MONITORING OF RADIOFREQUENCY RADIATION FROM SELECTED MOBILE TELEPHONES IN KENYA

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Abstract

The use of mobile phones in Kenya has increased tremendously in the recent past. This has increased the general population exposure to mobile phone radiation. Numerous mobile phone manufacturers, producing different handset models with varying standard qualities, have also emerged. Consequently, pegged on these circumstances, various questions arise: Is the radiation from the mentioned gadgets within the safe limits or not? How does the physical condition of handset under different exposure conditions affect the radiation thereof? Do anti-radiation filters suppress the said emissions or not? In regard to these, the intensity of radiation around various GSM phone models has been measured using broadband radiofrequency meter and spectrum analyzer and the results assessed based upon the established international safety standards on non-ionizing radiation. The results obtained in this study have shown the presence of radiation levels from all the selected mobile phone models, ranging from 0.01134 to 0.4671 mWcm-2 with the highest from Nokia Series (China) N95 and lowest from Nokia 1110. These radiation levels are within the recommended exposure limits. It has further been established that high radiation intensities from a transmitting handset appear between the dial and reception of a call. The use of different anti-radiation filters in abating mobile phone radiation has also been found effective, but with different degrees of efficiencies of which none meets the 99% efficiency asserted by the respective manufacturers. It has also been established that the radiation levels from a mobile phone are affected by the physical condition of the body. The International Mobile Equipment Identifiers (IMEIs) of the handsets under-study were also assessed for compliance to established standards.

Key words: Mobile phone, radiofrequency (RF), radiation, safety standards, broadband RF meter.

Introduction and Literature Review

The mobile communication industry in Kenya is experiencing rapid growth. This is a direct consequence of a high rate at which cellular technologies are emerging in the world and consequent increase in economic activities. The significant introduction of new products such as m-Pesa, Zap, yuCash and M-Kesho, reduction in the costs of mobile phone handsets, reduction in call charges and the growth of mobile penetration in Kenya have also fueled the expansion of this industry. Currently, there are about 19.4 million mobile phone subscribers in Kenya (CCK, 2010) and this is expected to rise to 29.28 million, or 66.7% penetration, by the year 2013 (ATMR, 2009; ITU, 2009). To support the growing demand of mobile services, the Communications Commission of Kenya has, at the moment, licensed four mobile operators: Safaricom, Zain, Orange and YU under the category of the Network Facility Provider (NFP) in a unified licensing framework, commanding 80.25%, 12.11%, 4.27% and 3.37% subscriber-base respectively (CCK, 2010; AWC, 2010). These operators use Global System for Mobile communication (GSM) or 2G-technology, and are advancing towards adopting the 3G-technology.

Mobile phones transmit and receive signals, via a base station system, using radio waves. Currently, there are about 4000 base stations in Kenya (RPB, 2008). And with the increasing use of mobile phones, more installation of base stations are expected; this would as well increase radiofrequency (RF) radiation in our environment. Exposure to RF radiation (RFR) is categorized into two: occupational and general-public exposure (ICNIRP, 1998). In occupational exposure, persons exposed as a consequence of their employment are fully aware of the danger of such exposure and take necessary precautionary measures. Otherwise, exposure that is not employment-related such as radiation from mobile phones is classified under general-public exposure. Various organizations such as the U.S.

Federal Communications Commission (FCC) and International Commission of Non-Ionizing Radiation Protection (ICNIRP) have set RF exposure limits, as shown in Table 1.

Exposure to RFR above the reference limits is termed as hazardous. Accruing health effects due to such exposures are thermally and non-thermally induced. Absorption of RF energy by biological tissues and the heating thereof is facilitated by electrical properties of bio-matter and the body's thermoregulatory mechanism (Hyland, 2000). The amount of heat produced in the exposed tissues depends primarily on exposure time and the intensity of radiation penetrating the system. The World Health Organization (WHO, 2000) has connected brain cancer with RF exposures, and Maneesh et al. (2009) have determined that the most thermally vulnerable organs include genitals and eyes. Other effects include a stinging sensation and a feeling of heat in the facial skin (Sandström et al., 1998). Non-thermal effects such as headache, dizziness, fatigue, stress, difficulties in concentrating and nausea have been reported by Krewski et al. (2007), Anita (2005) and Frey (1998). In this work, the intensities of RFR from selected mobile phones in Kenya are investigated under different exposure conditions and then assessed based on the established safety standards on non-ionizing radiation.

