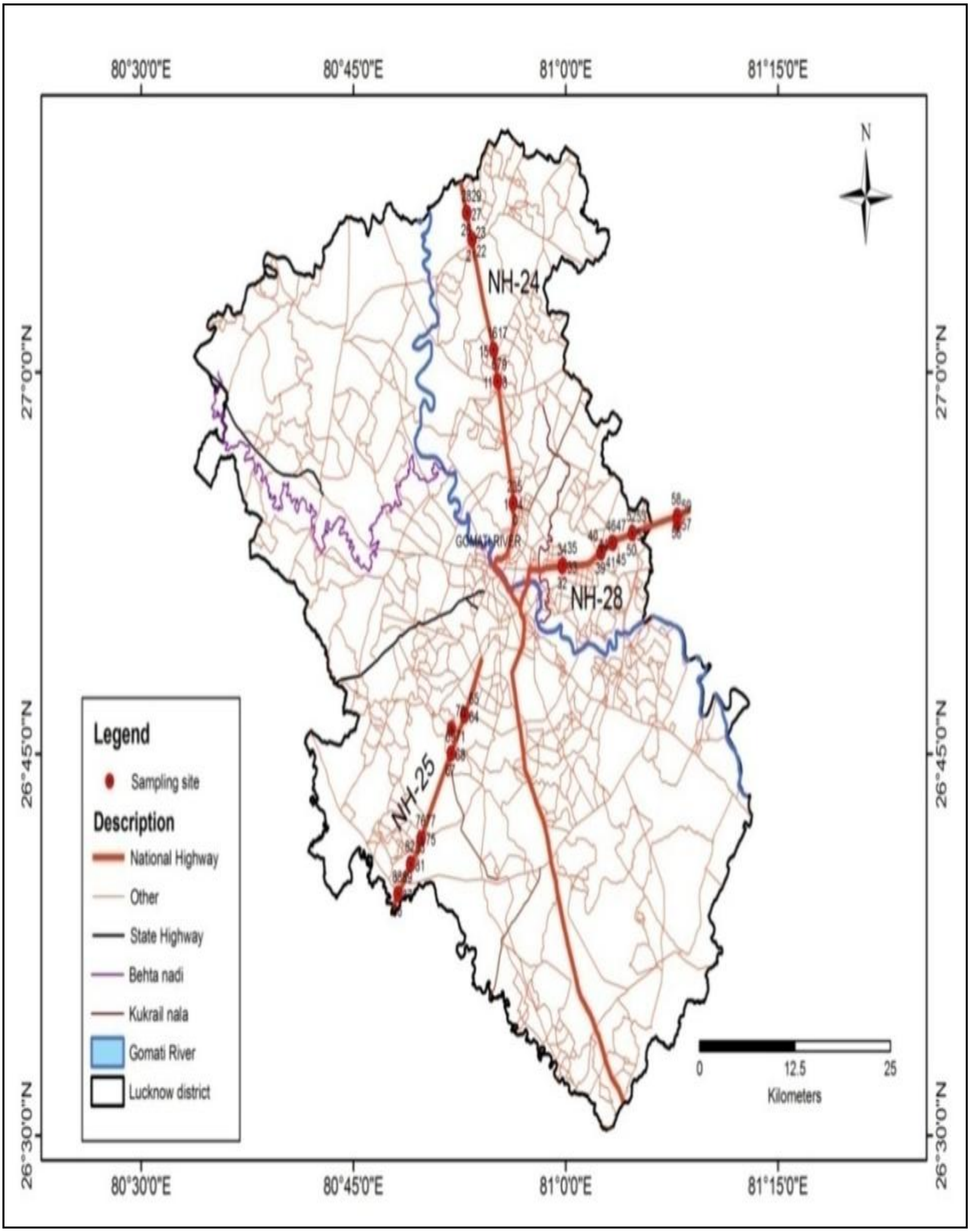

Figure 3: Average concentration of Zinc distribution in surface soil along NH-24, NH-28 & NH-25 using GIS Raster Interpolation method

Figure 4: Average concentration of Cadmium distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method

