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HEALTH COMPLAINTS BY INDIVIDUALS RESIDING IN THE PROXIMITY TO MOBILE PHONE BASE STATIONS AS A FUNCTION OF POWER DENSITY

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Abstract: The continuous emissions from mobile base stations may impact health on the residents nearby. In the present study health complaints of those residing near two base stations for four to ten years (n=113) and in those with no stations (n=53) were correlated with the emitting radiations. The groups matched for age, gender and smoking habits. Power density measurements (n=166) were significantly higher values in the areas with base stations (11.49±0.17 W/m^2, 11.18±0.13 W/m^2) in comparison to areas with no stations (0.04±0.00 W/m^2). Health complaints were reported only in 26.54% of those staying near base stations (50-300m). Headaches were significantly increased in areas with high power density and in those residing adjacently to stations. On regression analyses, mobile phone usage, SAR value and power density were predictors of health complaints. These observations have significant implications as non-specific health complaints are pre-dispositional towards circadian arrhythmia and neurological outcomes such as anxiety and depression.

Keywords: Radiation Frequency, Microwaves, Health effects, SAR value, Predisposition

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INTRODUCTION

There is ubiquitous communication worldwide because of wireless technology and India has more than 540,000 mobile phone towers creating a network throughout the nation. [1] Wireless technology depends on networks of base stations which act as two-way radios by connecting the cell phone users through radiofrequency (RF) signals. The Global System for Mobile Communication (GSM) uses the transmission bandwidth of 890-915 MHz with 1710-1785 MHz for up-linking (handset –to- base station) and 935-960 MHz with 1805- 1880 MHz for downlinking (base station –to- handset) and the Code Division Multiple Access (CDMA) phones use 824-849 MHz for up-linking and 869- 889 MHz for downlinking.[2] These ultra-high frequency radio waves are non-ionizing and their use in different communication devices has created electromagnetic fields (EMF) around us. The ubiquitous nature of these radiofrequency radiations (RFR) with possibility of health problems as well as the inadequacy of the recommended safety standards have become matters of concern.[3]

Physical symptoms attributed to EMF include redness, tingling and burning sensations in the facial area, fatigue, tiredness, lack of concentration, dizziness, nausea, heart palpitation and digestive disturbances.[4] Neurological effects from EMF sources include headaches, changes in sleep pattern, modification in neuronal electrical activity and disturbances in neurotransmitter release.[5,3]

Physiological dysfunction by oxidative stress causing interaction of DNA with free radicals, genetic damage, and interference with gene regulation to eventually promotion of carcinogenesis, have been reported as a consequence of mobile phone usage or due to proximity to cell phone base stations.[6] In fact besides affecting the well-being of persons living and/or working near mobile base stations, the cancer risk is more worrisome.[7]

Governmental agencies and international organizations have recommended limits for RF energy radiated from mobile base stations in order to safeguard human health. Levels of measured RF have typically been many times below these safety limits.[7,8] India, as per International Commission on Non-Ionizing Radiation Protection [9], had adopted radiation-limits (as power density measurements) from base stations to general public of 4.7 W/m^2 (for 800MHz) and 9.2 W/m^2 (for1800MHz). However, the Government of India in 2012 [1] put forth stringent cut-offs of 0.47 W/m^2 (for 800MHz), 0.92 W/m^2 (for 1800MHz) and 1.00 W/m^2(for ≥2100MHz) which match with those in China [10] (0.45) W/m^2 and in Italy [11] (1.0W/m^2) but Austria has lowest (0.001 W/m^2) limit.[12] Despite safety limits, low intensity, pulsed radiation used by mobile phones exert subtle non-thermal influences [13] and have been reported to cause adverse health consequences.[14,15] Current limits therefore appear to be inadequate for safety of human health.

