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Environmental Pollution of Cell-Phone Towers: Detection and Analysis Using Geographic Information System

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Abstract

Recent studies on environmental pollution from cell-phone towers have prompted a serious concern about their radiation hazards. Investigations in the present project are based on mapping the Electromagnetic Field (EMF) radiation levels in various locations in the north Jordan, which was shown to be highly radiated due to large number of cell-phone towers distributed throughout the region. Radiations comiung out of these towers were measured using spectrum analyzer, power strength meter and Geographic Position System (GPS). The present study focused on EMF radiation intensity measurement in crowded residential areas and public buildings and facilitated using far-field equation. The data of EMF radiation in the selected regions were processed and represented by digital map (2D and 3D) with interpolated using ArcGIS 9.3 software. Modeling and statistical analysis of the obtained results was compared with the international standards. In addition, this study demonstrated that both spatial and temporal factors contribute to residential EMF exposure and GIS technologies can be used to improve EMF exposure assessment and to guide the decision makers in Jordan to take serious and solid steps toward reducing radiation exposure limits and thus reducing health risks as much as possible.

Keywords: EMF Radiation, GIS Mapping, Spectral Analysis, Power Density.

1. Introduction

In the last few years, ElectroMagnetic Frequency (EMF) exposure effects on environmental pollution have been extensively studied worldwide. With the drastic increase of wireless electromagnetic radiation exposure, contradictory experimental proofs have been reported. Research studies on health risks, due to EMF radiation from cell-phone, cell-towers and base stations are still contradictory (Sharma, 2004). All over the world, people have been debating about associated health risk due to radiation from cell phone and cell towers. Recent studies on the (EMF) radiation from cell-phone towers have prompted serious concern about their radiation hazards. Several radiation effects of non-thermal has been reported (Singh and Kumar, 2012; AL-Akhras et al., 2001; Elbetieha et al., 2002; Saadet et al., 2012; Hashish et al., 2007; Usman et al., 2011; AL-Akhras et al., 2006, 2008a, 2008b; AL-Akhras et al., 2007a, 2007b; Aitken et al., 2005). Reports on exposure to electromagnetic radiation of 900 MHz from mobile phones showed that it could induce lipid peroxidation in human erythrocytes (Moustafa et al., 2001), in female and male rabbits (Güler et al., 2012) and in the hippocampus and brain cortex of rats as well as oxidative stress and histopathological changes in the rats' endometrium (Ilhan et al., 2004; Ferrari, 2012), induces a transient alteration of epidermal homoeostasis (Simon et al., 2012), effects which were reversed by antioxidants (Koylü et al., 2006; Guney et al., 2007). However, very few studies have been specifically focused on environmental pollution from cell- phone towers radiations, especially for people who live in crowded residential areas nearby the base stations or cell-phone towers. Recently, awareness about the effect of EMF radiation on human life is notably increasing. There are now growing claims (scientific, medical and public) that living close to power lines has a harmful health and environmental effects on human life (Sharma, 2004; Durduran et al., 2010; Moraru and Marica, 2011). Mapping and monitoring EMF radiation levels are still considered to be in its early stage. In this regard, more studies are needed using a highly sensitive measurement and mapping system for better understanding and minimizing the risk factors related to human health and environment. GIS and Global Positioning System (GPS) are known to be the most reliable method is used to identify and locate the various sources of EMF radiation. GIS is a scientific tool, involving the use of particular software, associated with hardware tools and digital geographic data in order to advance some specific scientific research objectives. These modern techniques have been applied to many applications to provide accurate positioning, data capturing, storing, analyzing, retrieving, and end ups with mapping and statistical modeling (Sen et al., 2008; Durduran et al., 2010; Moraru and Marica, 2011).

Many studies in different countries concentrated on mapping the pollution of the EMF radiation with different standards for the radiation limits (Australian standard 200µW/

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cm^2.; Russia, Italy and Canada allow only 10µW/cm^2; China, 6µW/cm^2 and New Zealand 0.02µW/cm^2). Surprisingly, cell phone towers in the United States are most lenient and least protective in the world - US allows 580 to 1,000 µW/cm^2 (Aldad et al., 2012). Durduran et al. (2010) studied the effect of EMF radiation of cell-phone towers, in order to map the pollution of the EMF radiation in Turkey. They found that the most intense area of EMF fields was in the center of the city and concluded that there is a strong relationship between the levels of EMF pollution and health. Giliberti et al. in 2009 studied the EMF radiation effect of radio base station (RBS) in Italy. They found that the exposure produced by electric field was less than the exposure limits stated by Italian standards (Giliberti et al., 2009). In contrast, effect mobile radiation is harmful and more destructive on liver tissue (Ghaedi et al., 2013), 2.1 GHz W-CDMA modulated MW radiation inhibited cell viability and induced apoptotic cell death via the mitochondrial way (Esmekaya et al., 2013). From the survey performed by Ammoscato et al. in the urban area of Palermo, values under the threshold have been obtained, about 2.2 V/m (1.2838 µW/m^2), except for some positions near Piazza Alcide De Gasperi, where maximum peaks of 10.18 V/m (27.4887µW/cm^2) have been recorded (Ammoscato et al., 2008). Gotsis et al. (2008) measured the variation of the electric field strength values on majority of the stations site and found to be below 3 V/m (2.387 µW/cm^2) which they consider it as a negligible value. Pollution analysis in a given propagation environment was done in a building of Yildiz Technical University, Turkey and found that Wireless Local Area Networks, WLAN (2.4 GHz) electromagnetic coverage does not lead to any electromagnetic pollution due to the low power levels used were the building generated using the selected network architectures to illustrate the results with an Artificial Neural Networks (ANN) (Sen et al., 2008). Results of other researchers suggests that GSM-EMFs of a mobile phone affect inter-hemispheric synchronization of the dominant (alpha) EEG rhythms as a function of the physiological aging (Vecchio et al., 2010), in contrast to a recent study by Trunk et al. (2013) found no measurable effects of a 30 min 3G mobile phone irradiation on the EEG spectral power in 1947 MHz UMTS RF exposure. Similarly p53 expression and its activation by phosphorylation in embryonic cells are not induced by exposure to GSM-900 MHz (Bourthoumieu et al., 2013), no any elevated risks of childhood leukemia associated with RF-EMFs (Merzenich et al., 2008).

