THE ENVIRONMENTAL RADIATION POLLUTION IN URBAN BUILDINGS

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Abstract

Indoor environmental quality is essential in urban buildings. Health of occupants depends on factors related to the air quality and space maintenance. However, a new form of indoor pollution has emerged in urban buildings due to the excessive use of electric and electronic products, in addition to the radiation spill from the external radio-frequency antennas located within the vicinity areas. The indoor environmental radiation is caused by the unavoidable emanation of electromagnetic waves in the free air and space penetrating the living organisms and causing adverse health effects over the long terms. There are increasing concerns over the lack of awareness within the construction community to account for a radiation-conscious design within the project life cycle. This paper sheds the light on quick and simple measurement procedures to conduct by the project stakeholders during the early stages of design and throughout the construction phases in order to identify and address any radiation-intoxication in the project site. Results of these measurements should give an indication over the severity of concerns related to the radiation spill, and subsequently, take the necessary measures and precautions to reduce/mitigate the in-situ electromagnetic fields.

Keywords: *electromagnetic fields, environmental pollution, radio-frequency radiation.*

1 INTRODUCTION

As cities grow and expand, more technologies are being employed to facilitate the societies' life and mitigate the consequences of the excessive population affluence and energy consumption in early 21st century. However, these technologies, which are represented through electric and electronic products, are increasingly becoming significant sources of an invisible form of environmental pollution called the Electromagnetic Radiation (EMR). These products include household appliances such as refrigeration equipment, stoves incl. cookers and microwave ovens, washing machines, air-conditioners and water heaters. The introduction of wireless devices made the information transmission and control technology more resilient at home by automating the essential building services such as air-conditioning, lighting, and heating. The usage of wireless and WIFI devices such as mobile phones, network routers and smart meters to control these services, filled up the indoor environment with unavoidable radio waves, referred to as Radio-Frequency Radiation (RFR).

On 31st of August 2012, Rajasthan state of India shut down 200 cell towers which were located near to schools, and banned another 500 towers near to jails and hospitals (Shetty, 2012). This action has come into effect after an expert committee submitted a report to the Ministry of Environment and Forest. This report included a review of 919 studies on the effects of mobile towers on animals, insects, humans and plants, where the panel found that 65% of these studies showed harmful effects (Shetty, 2012). Similarly, the Chilean congress has passed a Towers Act in June 2012 to strictly limit the power of antennas, and establish mitigation in areas saturated with antenna towers that are close to homes or institutions, such as schools, healthcare centers or kindergartens (United Press International Inc., 2012). In the same year, the German environment Minister has issued a 10 point plan, where point 6 is concerned about improving the protection from electromagnetic fields (Lang, 2012). Other developed countries has also taken similar steps to limit the radiation in urban areas. The international concerns about the health risks of living in proximity to radio frequency emitting technologies such as cell towers, antennas attached to buildings, cell

phones and wireless devices, were explicitly expressed. Nevertheless, it's still questionable how significant the relationship between the exposure to radio and microwave fields, and the consequent negative health effects over the long terms would be. While a number of studies conducted on the non-thermal effects of RF radiation showed no robust evidence of any effect (Vecchia et al., 2009), other reports indicated that there is a four-fold increase in cancer rates among people living over a decade within 350m of a cell tower (Wolf and Wolf, 2004). The tower exposure studies have also shown neurobehavioral malfunction, and lower than average performance tests for attention, memory and problem solving. In addition to a host of inexplicable illnesses such as headaches, fatigue, dizziness, heart palpitations, anxiety, insomnia, and difficulty breathing. (Abdel-Rassoul et al., 2007).

Given the serious situation, It's essential that the professionals in the construction industry learn to measure, monitor, detect and calculate the exposure hours to radiation based on the building location and spaces orientation in relation to the cell towers, in order to plan out remediating solutions and prevent as much as possible such harmful exposures. Such measures help to reduce the resultant risks of carcinogenic effects and other associated cumulative illnesses which build up by the time.

