Impact of Surrounding Infrastructure on Urban Environment: A Case Study of Karachi Metropolitan

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Abstract. Urban environment carries complex land-use and land cover (LULC), similarly Karachi as a metropolitan have multifaceted LULC and compact infrastructure. This study seeks to assess the impact of infrastructure of urban environment at mega city Karachi Pakistan. Approximately, fifteen different locations of metropolitan with different surroundings were evaluated based on the studied variables of surrounding such as temperature, humidity, formaldehyde (HCHO), total volatile organic compounds (TVOC) pollution, fine particulate matter (PM2.5) in air i.e., air quality, maximum noise pollution and minimum noise pollution were investigated. The readings have been collected through relevant instruments and the results have been generated through interpolation in ArcMap 10.8. The obtained results revealed that the physical factors affect the temperature and humidity conditions of the study area. While environmental and noise pollution depends on the surroundings, e.g. industrial surrounding effects on air quality, i.e. 180 recorded at industrial region of Korangi, while construction sites are catalysts of noise pollution and highest noise pollution are recorded at North-Nazimabad. Cancer causing substance, i.e. formaldehyde found along the petrol pumps, airports and transportation junctions ranges up to 0.99 ppm near Jinnah International airport and mass transit location of Shahrah e Faisal. While total volatile compound pollution has been found along the Malir catchment area, i.e. 0.4 mg/m^3. The lifestyle of Karachiites need to be transform there is a dire need to think about physical and mental concord of the citizens of metropolitan. Similarly, government should play some positive actions and introduced green and environmental friendly technology to control air and noise pollution.

Keywords: Urban Environment, formaldehyde, organic compounds, PM2.5, Noise Pollution, Interpolation.

1. Introduction

Urban sustainability has become a considerable task worldwide because of rapidly growing urbanization and mechanization (Mangi et al., 2020). It is the estimated that by the year 2025, population in urban areas will be around five billion (Grierson, 2007; Rahaman et al., 2022). Urbanization enhances quality of life as well as infrastructures development. In the development, infrastructure have positive and essential role (Breuste et al., 2015). Urban constructions improve socio-economically without conceding

ecological dimensions, which achieve a balance among people and natural resources (Rasoolimanesh et al., 2012). For the urban growth and regional distinctiveness, urban infrastructure is itself a resource and for future generation it can be re-formed, constructed and functionalized again (Galimi et al., 2022). For the urban development, infrastructure of many cities refabricated and regenerated to fulfill city dweller's requirements. So that there is the development of infrastructure in developing countries; every year billions of capital has been invested specifically on sanitation, means of communications and transportation, on electricity and water supply lines (Collier & Venables, 2016). Such investments for the city development cause environmental problem of metropolitan are always in discussions such as, for example, air pollution with lead due to a significant number of vehicles, which contributes to the occurrence of cardiovascular diseases (Karlova et al., 2017). In 1869, the concept of environmental pollution was first time used by the US Public Health Committee (Peterson, 2018). Even today we are living unhealthy environment where natural waters contain toxicants in dangerous doses (Hussain et al., 2022a; Khan et al., 2022), soils are contaminated with heavy metals (Hussain et al., 2022b; Ziarati et al., 2020), the air is heavily polluted due to technogenic activity (Mozaffari et al., 2022; Vaskina et al., 2019; Vambol et al., 2019), and numerous factors contribute to the emergence and concentration of dangerous viruses in the environment and in individual regions (Khan et al., 2023; El Morabet et al., 2023). The environmental notion, which is the sum of biochemical and social factors; effects directly or indirectly on all biotic, instantly or some period of time (Panagopoulos et al., 2016). Some built-up environment or congested infrastructure may also lead to severe environmental issues such as transportation infrastructure can enhance air pollution more rapidly rather than residential structure, similarly around industrial infrastructure air quality and noise pollution is far poor rather than leisure infrastructure. Solway (2004) carried out a project during 1993 and 1995 aiming to assess the natural hazards with reference to three case studies, cities Karachi (Pakistan), Jakarta (Indonesia) and Metro Manila (Philippines). Mangi et al., (2020) compared the urban development trends of Beijing and Karachi metropolitan Areas of Pakistan. Aslam et al. (2021) stated the urban overheating assessment through prediction of surface temperatures at Karachi Pakistan. Das et al. (2022). Quantified the cooling consequence of urban green space from urban parks in a tropical mega metropolitan area. The scientific question of present work was, how weather variables and chemical variables affected by land-use and land cover? It was hypothesized that the infrastructure of urban areas may increasing environmental and noise pollution. Novelty point of view, this research is genuine piece and did not find any research on Karachi, which is on location-based analysis. It helps government and common people to provide an overlook of weather and chemical variables effects environment geospatially. The main objectives of present study were 1) to analyze weather variables, i.e. temperature and Humidity through Interpolation Technique, and 2) to analyze chemical variables, i.e. formaldehyde (HCHO), total volatile organic compounds (TVOC) pollution, noise pollution, air quality PM2.5 through interpolation technique.

2. Materials and methods

2.1. Geographical distribution area of Karachi

Karachi is comprising mountains/barren land and coastline environment (79.9%), and Vegetation canopy (4.9%) however, the urban land cover is growing day by day. It has plain land, coastal zone and hilly ranges, 25% was either covered by urban settlement, whereas the rest is too far from the settlements or far from isolated pockets surrounded by hills. The planned development of the metropolitan has been mostly on the plain land. The likelihood of future expansion of urban cover lies around the plains near Hawks Bay, Pipri (Malir), and Gadap. Along the coastline, 75% of built environment occupied, and it has expanded due to reclamation of shore around Clifton and Defense Housing Authority (DHA), over the period of time. The southern part of the city is connected with the Arabian Sea. The land-use and land cover (Fig. 1).