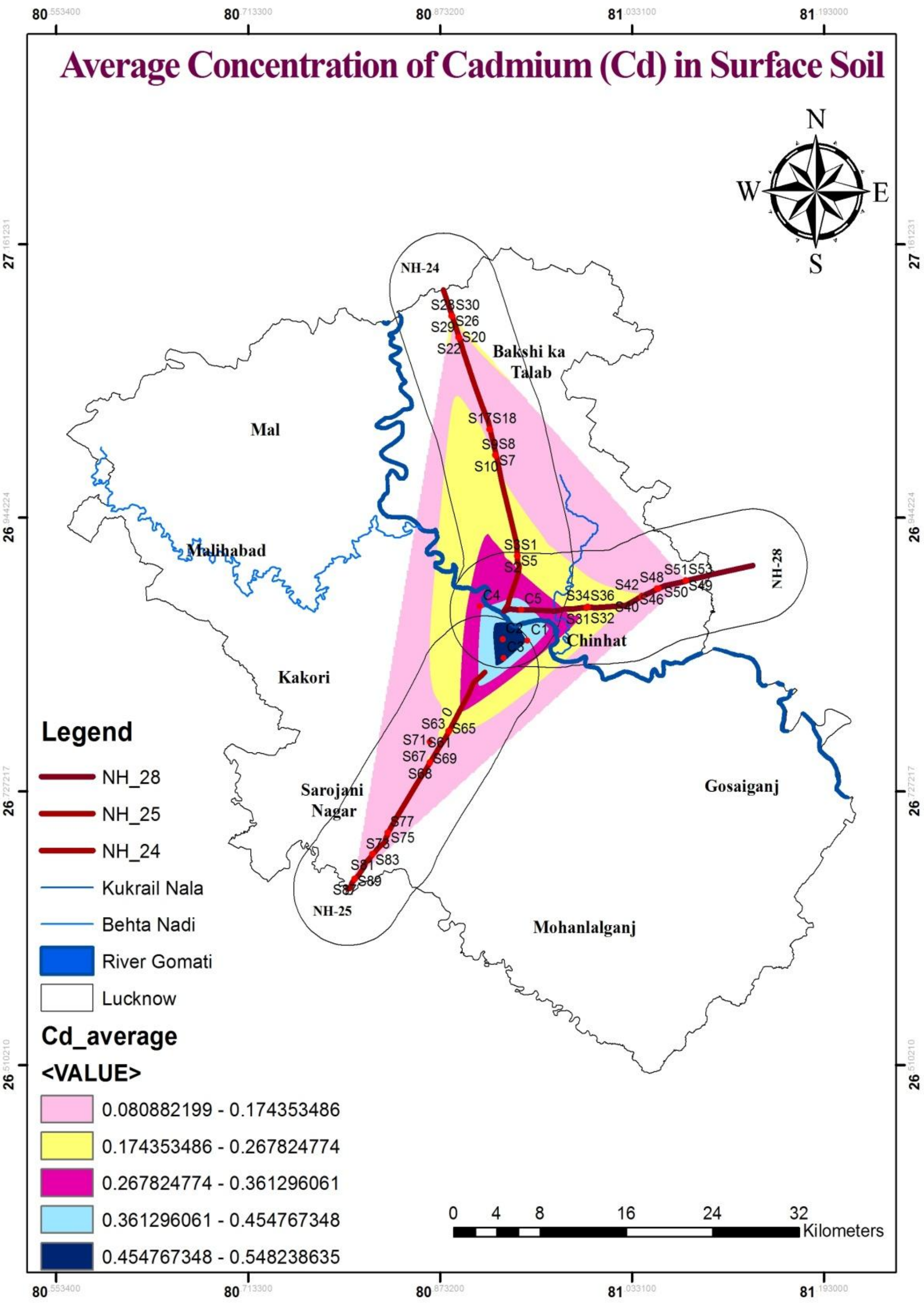

Figure 5: Average concentration of Copper distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method