2 RADIATION HEALTH IMPLICATIONS

In 1996, the World Health Organization (WHO), headquartered in Geneva, launched the EMF project in response to the increasing concerns over the exposure to the environmental radiation and its impact onto the population health over the short and long terms. The Electromagnetic Fields (EMF) project was a great initiative to coordinate a plethora of international studies, funded by the WHO member states and many non-governmental organizations, in order to assess the scientific evidence over the health effects from each of the irradiation frequencies. Additionally, the BioInitiative Group (2014), has made enormous efforts by the contributions of 29 academic authors from ten countries of highly distinguished entities, to study, review and address the growing health issues of short-term and chronic exposure to radiation. Circa one thousand eight hundred recent studies have been published in the last five years. The majority of these studies reported health implications at exposure levels, which fall below the safety standards by ten to hundred or thousand fold in most of the countries (Sage, 2014). Hardell and Sage (2008) point out that precautionary and preventive measures took a long period of time to be considered until early warnings were initiated based on scientific evidences. The precautionary principle should always be implemented in case there is a rational cause for concerns. On the other hand, the BioInitiative report compiles, in addition to other extensive reviews, a list of up-to-date 106 papers which were conducted as free radical studies on RF radiation. Interestingly, 88% of these paper provide evidence on effects resulted from the exposure to radiation well within the current safety standards (BioInitiative Working Group, 2014). The health effects caused by exposure to different types of non-ionizing radiation, especially the radio frequency emissions were reported to have an impact in the following areas (Sage, 2014): 1.Brain Tumors and Acoustic Neuroma. 2.Childhood Cancer and Leukemia. 3.Breast Cancer. 4.Immunological Changes. 5.Genotoxic Effects. 6.Nervous System and Brain Function. 7.Fertility.

3 RESEARCH STUDY

The subject study comprises of two residential apartments, A and B. Flat A is located in Discovery Gardens, Al-Zen district, a 1.5km walking distance from Ibn Battuta mall. Flat B is situated in Dubai Marina besides "Damac Properties" metro station. The reason behind choosing these locations is that both apartments are located in highly-developed urban areas exhibiting all transport and telecommunications facilities which implies that wireless systems have been intensively incorporated within these areas. The infrastructure is well-maintained by the developers through a preset schedule of works year-round. It's expected that these areas are the next urban hubs due to their proximity to Dubai World Central (DWC), Maktoum new airport, the expo 2020 site and the free zone areas. The second reason is that construction in Jebel Ali zone is moving forward steadily with more electric and electronic systems which are being employed to facilitate and enrich the urban setting with more care and services. However, the downside encompasses the exposure to more and more radio-frequency emissions within the

controlled and uncontrolled occupancy zones. One can realize the number of telecom antennas, which are aimed in all directions, installed on top of each establishment. In some other cases, due to the height difference between the buildings, a pile of dipoles is erected on one roof next to residential balconies, overlooking the health risks to which the residents are exposed. it's been speculated that the dense distribution of those equipment will have an impact onto people's lives, however, it is supposed that demonstrations were never performed to assess the radiation levels in order to justify such concerns. Nevertheless, some newspapers such as the National and Gulf-News, have drawn the attention to the public's discomfort over the installation of new antennas esp. near to schools. Addressing the radiation exposure demands a swift action to mitigate the environmental radiation pollution. The scope of this field experiment will be confined to the indoor environment of the aforementioned flats inclusive of the terraces. Outdoor measurements in public areas, which are way higher, may be further collected in other research studies. A plethora of areas can be explored in future studies depending on the aspects of interest. One of which would be the comparative relationship of the EMF epidemiological aspect between different neighborhoods in light of international previous benchmark data provided by peer-reviewed scientific papers. Results of this experimental study are for indication purposes only. Further verification and measurements should be conducted in order to acquire reliable data for statistics and other transdisciplinary usages. Moreover, findings do not necessarily give an assessment of the radiation level and human exposure at the macro-level of these districts. Further extensive studies are recommended to satisfy this respect.

4 RESEARCH INSTRUMENTATION

The hardware, which was used to collect the measurement values, is called "Electrosmog meter". Manufactured by CORNET Microsystems Inc. in the United States, the selected and online - purchased meter a model code of ED-78S. Relevant specifications can be found on the respective manufacturer's website.

Figure 1. Electrosmog Meter by CORNET Microsystems Inc.

5 CASE STUDY 1: FLAT (A)

Within a cluster of eight-floor-high buildings, flat (A) location at the corner allows to evaluate the east-south-west angle covering 75% of the directions due to the building rotated position. On the opposite rooftop, a cell phone antenna tower is installed 40m away from the subject balcony. The flat plan has been drawn in addition to the furniture distribution which is important to identify areas with the most occupancy levels around-the-clock. For instance, the kitchen is where most of the households spend in daytime, while beds are critical when it comes to the long hours sleep during the night. The field study took about 90 minutes, where spot and trawling measurements were taken between 8pm and 10pm at preset points marked on the studio-type plan layout (Figure 2).