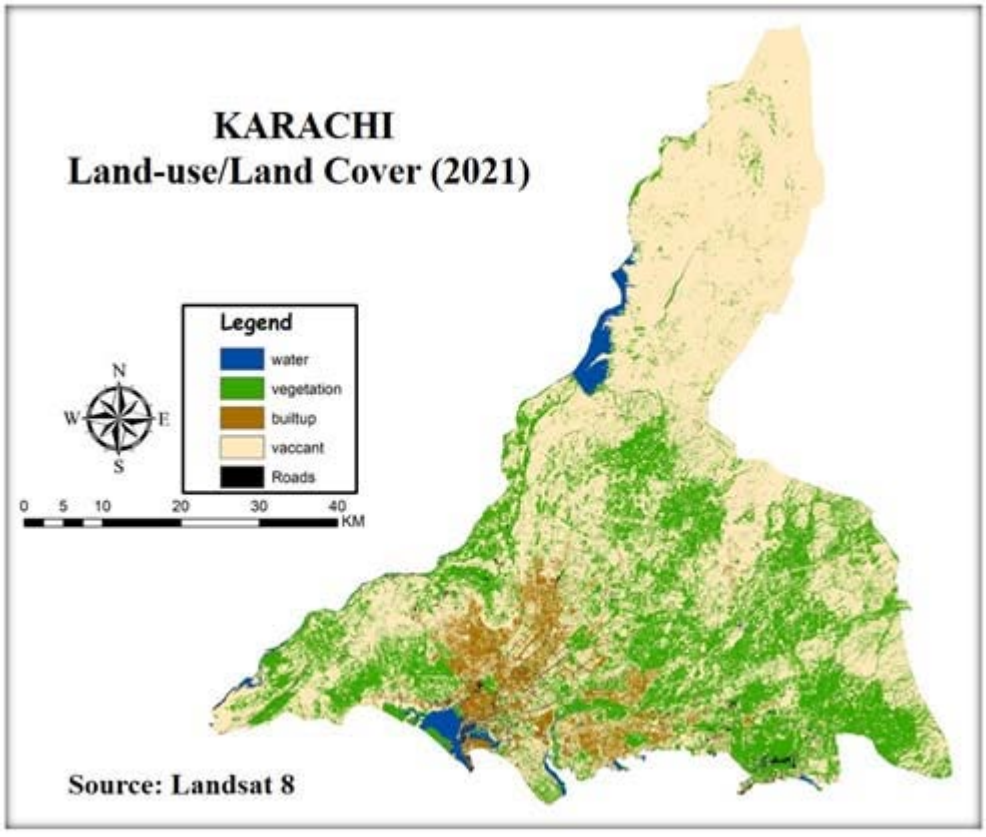

Figure 1. Land-use/Land Cover of Karachi (Calculated by Author)

Karachi; as a harbor city, with the population of 5,00,000 at the time of independence to the major urban Centre at present time (Ghaus, 1989). The Urban population of Karachi is increased from 5,208,000 in 1981 to 14,737,257 in 2017 and urban area from 8.35 km^2 in 1946 to 3,640 km^2 in 2017 (Kanwal & Khan, 2020). Now Karachi is the densely populated city of Pakistan with compact concrete infrastructure within the metropolitan area (Figs 2, 3 and 4). Existing study was performed based on fifteen locations

within the metropolitan. All locations are selected on the bases of its land-use/land cover to analyzing the impact of particular infrastructure on the environment.