Recently, World Health Organization (WHO's) international research agencies has classified electromagnetic fields from mobile phones and other sources "possibly carcinogenic to human" and advised the public to adopt safety measures to reduce exposures, like use of hand-free devices or texting. In this regard, with the rapid growth of the mobile users in Jordan, more than 6 million mobile phones are used in Jordan as reported by Telecommunications Regulatory Commission (TRC), which is more the number of populations about 103% in average. Most Jordanians have more than one cell phone or more than one line from different cell phone providers. Mobile towers are being built in a haphazard manner without any prior planning and regulation. People in Jordan nowadays raised real concern about the lack of cell-phone safety standards and policies and the adequacy of these standards to protect Jordanians. In light to evidentiary uncertainties and lack of public awareness about the cell-phone safety standards, we found that it is quite useful for our research team at Jordan University of Science and Technology (JUST), the Jordanian decision makers and civil societies to study the cell-phone towers EMF radiation in pilot regions in north Jordan. EMF radiation levels from selected base stations and certain spectrum range were measured using isotropic broadband and portable spectrum analyzer measurement. The results were processed in a digital map and interpolated using the ArcGIS9.3 software. Furthermore, to compare the exposure of EMF radiation mechanisms in the far-field region with standard levels, mapping and simulation of our data was also conducted and correlated with safety regulations.

The major goals of this research are; to provide quite graphical representation of the relatively high exposure levels (hotspots) and to identify the frequency, intensity, and dose of non-ionizing electromagnetic fields that could be harmful to the biosystem and ecosystem in Jordan;to provide experimental data as a solid evidence for the dissension makers in Jordan to guide and enable them to built-up a national strategies for the proper and ethical use of wireless technologies. Moreover, the financial revenues for cell phone providers must not be the only dominating factors when issues come to health risks and radiation pollution of the environment.

2. Methodology

In this study, ten selected cell tower sites in the north of Jordan at various locations with relatively high electromagnetic radiation intensity are studied. Just three of them namely; Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are presented in this manuscript. Experimental measurements of the cell-phone towers EMF radiation levels through detection, modeling and analysis was done using a portable experimental set-up described below.

The sites were divided into several environments (plains, plateaus, mountains …etc) nearby crowded buildings (residential, schools, hospitals, companies ....etc). Collected information about the technical data of the selected cell-phone towers, such as: (type of antenna, its gain and radiation pattern, vertical tilt (azimuthal) and frequency band), which is needed for the classification process was recorded. In order to evaluate the EMF cell-phone tower radiation, the total emissions in all locations was calculated, taking into account the total contribution of each tower. Throughout field data collection, we measured the total radiation, intensity of electric-field, magnetic-filed and power density in several points for each exposure site. The instrument and software used are Radiofrequency EMF strength meter (Extech Instruments frequency range 50 MHz to 3.5GHz, Model: 480836/USA), Handheld Spectrum Analyzer (Agilent Technologies frequency range 100KHz to 3.0GHz, Model: N9340B/USA) Magellan Explorist (Model: 510/USA), GPS device and ArcGIS 9.3 software. All points where located using GPS device to identify location coordinates (latitude, longitude and altitude) around the sources. The GPS is deemed as an outstanding navigational system due to the following: its capability to attain high positioning accuracy (ranging from tens of meters down to millimeters) and its signal availability to users anywhere on the globe (air, ground, and sea applications).

In addition, we used spectrum analyzer to identify RF sources and for assessment of the relative magnitude of signals in different frequency ranges. Spectrum analyzer with a calibrated antenna gives a sensitive and precise channel power measurement across selected frequency ranges and also provides precise measurement of strength for an individual signal for each source in the selected sites. To analyze data, electric field (E) and magnetic field (H) ware calculated by applying the classical field equation of the EMF intensity in the far-field region (the region extending farther than 2 wavelengths away from the source is called the Far-Field). As the electromagnetic waves transmitted through space, the energy is transferred from the source to other objects (receiver). The rate transfer of this energy depends on the strength of the EMF source where it becomes a rate of energy transferred per unit area (power density), which is the cross product of the electric field strength (E) and the magnetic field strength (H). In the far-field, E, H, and power density are combined together. Thus by measuring the electric field, we were able to calculate the power density ($P_d = E^2/377$) and the value of the magnetic field ($H=E/377$). Power level measurements were performed for base station in far-field points ($R>2D^2/\lambda$). The detector minimal distance used was about several meters from a portable detecting device.