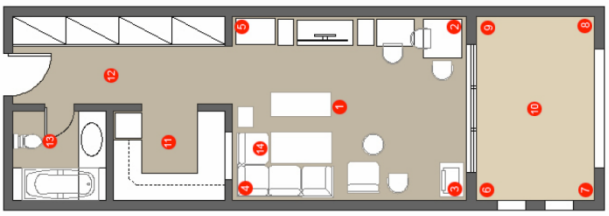

Figure 2. Flat A plan layout: indication of measured points

Measurement points address the four corners and the center of the main living room and the balcony as well as the center of the kitchen, corridor, bathroom and over the bed pillow. Before starting the test, it was necessary to make sure that most wireless LAN devices were switched off (including WIFI and GPS features in the cell phones). The mobile phone was not switched off, but rather set on a standby mode without making any calls that disrupt drastically the display values. TV, receiver and radio devices were all unplugged. The field test had to have minimal impact from local emitting equipment as rational as possible while avoiding

the ideal irrelevant situations where none of the electric or electronic products is operating, which is not the case in the actual life. Since the pulsed signals change in strength over the time, a short while was spent at each of the measurement points in order to obtain significant reading values that represent RF radiation levels in milliwatts per square meter (mW/m2) accordingly. The instrument was then configured to take the field strength in volts per meter (V/m). Measured values were then compiled in a table and analyzed.

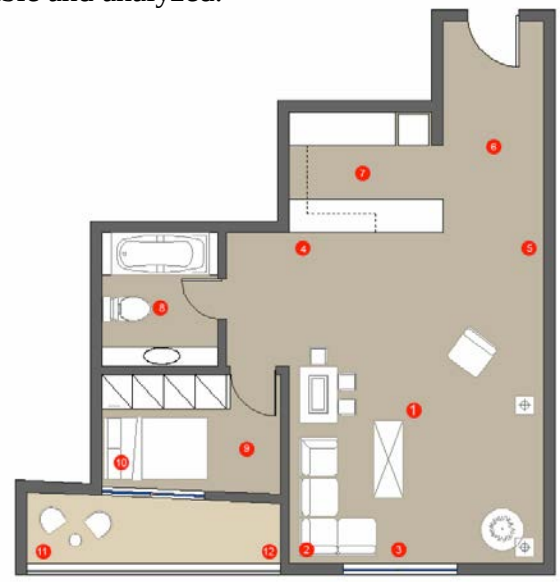

Figure 3. Flat B plan layout: indication of measured points

Figure 4. Flat B Balcony with indication points

6 CASE STUDY 2: FLAT (B)

This apartment is located in floor 4 at the diamond building assembly, it has a balcony that views the podium level swimming pool, a part of Marina walk and more importantly, a bunch of antenna towers erected on a lower height building not further than 20m from the edge of the terrace. Most wireless devices were set off including TV, receiver and radio devices. The critical exposure of flat location to adjacent mobile phone towers undoubtedly raises question marks on how those antennas have been designed and implemented within such a residential vicinity. The centre and corners of spaces were identified, measured and compiled for the study analysis.

7 RESEARCH RESULTS AND DISCUSSION

CASE STUDY 1: FLAT (A)

The reading average of the points identified on the plan layout should give a general idea about the radiation level spill into the indoor environment. As it shows in the tabulated values schedule, some of these points can be considered as "hot spots" where immediate concern is raised. Due to the lack of international consensus over the EMF-exposure limits (Foster, 2002), comparison was established against the most hitherto stringent values represented by the Bioinitiative group standards issued in 2012, as well as the guidelines of year 2007, which are similar to Salzburg resolution for pulsed signals. It was obvious that there was a tremendous deviation between the average and maximum values due to the burst nature of signals. However, Table (1) shows that more than 30% of the Max. values of field Intensity (mW/m2) exceed the Bioinitiative 2007 limits, while none of them complies with the 2012 standards. On the other hand, only ca. 15% of the average values of field intensity accord with the set guidelines. The field strength follows the same rhythm with a bit of difference, 1 out of 13 average value points comply with 2007 limits, while none of the Maximum recorded amounts concerts with the Bioinitiative standards issued in 2012. Figure (5) shows the reading values relative to the severity of concern which is based on the Bioinitiative 2007 guidelines. Apparently, points 1, 6, 7, 8, 9 and 10 can be considered the real hot spots in this apartment falling under the immediate concern zone, where remediation strategies should take place at the soonest. It's also apparent that the center of each space (points 1 &10) is located within the highest strength of the field, the living space and the balcony respectively, due to the lack of any obstacles around them. Looking at the furniture plan, there is low occupancy level, yet high circulation, in these points, an issue which draws the attention to have more limited and conscious stay in these areas.