Non-specific symptoms have been documented from staying near base stations and/or with mobile phone usage. [16-18, 8] However such studies from this part of the region are sparse [19, 20] and hence power density in residential areas near base stations were made and health problems recorded for residents (with no other exposures or disease) on a specifically-designed questionnaire using a face-to-face interview method. Healthy residents in areas without nearby base station and with no past/present exposures comprised the controls.

Materials and Methods

Study design: A cross-sectional case-control study was conducted after approval from the Institutional Ethics Committee. The study group comprised unrelated individuals surveyed randomly after written, informed voluntary consent from residential localities of Amritsar district with/without nearby towers.

Preliminary Site-Survey: A preliminary site-survey was conducted to earmark long-standing base stations in populated areas from where eventually the actual survey was conducted. The types and heights of masts and number and types of antennas were recorded. Tower-sharing by communication networks / service providers was queried from site-owners/residents and/or as revealed by the labeling /embossing on the antennas. A RF exposure-meter (Reliance KP100FL-01, India) was set to the appropriate frequency-range of the service provider at evaluated site and power density was recorded and compared with old (4.7-9.2W/m^2) [9] and recent (0.47-0.92 W/m^2) public exposure limits set by the Indian government.[1] A database was hence generated for tower-sites for comparison with installation norms.

A survey around each base station was further made to request study participation. Areas around each base station were then spatially demarcated starting from its base in multiples of 50m up to 300m; those residing within 50m refused to participate. Random design of sampling was adhered to with one person per household interviewed from every fifth house. Personal details and health history was recorded by administering a pre-designed questionnaire. A three generational pedigree was also drawn to record for any abnormal reproductive performance. Power density measurements at the residential thresholds of study participants were taken twice and the average documented.

Study-Area: The city of Amritsar (31° 37' N, 74° 55' E) is an A^+ class city of Punjab with the population of 2.5 million.[21] In India, the cell phone subscribers' base was 874 million in July, 2013.[22] Among prevailing networks/service providers are Bharat Sanchar Nigam Limited, Reliance, Airtel, Tata, Vodafone and Idea. Leg-work through the city/suburbs during 2008-2009 earmarked sites of 90 base stations. Localities around two longer-standing towers (>10y) were selected for the present study and power density measurements were taken. Some residents of

these localities were administered a questionnaire regarding their health using the interview method.

Mobile phone base stations: As both the towers were in population-dense areas (Sites I and II), hence non-adherence to siting guidelines was straight-away observed.

Site I: This site is a residential area opposite to the Guru Nanak Dev University in Kabir Park; the tower had been installed on the first floor of a residence in 1988 by the Airtel Service provider and had 11 sectorial and eight dish antennae on top of a lattice structure .The height of the mast was ~15m and installation height was 20m from ground level.

Site II: The Airtel tower is also a lattice structure erected in 1997 on the roof-top of the third floor (~36m from ground level) of Sukhbir Hospital. The mast height is ~20m with 10 antennae (4 dishes and 6 sectorial). The hospital wall adjoins the residences on its backside with the front facing the Grand Trunk road.

Study Participants: These comprised residents of Sites I and II towers. Healthy controls, with no exposures either at workplace or at home and staying in areas without nearby stations were from village Boparai of Amritsar district (31°38'29"N, 74°43'22"E) about 12km away from Amritsar city and from Labh Nagar, behind the university campus. Information on demographic variables (age, gender), lifestyle patterns (diet, alcohol consumption, smoking, cell-phone use), any exposure history, location of residence, distance and duration of stay in vicinity of towers, and ill-health effects, if any, were recorded on a pre-designed questionnaire.

Exclusion criteria: This comprised the non-administration of the questionnaire to relatives, persons with any work occupational/incidental exposures or with disease(s), minors and the elderly.

Inclusion criteria: These included unrelated, healthy adults (8-45y), neither on medications nor food supplements and staying near towers for at least four years.