Materials and Methods

The GSM handsets under study are Nokia-1100, 1110, 1200, 1202, 2626, 1661, 6300; Nokia Series (China) N95; Smadl-A30, A56; Tecno-T570, T780; TV22i; iPhone-i9+; Long Ke- S350; TOP-1 006; J-Max: Double-Life; Samsung- GT-E1080T; Blackberry-7290 and Motorolla C118. These handsets were fully charged so as to avoid the risk of switching off during the measurement process.

The intensity of RF energy radiated from each handset was measured by broadband RF meter (NBM-550) connected with E-field isotropic probe (EF1891). In monitoring the signal strength and frequency specific to GSM band (900 MHz), a spectrum analyzer (FSH18) was connected with broadband active directional antenna (HE300). The frequency range of the E-field probe is 3 MHz to18 GHz and electrical field strength of 1.0 – 600 mVm-1. This probe was used to detect and measure (in XYZ planes) the RF signal from a transmitting handset, and would perform vector addition of individual readings and send the results on the display provided by the broadband RF meter. Radiation levels at close proximity to the transmitting handset, 5 cm from the ear piece, were first determined and referred to as normal radiation level N.

Radiation levels at the back (around the battery compartment) of the activated handset, with and without battery/ rear-body cover, were also measured and compared with respective Ns. The intensity of radiation from each of the selected handsets was also suppressed using three anti-radiation filters from different manufacturers and their effectiveness assessed and compared. The radiation measurement set-up is shown in Figure 1.

The measurement meter consisted of the broadband RF meter and spectrum analyzer connected to the computer via USB and RS-232-C optical interface respectively. The broadband RF meter measures the cumulative radiation, contribution of background and mobile phone radiation. To obtain the actual radiation level for each handset, respective average background radiation was off-set from the measured value. Radiation measurements for each phone were taken six times at intervals of one minute each and an average value was calculated. The process was then repeated thrice to determine the consistency of the results.

Results and Discussion

Background Radiation

In this study, measurement of background radiation (BGR) was carried out within the measurement vicinity -Communications Commission of Kenya (CCK)- so as to determine the baseline exposure of the general public to electromagnetic radiation. The BGR was the cumulative contribution of the radiofrequency radiation from the transmitting sources around the measurement vicinity such as base transceiver station, 200 m away from the CCK premises. This assessment enabled the monitoring and isolation of the BGR levels (in the measurement room) from the mobile phone radiation level(s). Figure 2 shows a graphical representation of average BGR levels with time of the day.

The results showed that the intensity of BGR ranged from 0.007681(1.7% of ICNIRP reference level) to 0.010643 mWcm-2 (2.4% of ICNIRP reference level). Minimum and maximum peak intensities were, respectively, observed at 9.32am and 12.57pm. The average BGR level is 0.009048 mWcm-2 (2.0% of ICNIRP reference level), with 4.3735 10-7 variance index.

In Figure 2, it is also evidently clear that the BGR in the morning and afternoon greatly contrasts. Average BGR before noon is 0.00861 mWcm-2 (1.9% of ICNIRP reference level) whereas in the afternoon, it is 0.00925 mWcm-2 (2.1% of ICNIRP reference level). The low BGR levels witnessed in the morning hours are as a result of little mobile-communications owing to a hub of office activities and may also be attributed to low solar activity. Notable increment of BGR is also however observed between 10.30am to 11.15am; this can be attributed to increased communications by staff during the tea break session. Maximum peak radiation levels were observed at lunch break, between 12.56pm and 2.15pm. During this period, the traffic in the GSM network is usually high; hence the increase in radiation in the measurement vicinity.