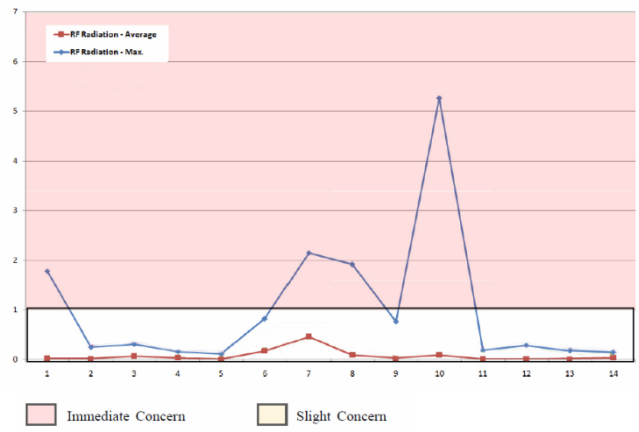

Figure 5. Flat A - Values vs. Severity of concern

	Reading Values (Flat-A)		
	Measurement Points	RF Radiation mW/m^2	Field Strength V/m
Average	1	0.0195	0.091
Max.		1.786	0.74
Average	2	0.0159	0.0784
Max.		0.2465	0.2907
Average	3	0.0663	0.175
Max.		0.3104	0.3621
Average	4	0.0317	0.0714
Max.		0.1555	0.1943
Average	5	0.0032	0.0511
Max.		0.1127	0.1813
Average	6	0.1705	0.2714
Max.		0.816	0.567
Average	7	0.4591	0.388
Max.		2.147	0.802
Average	8	0.0916	0.2594
Max.		1.914	0.869
Average	9	0.027	0.0859
Max.		0.761	0.4888
Average	10	0.0895	0.2155
Max.		5.271	1.214
Average	11	0.0091	0.1069
Max.		0.1745	0.2562
Average	12	0.0039	0.0383
Max.		0.2831	0.2714
Average	13	0.0162	0.0784
Max.		0.1745	0.2388
Average	14	0.034	0.1081
Max.		0.1451	0.218

Table 1. Flat A Reading Values

The minimum average levels achieved in flat-A were at points 5, 12, 11, 2 and 13 respectively, indicating that the interior facilities such as the kitchen, corridor and bathroom are the least exposed to Electromagnetic Fields (EMF). This can be explained by the thickness of the partition walls protecting these spaces from a higher potential exposure. In contrast, the highest values acquired on average, were attributed to the terrace space. One 250x135mm opening at the southeast direction and two 60x135mm openings at the southwest allow a free access of EMF waves from the adjacent building antenna installed on the rooftop. It's worth to note that reading values at the outer side of the wall, i.e. points 6 & 9, are about 2.5 higher than their counterparts at the inner side of the wall, 3 & 2 respectively. The electromagnetic fields intensity and strength are culminated at point 10 centered in flat-A terrace space. On the other hand, It's worth to mention that EMF-values amount at Max. 0.1451 mW/m2, 0.218 V/m, averaging at 0.034 mW/m2, 0.1081 V/m over the bed pillow which tremendously exceed the Bioinitiative 2012 standards.

CASE STUDY 2: FLAT (B)

The general impression on the tabulated values is not positive comparing to flat-A case. The living space and the adjacent balcony are exposed to considerably higher radiation levels. About 43% of the Max. readings exceed the Bioinitiative 2007 guidelines while none of the average measurements falls under the limits issued in 2012 except points 7 & 8, the kitchenette and the bathroom respectively. The field strength follows approximately the same statistical significance with ca. 35.7% of the 2007 non-compliant peak values, while 78.6% of the average readings exceed the Bioinitiative standards of year 2012. Figure (6) gives an overview on the recorded values and the corresponding severity of concern. EMF mitigation methods against this case will be addressed within the next chapter. The terrace overlooks the rooftop of the opposite tower and is exposed directly to the mobile phone antennas recording the highest value in this research at point 12 where the display read 5.52 mW/m2 on Avg. and 39.99 mW/m2 at Max. while Table (2) shows that the field strength peaked at 3.498 V/m and averaged at 1.12 V/m in point 12. Such results call for extreme concerns especially that the balcony is used occasionally by the apartment end-users for sitting and relaxation.