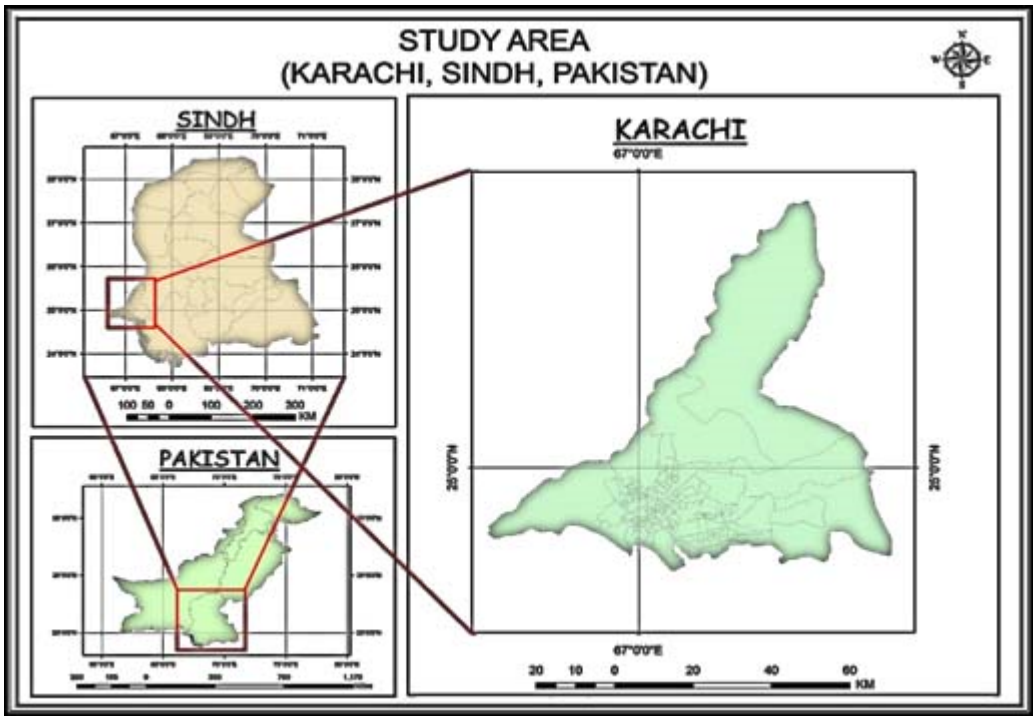

Figure 2. Relative location of study area

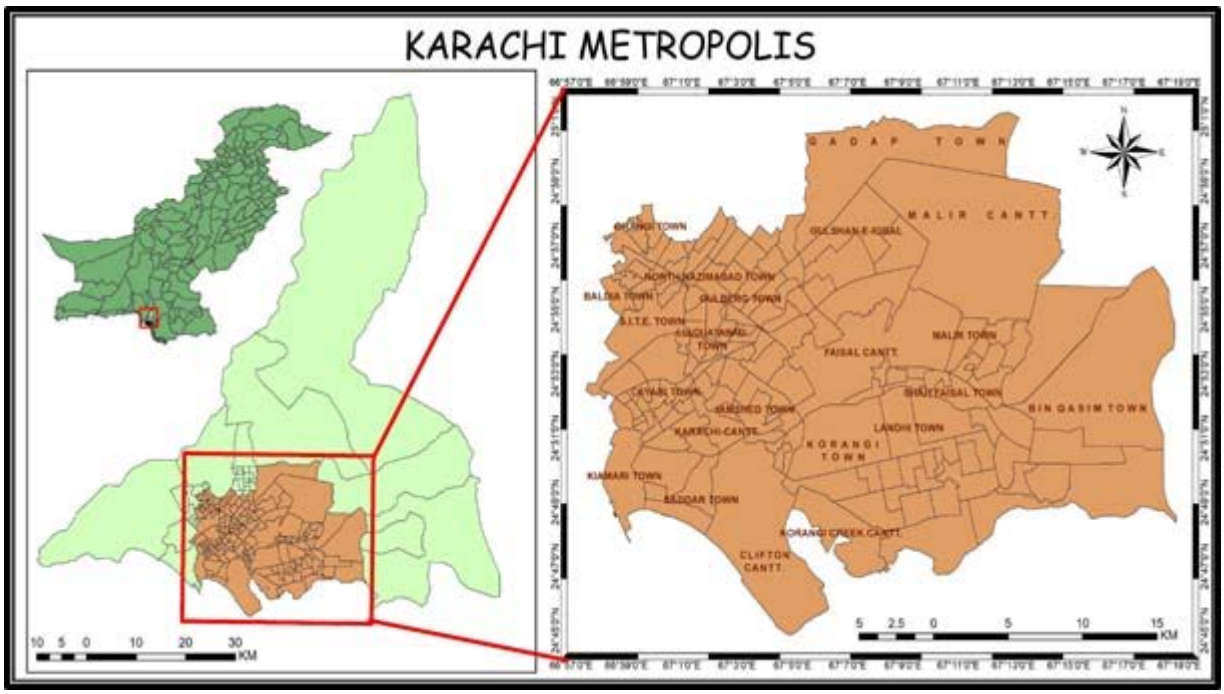

Figure 3. Metropolitan Zone in Karachi

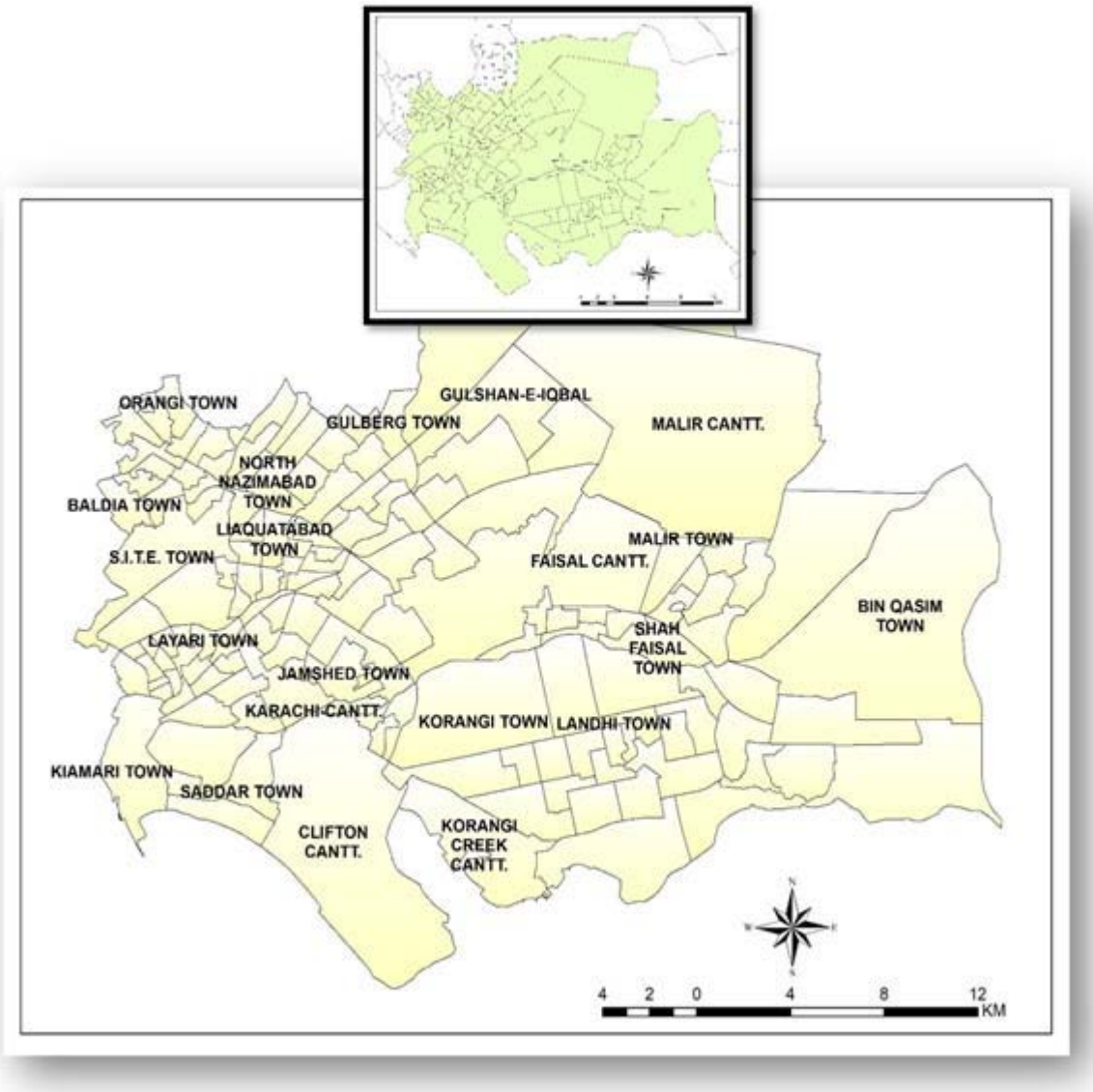

Figure 4. Administrative divisions of study area

2.2. Study area

Study area of present research was comprises 15 locations of Karachi Metropolitan (Table 1).

Table 1. GCP's of surveyed points.

Map Code	Location Name	Latitude (Degree)	Longitude (Degree)
1	University of Karachi-Gulshan e Iqbal	24.940238	67.122867
2	Petrol Pump-Malir Cantt.	24.922502	67.184233
3	AirPort-Model Colony	24.9034974	67.1821871
4	Railway Station-Malir Halt	24.884598	67.1745152
5	Shopping Center-Shah Faisal Town	24.88112	67.1455717
6	Urban Agricultural Land- Korangi	24.865048	67.158142

7	Pharma Industry-Korangi	24.8408583	67.13236
8	Malir River Mouth-DHA	24.80261	67.07843
9	Sea View Beach-DHA	24.7854117	67.0482
10	Native Jetty Bridge-Saddar	24.8445	66.992
11	Port Grand Near-Karachi Port	24.8441	66.9918
12	Scout Head Office-Saddar	24.85334	67.022515
13	Empress Market-Saddar	24.864	67.02751
14	Lasbella Market-Garden West	24.886751	67.033462
15	Dolmen Mall-North Nazimabad	24.9355	67.0408

All locations have specific surrounding (Fig. 5). Location 1 is university of Karachi, which have comparatively large proportion of green cover. Location 2 is on Petrol Pump at Jinnah Avenue, a huge open space of Malir Cantt is just behind it. Location 3 is taken near the Jinnah International Air Port. Location 4 is on Shahrah e Faisal near Railway Station at Malir Halt. Location 5 is Shopping Center (Shama Shopping Mall) in Shah Faisal Town. Location 6 is Urban Agricultural Land, which is located in the vicinity of Korangi Town. Location 7 is among the Korangi Industrial Area at Pharma Industry. Location 8 is Malir River Mouth where the Malir River drained into Arabian Sea. This location at DHA. Location 9 is on Sea View Beach- DHA. Locations 10 and 11 are comparatively very near to each other. Location 10 is on the historical Native Jetty bridge on which heavy vehicles movement all the day and night while Location 11 is Port Grand which is well known Leisure zone of Karachi. Location 12 is Scout Head Office located at Saddar; the CBD of Karachi (Kausar et al., 2022). Location 13 is the busiest location of Saddar, i.e. near Empress Market. Location 14 is at Lasbella market, the place where the reading has been taken is actually a congested road with heavy infrastructure of BRT surrounded by market area. Location 15 is the afront of Dolmen Mall of Nazimabad. Nazimabad is considered as one of the historically planned areas. These all 15 locations were cover almost metropolitan extent of Karachi (Fig. 6).

Figure 5. Absolute locations of all 15 surveyed locations of Karachi metropolitan

Figure 6. Ground Control Points (GCP's) of surveyed area Karachi metropolitan

2.3. Analysis through instruments

The air quality detector Model JSM-131 SC, Voltage SV, Standard JJF10591-2012, JJG 1022-2016,was used to record Formaldehyde (HCHO) and total volatile organic compounds (TVOC) pollution. The sound level meter UT353/UT353BT Mini Sound Level Meter was used to record maximum noise pollution and minimum noise pollution. The air quality meter UNI-T UT338C Meter PM2.5 air quality humidity detector to record fine particulate matter (PM2.5) in air, i.e. air quality. The weather meter kestrel 3000 Pocket weather meter / heat stress monitor to record temperature and humidity. The data have been collected for the month of November 2022 from 15 different locations through the GPS (Global Positioning System) (Fig. 5, Table 1). Data on 7 variables have been collected (Table 2). For this following method have been conducted.