Statistical analysis: Demographic variables are means ±S.E.M. while individuals with symptoms are in numbers and percentages. Statistical analysis was performed using the MedCalc (Chi-square) for categorical variables. SPSS (version 16) was used for the Students't-test analysis (comparison of means) and the Pearson correlation analysis for finding the association (if any) between health complaints and the study variables. The univariate and multivariate linear regression analyses were performed for predictors of health complaints.

Results

The questionnaire was administered to a total of 166 residents with 113 residing near a mobile phone tower (exposed group) and 53 in areas without any nearby towers (control group). There were no other sources of environmental pollution. The exposed group comprised students (47.78%), housewives (15.92%), clerks (10.61%), teachers and shopkeepers (8.84%), land owners and salespersons (2.65%),etc. The Chi-square and Student's t-test analysis revealed that both the exposed and control groups matched for age, gender and smoking habits (Table 1) but differed for dietary pattern, alcohol drinking and mobile phone usage. The exposed group comprised 55.75% participants at Site 1 and 44.24% near Site II including 44%females and 56%males. The period of stay near towers was 4-11y (8.48±0.18y); residences were either opposite (58.40%) or adjacent (41.59%) to the towers. Incidentally, the two sites were ~2km apart.

The exposed group participants had non-vegetarian diet preference (52.21%) with alcohol drinking (23.89%) and smoking (2.65%) as other lifestyle habits. No abnormal reproductive performance was observed among married exposed (28%) and controls (35.84%). Mobile phone use was by 99.11% and daily usage varied from 0.25-7.00h (1.90±0.13h) while duration of phone usage was 0.50-10.00y (3.76±0.19y). The specific absorption rates (SAR) of the handsets were obtained from the internet (www.sarvalues.com) while preferred brand was Nokia (72.32%).

Power density measurements were taken at each of the 113 residences and at 50m intervals from the towers from 50-300m (Table 2). Power density values with no towers (from where the control group was surveyed) were 0.01-0.1W/m^2 (0.04±0.00 W/m^2). On statistical analyses, the power density measurements from Sites I (11.49±0.17 W/m^2) and II (11.18±0.13 W/m^2) were comparable (p=0.166) but significantly increased (p=0.000) in comparison to those in areas from where controls were surveyed. Power density levels decreased as a function of distance from the towers. On averaging the power density at 50m, it was significantly elevated compared to levels at 151-200m (p=0.001), 201-250m (p=0.009) and 251-300m (p=0.000) distances. Statistically significant differences were also observed on comparing power density levels at 101-150m with those further away at 151-200m (p=0.001), 201-250m (p=0.018) and 251-300m (p=0.000). The power density were mostly higher in residences located opposite to / facing the station. Siting guidelines were violated for tower installation (Table 3). Tower-heights and number of antennas per tower were as per guidelines but average power density measurements were 1.23 folds higher than the limits. Nearby buildings was less than 3m distance from the towers, which is another violation. The tower at Site I only had a warning sign board at height 204m; both warning and caution signages were absent at both Sites I and II. The colour and signage of the danger sign was according to the TEC guidelines.[23]

In Table 4 are presented the reported health problems among the surveyed residents. The control group was healthy with no complaints. Among exposed, 26.54% reported non-specific health symptoms. Headaches (probably also from mobile phone usage) were most prevalent (12.38%) as was tinnitus (10.61%), followed by pain/irritation in ears (6.19%), general irritability (3.53%), nausea (1.76%), discomfort (2.65%) and redness of ears (2.65%). On Chi-square analysis, symptoms were significantly higher ($p<0.0001$) in the residents near Site I (power density 11.49±0.17 W/m^2) compared to those staying near Site II (power density=11.18±0.13 W/m^2). Female residents at Site I (20.00%) were more affected by headaches though 16.00% of both males and females near Site II complained about these. Irritability, tinnitus, discomfort and nausea were more prevalent in those residing at Site I whereas those from Site II had complaints only of pain/irritation and redness of ears. Combinational ill-health effects were observed in 6.19%. On stratification (Tables 5, 6) for distance, power density and location from towers, headaches were observed to be significantly ($p=0.016$) more prevalent in those residing adjacent to the tower and with power density of 12.07±0.08 W/m^2 (11.24 W/m^2-14.59 W/m^2).