Electromagnetic Radiation Levels from Mobile Phone Handsets

The intensity of radiation from various mobile stations when establishing a call and during conversation was measured and observed to vary as shown in Figure 3. The high power(s) witnessed when dialing the GSM network is needed by the mobile station in reaching and picking a signal from the base transceiver station (BTS). The apparent drop in power during conversion is attributed to adaptive power control (APC) and discontinuous transmission (DTX). APC minimizes transmitter power of the handset and reduces multiple-access interference effect in order for the BTS to receive the usable signal. DTX turns off transmission during pauses within speech; so, the user is exposed to the radiation arising from the conversation a part of the time only. The said phenomenon is witnessed whenever a transmitting handset is placed next to a speaker; the cracking noise (adverse electromagnetic interference effects) in the speaker which decreases with time after connection acknowledgement.

From the obtained results, it is apparent that mobile phone users who take long before "answering" a call are likely to be exposed to higher radiation levels. The accruing health effects may include heating and tingling of the exposed tissues especially the ear and thighs, headache and psychological disorders as reported by Barnes (1999) and Krewski et al. (2007).

A comparative study of average intensities among different activated mobile phones, during conversation, is presented in Figure 4. The mean intensity from each of the handsets under study had the BGR subtracted and was shown to vary with handset model. The highest and least radiating

handset was, respectively, Nokia Series (China) N95 (0.467 mWcm-2, 104% of ICNIRP reference level) and Nokia 1110 (0.0113 mWcm-2, 25% of ICNIRP reference level). The intensities of all the tested handsets, except N95, were below ICNIRP's recommended limit; however, the limit of N95 is within FCC reference level.

In this work, the intensity of radiation from N1100 was 0.1537 mWcm-2; which is comparably smaller than 0.45 mWcm-2 reported by Usikalu and Akinyemi (2007). Such variation would be a consequence of change of the manufacturing technologies and different RF detection capabilities of measuring equipment used in these studies.

In determining the intensity of sampled handsets, the base signal strength was constantly monitored. The signal strength within the measurement room was always determined to be stable. However, according to Stewart (2000), if the measurement is carried out in poor network environment, the power density would increase since a lot of power would be required in order to hook-up the mobile station with the BTS. Furthermore, Usikalu and Akinyemi (2007) have shown that if calls are made while charging the batteries of mobile phones, extremely low frequency radiation would also enhance the measured radiation. Some properties such as Bluetooth services could also increase RF emissions (Damir et al., 2004). In this regard therefore, the use of N95 under such conditions would possibly be unsafe.

Effectiveness of Anti-Radiation Filters

The use of anti-radiation filters in suppressing RFR from different selected mobile phone models was investigated. In Figure 5, it has clearly been demonstrated that the use of anti-radiation filters led to a significant reduction of radiation levels. Radiation reduction efficiency is also shown to vary with the type of anti-radiation filter.

The results have explicitly shown that incident RFR is suppressed at different rates. Of the three filters used, "EM Wave Protection Sticker" from LG (Korea) was the most effective (44.8%); "Wave Scrambler" (China) was 23.2% and "Safe Guard" (Japan) was 34.8% effective. All manufacturers of such products guarantee consumers 99% radiation reduction efficiency. However, it is evidently clear that none of them meets this claim.

Based upon the obtained results, the variation in efficiency can clearly be attributed to the quality and material composition of the anti-radiation filter. The "Wave Scrambler" is made of special ceramics and copper, "Safe Guard" is made of fine strands of polyester coated with copper, nickel and carbon whereas "EM Wave Protection Sticker" is made of epoxy resin and lead. These materials have different thermal conductivities and dielectric constants as reported by Yoshihiro and Takahashi (2008), who have also shown that the type, amount and size of metamaterials determine the effectiveness of such devices in suppressing mobile-phone radiation. In the present study, the effect of surface area of these anti-radiation filters on radiation reduction efficiencies is observed. Of the three filters, the surface area of "EM Wave Protection Sticker" was the largest. This implies that the EM waves were exposed over a large area, and thus neutralization and EMR shielding effectiveness was high.