Data collected from the power strength meter and the GPS devices were tabulated as the power density and location at each point. ArcGIS 9.3 was used to provide a map of the EMF data, based on the mapped EMF radiation at various points in each site. The software plot the 2D and 3D maps using interpolation depends on inverse distance weighted (IDW). The interpolation technique estimates point values by averaging the values of sample data points around each processing point. Thus, new values could be found by IDW technique, which assumes that each point has a regional effect; the effect is inversely proportional to a distance between interpolation point and measurement point. Eventually a comprehensive digital 2D and 3D map of the selected regions is produced. Data obtained using spectrum analyzer in each cell tower site were analyzed and compared with other selected locations. Highest radiating sources and average power density for each location are represented in histograms.

3. Results

In all figures the cell towers locations are marked with stars and measurement points are marked with dots. Selected location and cell phone towers sites with different environmental condition are presented as follows:

Fig. 1 shows a Google and 2D ArcGIS maps of site Ajloun-Ebleen. At this site, power densities of three cell towers from different points around the towers were collected and recorded. In this region, places under investigations were as follows: crowded residential area nearby cell-towers, places far away from residential area and towers, and most frequently visited places such as mosque, church, school, shops, health center and farms. Mapping of the power densities are shown in Fig. 2a, (2D) and 2b (3D). Red color represents the hotspots where places received high radiation doses.

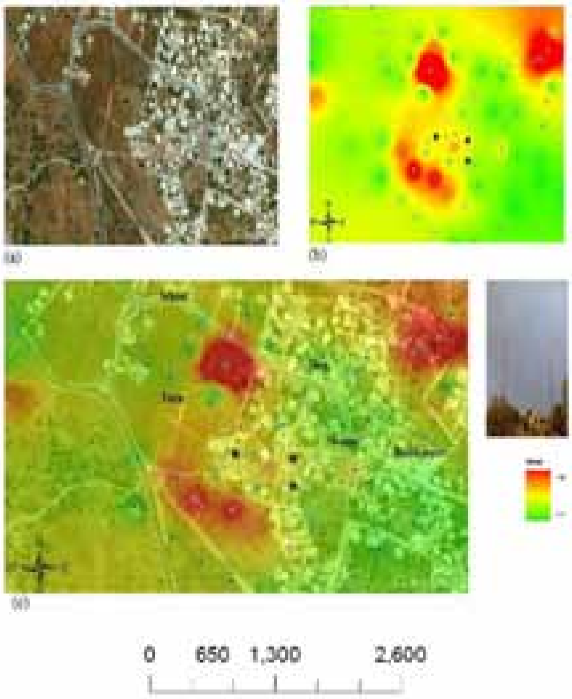

Figure 1. (a) Google earth map of Ajloun-Ebleen site (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

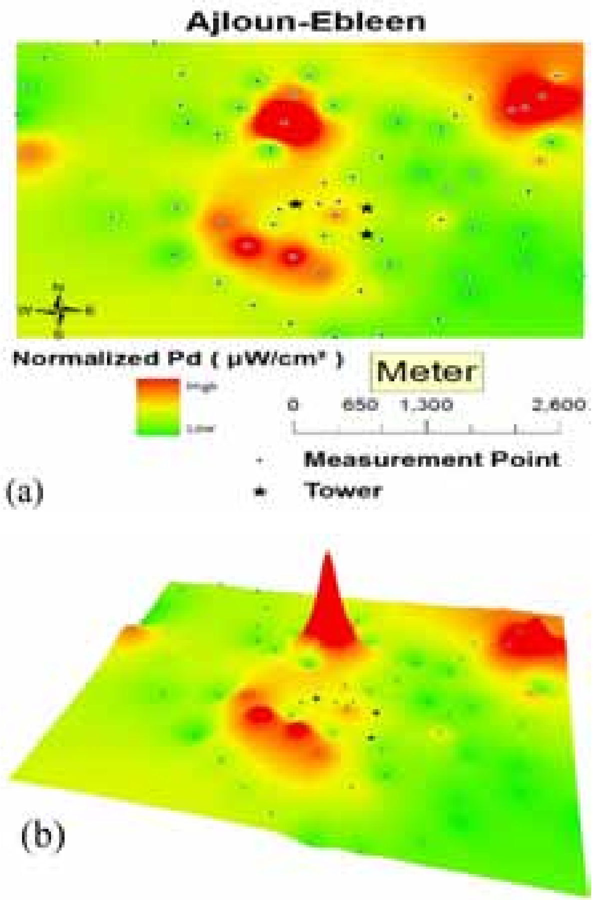

Figure 2. (a) 2D & (b) 3D representation of measurement values at RF radiation in Ajloun-Ebleen.

Fig. 3 shows a Google and 2D ArcGIS maps of site Irbid-BeitRas. At this site, a group of three cell towers locations are marked by a star at the 2D map. A Radio and TV Stations are installed at this site to covers the northern part of Jordan. VHF/UHF radio and TV towers are placed on the highest point in an area so the transmitted signal has a clear path to receiving antennas. The 3D mapping of the power densities is shown in Fig. 4.

