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POTENTIAL IMPACT OF COMMUNICATION INFRASTRUCTURE ON TERRISTRIAL HABITAT AND SPATIAL RELATIONSHIP BETWEEN MULTIPLE DISEASES AND INSTALLED CELLULAR TOWERS

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ABSTRACT

A large number of cell phone towers are installed for mobile communication by many telecom service providers in the study area. These cell towers have installed antennas at a certain height which radiate electromagnetic radiation i.e. radio waves used by smart phones, tablets, laptops etc. In these days smart phones are widely used for communication so we are continuously in contact with the electromagnetic radiation while a long period exposure to these bands may be harmful to human health. Cell phones operate within the frequency band of 800 MHz, 900 MHz and 1800 MHz and the latest 3G technology works between 1900-2200 MHz. The growing use of wireless gadgets has introduced concerns about health risks in residential areas. Radiations coming out from cell tower antennas are measured by using dbm meters at different location and at different distances from cell towers by using Global Positioning System (GPS). This study focused on intensity of radiation and its possible impact on human health in different areas. Questionnaire surveys are also conducted to find out the health status of the residents. All the field data are processed, analysed, evaluated and presented in the form of intelligent maps to demonstrate how GIS technologies remain helpful to find out the vulnerable areas and to guide decision makers to take possible necessary measures for reducing health risks.

KEYWORDS: Cellular towers, EMF Radiation, GIS Analysis, GPS Surveys, Power Density, Questionnaire

INTRODUCTION

Since last few years the telecom industry in Pakistan has grown tremendously and a large number of companies provide telephony services by spreading their network and installing cellular towers throughout the country. With the expansion of cell towers network business of telecom service providers is growing up while on the other side we are directly or indirectly exposed to the ectromagnetic radiations. Whole population is now exposed to varying degrees of electromagnetic radiation and the levels will continue to increase as technology advances.

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The growing use of wireless communication in the last decade has introduced concerns about health risks (Kumar, 2013). The cellphone towers/base stations are transmitting continuously and produce constant pulsed microwave radiation even when nobody is using the phone that are affecting the people inside and outside public and residential buildings (Marinescua and Poparlan, 2016).

According to the Department of Interior charges, United States, Cellphone towers are not only dangerous to human health but also pose a great threat to the plants, wildlife and especially birds and bees (More Desk, 2016). A number of animals near mobile towers are prone to various dangers and threats to life including birth deformities, abortions and general decline in overall health (Durgam, 2017). According to a research conducted in Croatia the experiments results verified that the mobile phone affect the honeybees' life system (Halabi, 2014).

There are more than two billion people that are using mobile phones in the entire world. Modern technologies that are using in Europe are GSM 900, GSM 1800 and UMTS. According to a report generated by IARC in 2012 Brain/Nervous Cancer is the third largest chronic disease reported in Pakistan. It may be due to long-term use of mobile/cell phones which are in contact with cellular towers via Electromagnetic Radiation that acts as carcinogens. To measure the thermal effect of electromagnetic radiation on the human body, the specific absorption rate (SAR) is used, which is a measure of the power density per unit mass (Medeiros and Sanchez, 2016).

Background

In 2013, National Institute of Young Scientists issued a report on awareness about cancer in Pakistan. According to the report Sindh province stands second with 33.5% patients diagnosed with cancer after Punjab having 54.4% patients. It shows that cancer is growing up gradually in Sindh as well. There may be many different reasons of the said diseases but we cannot avoid impact of electromagnetic radiation, which acts as carcinogens, emitted from widespread installations of cellular towers on the roof of residential, commercial and educational buildings. Those individuals who are more sensitive to EMR reported symptoms for headaches, fatigue, dizziness, sleep disorders, hearing loss and tinnitus (Kucer and Pamukcu, 2014). Various symptoms involving one or more organs on the same individual have already been related to the exposure to electromagnetic fields (Bensefa-Colas and Dupas, 2014).

This study is basically conducted to find out the effects of radio frequency on human being. This research has investigated a variety of possible effects and detailed study suggests that use of mobile phones for a period of less than ten years do not increases the risk of chronic diseases like brain tumors and others, depend on the synthetic absorption rate of radiation. However, some cases are reported from those users who talks long hours on mobile phones. Such cases indicate the possible association of RF fields and mobile telephones. On the basis of which we can say that long term users are at greater risk of diseases.

With the significant increase in mobile phone usage, possible health risks related to RF exposure have become the subject of considerable attention (Pachuau, 2013). If an individual is exposed to electromagnetic radiation, it receives radiation, because the body is 70% fluid. It is likely to cook in the microwave furnace. There will be varied vibrations of broadcasting frequencies within the body, which generates localized warming within the body. This leads to boils, dehydration of fluids nearby eyes, joints, brain, abdomen, heart, etc. (Mohril, 2020) Some specific diseases are reported frequently within the study area where there are a large number of cell towers installed in less than 300m distance. With traditional methods inadequate for control and eradication, remote sensing (RS) and geographic information systems (GIS) offer potential to combat these diseases through development of risk maps, that is, maps which show areas where human populations live in environmental conditions susceptible to disease infestation (Kazmi, 2009) The purpose of the study is to analyze the spatial relationship between cellular tower antennas and the diseases from which residents of the study area are suffering and to develop the risk maps or point out the vulnerable areas.