Effect of Handset's Physical Condition on Mobile Phone Radiation

Unlike RF radiation from base stations, radiation from mobile phones is non-directional; that is it spreads over and around the user. Any opening, such as earpiece and battery cover, serves as exiting points for such a radiation. In this study, the effect of handset's physical condition on radiation exposure levels has been examined by considering the state or nature of its casing and naked-state. Respective mobile phone radiation levels around the earpiece region, normal radiation level (N), are compared with radiation levels around the battery compartment area: with and without the battery cover.

In Figure 6, the intensity of radiation around a battery compartment of transmitting (battery) uncovered handset was observed to be comparably higher than a transmitting battery-covered handset. The battery cover served as an attenuating medium; therefore in its absence, the air acted as an attenuator. The radiation levels for TV22i, S350 and i9+ were lower than their respective normal radiation levels (Ns); only Blackberry 7290, Smadl A30 and Nokia 1202 had slightly higher intensities than their respective Ns. The battery covers of S350, TV22i and i9+ were metallic but the casing of Blackberry 7290, Nokia 1202 and Smadl A30 were plastic in nature; This accounts for their difference in attenuating capabilities with metals attenuating more than plastic casing.

Possible Implications.

This study has demonstrated that the use of an activated mobile phone with uncovered battery compartment would increase the user's exposure to RF radiation. Though none of tested phones emitted radiation levels above recommended limits, the battery-covered handsets are much safer to use. It thus means that although the mobile phone can operate normally even in the absence of the battery-cover or even the rear body-cover, its effect on the emitted radiation cannot be ruled out. The loss of either part of the mobile phone, irrespective of its working condition, should therefore be replaced.

Assessment of Mobile Phones Compliance to IMEI Standards

The international mobile equipment identifiers (IMEIs) of the tested mobile phones were checked based on two methods: reading the IMEI on the compliance plate (white paper in the battery compartment) and IMEI displayed by the handset's software (by dialing *#06#). Both methods ought to give the same IMEI per mobile phone under-study. Each IMEI was then analyzed on two accounts: Luhn Check-digit computation and International Number Plans (INP) scheme. The full spectrum of the IMEI results is presented in Table 2.

From the obtained results, the mobile phones whose IMEIs on the screen coincided with the code on the compliance plate include: Nokia 2626, 1100, 1661 and 6300, Tecno T780, Samsung- GT-E1080T, J-Max Double-life and Blackberry 7290. Of all these IMEIs, only Blackberry 7290, Tecno T780, Nokia 2626 and 1661 perfectly matched with type allocation holder (manufacturer) as well as mobile equipment type in the INP database.

The mobile phones whose type allocation holder(s) and equipment type(s) were not available in the INP database include: Nokia 1100, Nokia 6300, Smadl A56, Samsung GT-E1080T, iTel IT510, Long Ke S350, Nokia 102, Tecno T570, N95, iPhone i9+ and TOP-1 006. Mobile phones whose IMEIs were accredited to different manufacturers and model types were Smadl A30 (Hitachi, HTG-989), J-Max Double-life (Siemens, S40), Nokia 1200 (Kejian, K7100; Nokia, N1600), Simba FV100 (Amoi, M350) and Zetel N85y (TCL Mobile, E757).

Some phones such as Nokia 1200 and 1202, iTel IT510 and Long Ke S350 displayed only one IMEI on the screen but a different code on the compliance plate.

The IMEI displayed on the screen of IT510 was invalid; it would not be identified with any Reporting Body Identifier nor did it comply with Luhn Check-digit computation and specific information regarding this phone was missing in INP database. Mobile phones with more than one IMEI codes displayed on the screen include: G-Tide G19, Zetel N85y, TOP1-006, iPhone i9+, Nokia Series N95, Simba FV100 and Tecno T570. One of these IMEIs coincided with the one on the compliance plate of the corresponding and respective mobile phone. One IMEI of FV100 and T570 was 000000000000000, an IMEI allocated only to test mobile phones.