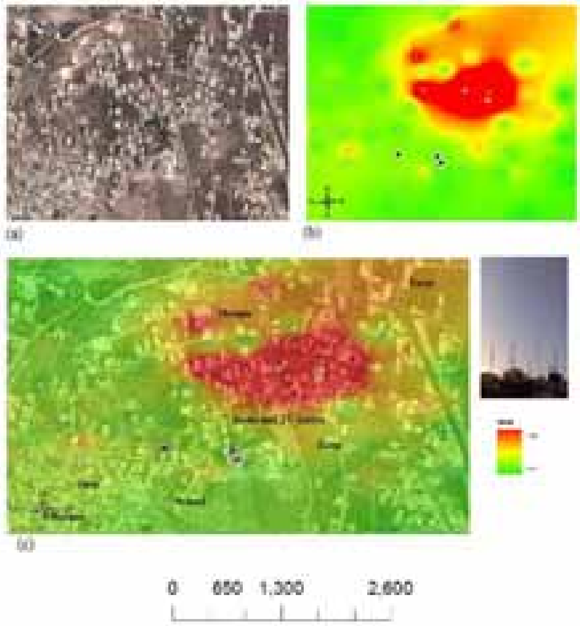

Figure 3. (a) Google earth map of Irbid-BeitRas (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

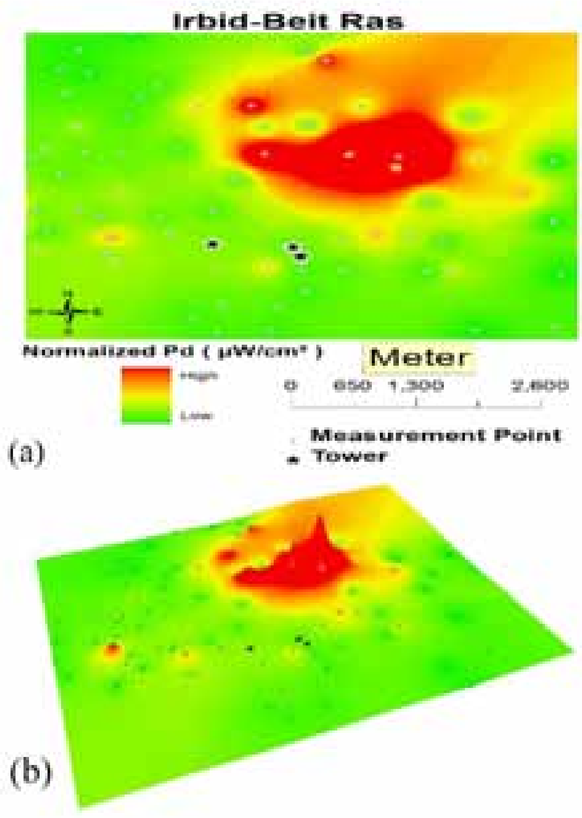

Figure 4. (a) 2D and (b) 3D representation of measurement values at RF radiation in Irbid-BeitRas.

The transmitted antennas patterns in this area are designed so that the radiating beam is projected away from the tower almost horizontally to cover as much areas as possible. This minimizes the signal strength at ground level near the tower. The higher level fields occur at a height that not accessible to the general public. Therefore, residence living nearby cell phone towers received weak coverage with low radiation dose.

Since Irbid is the largest crowded city in north Jordan with a population of more than one million, an extensive effort is required on EMF radiation detection and assessments by the health organization and national research institutes. The city has so many educational, industrial, health and commercial centers. Our initial survey study found that there are various sources of EMF radiation such as: Cell towers, roof towers (microcells) which operate 2G, 3G, FM Radio and TV stations. A typical example of cell towers radiation map in some of selected site in Irbid city center are shown in Fig. 5. There are three cell towers in the selected site. Two are roof towers and one huge stand alone cell tower in the middle. Collected data points of the power densities around those three towers are plotted in 2D and 3D mapping as shown in Fig. 6.

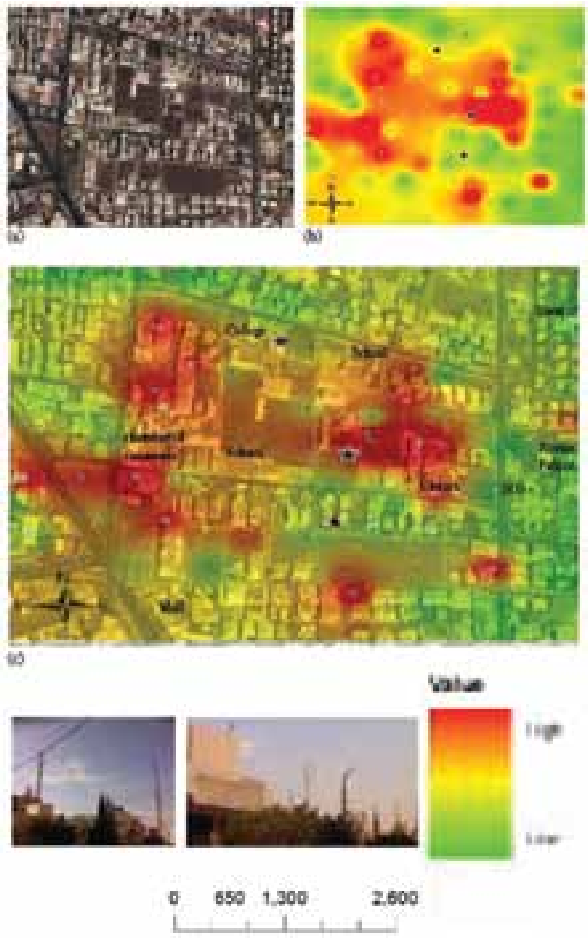

Figure 5. (a) Google earth map of Irbid City center (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