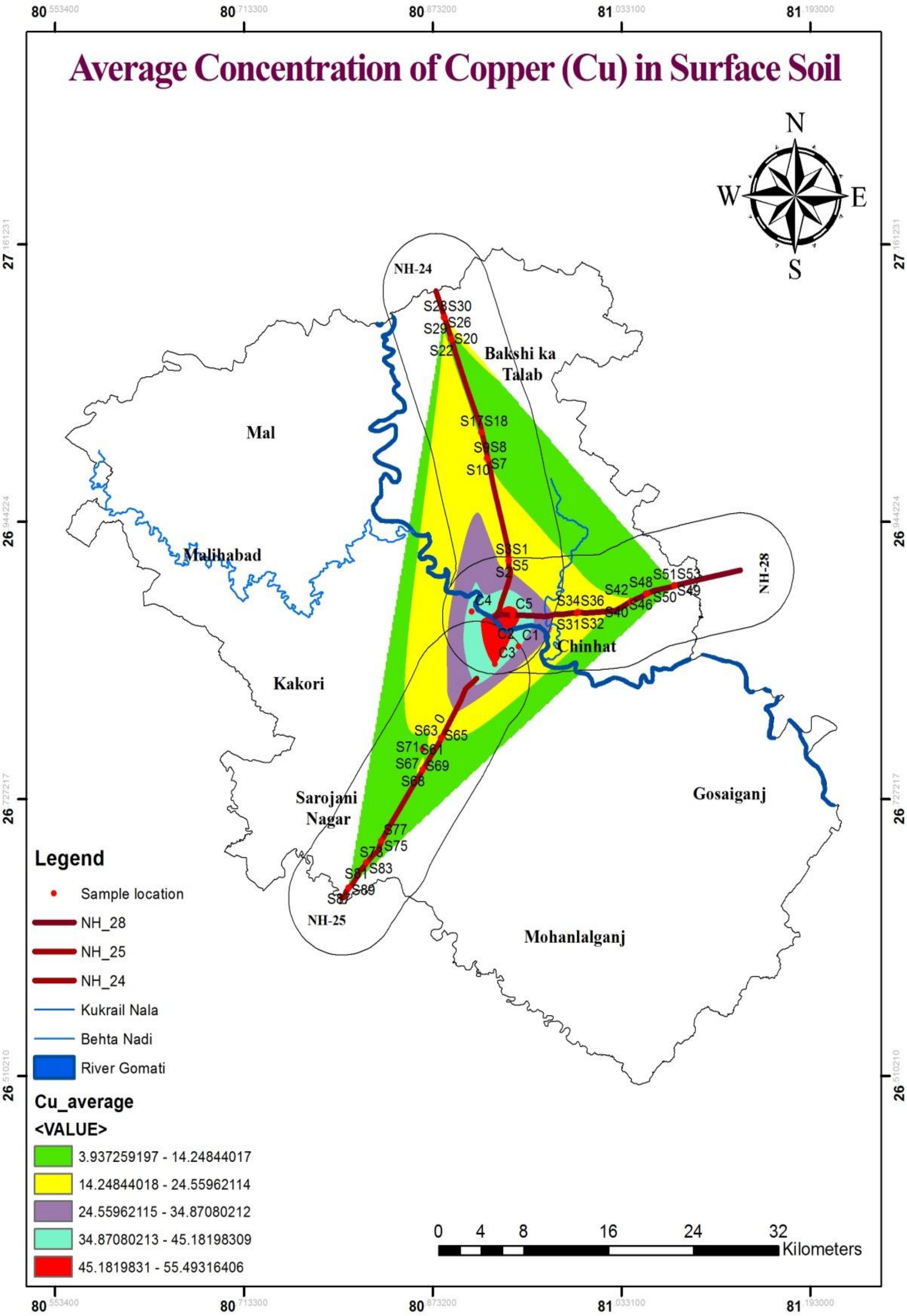

Figure 6: Average concentration of Iron distribution in surface soil along NH-24, NH-28 & NH-25 using GIS Raster Interpolation method