In order to discern any effects on health symptoms from confounding and specific factors/ variables (age, gender, time since residing/working near tower, distance from mobile phone base station, location with respect to base station, mobile phone usage, SAR values of phone sets and power density), correlation analysis and linear regression analyses were carried out (Table 7) which revealed mobile phone usage, phone set SAR value and power density as significant predictors ($p=0.000$) of the observed health complaints; on multivariate analysis only daily mobile phone usage was significantly ($p=0.016$) associated with health complaints among the residents near mobile phone base stations.

Table 1. Demographic Characteristics of the Study Group

Characteristics		Range	Exposed group		Control Group		χ^2_{cal}/t_{cal}	P value
			N (%)	[T]Mean±S.E.M.	N (%)	[T]Mean±S.E.M.		(χ^2/t-test)
Age (y)		18-30	80(70.08)	27.15±0.72	37(69.81)		0.003/0.312	**0.957/0.756**
		31-45	33(29.20)		16(30.18)	27.54±1.01		
Gender		Males	63(55.75)	-	27(50.94)	-	0.170	**0.678**
		Females	50(44.24)		26(49.05)			
Lifestyle/ habits	Diet	Veg	54(47.78)	-	36(67.92)	-	5.110	**0.0238**
		Non Veg	59(52.21)		17(32.07)			
	Alcohol drinking	Yes	27(24.10)		04(7.54)		5.317	**0.021**
		No	86(76.78)		49(92.45)			
	Smoking	Yes	03(2.65)		02(3.77)		0.009	**0.9252**
		No	110(97.34)		51(96.22)			
Mobile Phone using since(y)		0.5-5.0	94(83.18)	3.76±0.19	23(100.00)	0.54±0.14	2.949/10.435	**0.085/0.000**
		6.0-10.0	18(15.92)		-			
Power density(W/m^2)		Site I	7.60-14.59	11.49±0.17		0.04±0.00	68.014	**0.000**
(Range)		Site II	8.82-13.22	11.18±0.13	0.01-0.10			
		Total	7.6-14.59	11.35±0.11				
Mobile Phone		User	112(99.11)	-	23(43.39)	-	70.128	**0.0001**
		Non user	01(0.88)		30(56.60)			
Daily Mobile phone use(h)		0.25-3.0	94(83.92)	1.90±0.13	23(100.00)	0.16±0.03	2.98/8.982	**0.08/0.000**
		4.0-7.0	18(16.07)		-			
Phone set SAR value(W/kg)		0.38-0.60	36(32.14)	0.72±0.01	08(34.78)	0.32±0.05	0.000/8.766	**0.998/0.000**
		0.62-1.75	76(67.85)		15(65.21)			
Time since residing/working in the vicinity of the base station (y)		Site I	4.0-10.0	7.42±0.25	-	-	-	-
		Site II	5.5-10.0	9.82±0.10				
		Total	4.0-10.0	8.48±0.18				
Distance from mobile		50-100	24(21.23)	162.81±6.22	-	-	-	-

phone base station (m)	101-150	35(30.97)					
	151-200	36(31.85)					
	201-250	09(7.96)					
	251-300	09(7.96)					
Location of residence with respect to base stations	Opposite	54(47.78)	-	-	-	-	-
	Adjacent	**59(52.21)**					

† Students' t-test; P-values in bold are significant ($p<0.05$)