The IDW (Inverse Distance Weighted) technique is used for the interpolation of data.

Steps for IDW in ArcMap

- The open ArcToolbox, expand spatial analyst tool, then expand interpolation and select IDW.
- IDW window appears select Input point features data, select Z value field, then choose output raster destination.
- Define Raster Extent by clicking on Environment. Finally, click the OK button.

Maximum Likelihood method was used for the classification of Karachi Land-use/ Land Cover for initial introduction (Fig. 1). In ArcMap this has be done through following steps.

- Open ArcToolbox and expand Spatial Analyst Tool, Select Create Signatures in Multivariate to assign training areas according to different classes.

- Now, Select Maximum likelihood classification from Multivariate dropdown list.
- A dialogue box will appear select Input Raster data and previously created signature file, then choose location for Output Classified Raster. Finally, click OK button.

3. Results and discussion

Table 2 represent data of seven variables for the month of November 2022 from the fifteen locations (Fig. 6). All variables' data have been interpolated through the Spatial Analysis tool on the method of IDW (inverse distance weighting). IDW is the method.

Table 2. Seven variables' data for fifteen locations for the month of November 2022.

S.No.	Location name	Temperature	Humidity	HCHO	TVOC	PM2.5	Noise (Max)	Noise (Min)
		℃	%	ppm	mg/m^3	ppm	dB	dB
1	University of Karachi-Gulshan e Iqbal	24	60	0	0.005	70	76.9	58.5
2	Petrol Pump-Malir Cantt.	28	50	0.001	0.007	72	90.5	72.5
3	AirPort-Model Colony	28	51	0.09	0.058	90	83.5	71
4	Railway Station-Malir Halt	28	53	0.072	0.327	121	97.4	76.4
5	Shopping Center-Shah Faisal Town	27	56	0.003	0.01	105	88	57.2
6	Urban Agricultural Land- Korangi	27	55	0	0.456	88	90.4	70.2
7	Pharma Industry-Korangi	30	46	0.025	0.216	180	99.4	78.5
8	Malir River Mouth-DHA	27	52	0.01	0.2	78	87.4	70
9	Sea View Beach-DHA	28	46	0	0.2	73	105.53	63
10	Native Jetty Bridge-Saddar	31	42	0.015	0.152	101	97.1	81.4
11	Port Grand-Karachi Port	29	45	0.001	0	56	88.1	64
12	Scout Head Office-Saddar	30	44	0	0.02	81	95.8	74
13	Empress Market-Saddar	30	47	0	0.048	108	95.6	84.1
14	Lasbella Market-Garden West	29	49	0.001	0.08	117	92.3	83.9
15	Dolmen Mall-North Nazimabad	31	43	0.015	0.0002	103	857.7	76.5

There is the highest temperature variation (30.22-30.99℃) have been recorded on the north-western side of metropolis (Fig. 7), there can be three reason one is; the location (North Nazimabad) is away from coastline, second reason is; it is concrete jungle of build-up land and third is; on northwestern margin there is a mountainous range (Katti Pahari). The completely western part of metropolis is shows high temperature range (28.66 to 30.22℃) one of the prominent reasons is build-up structure and another is away from the coast. Among the high temperatures (27.11-29.44℃) have been recorded at Korangi as well and the reason is this location surrounded by the industrial infrastructure. Another location of Korangi, i.e. location 6 give different temperature range, i.e. 25.55-26.33℃, even shortest distance between location 6 and 7 is around 3.7 km and topography is plain even than temperatures rationally differ between two locations reason is none other than location 6 is urban agricultural zone where the paster grown for the animals, those kept by farmers and other is Industrial Zone, i.e. location 7. It clearly shows the area with the green cover have less temperatures rather than area with the industries. The lowest most temperature readings have been recorded around Location 1 which is lie in university of

Karachi (Gulshan e Iqbal) and prominent feature its green cover, which can also observe in Fig. 3.1. Karachi university have variety of trees and natural vegetation which gives its temperatures ranges quite normal (24-26℃) even when metropolitan temperatures exceeded to 31℃.

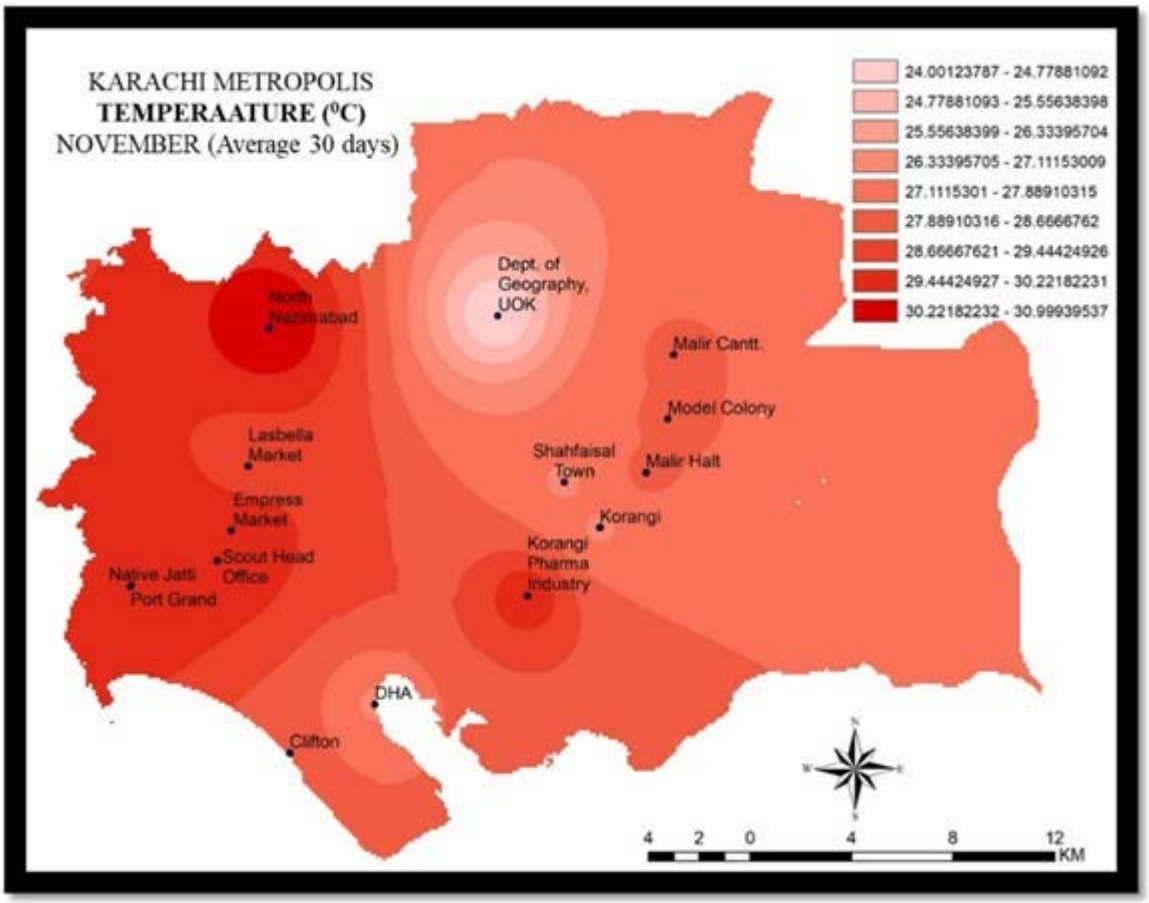

Figure 7. Karachi metropolis temperature (℃) for the month of November

According to Figure 8 Highest Humidity (58.1-59.99%) recorded around location 1 (University of Karachi) followed by location 6 (Korangi urban agricultural zone), location 5 (Shah Faisal Town near Malir River catchment). It is obvious that all location has an extensive green cover in surroundings, which makes the region more humid. The lowest humidity ranges (42-48%), have been recorded on the western and North Western portions. Three locations 9, 10 and 11, i.e. Sea View Beach at DHA, Native Jetty Bridge and Port grant respectively are the located in west also connect with the coastline even than humidity is in low percentage. One prime reason is it is the month of November post monsoon time along with starting of winter season when evaporation rate is comparatively less and readings are of daytime when off shores winds (from continent) can blow only.