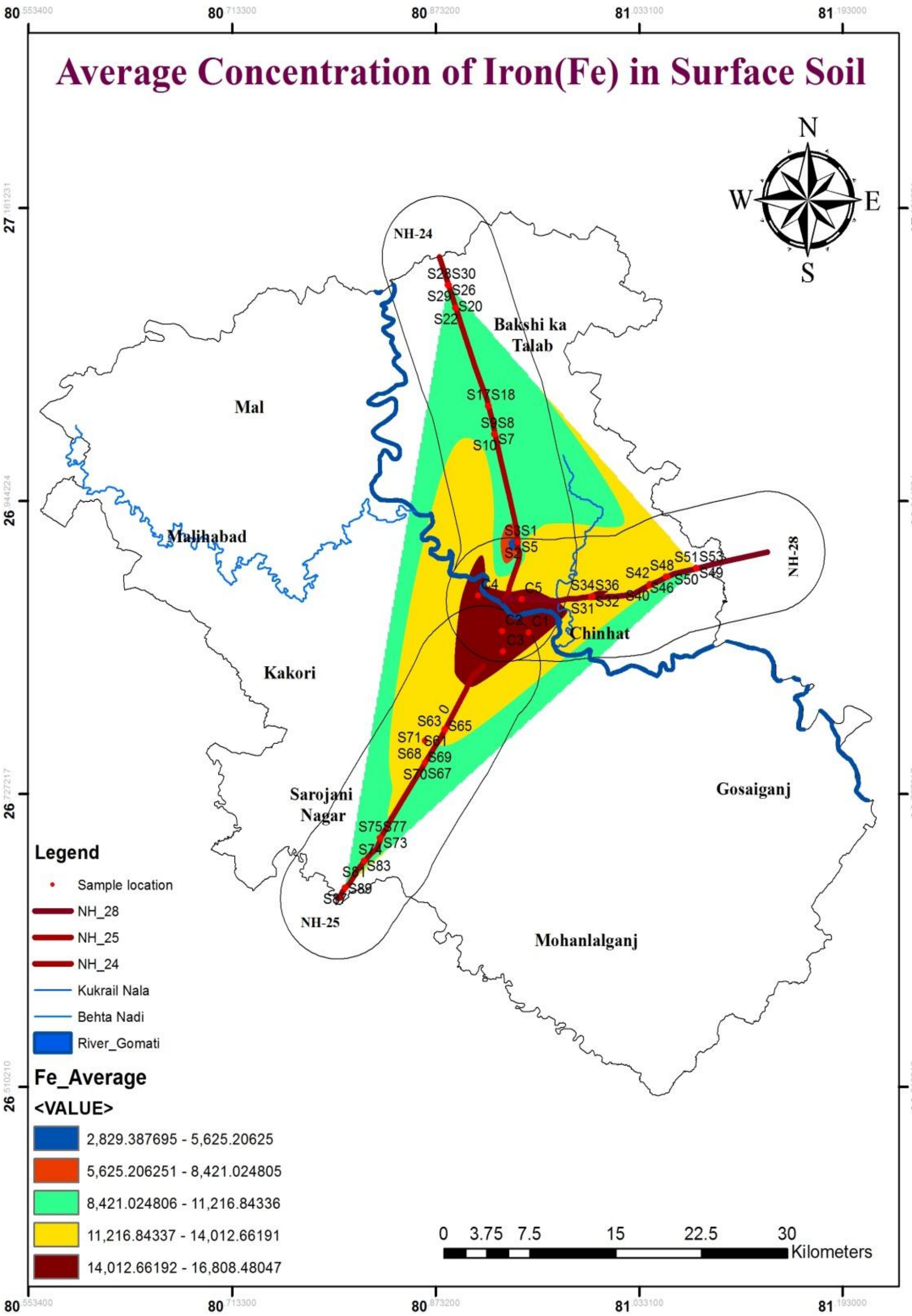

Figure 7: Average concentration of Manganese distribution in surface soil along NH-24, NH-28 & NH-25 using GIS Raster Interpolation method