Study Area

Karachi is the largest city in Pakistan and the capital of the Sindh province. It is located on the coast of the Arabian Sea between 24-56'-00" N and 67-01'-00" E. It is the major commercial and industrial center as well as the largest seaport. The city of Karachi is divided into six districts. Among the six, District Central has four towns namely Gulberg Town, Liaquatabad Town, North Nazimabad Town and New Karachi Town. New Karachi town is the area where pilot study has been conducted.

New Karachi town has thirteen union councils and according to SBCA having population ten lac thirty eight thousands approximately. Within the study area some particular diseases are increasing as reported by some well reputed private as well as government hospitals. There is a need to do research for finding the relationship between the diseases and electromagnetic radiations emitted from cellphone towers as there are

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170 cellphone towers installed on residential, commercial and educational land-use within the study area which are definitely radiating all the time.

Hypothesis

Radio/microwaves radiated from cellular tower antennas may have an adverse impact on human health.

METHODOLOGY

In this study research objectives are achieved with the help of two types of data acquisition. One is the high resolution Satellite data *i.e*. google earth which is used for the development of base map and confirm the existence of cellular towers and other one is the Collateral data consists of primary and secondary data acquired from GPS surveys, questionnaire surveys and EMR surveys conducted in the area of study. The uses of Remote Sensing and GIS technologies have tremendously helped the preparation of susceptibility maps with greater efficiency and accuracy in nowadays (Bansal Deep and Singh, 2012).GPS surveys are conducted to identify the location of cell phone towers within the study area while intensity of Electromagnetic Radiation is measured at different distances with the coordination of telecom engineers. There are 170 tower sites in North Karachi for which surveys are conducted while 300 questionnaires are collected.

A GIS-based approach utilizes users and mobile towers locations to detect the exposure area. The radiation amount affecting nearby users is calculated using ArcMap as a GIS solution from Esri Company. This helps to build an analysis maps based on information we provide to show the affected area with respect to the tower location (Al-Sahly, 2018). Decision support in GIS refers to the tools and information provided by/to people during all aspects of their decision-making processes (Nyerges, 2010).

In this study spatial analysis is performed to find out the effects of radiation on human health in particular areas. On the basis of overlay analysis of cell tower density, intensity of electromagnetic radiation and disease data collected through questionnaire survey advance risk analysis is performed to categorize the area into low, moderate and high risk areas.

Geodatabase Design

To store spatial, non-spatial information and perform analysis in a well-defined geometry, geodatabase is used. It's a common data management framework for GIS application.

In order to store relevant data it was mandatory to develop proper geodatabase model. In this study Geodatabase model is based on

Coordinate system (GCS-WGS 1984), which covers data content and validation rules, processing and modification rules and more specifically relationships among all objects. The model is based on information collected from various organizations, district hardcopy maps and data collected from field surveys.

GPS (Global Positioning System) Surveys

In this research GPS surveys are conducted to mark and store the geographic locations of cellular towers that are installed on different landuse. In the meanwhile some other records are completed e.g. site address, service provider and downlink frequency etc.

EMR Intensity Surveys

To note down the strength of electromagnetic radiation (radio wave and microwave) emitted from cellular towers at different distances, EMR intensity surveys are conducted.113 sites are selected for finding the intensity of radiation at different distances. EMR detector is used to find out the radiation in **dbm** and then converted into milli-watts by applying formula.

Statistical Calculation

Electromagnetic radiation power is actually calculated in decibel milliwatt (dbm). There is simple conversion of power from dbm to milliwatt.

The power conversion from dBm to mW is calculated by the following formula:

$$P_{(mW)} = 1mW \cdot 10^{(P(dBm)/10)}$$

So

$$1dBm = 1.258925mW$$

Gain of Cell Tower's Antenna

Every Antenna has its own gain when electricity is supplied. Nearly all antennas installed in the study area on different towers have a 20 db gain. 20 dB gain means signals of radio waves are enhanced by 100 times. In the study area, as all tower's antenna are having 20 db gain so all of these tower antennas required 100W power each to radiate the signals 100 times in the free space. The power required by antenna to radiate may be calculated by using following formula:

$$\boldsymbol{P_{(W)} = 1W \cdot 10^{P(dBW/10)}}$$

So, required electricity power to a 20 DB antenna is calculated as:

$$\boldsymbol{P_{(W)} = 1W \cdot 10^{(20dBW/10)}}$$

$$\boldsymbol{P_{(W)} = 100W}$$

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Free Space Path Loss Calculation (FSPL)

There are losses in RF signals in free space right after radiated from the source i.e. cell towers antenna. These losses are calculated at different distances from cell towers antenna in this study by using following formula:

$$\text{FSPL} = 20\ \log_{10}(d) + 20\log_{10}(f) + 20\ \log_{10}(\frac{4\pi}{c}) - G_{Tx} - G_{Rx}$$

Where,

d = Distance between the antennas.

f = Frequency

G (Tx) = The Gain of the Transmitting Antenna (Cell tower's Antenna).

G (Rx) = The Gain of the Receiving Antenna (cell phone)

c = Speed of light in vacuum (Meters per Second)

Above formula is used to find out the free space path losses at 113 different locations and at different distances. The gain of transmitting antenna (cell towers) is 20 db. While the gain of receiving antenna (cell phone) is 2 db. Speed of light is constant i.e. 3 x 10^8 m/s and distances from towers are variable i.e. 100m, 200m and 300m. For this research study Power density (PD) of cellular towers is calculated only for downlink frequencies optimized for GSM 2100 MHz in mw/m².