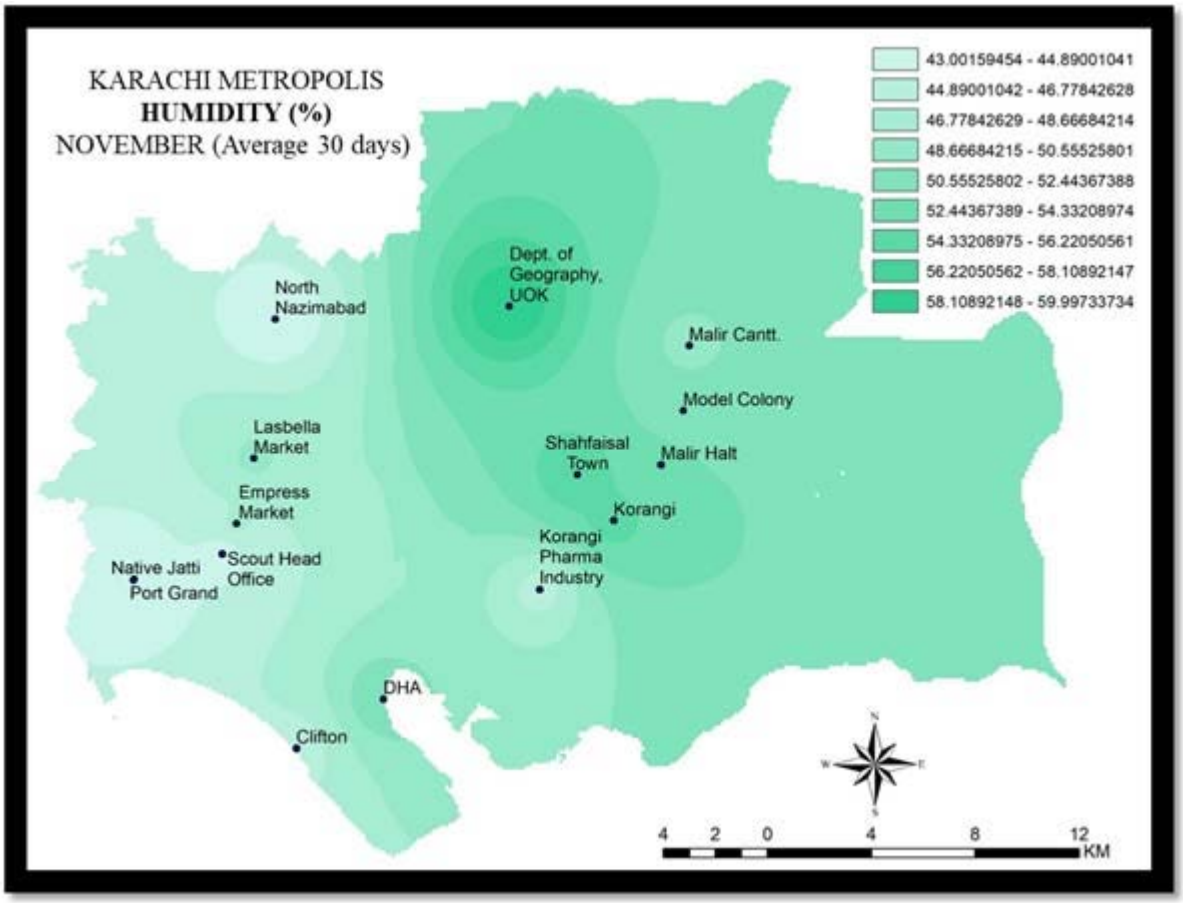

Figure 8. Karachi metropolis humidity (%) for the month of November

According to the Figure 9, Formaldehyde is the hazardous cancer-causing air pollutant (Zhu et al., 2017) is present up to 0.0899 level at two surveyed locations, i.e. location 3 and 4 (Model Colony and Malir Halt). Location three on the Jinnah Avenue Road along the Airport at one side while petrol pump on the other side. While location 4, which in Malir Halt there is a Major Road Shahrah e Faisal on which there is a heavy traffic almost the time. On these locations cancer causing pollutant present at the highest rate (0.0799-0.0899). According to the monitor guide (available instrument) If the reading is less than 0.061 it means hazard level is fresh while if the reading is less than 0.1 it means pollutant level is normal so the environment is not much hazardous. According to the Figure 9, it is obvious areas along the coast have fresh environment rather than inland areas.