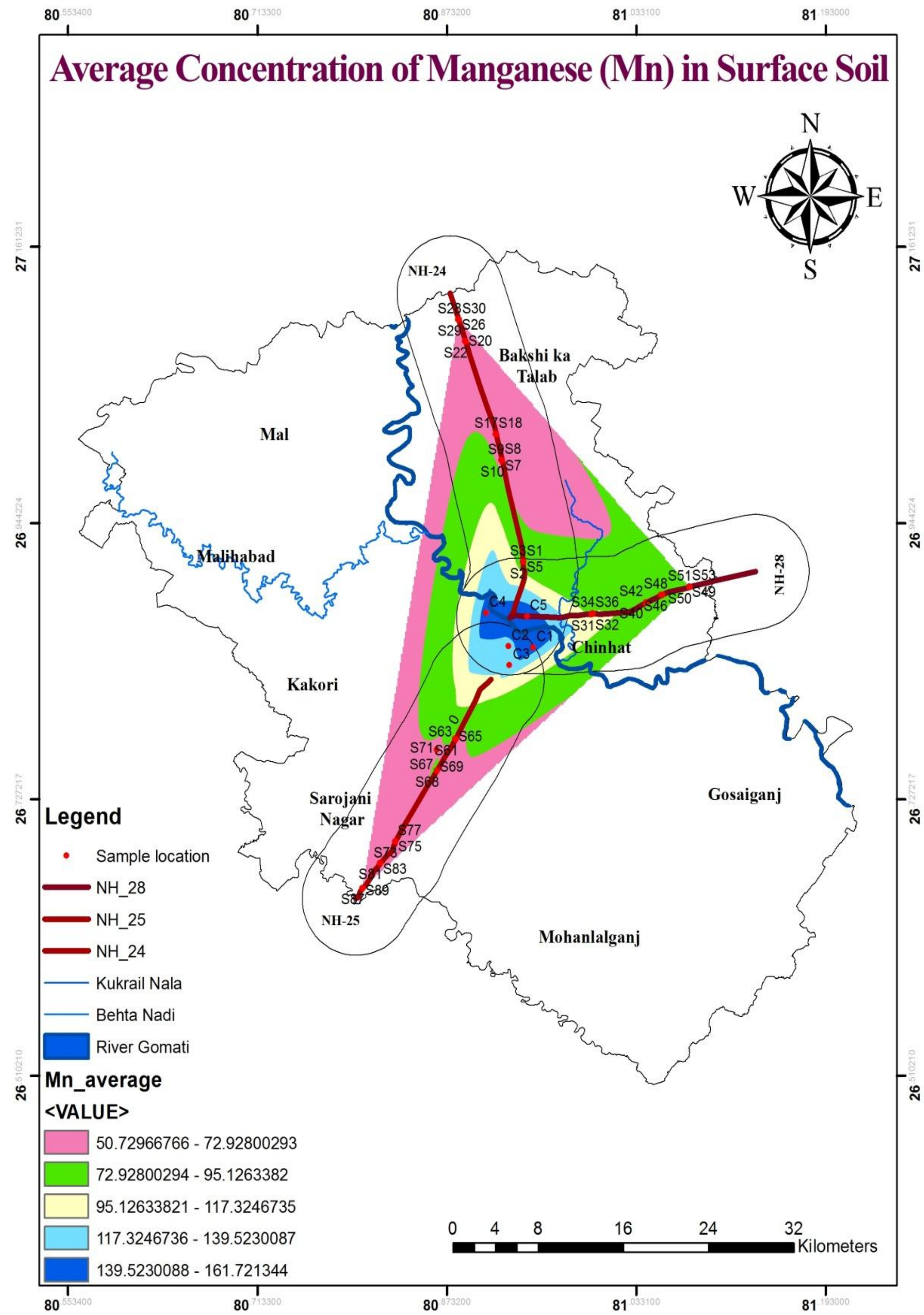

Figure 8: Average concentration of Nickel distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method