Electromagnetic Radiation Power (dbw to dbm)

Radiated Electromagnetic Power is calculated in dbm at different distances or locations after subtracting the free space path losses by using following formula:

$$P_{(dBm)} = P_{(dBW)} + 30$$

Power at 0m distance.

For a 20 db gain of antenna the radiated power in dbm at 0m distance can be calculated as:

$$P_{(dBm)} = 20dBW + 30$$

$$P_{(dBm)} = 50dBm$$

It means when a 20 DB antenna starts to radiate into the free space its equivalent radiated power at 0 m is 50 dbm. As the distance increases from the antenna its radiated power decreases. This reduced radiated power is calculated by subtracting the path losses from 20.

Microwave Radiation at different distances.

A number of different locations have been selected to collect the radiation intensity of cellular towers directly in line of sight of towers or without line of sight. It is observed in this study that the locations that are directly in line of sight of low antenna/ rooftop e.g. schools, religious places and markets at a distance of less than 100 m are experienced values in range 0.0003237 to 11.263106 μW/m²

At variable distances, excluding terrain and other obstacles, radiated power from transmitting antenna is calculated in dbm after subtracting path losses as follows:

dbw at 100 m = 20 - fspl
= 20 - 57.88
= - 37.88 OR approx. -38
= -38
Power in dbm = -38 +30
= -8 dbm

dbw at 200 m = 20 - fspl
= 20 - 62.90
= -42.9 OR approx. -43
= -43

Power in dbm = -43+30
= -13 dbm

dbw at 300 m = 20 - fspl
= 20 - 66.43
= - 46.43 OR approx. -46
= -46
Power in dbm = -46 +30
= -16

Questionnaire Surveys (Random Sampling).

Scientists have tackled most of the methodological issues concerning surveys and the scientific literature offers excellent proposals for planning and conducting surveys (Davino and Fabbris, 2013). A questionnaire is developed for the residents of the study area especially for those who are

living in such areas where cellular tower's radiation overlapped with more than one tower. This questionnaire have a number of questions to get the information about the usage of smart cell phones, daily usage time, wireless services availed, may or may not have suffered from included diseases and so on. About 300 questionnaires are collected within the study area.

Raster Analysis.

A base map is developed after digitization of satellite data to perform Raster Analysis. All scanned and geo-referenced maps of the study area need to be digitized before further processing. On the basis of landuse, whole area is divided into six classes. Each Union council of the area is different in shape and having different area in sq.km. Number of mobile towers installed is also different that's why density calculation in a specific area may not be perfect. Point Density analysis has solved this issue. Point density calculation tool is used in this study to find out the density of cellular towers in the entire study area.

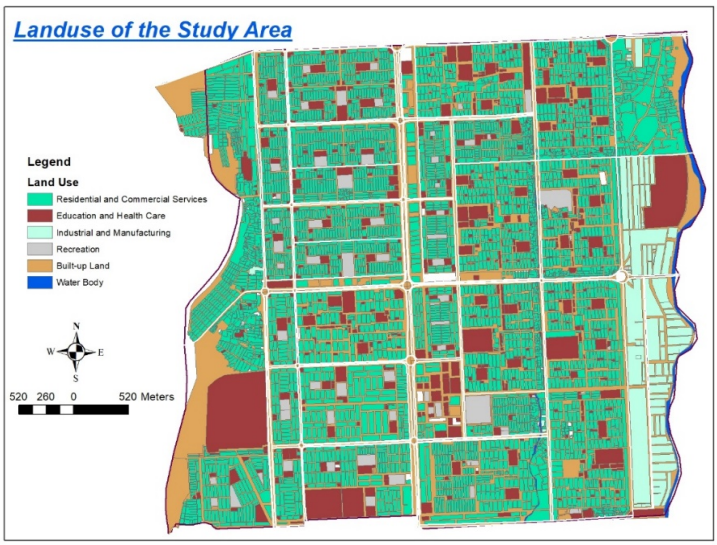

Figure 1: Landuse of the Study Area Source: Author

Fig.1 shows the landuse of the study area. Whole study area is classified into six classes. Majority of the landuse is covered with residential and commercial services. Education and healthcare facilities are the second major landuse of the area while rest of the area is divided into recreation, water body and built-up land. Industrial area of the land is also highlighted as a landuse of the study area.

There are 170 towers in the study area, as showed in Fig.2, installed by different cellular companies e.g. Mobilink having 48 towers, Telenor

having 41, Ufone having 24, Warid having 17 and Zong having 40 towers. All antennas installed on towers are having gain of 20 db. Power density (PD) of the antennas is calculated only for downlink frequencies optimized for GSM 2100 MHz.