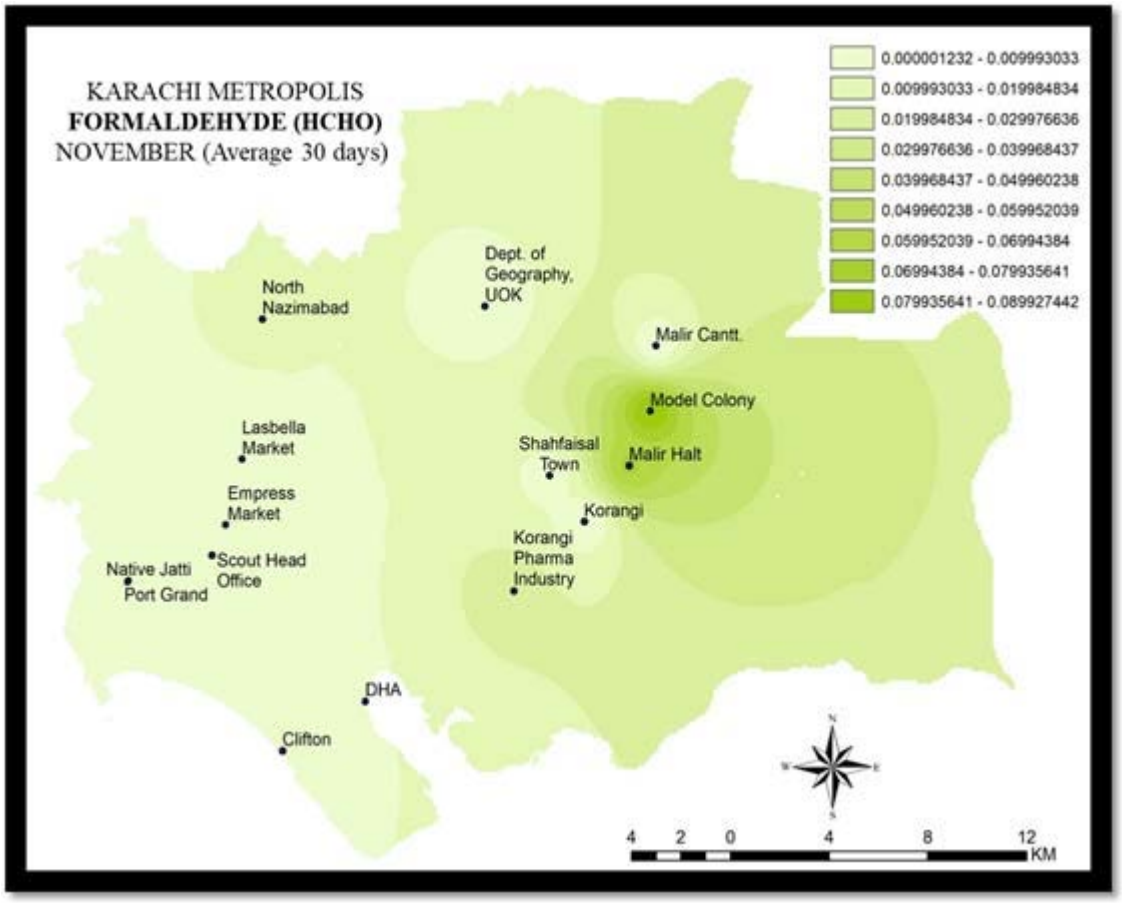

Figure 9. Karachi formaldehyde (HCHO) for the month of November

According to the Figure 10, interpolation results reflect Total Volatile organic compounds (TVOC) pollutants are higher at Korangi (location 6) and Malir Halt (location 4). Most of the VOC's are man-made chemicals, with the high vapor pressure and solubility, these are typically industrial solvents, mostly "used and produced in paint manufacture, pharmaceuticals, and refrigerants, by-products of chlorination in water treatment, are often components of petroleum fuels, hydraulic fluids, paint thinners, and dry-cleaning agents" are emitted in form gases, certain solids and liquid (Wong et al., 2012; Boal et al., 2015). At location, 6 that is the Malir river catchment area where many waste of brown field added from the Landhi and Quaid Abad Industrial areas. If the TVOC level concentration of less than 0.5 mg/m^3 was deemed acceptable (Rigler et al., 2011). At location 6 the highest concentration (0.405-0.455 mg/m^3) which almost a limit of acceptance. The data in (Fig. 10) also suggest the southern portion of metropolitan at higher readings and compare to northern portion. It is clear fact industrial waste in any form, i.e. gas, liquid or solid contain TVOC pollutants and there should be more researches are required to analyze air pollutants in the atmosphere.

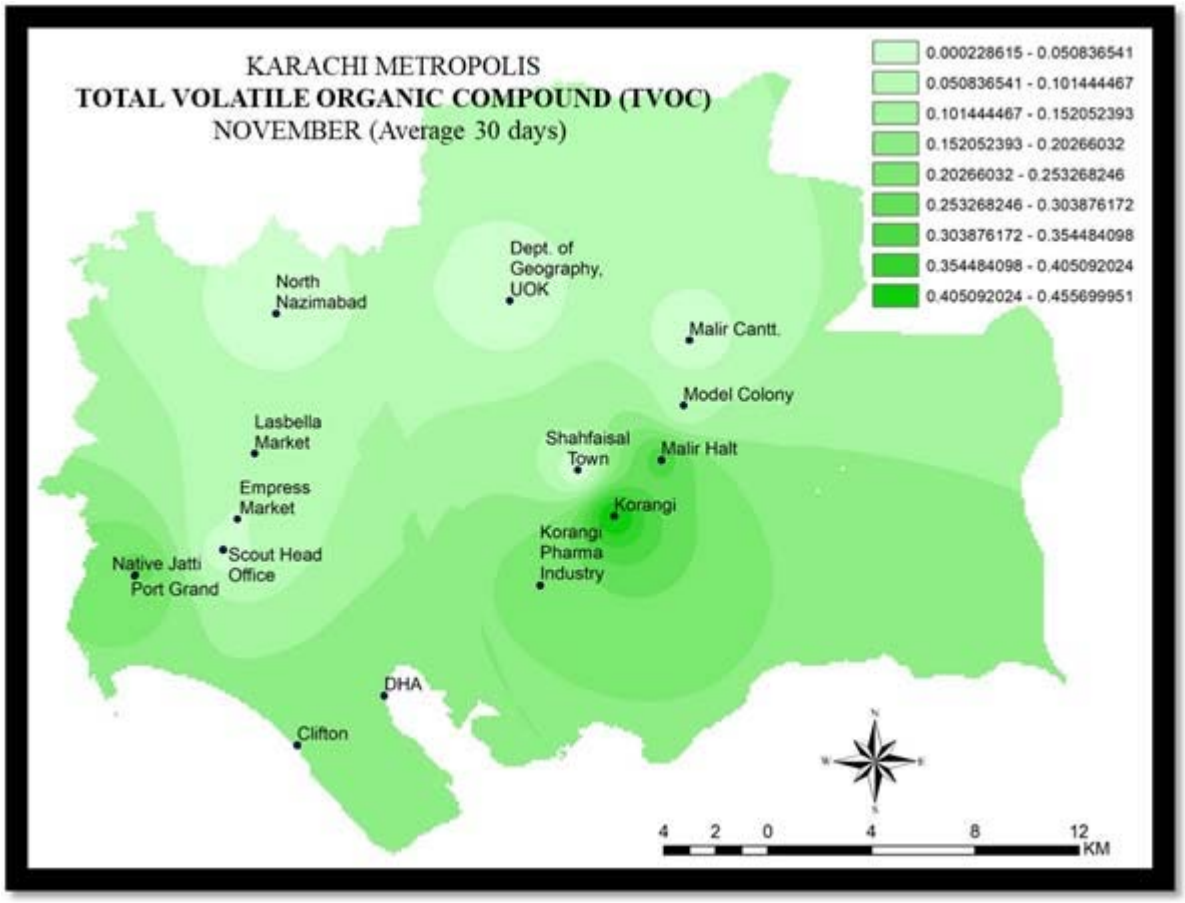

Figure 10. Karachi total volatile organic compounds (TVOC mg/m^3) for the month of November

Fine particulate Matters (PM2.5), i.e. Air Quality Index (AQI) of study area (Fig. 11) ranges moderate (above 50) to unhealthy (up to near 200). The hotspot extracted through the interpolation is Korangi Industrial Zone (location 7). The highest reading is 179.98 ≅ 180 which is unhealthy and caution statement for this level is “not good for anyone”. Followed by Malir Halt (location 4) where the reading is around 121 (Table 2), for such level caution statement is “harmful for sensitive group” (Dhopte & Daga, 2022). Another location Lasbela market (location 14) has reading 117 (Table 2), it is also lie in the range of location 4, therefore the similar caution statement, i.e. “harmful for sensitive group”. The moderate air quality is found DHA, Native Jetty, Malir Cantt, and university of Karachi. Which is unhealthy and caution statement for this level is “not good for anyone”. Followed by Malir Halt (location 4) where the reading is around 121 (Table 2), for such level caution statement is “harmful for sensitive group”. Another location Lasbela market (location 14) has reading 117 (Table 2), it was also lie in the range of location 4, therefore the similar caution statement, i.e. “harmful for sensitive group” The moderate air quality is found DHA, Native Jetty, Malir Cantt, and university of Karachi. Reason is obvious coastal areas, open land and green lands moderate the air quality for some extent.