Table 1

Levels of Occupational and General-public Exposure (Barnes1999)

Standard	Intensity at 900 MHz ($mWcm^{-2}$)		Intensity at 1800 MHz ($mWcm^{-2}$)	
	Occupational	General Public	Occupational	General Public
ICNIRP	2.418	0.451	4.297	0.902
NCRP/FCC	3.0	0.6	5.0	1.0
1992 ANSI/IEEE	3.0	0.6	6.0	1.2

Table 2

IMEI Results and Analysis

Mobile equipment (ME)	IMEI		Origin	IME evaluation (INP)	
	Code displayed on screen (*#06*)	**Code read on the compliance plate**		**Type allocation holder**	**Mobile Equipment Type**
Nokia 2626	353942017756715	353942017756715	Hungary	NOKIA	NOKIA 2626
Blackberry 7290	357779000735454	357779000735454	Canada	Blackberry	Blackberry 7290
Tecno T780	354609020997706	354609020997706	China	TECNO	TECNO T780
Nokia 1661	355205031721638	355205031721638	India	NOKIA	NOKIA 1661/1662
Nokia 1100	357264013079151	357264013079151	Hungary	-	-
Nokia 6300	352943015160042	352943015160042	Hungary	-	-
Samsung GT-E1080T	357064038877945	357064038877945	Philippines	-	-
Smadl A56	354726030217642	354726030217642	China	-	-
J-Max Double Life	350077215552989	350077215552989	China	Siemens	Siemens S40
Smadl A30	353304000128305	353304000128305	China	Hitachi	Hitachi HTG-989
Nokia 1200	**350622020218092**	353265016021331	Hungary	**Kejian**; Nokia	**Kejian K7100**; Nokia 1600
iTEL IT510	135790246811220	353261030056783	China	-	-
Long Ke S350	354756500713920	354756500713919	China	-	-
Nokia 1202	357622024778177	355005360081046	Hungary	-	-
Tecno T570	357170023202005	357170023202005	China	-	-
	000000000000000			-	Test phone
Simba FV100	356688000028730	356688000028730	China	Amoi	Amoi M350
	000000000000000			-	Test phone
Nokia Series N95	357087084598438	357087084598438	China	-	-
	357087084598446			-	-
	357087083837787			-	-
iPhone i9+	354236021053491	355200903192324	China	-	-
	356893066053491			-	-
TOP-1 006	357357030179017	357357030179017	China	-	-
	357357030279015			-	-
Zetel N85y	352154000546902	352154000546902	China	TCL Mobile	TCL GA16 / TCL E757
	352154001546901			TCL Mobile	TCL GA16 / TCL E757
G-Tide (G19)	359005034010385	359005034010385	China	G-Tide	G-Tide M8 / G19 / G28