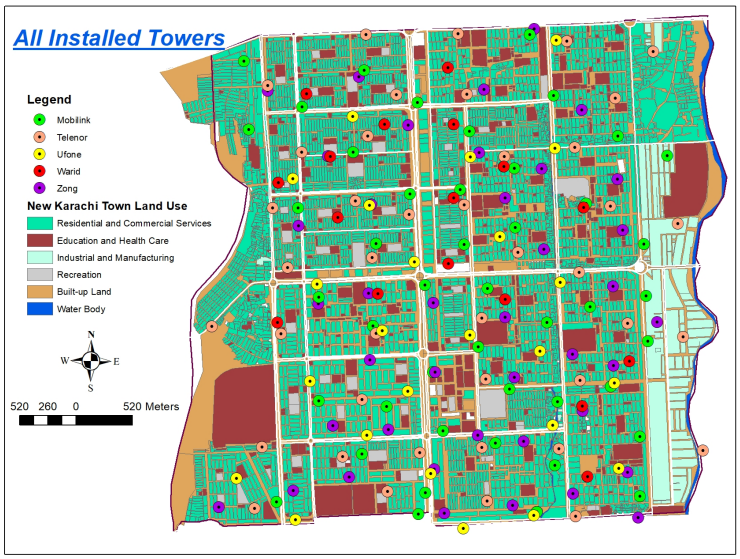

Figure 2: Installed Cellular Towers Source: Author

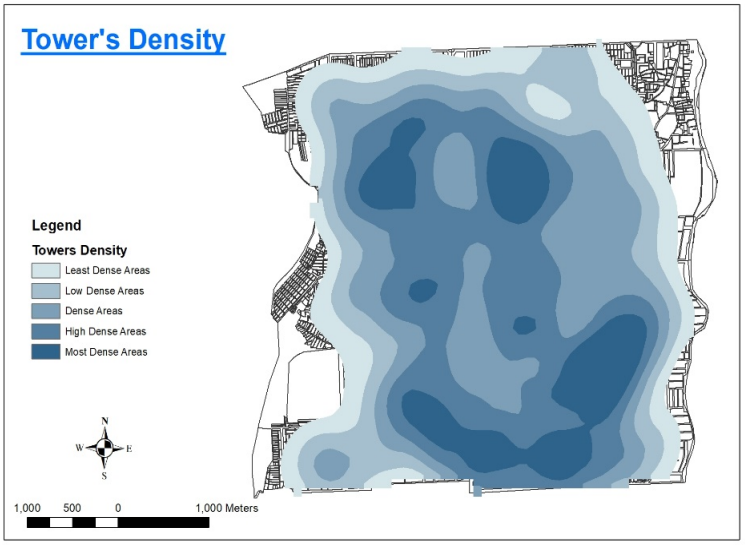

Fig. 3 sh **Figure 3:** Installed Cellular Towers Density Source: Author dy area. This figure shows that on the basis of density, study area is classified into five classes ranging between 0.007 to 14.5 per sq.km.Fig.4 shows the areas having dense number of cellular towers. The most dense areas are

selected using raster operations and rest of the areas having least number of cell towers are deducted.

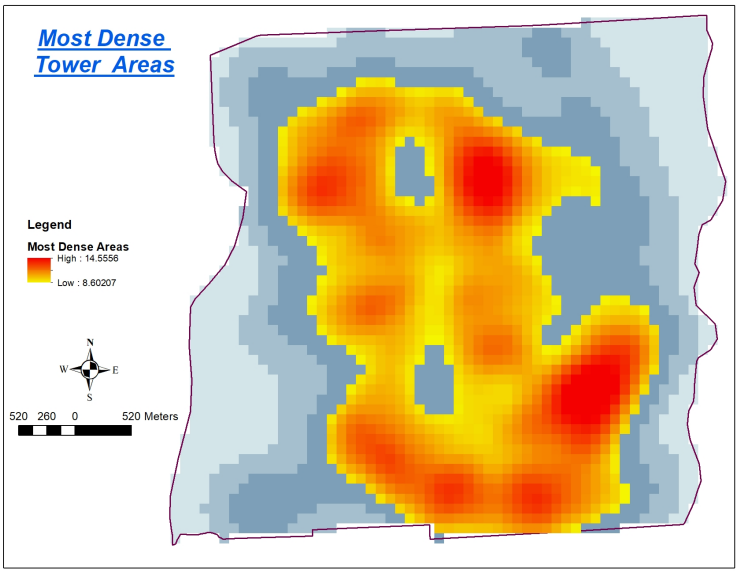

Figure 4: Dense Cellular Towers Area Source: Author

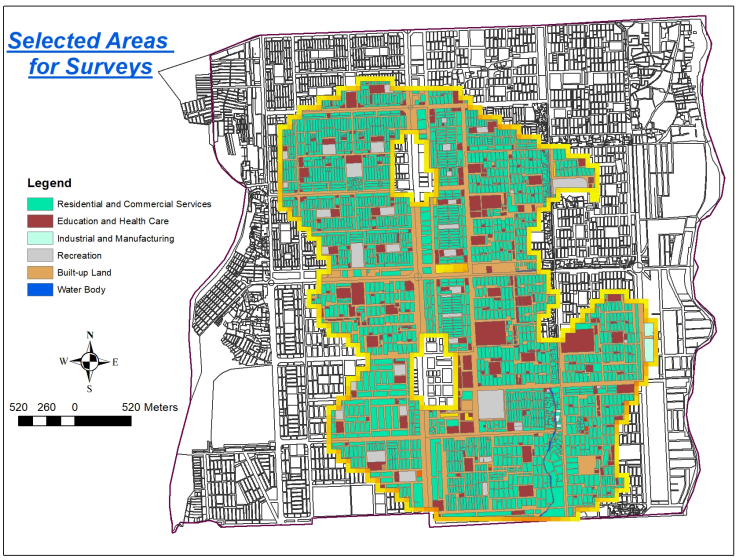

Figure 5: Surveyed Area Source: Author

Fig.5 shows the clipped areas where surveys for finding the power of electromagnetic radiation is planned. This area is clipped on the basis of most dense areas by overlying the raster data of most dense areas and the landuse of the study area.