Table 2. Power Density measurements at Sites I and II

Distance from mobile phone base station (m)	Location with respect to mobile phone base station	Power Density(W/m^2)						Areas without Mobile phone base station Range(N=53)
		Site I		Site II		Total		
		N	Mean±S.E.M.	N	Mean±S.E.M.	N	Mean±S.E.M.	
50-100	Opposite	06	12.14±0.34	07	12.00±0.49	13	12.14±0.34	
	Adjacent	07	11.85±0.37	04	11.35±0.71	11	11.85 ±0.37	
	Total	13	12.21***±0.32	11	11.76***±0.39	24	12.01***±0.25	
101-150	Opposite	10	12.35±0.21	09	11.17±0.19	19	11.79±0.19	
	Adjacent	08	12.28±0.29	08	11.24±0.23	16	11.76±0.22	
	Total	18	12.32***±0.17	17	11.20***±0.14	35	11.78***±0.14	
151-200	Opposite	06	11.27±0.65	09	10.36±0.28	15	10.72±0.32	
	Adjacent	08	10.83±0.57	13	11.24±0.23	21	11.08±0.25	
	Total	14	11.01***±0.42	22	10.88***±0.20	36	10.93***±0.20	0.01-0.1 W/m^2
201-250	Opposite	02	11.09±1.36	-	-	02	11.09±1.36	
	Adjacent	07	10.46±0.40	-	-	07	10.46±0.40	
	Total	09	10.60***±0.39	-	-	09	10.60***±0.39	
251-300	Opposite	05	10.39±0.32	-	-	05	10.39±0.32	
	Adjacent	04	10.44±0.37	-	-	04	10.44±0.37	
	Total	09	10.41***±0.22	-	-	09	10.41***±0.22	
Total	Opposite	29	11.69***±0.24	25	11.11***±0.22	54	11.42±0.16	

	Adjacent	34	11.32***±0.32	25	11.00***±0.15	59	11.29±0.15	
	Total	63	11.49***±0.17	50	11.18***±0.13	113	11.35***±0.11	0.04±0.00

***Very highly significant (p=0.000) from areas with no mobile phone base station; non-significant between and within sites

Table 3. Base Station Towers- Guidelines and Recommendations for Installation Specifications and Tower Features

Installation Specifications and Features	**†Recommendations**			**Mobile Phone Base Stations**	
				Site I	**Site II**
Height (m)	Ground- based tower	30-200 (mostly 40)		-	-
	Roof- top tower	9-30		20	36
Number of panel antennas	Ground-based tower	30-40 m height	12	-	-
	Roof- top tower	20/25/30 m height	12	11	06
		15/10 m height	06	-	-
Number of microwave solid dish antennas	Ground- based tower	3 (0.6m diameter)		08	04
	Roof- top tower				
Radiation norm (ICNIRP,1998)	Transmitting Band (Power density)	GSM 900 (935-960 MHz)	4.7 W/m^2	7.60-14.59 (11.49±0.17)	8.82-13.22 (11.18±0.13)
		GSM 1800 (1810-1880 MHz)	9.2 W/m^2	-	-
New DoT limits (w.e.f. 1.9.2012)	Transmitting Band (Power density)	GSM 900 (935-960 MHz)	0.47 W/m^2	7.60-14.59 (11.49±0.17)	8.82-13.22 (11.18±0.13)
		GSM 1800 (1810-1880 MHz)	0.92 W/m^2	-	-
Safe distance w.r.t. multiple installed antennas (Both ground- based and	Number of antennas/Tower		Distance to next building (m)		
	2		35	Violated as distance from nearest building	Violated as distance from nearest
	4		45		

roof-top towers)	6		55	10m	building~08m
	8		65		
	10		70		
	12		75		
Prohibtions w.r.t. mobile tower installation	On structurally unsafe buildings			-	-
	Within premises of schools and hospital			-	Violated
	Nearby building /in front of antenna			Violated	Violated
	Narrow lanes (≤5m)			Violated	Violated
Recommendations	Wire fencing around tower			Lacking	Lacking
	Locked doors on roof-top			Lacking	Lacking
	Sign boards/Warning signs (Danger RF radiation, Restricted area, Do not enter)			Danger Sign	Lacking
*Colour Code and Placement of Signage	Danger	Red		On tower at height of 2-4m	Present	Lacking
	Warning	Orange		Exclusion zone in public accessible area	Lacking	Lacking
	Caution	Yellow	Roof top	At entry point of roof of building of base station	Lacking	Lacking
			Ground Base Station	At entrance of base station compound	Lacking	Lacking
*Size of Signage	Width			2 feet	Only Danger sign present	Lacking
	Height			3 feet		