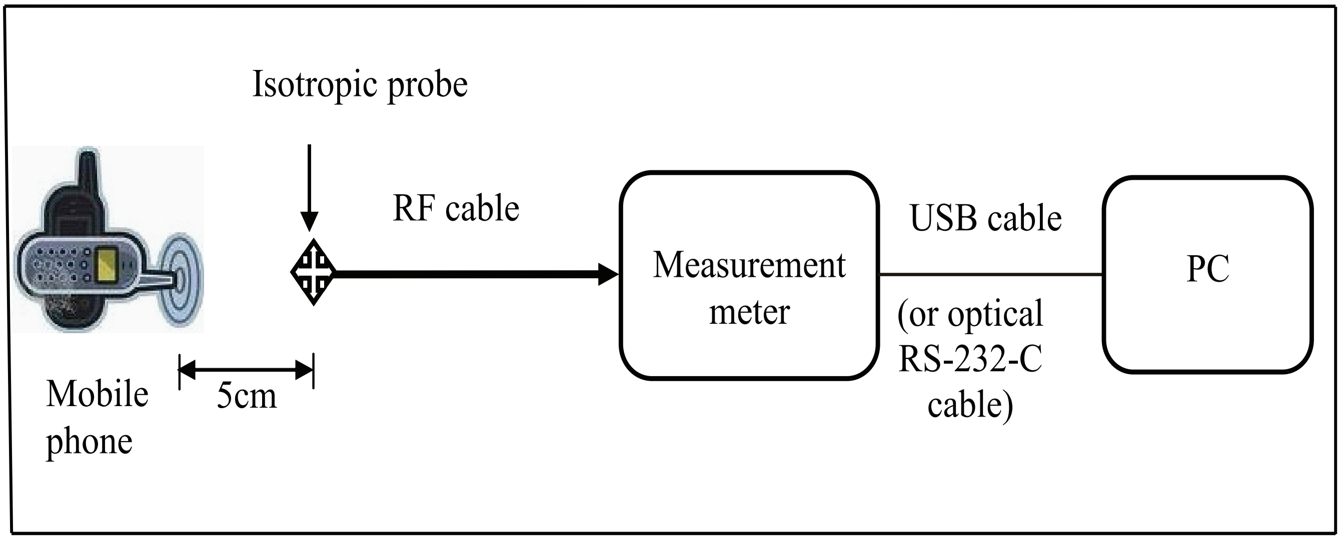

Figure 1

Experimental Set-up for Mobile Phone RF Radiation Measurement

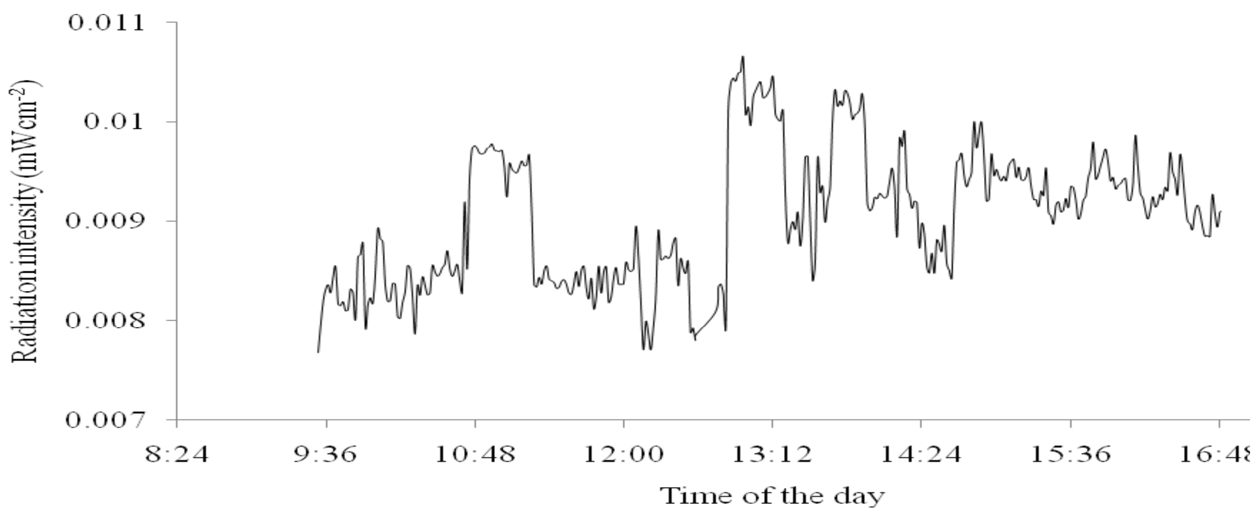

Figure 2

Variation of Average Background Radiation with Time

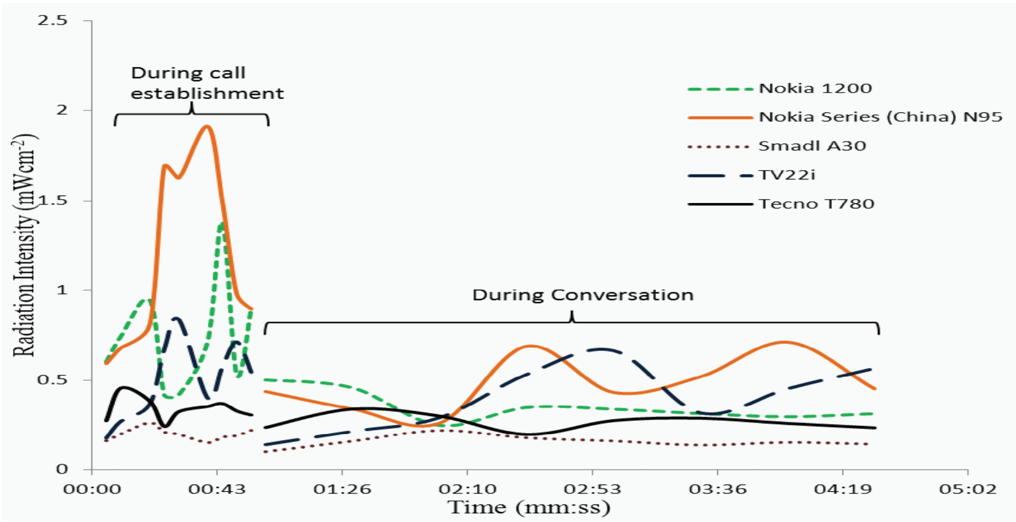