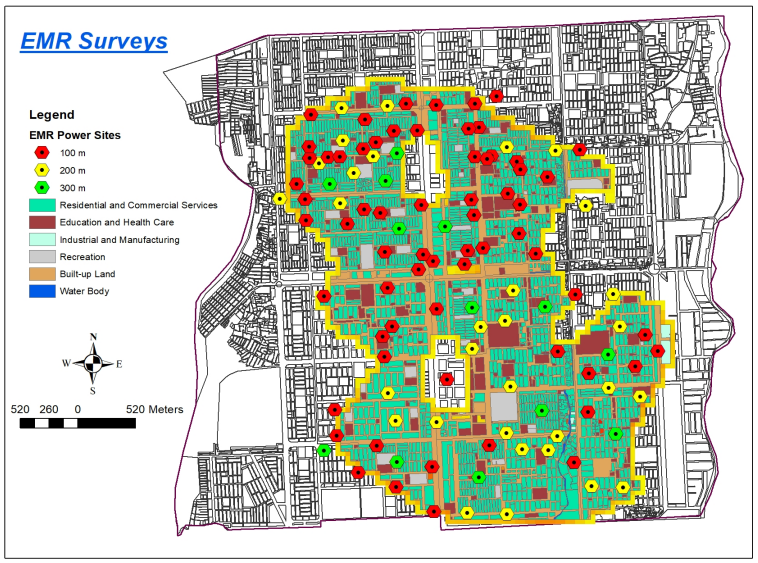

Figure 6: Electromagnetic Radiation Survey Source: Author

Fig.6 shows the EMR sites at which power of electromagnetic radiation is calculated at different distances. There are 113 sites out of which 13 sites are at 300m horizontal distance, 31 sites are at 200m and 69 sites are at 100m horizontal distance from the tower site.

Table 1 shows some records of accumulated power of electromagnetic radiation emitted from cellular tower of different cellular companies. These powers then converted into milliwatt and microwatts for understanding of general public. It is clearly noted that there are higher values of radiation within 100m distance from cellular towers as compared to the values at a distance of 300m.

RESULTS AND DISCUSSIONS

In this research it is found that radiating power of cell tower antennas are controlled manually from a central point/ hub. It is also found that during peak hours its radiated power is increased so that calls may not be dropped. As a result, one can expose to high microwave radiation in the peak hours *i.e*. evening hours which causes tinnitus, headaches, fatigue, sight losses and in some cases brain tumor and neurological disorders. Fig.7 shows below the power density in the form of raster data and is created using raster analysis tool. On the basis of power density raster data is classified into three classes as areas are having different values.

On the basis of EMR power density calculated in the study area through surveys raster surface is created. This surface is classified as having low, moderate and high intensity areas. Three hundred questionnaires are conducted in the study area particularly in those areas which falls in high

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intensity areas. The targeted audience for questionnaire surveys are male/female young, old and permanent residents of the area. On the basis of questionnaire following analysis are made.

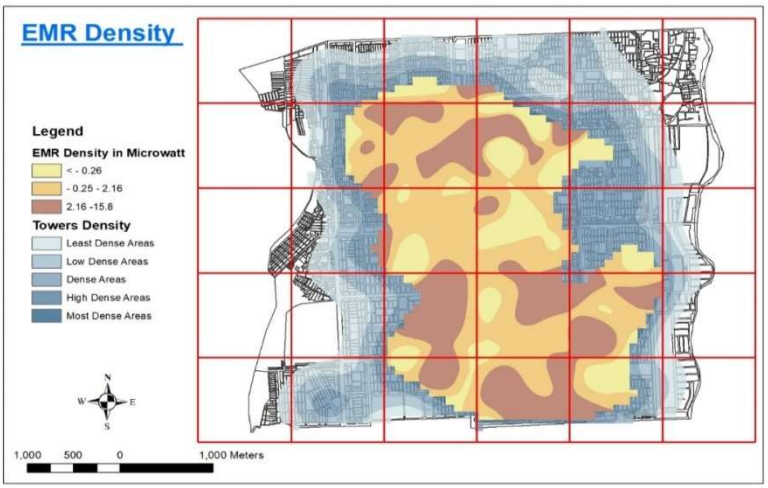

Figure 7: EMR density analysis Source: Author

Table 1. Analysis of questionnaire Source: Author

Total No. of Participants	Gender		Types of Cell Phone		Living Time period			Usage Time/day			Family History of Chronic disease
	Male	Female	Ordinary Cell Phones	Smart Cellphones	Above Twenty Years	10 to 20 Years	Less than 10 years	Less than 1 hour usage	1 to 3 hours usage	Above 3 hours usage	
300	214	86	29	271	269	27	4	20	30	250	14
100%	71.33	28.67	9.67	90.33	89.67	9.00	1.33	6.67	10.00	83.33	4.67