†As per [9], [1]; *[23]

Table 4. Health Complaints by Residents staying/working near Mobile Phone Base Stations

†Health Complaints		Site I			Site II			Site I+ Site II
		Kabir Park			Sukhbir Hospital			
		Males (%)	Females (%)	Total (%)	Males (%)	Females (%)	Total (%)	Total (%)
Tinnitus		05(13.15)	07(28.00)	12(19.04)	-	-	-	**12(10.61)**
Irritability		03(7.89)	01(4.00)	04(6.34)	-	-	-	**04(3.53)**
Discomfort		02(5.26)	01(4.00)	03(4.76)	-	-	-	**03(2.65)**
Nausea		01(2.63)	01(4.00)	02(3.17)	-	-	-	**02(1.76)**
Pain / irritation in ear		-	-	-	04(16.00)	03(12.00)	07(14.00)	**07(6.19)**
Redness in ear		-	-	-	02(8.00)	01(4.00)	03(6.00)	**03(2.65)**
Headache		01(2.63)	05(20.0)	06(9.52)	04(16.00)	04(16.00)	08(16.00)	**14(12.38)**
Combined health effects	tinnitus + Irritability	01(2.63)	01(4.00)	02(3.17)	-	-	-	**02(1.76)**
	Tinnitus + discomfort	01(2.63)	01(4.00)	02(3.17)	-	-	-	**02(1.76)**
	tinnitus + Irritability+ discomfort	01(2.63)	-	01(1.58)	-	-	-	**01(0.88)**
	Nausea+ tinnitus + Irritability	01(2.63)	-	01(1.58)	-	-	-	**01(0.88)**
	Pain / irritation in ear+ Redness in ear	-	-	-	-	01(4.00)	01(2.00)	**01(0.88)**
	Headache+ tinnitus	-	01(4.00)	01(1.58)	-	-	-	**01(0.88)**
	Headache+ Pain / irritation in ear+ Redness in ear	-	-	-	01(4.00)	-	01(2.00)	**01(0.88)**
	Headache+ Redness in ear	-	-	-	01(4.00)	-	01(2.00)	**01(0.88)**
	Headache+ Pain / irritation in ear	-	-	-	-	01(4.00)	01(2.00)	**01(0.88)**
Total		**06(15.78)**	**11(44.00)**	**17(26.98)**	**07(28.00)**	**06(24.00)**	**13(26.00)**	**30(26.54)**

†Significantly higher in exposed group as there are no symptoms in controls; Non-significant differences between residents of Sites I and II

Table 5. Health Complaints as a function of Distance (of residences) from Base Stations

Complaints	50-200m(n)	201-300m(n)	χ^2	P value
Irritability	02	02	0.250	0.617
Tinnitus	08	04	0.750	0.380
Discomfort	03	01	0.250	0.610
Nausea	01	02	0.500	0.470
Pain / irritation in ear	07	-	-	-
Redness of ear	03	-	-	-
Headache	11	03	3.500	0.061
Total	35(36.84 %)	12(66.66 %)	10.29	**0.001**

P value in bold (p=0.001) is significant on comparison between 50-200m and 201-300m

Table 6. Health complaints as functions of Power Density and of Location of Residences from Base Stations