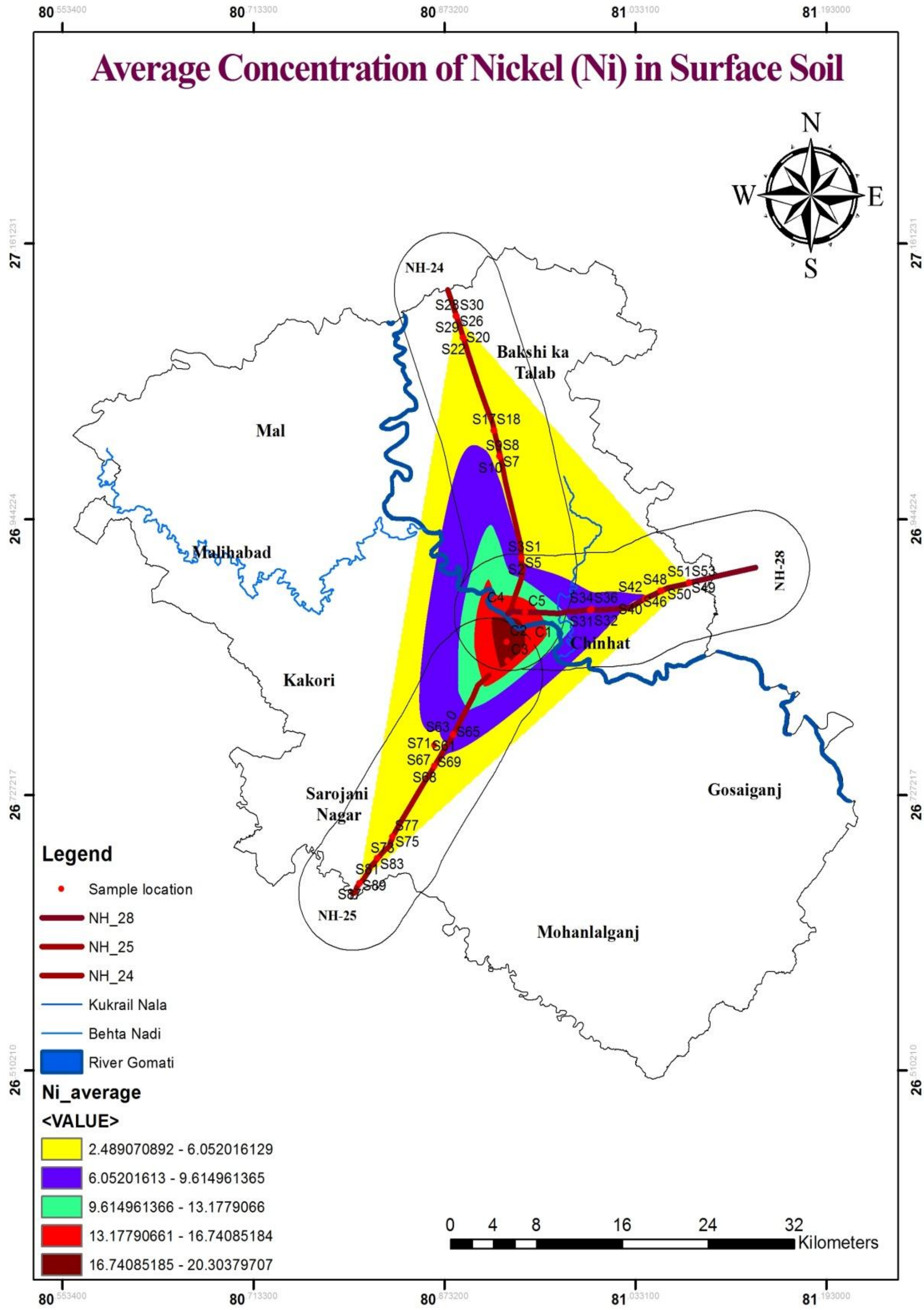

Figure 9: Average concentration of Lead distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method