It is observed in table 1 that total 300 questionnaire are conducted in the field among which 71% of the participants were male and 29% are

females. It is amazingly noticed that 90% of the participants are using smart cell phones while rest of the 10% are having ordinary cellular sets. The important factor is the living time period at a certain place. Statistics of the survey says that about 90 % of the total participants are living at their place for above 20 years and approximate 9% are living at their place for about 10 years while remaining 1 % of the participants who are mainly tenants are living at their place less than 10 years. Usage time of the cellular phones is also an important factor for the exposure to electromagnetic radiation. According to the statistics of the conducted questionnaire 83% of the participants are attending their cell phone above 3 hours per day, 10% are using for 1 to 3 hours per day while approx. 7% are attending their phones less than 1 hour per day. As far as family medical history of the participants are concerned during this study it is found that only 4% of the participants are having medical history of their family members for some chronic diseases like cancer, tumor and heart disease.

Table 2. Analysis of cell phone users Source: Author

Age Group	**Age Group Vs Cell Phone Usage/day**		
	Less than 1 hr.	**1hr to 3 hrs.**	**Above 3 hrs.**
below 25	2	8	38
26-35	7	11	157
36-45	11	11	55

Table 2 shows the cell phone users with duration and the age group. It is observed that only 2 participants of age group below 25 years attend their phone for a time period of less than 1 hour while 38 participants are using above 3 hours. Similarly, 11 participants from the age group 36-45 are attending their cell phones less than 1 hour while 55 participants declared that they are using their phones above 3 hours. Amazingly, it is noted that most of the participants i.e.157 out of the total 300 participants belong to the age group 26-35 are using their cell phones for above 3 hours while only 7 participants of this group are attending less than 1 hour. It means that large number of young generation are involved in using gadgets. These gadgets are also radiating devices which may increases the health risk.

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Table 3. Classification of multiple diseases and symptoms Source: Author

Classification of Diseases and Symptoms Reported during Questionnaire Survey					
Class	**1**	**2**	**3**	**4**	**5**
Disease & Symptoms	Headaches, Tiredness, and Tinnitus with heart diseases, Neurological disorder and frequent miscarriages	Stress and headaches with tiredness, No Chronic disease	Tiredness and Nausea with No Diseases and No Medical History	No any diseases reported while suffering from Tinnitus and headaches.	No any Symptoms and No chronic Diseases reported
Type of Mobile Phone	Smart	Smart	Smart and Ordinary	Smart and Ordinary	Smart and Ordinary
Cell phone usage	Above 3 Hours	Above 3 Hours	Above 3 Hours	Less than 1 hr. to 3 hours	Less than 1 hr. to 3 hours

Table 3 is describing the classification of diseases and symptoms made for developing risk analyses. Participants suffering from any of the chronic disease and feeling some symptoms are fall in class 1, while class 2 is having those participants who are not suffering from chronic disease while feeling only different symptoms. The participants of these classes are enjoying broadband services through smart cell phones over a time

period of above 3 hours. Participants of rest of the three classes are using ordinary cell phones in large numbers over a time period of 1 hour to 3 hours having no disease history and no chronic disease reported.

Table 4. Risk values for geo-processing Source: Author

Assigned Risk Values for Geoprocessing					
Analysis Buffers	**Diseases with family history**	**Only Symptoms without any disease**	**Radiation Intensity**	**Cell Towers**	**Total Risk Values**
100	6	5	6	6	23
200	3	2	3	3	11
300	1	1	1	1	4

Table 4 is showing the assigned risk values to multi-buffers created for different features as headed in the table above. Higher risk values are assigned to those areas which falls under 100m distance of that feature while lower risk values are assigned gradually beyond 200m and 300m areas away from that particular features. Union tool is used to accumulate the required data and a sum of all assigned risk values is calculated in total risk values field. On the basis of total risk values advance risk analysis is performed through geo-processing tool to find out the high and low risk areas in the study area.