On the other hand, It's worth to mention that the EMF radiation was reduced drastically indoors, yet exceeding the limits. That can be implicitly attributed to the aluminum profile of the door, IR-reflective glass and the thickness of the balcony wall. Nevertheless, there is still a concern that the bedroom -as it shows in the plan layout- receives an intolerable amount of electromagnetic fields requiring immediate remediation strategies to take place. An unexpected result sprung from point 6 in the middle of the entrance corridor recording a value of 2.465 mW/m2 indicates clearly that these radio-frequency emissions were generated from devices attached inside the stairs and/or the elevator shaft of the building. The thickness of walls and the finishing layers were not sufficient to block such a considerable spill towards the private premises. It was noted that point 2 at the inner side of the wall receives around 5.8 times the amount of radiation at point 3 which faces the window. This finding points out to the fact that reflective window films might be more efficient in mitigating the EMF levels than the block walls. A finding that requires further justification in other potential researches. The lowest average ever recorded in flat-B was inside the bathroom where point 8 indicates 0.0012 mW/m2. It would not seem too strange to obtain such a value, especially, by looking at the amount of barriers separating this space from the terrace and making it an EMF-protected little fortress. Such results should be targeted in all over the apartment space to achieve a healthy and safe environment with respect to "uncontrolled occupancy" levels.

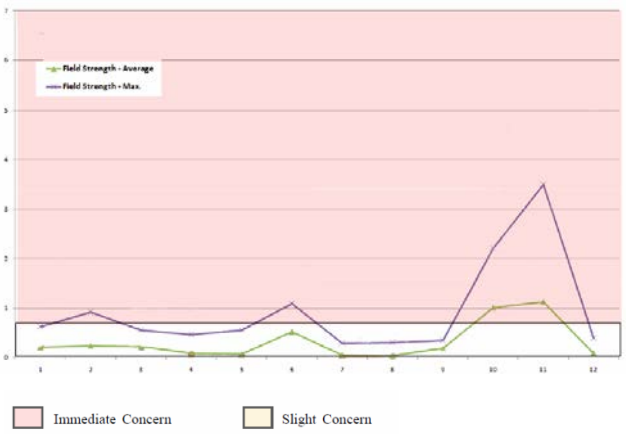

Figure 6. Flat B - Values vs. Severity of concern

Due to the disconcerted design of this apartment in relation with the surrounding antenna towers, unexpected results were exhibited at different locations suggesting that incident waves are reflected from some of the furniture objects, such as mirrors and metal hardware, which might have worsened the situation by increasing the exposure of some areas.

	Reading Values (Flat-B)		
	Measurement Points	RF Radiation mW/m^2	Field Strength V/m
Average	1	0.205	0.2035
Max.		0.981	0.622
Average	2	0.727	0.2309
Max.		2.581	0.91
Average	3	0.1264	0.2129
Max.		0.959	0.554
Average	4	0.0459	0.083
Max.		1.451	0.4559
Average	5	0.017	0.0731
Max.		0.048	0.548
Average	6	0.2197	0.511
Max.		2.465	1.081
Average	7	0.0013	0.0511
Max.		0.619	0.2907
Average	8	0.0012	0.0349
Max.		0.0129	0.3008
Average	9	0.0303	0.1813
Max.		1.207	0.3457
Average	10	0.0079	1.009
Max.		0.1101	2.205
Average	11	2.523	1.12
Max.		15.92	3.498
Average	12	5.52	0.0821
Max.		39.99	0.3836

Table 2. Flat B Reading Values

8 RESEARCH PRACTICAL OUTCOMES

The experimental research study gave a clear overview on the Electromagnetic Fields (EMF) readings inside two of urban buildings in Dubai. The results were concerning especially that a considerable percentage of EMF-radiation level is escaping towards the indoor environment. Maisch et al. (2006) in the BDP Environment design guide, published by the Royal Australian Institute of Architects (RAIA), confirms that there is sufficient evidence to take steps ahead within the early stages of design to mitigate unnecessary exposure levels. Such actions should be accomplished by the collaboration of all project stakeholders, primarily architects, designers and planners. Early considerations accounted into the

design processes will definitely save future costs on shielding and implementing protection techniques from Electromagnetic Fields at the occupancy period (Maisch et al., 2006).