Figure 3

Variation of Radiation Intensity with Time-During Call Establishment and Conversation

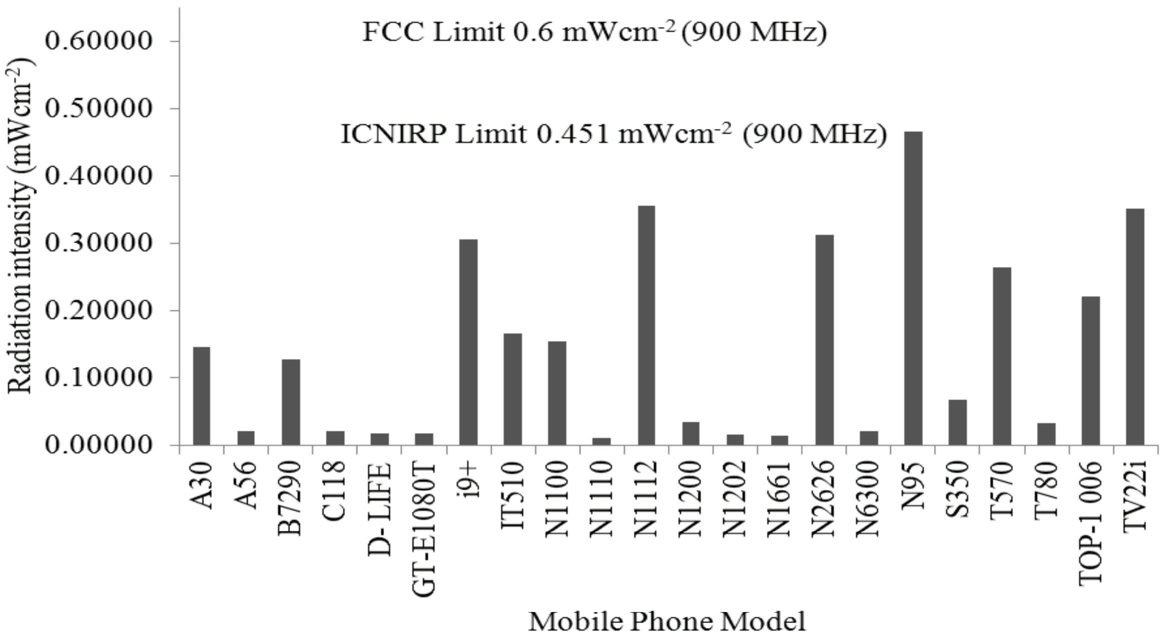

Figure 4

Intensity of Radiation Measured at the Ear-piece Among Different Handset Models During the Conversation Mode