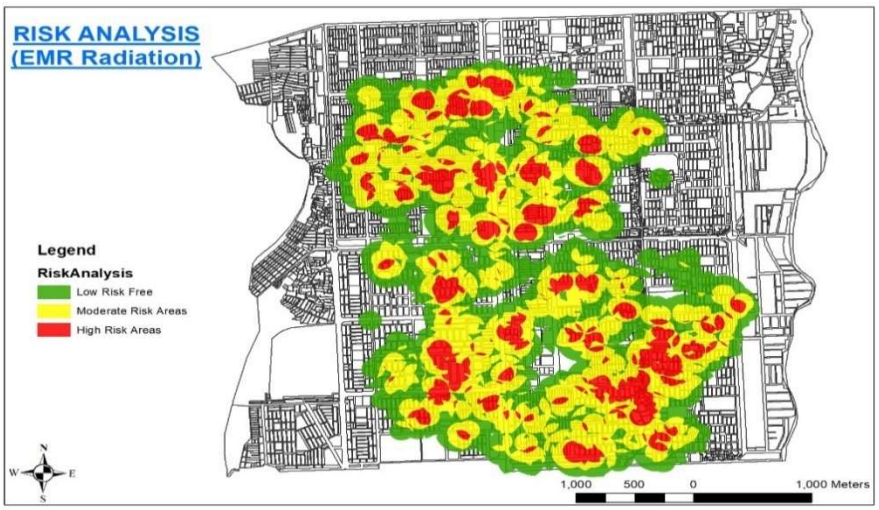

Figure 8: Advance Risk Analysis Source: Author

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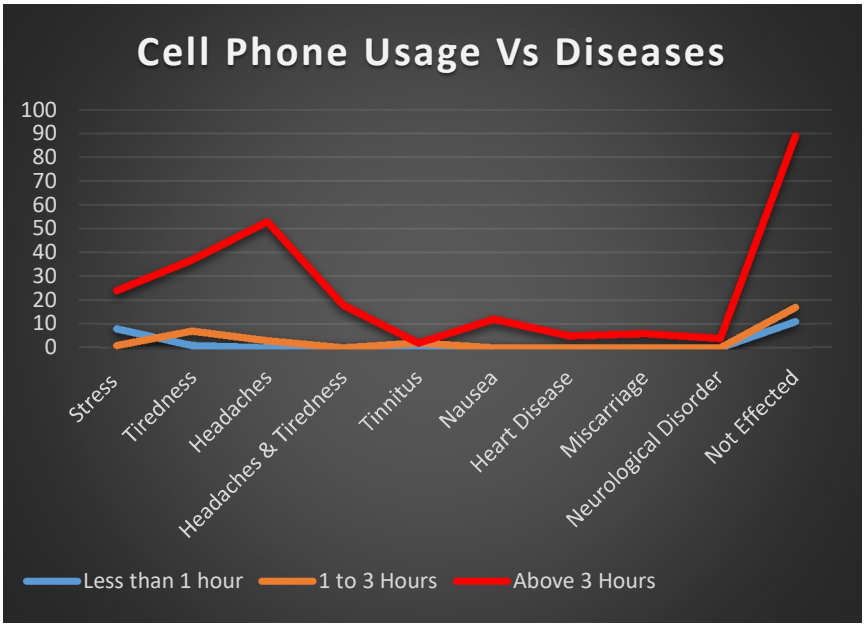

Figure 9: Time Period and Disease Analysis Source: Author

Fig. 8 shows the advance risk analysis after conducting surveys in the study area. This analysis map shows the high risk, moderate and low risk areas. It is observed that the areas near cell phone towers experiences more electromagnetic radiation and hence participants who are living near cell tower in direct line of sight of antennas are at larger risk than those who are not in the direct line of sight. A large number of participants declared that they didn't feel any change in their health while using cell phones and they perform their routine work normally. While the second largest group of participants declared that they are suffering from headaches continuously when using cell phones more than 3 hours. Tiredness is the second most noted symptoms in the study area.

Fig.9 shows the disease analysis in the study area. It is observed that those participants who are using their cell phones not only for attending calls but also for browsing, watching videos and enjoying other stuff are more vulnerable than those who are using cell phone less than 1 hour. In the below mentioned graph it is clearly visible that nearly all types of noted symptoms are reported from those who are using their gadgets above 3 hours while remaining participants are effected in less numbers.

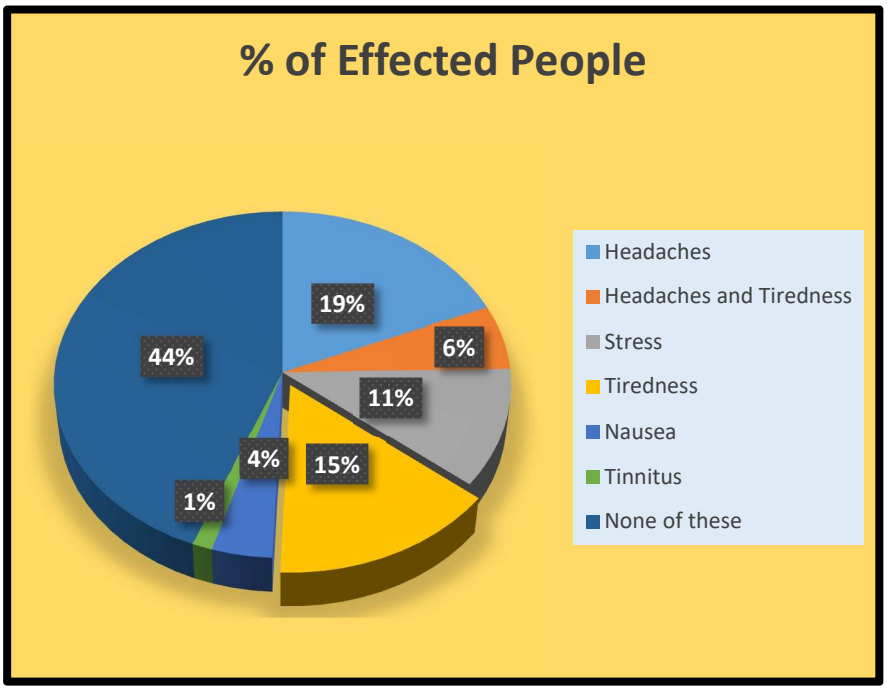

Figure 10: Effected People Source: Author

Fig.10 shows the percentage of those effected people who are having week immune system as compare to others causing them hypersensitive to electromagnetic radiation. Result shows that about 44% of the total participants have no effect of EMR radiation on their health and didn't feel any of the noted symptoms. While rest of the 56% participants are effected as suffered from headaches, tiredness, stress, nausea and tinnitus in decreasing order respectively.