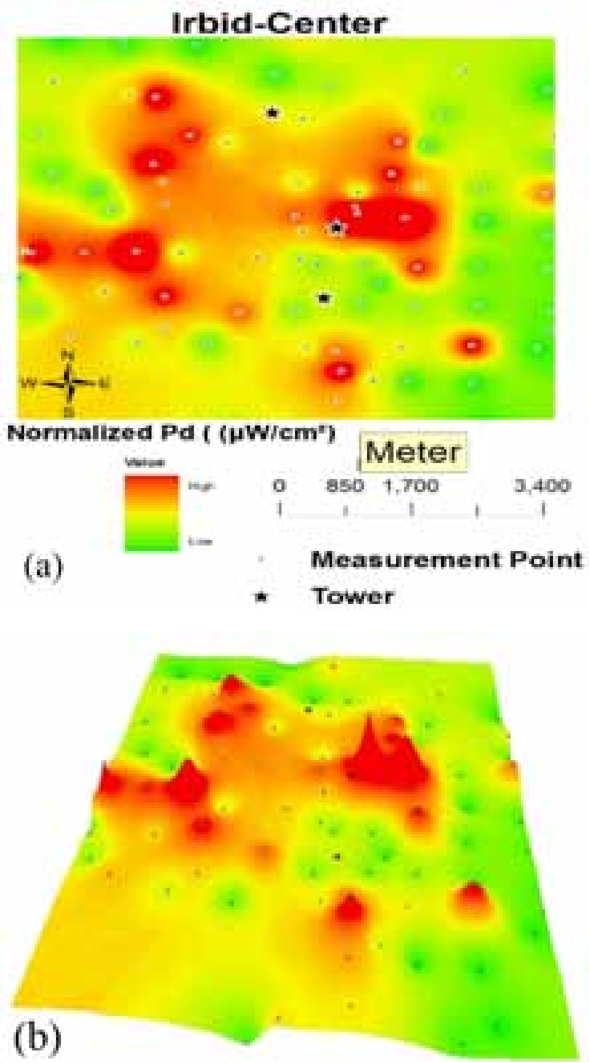

Figure 6. (a) 2D and (b) 3D representation of measurement values at RF radiation in Irbid city center.

Comparison between measurements of spectrum analyzers and RF power meters.

A comparison of the power density measurements using Spectrum Analyzer and Power Meter are shown in Table 1. Average RF exposure measurements for all cell towers in Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are summarized in Table 2 and Fig. 7. Frequency band measured by spectrum analyzer at the selected locations Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are shown in Fig. 8.

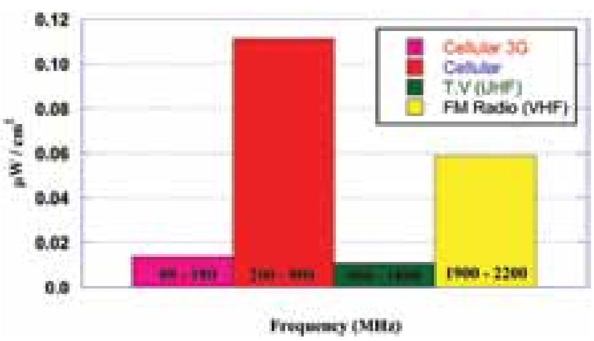

Figure 7. The average RF exposure measurement for all cell towers in Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center by using spectrum analyzer-Agilent N9340B/USA.