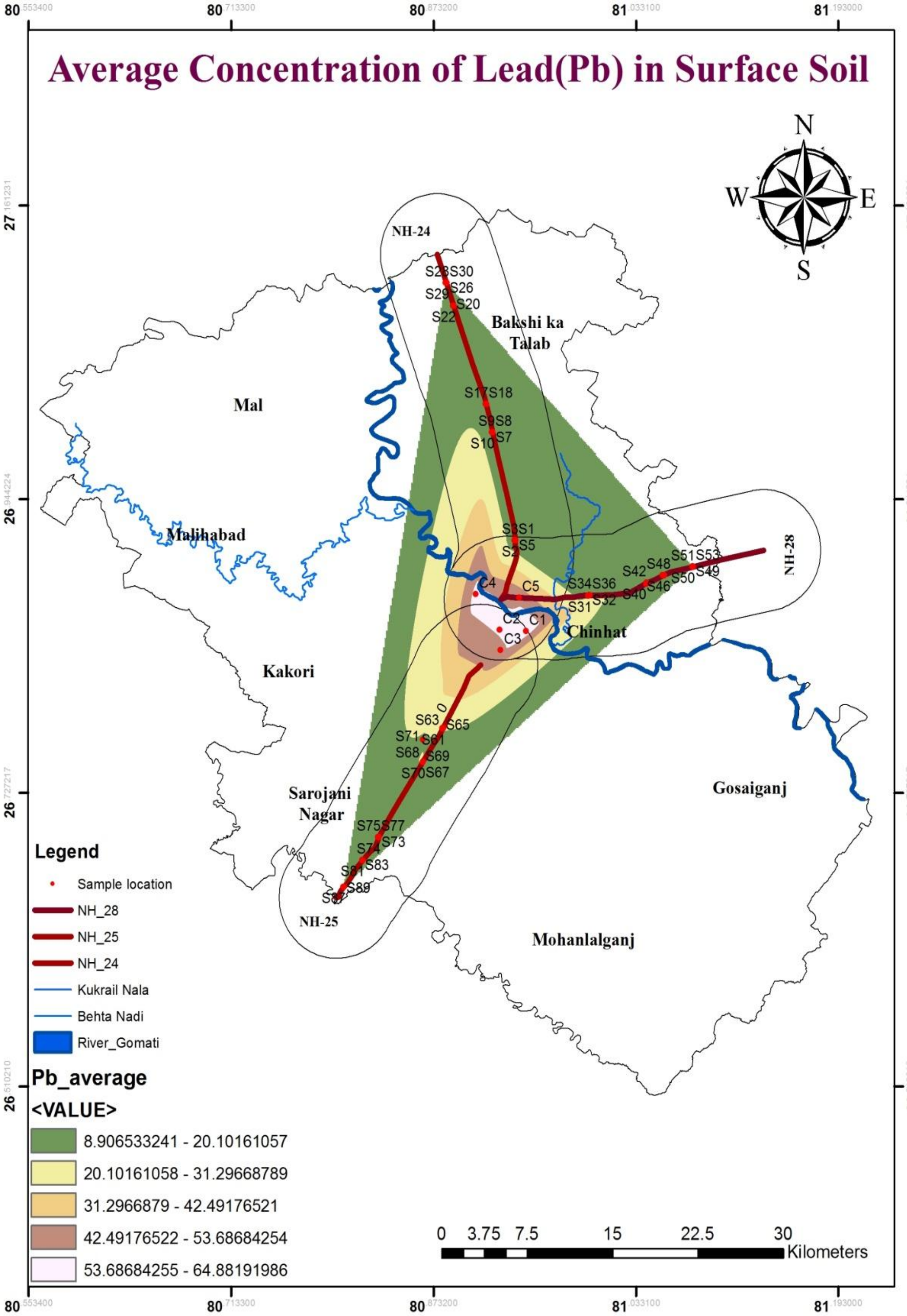

Figure 10: Average pH value distribution in surface soil along NH-24, NH-28 &NH-25 usingGIS Raster Interpolationmethod

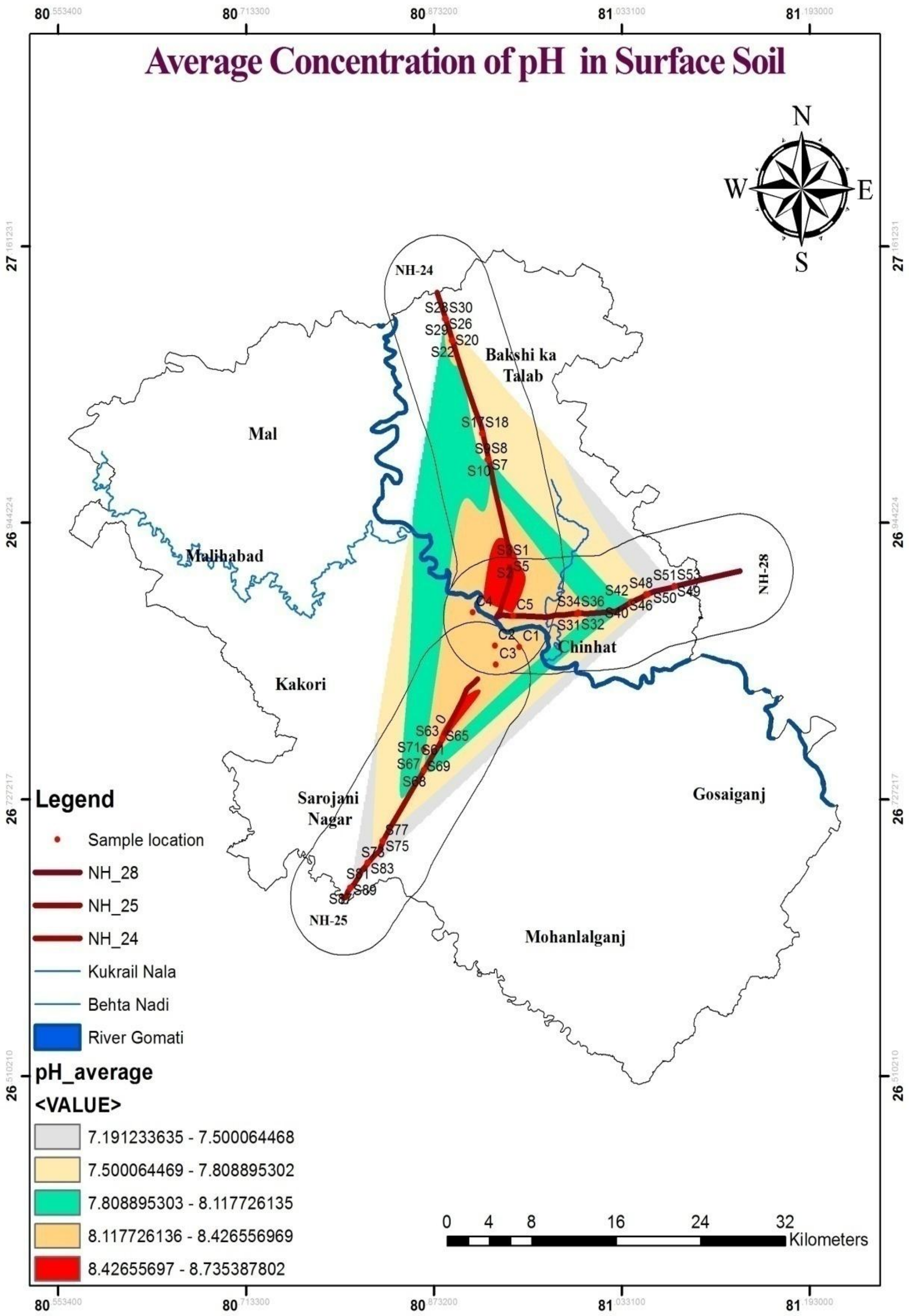

Figure 11: Average Electrical conductivity value distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method