8.1 NEW CONSTRUCTION

Architects and designers, who proactively consider and plan radiation-conscious projects within the early stages of design can use simple and quick EMF measurements to determine the site radiation-intoxication levels. These measurements should be focused on RF levels in case mobile phone antennas are addressed within the close vicinity. Additionally, magnetic fields should also be measured if power lines cross near the site construction. Distribution map of electric stations and dipole locations should be sought from local authorities and telecommunication agencies based on the site investigation requirements. Dual-frequency meters, such as the device used in the experimental study, that can measure the magnetic and electric strengths are available in consumer products within affordable prices. If the taken measurements are of a concern, the architect should accommodate changes in the environmental and/or functional architecture setting in order to mitigate the EMF-trespass to the project site. The design team highlights the areas where EMF levels exceed the norms in order to strategically protect them and avoid allocation of high-occupancy spaces throughout the exposed zones. Some of the solutions, which can be inferred on the functional aspect, are the allocation of non-occupied warehouses and general storage rooms in the exposed areas. Access will be temporary and short-term exposure will only be experienced. Highly-occupied areas such as office desks, kitchens, service counters, bedrooms, living spaces, etc. should be carefully planned within well-shielded zones. The wall thickness and constituent materials affect the partition/separator resistance to EMF spill. Specification of these elements should carefully be made in collaboration with reliable manufacturers. Some of these materials include the insulating aluminum foil (Burrell, 2010). The deliberate allocation of electrical rooms including the drivers, transformers, ballasts, junction boxes, etc. helps to keep the low-frequency fields away from the occupants. Shielding these equipment reduces significantly the induced spills. Similarly, the accommodation of WIFI devices, wireless meters and Bluetooth accessories away from high activity areas is essential to protect the relevant occupant as well as the neighboring premises.

8.2 EXISTING RENOVATION

As the experimental study showed, the reading values behind the glass were significantly lower than outside. A result that suggests that glazed doors were already equipped with films to reflect the radiation waves beyond the optical range. Nevertheless, due to the proximity of antenna towers, a fair amount of radiation still escapes through the glazing components towards the indoor environment. Extra layers of EMF-resistant films can be added to maximize protection. In case of opaque walls, water-based shielding paints can be applied on the outer surface of the wall. Further measurements should always be conducted to ensure the efficiency of these solutions. Care should be taken while implementing these techniques indoors, because they may reflect the Radio-Frequency waves internally and cause the amplification of Electromagnetic Fields instead of mitigating them. Accent protection to critical areas such as the bed can be considered such as Faraday bed canopy which is an ultra-fine metal composite mesh suspended over the bed space (Burrell, 2010). The application of shielding materials turns the space walls into a conductive enclosure, therefore, grounding should always be performed on these materials with the assistance of an electrician. Being thorough and methodical about EMF-protection strategies is a key role to effectively reduce the exposure to radiation within affordable time and budget constraints (Burrell, 2010).

9 CONCLUSION

Exposure to Electromagnetic fields radiation in public and private premises is unavoidable. The research study identified high levels of radiation-intoxication in the subject apartments suggesting that action plans should be initiated from the early stages of the architectural and environmental design of urban buildings. Preliminary evaluation of the EMF levels in the project site and designed spaces must be performed so that technical advice and further investigation can be planned according to the severity of situation. Buildings, that are designed to be intelligent, do not only enhance the occupants lifestyle and controllability over the services, but more importantly, prevents the excessive use of energy and maintains the occupants health and security. The environmental radiation protection requires that the construction community, including the project developers and designers, are aware of the negative health effects of the electromagnetic fields onto humans and

living organisms. Most of urban areas are considered "uncontrolled exposure zones" and require careful planning of wireless and EMF infrastructure in relation with the human activity areas. To conclude, The research study is a pragmatic example to measure and understand the EMF reading values in light of the international guidelines and standards. Results of this research showed a significant spill of radio-frequency waves into the subject spaces. The proximity of cell phone antennas to the case study units exhibited real concerns which were justified by the measurements taken at different points in the respective plan layouts. Findings and discussion should magnify the importance of considering, and hence mitigating, the site exposure to radio-frequency radiation, especially if the project encompasses education or medical facilities such as schools, kindergartens or hospitals (Dhami, 2011). Elaborate analysis of the site radiation-intoxication must be deliberately conducted in this case. Several techniques can be employed to reduce the increased exposure levels inside urban buildings depending on the situation identified.

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