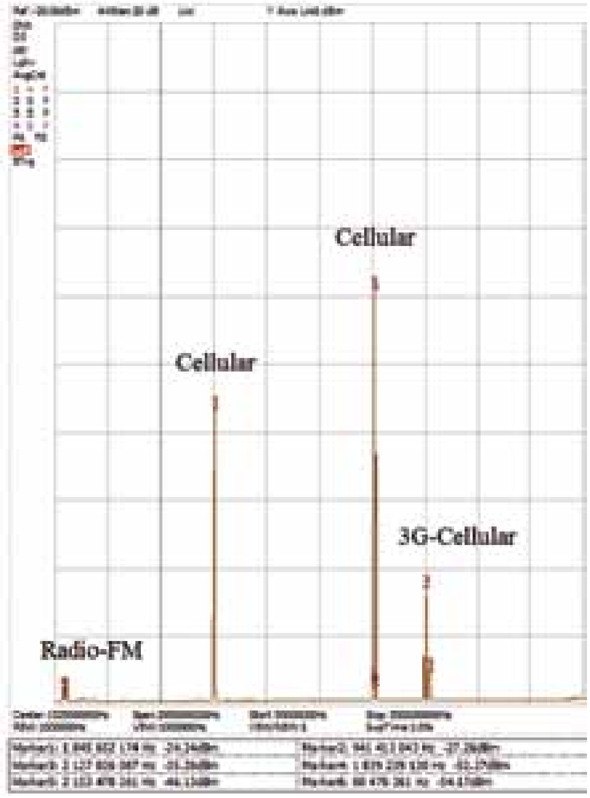

Figure 8-a. Ajloun-Ebleen

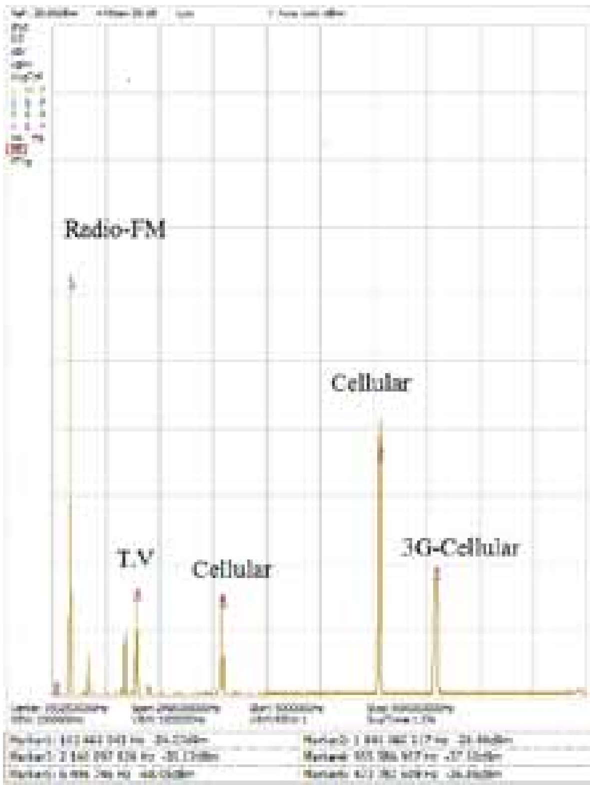

Figure 8-b. Irbid-Beit Ras

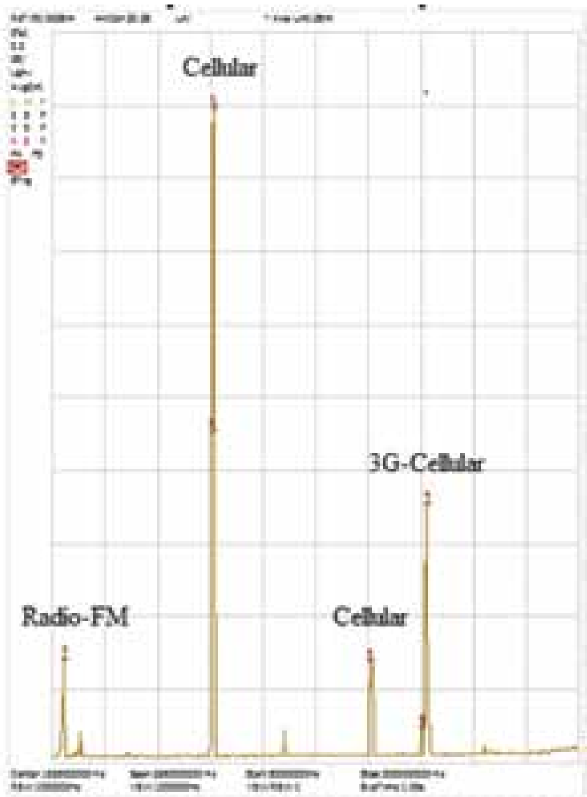

Figure 8-c. Irbid city center

Figure 8. Frequency band from the spectrum analyzer-Agilent N9340B/USA with spectrum range (50 MHz to 3GHz) at the selected locations; 8. a: Ajloun-Ebleen, 8. b: Irbid-Beit Ras and 8. c: -Irbid city center.

Table 1. Comparison between the measured values for RF radiation levels emitted of spectral subdivision by spectrum analyzer and power strength meter at different locations in Northern part of Jordan.

Location	Average Power density (μW/cm²) RF Power Meter	Spectrum Analyzer
Ajloun-Ebleen	0.0835	0.2003
Irbid-Beit Ras	3.5400	0.2722
IrbidCityCenter	0.1350	0.1745

Table 2. RF radiation levels of spectral subdivision by spectrum analyzer- Agilent N9340B- for all cell tower sites.

Location	FM Radio (VHF)	T.V (UHF)	Cellular	Cellular 3G	RF expose
Ajloun-Ebleen	0.0019	0.0001	0.1790	0.0192	0.2003
Irbid-Beit Ras	0.1740	0.0219	0.0725	0.0038	0.2722
IrbidCityCenter	0.0009	0.0000	0.1500	0.0235	0.1745
Average	0.0589	0.0109	0.1113	0.0137	0.2157

4. Discussion

Fig. 1 and Fig. 2 represent the measurement values of EMF radiation in Ajloun-Ebleen. The power densities at the most populated residential area of the city are low. Relatively high power densities were measured at different places outside residential area.

The maximum reading of the power density was 0.083μW/cm² from the power meter and 0.200μW/cm² from the spectrum analyzer. Those obtained readings are from empty locations with no buildings or people living around. This suggests that the randomness in the cell tower site selection process indicates that there are no regulations and real time studies for the radiation levels done by the cell phone providers and the official telecommunications departments in the country. It gives clear evidence that the cell towers were installed and designed in a haphazard way without taking into account the human exposure to the EMF radiation or even the transmission coverage areas. Mapping of our collected experimental data are plotted in 2D and 3D as shown in Fig, 1 and 2. In those figures, clear hotspots are marked with red colors. Similarly mapping with comparable findings is reported by (Gumusay et al., 2007). In their study 3D electromagnetic coverage and electromagnetic pollution modeling with Artificial Neural Network (ANN) using back propagation algorithm is realized and modeled in GIS environment. Average of ANN is about 0.261 V/m which is nearly equal to 0.0180 μW/cm² [Gumusay et. al., 2007]. Furthermore, similar hotspots were assessed reported by (Aerts et al., 2013), the maximum total electric-field strengths ranging from 1.3 to 3.1V/m (0.448 to 2.5491μW/cm²) were found and satisfy the reference levels issued by the International Commission on Non-Ionizing Radiation Protection for exposure of the general public to RF-EMF. Spectrum analyzer measurements in these hotspots revealed five radio frequency signals with a relevant contribution to the exposure (Aerts et al., 2013).