Complaints	Power Density (W/m^2)				Location			
	7.60-11.40 (10.13±0.11)	11.24-14.59 (12.07±0.08)	χ^2	P value	Opposite	Adjacent	χ^2	P value
Irritability	01	03	0.250	0.617	03	01	0.250	0.617
Tinnitus	04	08	0.750	0.386	05	07	0.083	0.772
Discomfort	01	03	0.250	0.617	-	04	-	-
Nausea	02	01	0.000	1.000	02	01	0.000	1.000
Pain / irritation in ear	02	06	1.125	0.288	02	06	1.125	0.288
Redness in ear	-	03	-	-	-	03	-	-
Headache	02	12	5.786	**0.016**	02	12	5.786	**0.016**
Total	12(28.57)	36(50.70)	11.021	**0.000**	14(25.00)	34(57.62)	7.521	**0.006**

P value in bold (p<0.05) is significant on comparison of health complaints

Table 7. Association/Predictors of Health Complaints as a function of residence near Mobile Phone Base Stations

Study Characteristics	Pearson Correlation Analysis		Univariate Linear Regression			Multivariate Linear Regression		
	r	P	B(95%CI)	t	p	B(95%CI)	t	p
Age	-0.11	0.884	-0.011(-0.008-0.007)	-0.146	0.884	-0.005(-0.008-0.007)	-0.068	0.946
Gender	0.103	0.188	0.103(-0.039-0.198)	1.321	0.188	0.130(-0.012-0.213)	1.757	0.081
Mobile Phone using since	0.335	**0.000**	0.335(0.031-0.078)	4.554	**0.000**	0.168(-0.005-0.060)	1.653	0.100
Daily mobile phone usage	0. .376	**0.000**	0.376(0.063-0.141)	5.193	**0.000**	0.226(0.012-0.111)	2.446	**0.016**
Phone set SAR value	0. .276	**0.000**	0.276(0.150-0.497)	3.681	**0.000**	**0.046** (-0.154-0.261)	0.512	0.610
Power density	0. .322	**0.000**	0.322(0.013-0.034)	4.356	**0.000**	0.069(-0.010-0.020)	0.666	0.506

P values in bold are significant ($p<0.05$)

Discussion

To the best of our knowledge and from the perusal of the literature, this is the first study from this part of the region on the prevalence of health complaints from proximity to mobile phone base stations and the radiation fields (power density) measurements. The presence of a host of complaints among 27.00% of the residents of Sites I and II and the complete absence of such complaints among the control group emphasizes that these are of considerable concern given that radiofrequency radiations from mobile phone base stations may be the only proponents for the same. The power density measurements also do not fall within the recommended cut-offs [1] and are also obviously significantly higher than those from areas with no towers (control areas) implying that RF radiations have become important environment components in areas with mobile phone base stations.

Though the mechanism of action of RFR in causing health dysfunction is not clearly understood, the high-intensity continuous RF-EMF can cause a thermal and thermal effects which have serious implications for human health.[24] The recorded health complaints and the power density measurements during the course of the present study imply that the safety guidelines (SAR value not greater than 2W/kg. and power flux density not greater than 4.5W/m^2) may not be adequately protective for chronic exposure in the long-run.[25] The observed health complaints could well be early indicators of the adverse health effects and disease-causation, because disease-causation does not occur from a single factor; rather a multitude of interactive components, endogenous and exogenous to the subject, can cause disease manifestation.[26] Health effects or disease-manifestations however vary: from being barely discernible, rapidly

reversible symptomatic disorders, to being severe and irreversibile causing a grave disease-state leading to morbidity and mortality.[27]

The health complaints of irritability, tinnitus, discomfort, nausea, pain/irritation in ears and redness of ears reported by participants of the present study also find parallels in literature. A study in France [16] reported significant influence of distance and gender in individuals residing within 300m from the mobile phone base station with nausea, loss- of -appetite, visual disruptions, difficulty in moving as being common in individuals in immediate vicinity of base stations(<10m); irritability, depression, difficulties in concentration, loss of memory, dizziness, lowering of libido at 100m; at 100-200m, headaches, sleep disruption, discomfort and skin problems were common while beyond 200m, fatigue was only common. Women experienced nausea at <10m and headaches at 10-50m,50-100m,100-200m and 200-300m intervals more than men who often reported a decreased libido at 50-100m from base station; the women also had more headaches, nausea, loss- of- appetite, sleep disruption, depression, discomfort and visual disruptions compared to the males.[16] In the present study also, there were more complaints by women for irritability and irritation in ears than by the males.