Fig.11 shows below the directional antennas (Microwave) mounted at low height on a tower installed on residential building. These towers are more vulnerable than the omnidirectional antenna. Microwave radiated in a single beam to communicate with the other towers. At these low heights it penetrates with more intensity and direct exposure to this directional antenna is dangerous to living organisms including birds. Installation of these towers may have potential impacts into the bird's aviation. Terrestrial habitat pattern could be changed or disturbed depending to the height and type of towers to be stationed. Potential impact will be more significant if the new towers are placed along the corridor of bird migration.

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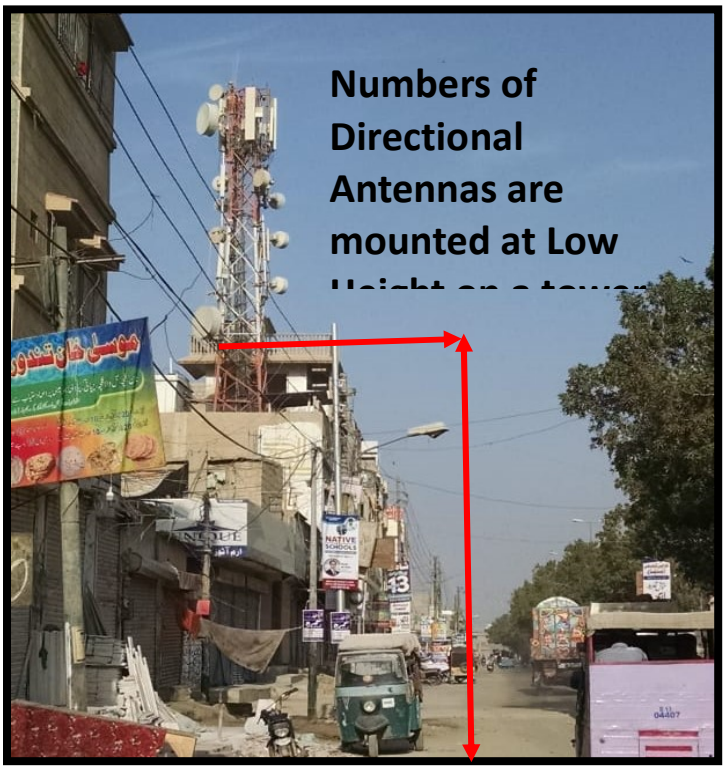

Figure 11: Low heights antennas Source: Author

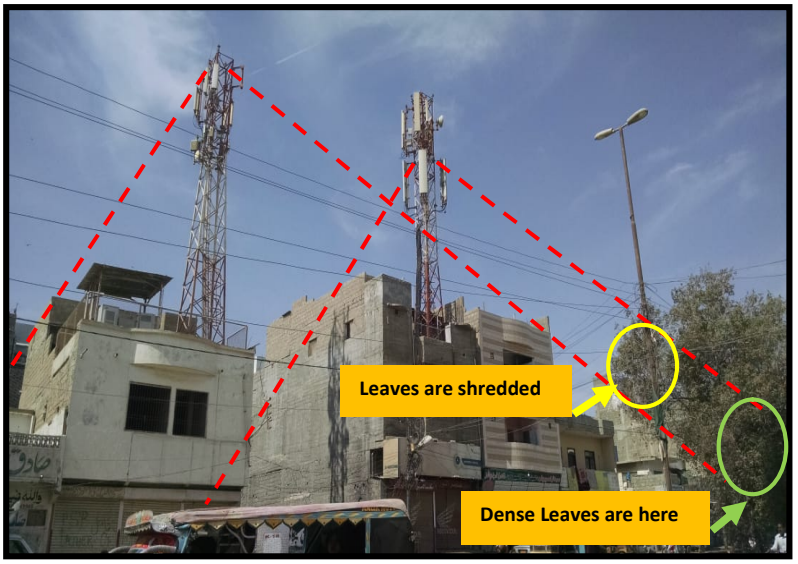

Figure 12: Radiation impact on trees Source:

Fig.12 shows the tree that is in direct line of sight with cell tower antennas may become week and their leaves started to be shredded from the sight which is facing the antenna while the other side has green in appearance having dense leaves and after a certain period of time whole tree become effected.

CONCLUSION

On the basis of the study it is concluded that the radiation emitted through cellular tower antennas are responsible for the said diseases especially in those areas where residents are living in 100m radius of cell tower antenna and expose in direct line of sight of microwave. It is also concluded that a specific age group i.e. 26 -35 is having a larger number of those participants who are using smart cell phones and other gadgets more than 3 hours per day for browsing, watching videos etc. These participants are suffered mainly from headaches, tiredness and stress. Six cases of miscarriages from the age group of 26-35 are reported who are living in direct line of sight of towers, while two cases of neurological disorders and heart disease belong to the age group of 36 to 45 are noted in the study area. There might be other causes of these diseases however unusual and long term exposure to electromagnetic radiation should also be considered.

There is a need of reducing the towers net within the residential areas especially it should be removed from the educational institutes, religious places and hospitals. Cellular companies should revise their policies to sanction the limits of radiated powers and these powers should not be increased in peak hours within the residential areas. Awareness campaign should be launched for general public about the impacts of electromagnetic radiation.

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