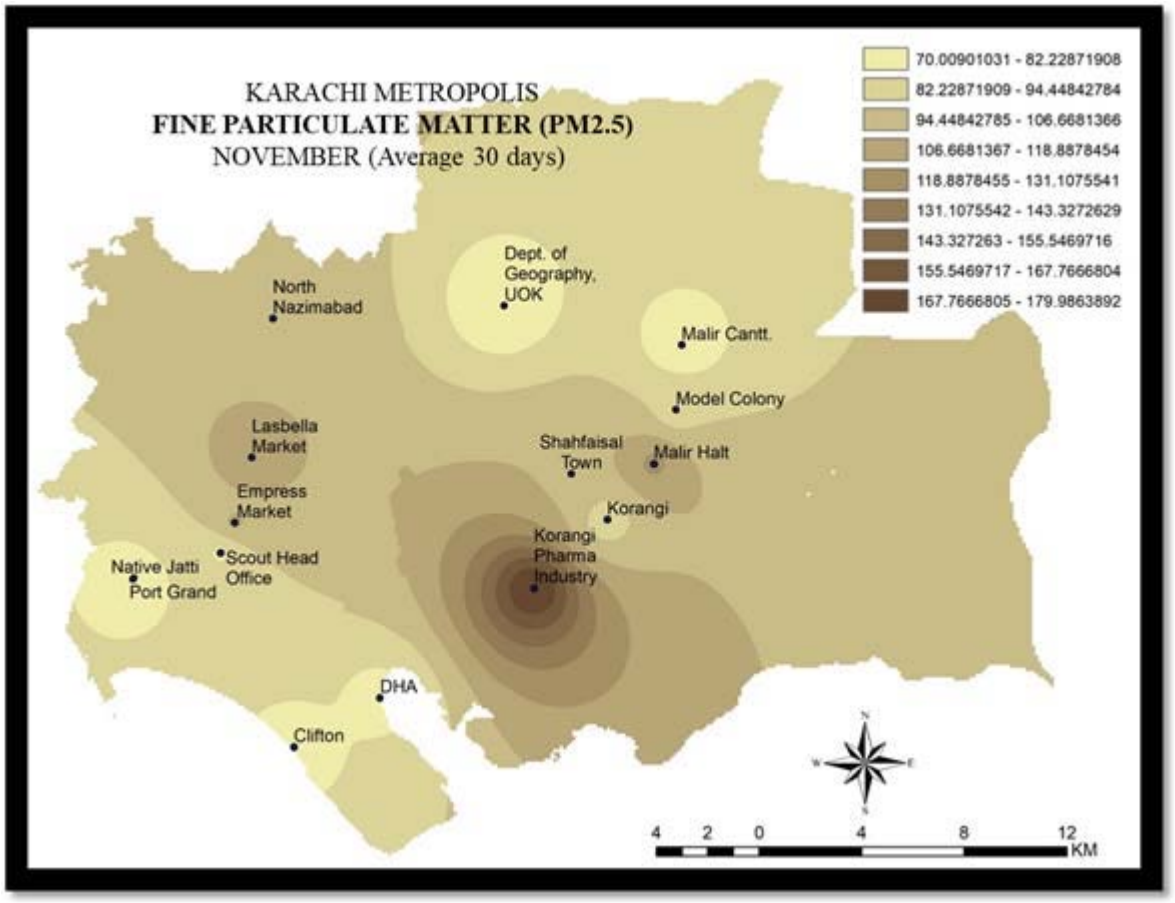

Figure 11. Karachi fine particulate matters (PM 2.5) for the month of November

The results in (Figs 12 and 13) found that the maximum and minimum noise pollution areas during the month of November. The highest value of maximum noise has been recorded at North Nazimabad; it is considered a posh and well-developed area of Karachi. The main source of sound is construction sites and heavy traffic flow. Almost all the urban and industrial areas face the maximum noise caused by transport or traffic, industries, heavy machines and construction sites. Traffic noise also includes the air and railway traffic, even the Figure 13 was not justifying the noise level as the minimum noise pollution level according to interpolation classes started from 57 dB, and this level is not good for senses. Grebennikov and Wiggins (2006) indicated that 40% of teachers were subjected to every day or highest sound exposures beyond the extreme allowable levels as per Australian Occupational Health and Safety (OH&S) standard. The sound level is not harmful to living organism if it is less than 70 dB despite how longer exposure (Muzet, 2007), but it is hazardous if living organism exposed beyond 85 dB for more than eight hours (Kurmis & Apps 2007).

In minimum noise, map (Fig. 13) it is seen clearly Lasbela Market and Empress Market; location 14 and location 13 respectively are just about to touches the level of 85 dB. Noise Pollution effects human health in many ways, e.g. “Hypertension”, “Hearing loss”, “Sleep disturbances”, “Child

development", "Ccardiovascular dysfunctions", "Dementia", "Psychological dysfunctions" (Morillas, 2018).