In a study carried out in Spain [17], significant correlation of severity of symptoms (discomfort, irritability, appetite loss, fatigue, headaches, difficulty in concentration, sleep disturbances, auditory dysfunction, gait difficulty and cardiovascular problems) was observed with the measured power density values at distance < 150 m (0.11 μW/cm² group) and at > 250 m (0.01 μW/cm²). After adjustment for sex, age and distance; significant positive exposure-response associations were documented between the electric fields (0.02-0.04/0.05-0.22/0.25-1.29V/m) in the vicinity of two mobile phone base stations and health outcomes i.e. fatigue, irritability, headaches, nausea, loss- of- appetite, sleeping disorder, depressive tendency, feeling of discomfort, difficulty in concentration, loss of memory, visual disorder, dizziness and cardiovascular problems.[12] One report from Egypt [8] observed that despite lowered RFR values than the allowable mobile phone base stations antennas' standard level of 0.4 mW/cm^2, the prevalence of headaches, memory changes, tremors, dizziness, depressive symptoms and sleep disturbances among exposed subjects were significantly higher than among controls residing two km from a mobile base station. Study participants working/residing beneath the base station had prevalent sleep disturbances compared to those working opposite it. A significant correlation dependent on dose-effects (for sleep disturbances, depression, cerebral symptoms, joint illnesses, infections, skin changes, cardiovascular disorders, and disorder of the optical and acoustic sensory systems and the gastro-intestinal tract) with the residential proximity to a mobile base station in Germany have also been documented.[28] Despite the lower total high frequency electromagnetic field in the rural (0.05 mW/m^2, distance 24-600m) and urban (0.02 mW/m^2, distance20–250 m) areas versus the recommended cut-offs (4.1

mW/m^2), significant relation of some symptoms to measured power density was also observed in Austria [29] , being highest for headaches; there was perceptual speech increase though accuracy decreased significantly with increasing exposure levels. However, no significant effect on sleep quality was reported. Though there was no significant correlation between electric field strength and the distance of examined flats from the base stations in Poland, headaches were declared more by individuals living 100-150 m away from the base station compared to people living at farther distances while those living at a distance more than 150 m also reported impaired memory. [30]

Cell-phone base station RF radiation also have a cancer-promoting effect as was evident from the causal association between RF radiation (5.3 $\mu W/m^2$) emitted from the cell-phone base station within 350 m radius and the occurrence of various cancer cases (breast carcinoma, ovary carcinoma, lung carcinoma, Hodgkin's disease, osteoid osteoma, and hypernephroma) reported in Israel.[31] In Germany, two studies concluded that the proportion of newly developing cancer cases was significantly higher among those patients who had lived up to 10 years [32] and in those living around the mobile base sites for five years [33] at a distance within 400 m from cellular transmitter site, compared to those living further away. Deaths due to neoplasia were reported in an area in Germany [15] where power density ranged between 40.78 $\mu W/cm^2$ to 0.04 $\mu W/cm^2$.

It may hence be concluded in terms of Hardell [34] that even though the radiation is of very low intensity, yet the oscillatory similitude between this pulsed microwave radiation and certain electrochemical activities of the human beings prompts concern. In India, the emission limits from base stations have been revised to one-tenths of the existing levels and the SAR value of mobile hand-sets to 1.6 Watt per kg^1 keeping in mind the adverse health effects from mobile phone base stations and mobile phone usage as a function of long-term exposures. The strengths of the associations reported in literature as well as the observations of the present study even at far lower RF values are sufficiently strong that taking action to reduce exposures as a precautionary approach is imperative for the well-being of the general population.

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