Measurements of typical transmitter sites in Irbid-BeitRas showed that the signal levels on the ground near the towers are typically 1% or smaller than the general public exposure limits Fig. 3 and 4. The low level values are may be due to transmitted antennas pattern in this area which are designed in such a way that the radiation beam is projected almost horizontally to cover as much areas as possible. Therefore, minimum signal strength at ground level near the tower is measured and higher power levels were measured at heights that are not accessible to the general public. Even though, in our study, the maximum power density recorded by the power meter at this site was 3.54μW/cm² and this was the highest value for all selected sites while the maximum reading of the power density recorded by spectrum analyzer was 0.174μW/cm². These spots with relatively high radiation levels indicate that people who are living or working in or nearby the TV and Radio stations are potentially exposed to EMF radiation hazards.

Fig. 5 and 6 represents the measured values of EMF radiation in Irbid-city center. It can be easily seen that the radiation coverage is much more distributed over the region than what we have observed in the other sites. Note that most of the main buildings are under a relatively high radiation levels. Furthermore, we have seen at many places a building's roof has up to two or three towers on first floor and these towers in some cases are directly facing second floor of adjoining building similar to that at Yarmouk University Street. This street is internationally well-known because it is less than 1 km long but has more than 130 Internet cafes, making it one of the densest streets worldwide in number of Internet cafes. The number of internet cafes per capita is the highest in the world that may took Irbid to the Guinness Book of World. The maximum average reading of the power density at some accessible places was 0.135μW/cm^2 from the power meter and 0.174μW/cm^2 from the spectrum analyzer. Researchers in some other countries report several exposure values in several locations. For example, if a mobile phone base station is mounted to the roof of the office building or another nearby building, EMF exposure levels can increase to several thousands to ten thousands of microwatts per square meter (Thansandote et al., 1999; Sage, 2000). If the base station sits at the disk, continuous RF radiation exposure can range from about 2 μW/cm^2 (1 m distance) to about 350 μW/cm^2 (20 cm distance) (Kramer et al., 2005). Another study, reported a fourfold increase in the incidence of cancer in people living within 350 meters of a cell phone tower as compared to the general population. They also reported a tenfold increase specifically among women (Wolf et al., 2004). Significant changes of the electrical currents in the brain by a cell phone base station at a distance of 80 meters were also reported (Lebedev, 2010). It has been reported that, when holding the handset against the head during a call, EMF radiation exposure will be even higher. In the case of a mobile phone handset, the head's exposure was quite above 100 μW/cm^2 (Maes, 2005). Overall, our obtained results could be helpful to cell phone towers and EMF designers to consider queries concerning the electromagnetic radiation, coverage, environment pollution, and helps to determine the communication signal quantity and quality. In addition, further investigations should be conducted at these special areas. From our data analysis we found that cell phone providers in Jordan don't build sites where they expect future population growth; they build because there is a specific and current need and most of these sites are randomly distributed throughout the whole areas in north Jordan without any professional mapping of the real signal coverage needed at these areas.

Northern part of Jordan is known for its wonderful wildlife, nature reserves, and beautiful mountain which contain one of the last remaining examples of a pine–oak forest in the Middle East. Despite the apparent efforts to protect these and unique areas, it is gradually and systematically being destroyed by the establishment of modern cement projects for industrial and commercial purposes. Moreover, with the communications revolution during the last two decades, cell towers in all shapes and sizes have invaded the virgin environment and thousands of new communications towers have been installed randomly in the cities and the countryside. Unfortunately, the telecommunications regulations make it illegal for local governments to reject installations of new towers. The law also makes it difficult, and in many cases impossible, for communities to restrict the size, location, appearance or number of towers. Despite huge number of cell towers distributed almost everywhere, still peoples in some areas are complaining a lack of towers close to them due to low transmission coverage.

In this work and for the first time in Jordan we raise concern about the environmental pollution of cell tower radiation. To do this, we have selected some tower sites in the cities of Irbid and Ajloun and their rural areas in north Jordan. Measurements have been made at locations that could be assumed to have higher radiation levels than would be the case if measurement locations were selected randomly. In light of the sites selection discussed above, one can take the precautionary principle approach and reduce EMF radiation effects of cell phone towers by increasing height of towers, changing the direction of the antenna, or relocating towers away from densely populated areas and placed where they don't harm people (Sivani et al., 2012). The Orange phone company in Bristol, England is being forced by residents and local authorities to remove its cell towers when cancer rates in the building raised ten times above the national average (Lebedev, 2010). Furthermore, all measurements have been stationary, and there is today no knowledge about the level of exposure that an individual will have throughout the day. In the selection process, the drive short aims were to check radiation levels from cell towers located in vicinity of schools, mosques, churches, hospitals, wildlife and residential areas, while the long term project is to cover the whole country taking into account the health issue. In addition to long term goals, protection and EMF shielding will be studied.