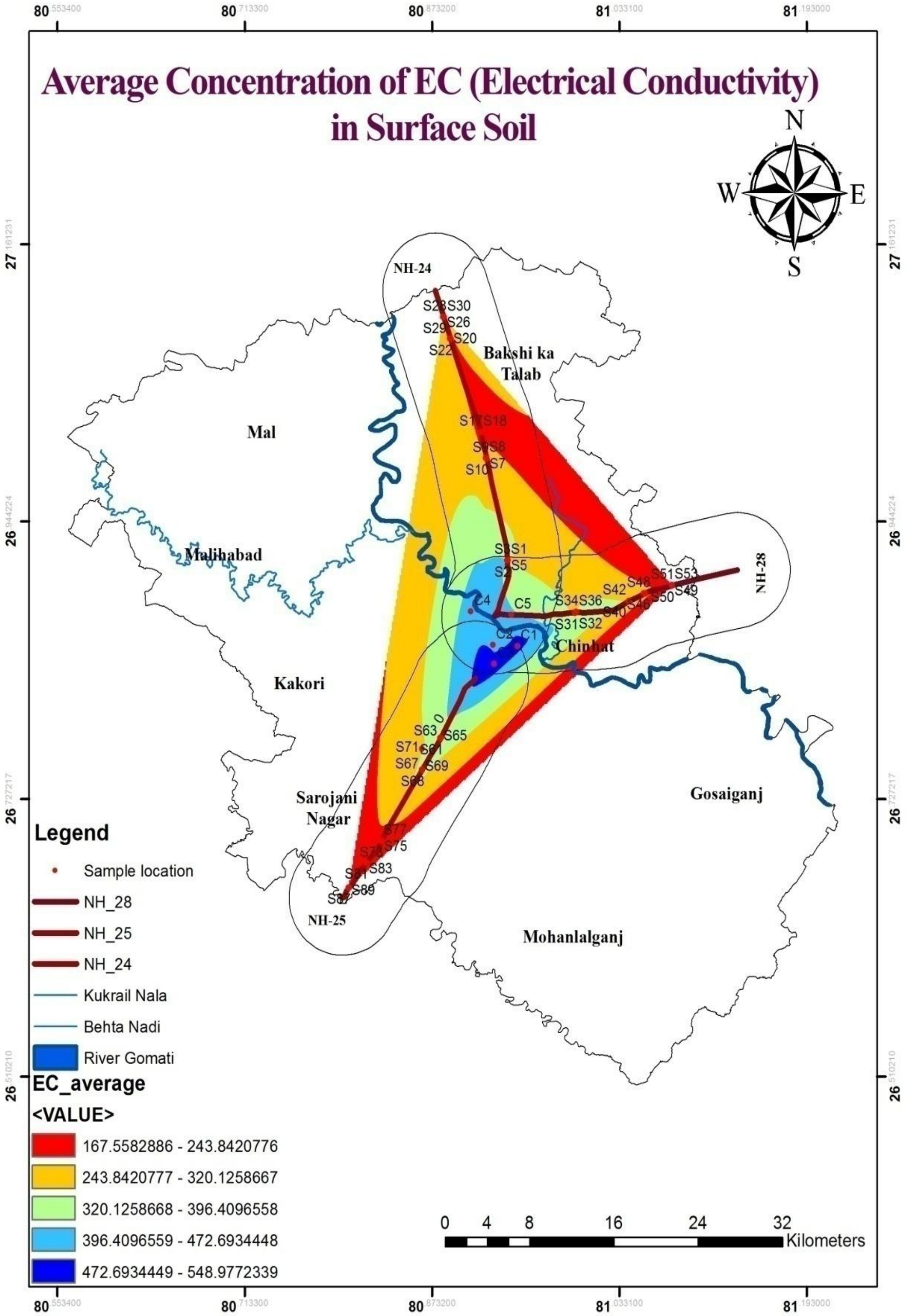

Figure 12: Average Organic carbon value distribution in surface soil along NH-24, NH-28 &NH-25 using GIS Raster Interpolation method