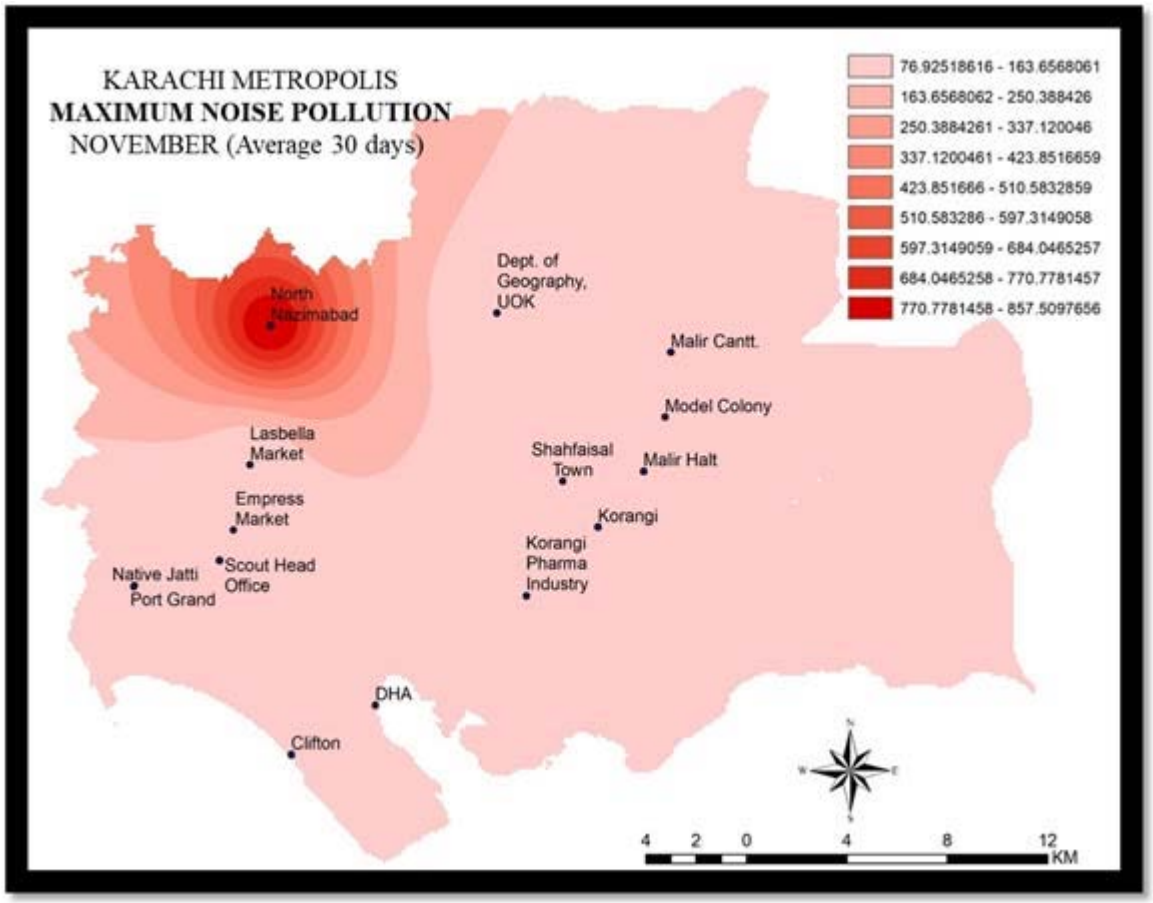

Figure 12. Karachi maximum noise pollution (dB) for the month of November

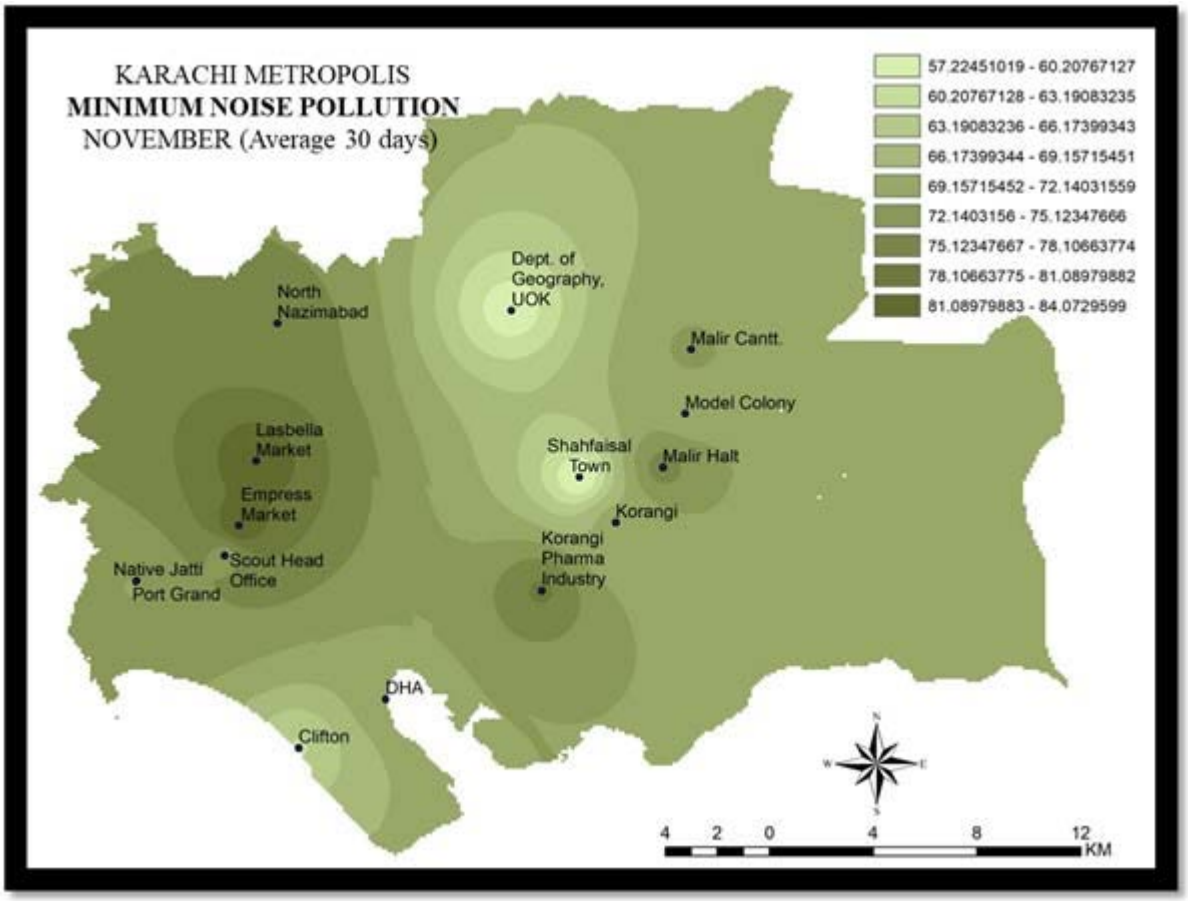

Figure 13. Karachi minimum noise pollution (dB) for the month of November.

4. Conclusion

The northwestern and western part of Karachi metropolis shows high temperature ranges, i.e. 28-31℃, while low temperatures are recorded at Gulshan e Iqbal because of green cover prevalence. In contrast, the highest humidity have been recorded from the Gulshan e Iqbal (University of Karachi), i.e. 60 %, followed by Korangi urban agricultural zone and Shah Faisal Town near Malir River catchment. It reflects the areas with the high amount of green cover have high humidity. Formaldehyde which is the cancer-causing hazardous compound have found at Model Colony near Airport (0.09 ppm) and Malir Halt (0.072 ppm) along shahrah e Faisal at one side and railway station on the other side. Both places have the highest reading among all other locations, which means his location and its surrounding is catalyst to such situation.

The presence of Total Volatile organic compounds are the pollutants are higher at Korangi (urban agricultural area) and Malir Halt (transport junction). The reading is significantly high in air (0.456 and 0.327 mg/m^3) in the month of November and these appraisals might approach its hype in summer season. Fine Particulate Matters (PM2.5), i.e. Air Quality Index (AQI) is high in general in all over the metropolitan. Highest reading 180 recorded at Industrial area followed by Lasbela Market; 117, where the congested infrastructure of roads, bus rapid transport and built-up land makes the air quality up to

susceptible. Noise pollution of Karachi is at its peak. The hotspot exposed at North Nazimabad where 858 dB followed by at Beach 105.5 dB. The difference between both places in noise level was observed at North Nazimabad, the noise level was constant, due to construction sites while at beach, it was variable and the reason is vehicle with the high speed.

4.1. Suggestions and recommendations

- Government should take responsibility to provide healthy environment by introducing Greenways along the transportation routes.
- Either air pollution or noise pollution; both effects the physical and/or mental health, it is therefore, Karachiites should change their lifestyles and think about their physical and mental concord.
- Surrounding Infrastructure matters. If they live in mixed land-use, they can alleviate air quality by introduction of home plantation and community gardens. They can also alleviate noises by application of soundproofing (sound barriers) at their residences and at workplace as well.
- On public places, people should use the mask from the exposure of unhealthy environment and use air plugs and noise-cancelling headphones to overcome unnecessary noises.

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