4.1. Power Measurement of the Selected Sites

A cell tower and its transmitting power are designed in such a way that cell phone should be able to transmit and receive enough signal for communication up to a few kilometers. Majority of these towers are mounted close to the residential and office buildings to provide good mobile phone coverage to the users. These cell towers transmit radiation day and night, so people living within in the vicinity of the tower will receive more than ten thousand times stronger signal than required for cell phone communication.

An antenna transmits in certain frequency band. This frequency band is divided into sub-bands, which are allocated to different operators with several carrier frequencies allocated to one operator. Each carrier frequency may transmit 10 - 20W of power and the total transmitted power may be 200 to 400W. In addition, directional antennas may have a gain of around 17 dB, so effectively; several kilo watts of power may be transmitted in the main beam direction. However, radiation density will be much lower in the direction far away from the main beam.

ICNIRP guidelines has givens adopted radiation norms in Jordan for safe power density of f/200, where f is the frequency in MHz, and the transmitting band is (935-960 MHz) for GSM900 with a power density of 4.7W/m^2 and transmitting band (1810-1880 MHz) for GSM1800 with a power density of 9.2W/m^2. One of the most significant RF radiation signal measurement problems, and one responsible for some of the greatest inaccuracy, involves an instrument erroneous response that can occur when there are two or more strong signals present at the same time. Instrument design can minimize this problem, but many of the commonly used isotropic broadband meters perform very poorly in this multi-signal environment. The result is a reading that is much higher than actual; sometimes double. In this study, we have measured the power density by using both the sensitive spectrum analyzer and the power meter. The use of these instrument with a calibrated antenna will allow a sensitive and precise "channel power measurement" across selected frequency ranges, or measurement of the strength of an individual signal. The measurements were repeated several times during a fixed time interval of and averaged for each point in all possible direction near the cell tower site. The data of the two methods were compared and discussed.

An additional challenge results from the fact that power density levels at a cell tower site itself are not always constant, as they usually are at a broadcast antenna site. People use their cell phones more at some times of the day, and on some days of the week, than at others. The cell phones providers maintain additional capacity in the form of multiple channels which will become active as needed to meet demand. Each active channel adds to the measured power density at the cell site. The variable nature of power density levels at some sites must be taken into account. When necessary, we employ timed signal averaging or data logging to produce an accurate assessment.

4.2. Mapping of EMF Radiation Levels

Measured data using the Spectrum Analyzer, Power Meter and GPS has been used to make interpolation over complete area in the IDW (Inverse Distance Weighted) module of ArcGIS software. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. Thus, new values can be found by IDW method. This method assumes that each point has a regional effect and this effect is inversely proportional to the distance between interpolation point and measurement point. Similarly, ArcGIS software was used to make a 2D and 3D map from the data. The area having various radiation levels was determined by combining this data with digital Google map of all selected sites showing radiation levels in different colors have been set up, by using the data obtained. Through this map, areas with relatively high power densities were identified easily in the vicinity of the cell tower. It has been found that some cell towers had relatively higher radiation values compared to the others. In the following we will present these maps for each site alone and compare them with some other measured and standard values.

4.2. Comparison between Spectrum Analyzers and RF Power Meters

RF power meters are used not only for measuring power levels in RF systems, broadcast systems, and radar/satellite systems, but for calibrating other measurement instruments and probes are needed. Unfortunately, an RF power meter is designed for broadband frequency coverage and cannot determine the carrier frequency associated with a power reading or whether the measured power is within the proper bandwidth or not. Normally, a spectrum analyzer is also needed to get these determinations. No matter where the RF signal is centered, the power meter reads the same total average power value. However, the RF power analyzer is programmed to read the power only in the channel in which the mobile device is supposed to be transmitting. Moreover, the ability of the RF power analyzer to measure power within specified frequency bands enables it to spot defects that an RF power meter cannot.

Conclusions

We argue that due to potential radiation hazards, these existing cell towers near schools, hospitals and residential areas must be moved out of such areas, as studies show that radiation levels at such facilities could cause cancer, miscarriages, disturbance of the nervous system and other diseases. Large disparities between national radiation exposure limits and international guidelines based on contradictory studies can foster confusion for regulators and policy makers, increase public anxiety and provide a challenge to manufacturers and operators of communications systems. In this regard, well designed and conducted useful and information studies should be known to all, because negative results (no effect observed, below standards) are as useful as positive studies (effect observed, above standards) when evaluating the scientific evidence. Furthermore, radiation exposure standards that limit human EMF exposure should be based on studies from various disciplines of health sciences, including biology, epidemiology and medicine, as well as physics and engineering. All of these play important individual and collective roles in identifying possible adverse effects on health and in providing information on the need for, and appropriate levels of, protection.

In Jordan, unsystematic with random location of RF-EMF sources over all the place form all the cell phone companies are noticed. Similarly, haphazard exposures with very high range in some places and sometimes empty places were found. Therefore, we believe that it is time now for national advisory and/or regulatory bodies to develop new standards for EMF, review the basis of their standards, or reconsider specific quantitative values such as reference levels and safety factors. The overall purpose of this protocol is to provide advice on how to develop science-based exposure limits that will protect the health of the public and workers in Jordan from EMF exposure. Up to our knowledge, this is the first studies in Jordan and therefore further studies should address these issues in more details and more locations should be covered. In conclusions and on the bases of our study it is recommended that installation and operation of a cell towers should be subject to protocol or guidelines, searching for alternative locations for the cell-towers with monitoring before and after installation, and conducts laboratory studies and monitors external research on the biosystem and ecosystem.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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