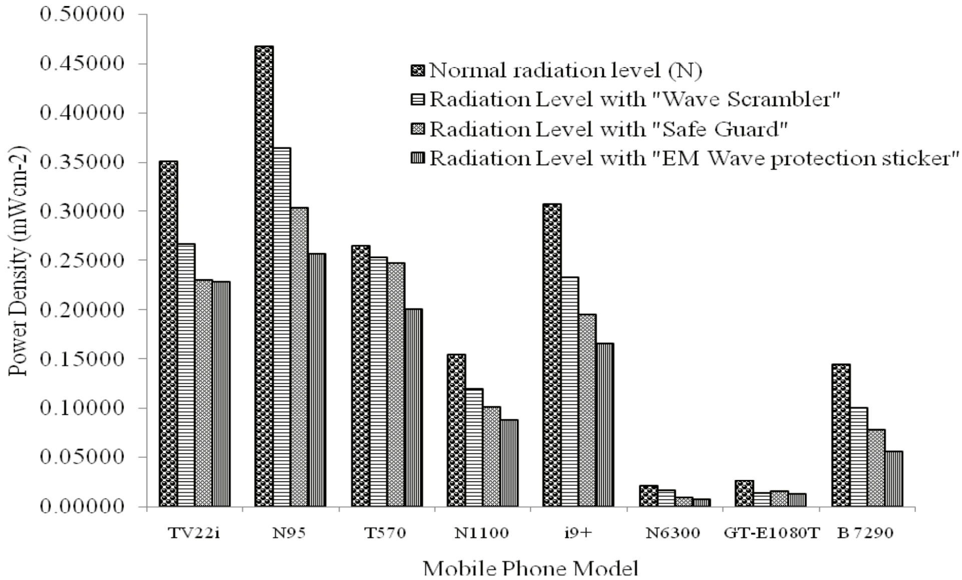

Figure 5

Radiation Levels from Different Activated Handset Models with Anti-radiation Filters

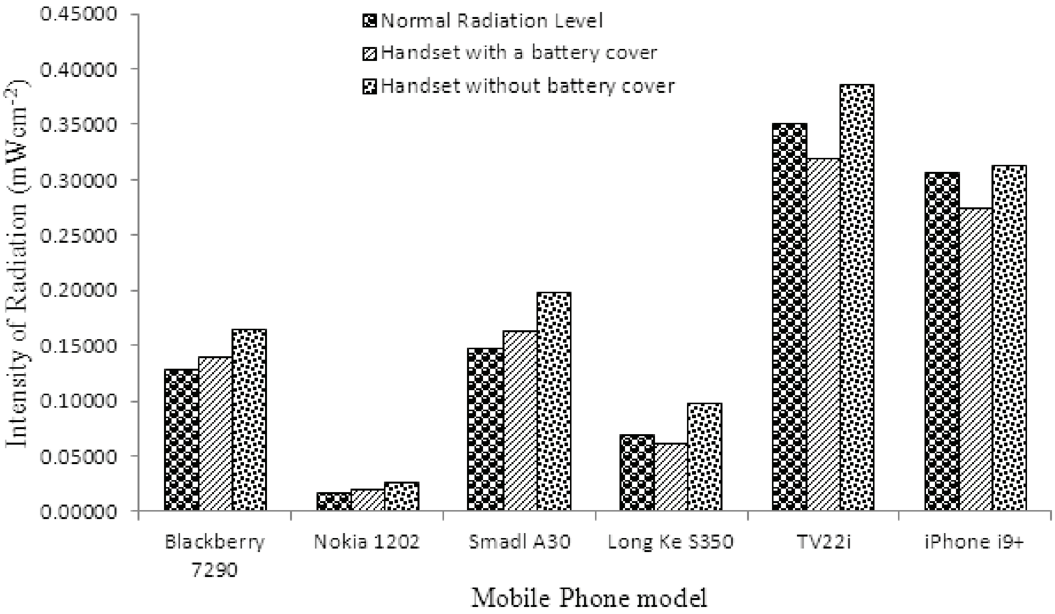

Figure 6

Radiation Levels from Selected Handset Models With/Without Battery Cover

Conclusion

Electromagnetic radiation levels varied with mobile phone models. The radiation levels ranged from 0.113 to 0.467 mWcm-2 with the highest radiating mobile phone being Nokia Series (China) N95 while the least was Nokia 1110. All the radiation levels of the 22 handsets were within the safe exposure limits.

The radiation intensities from a transmitting handset are high while dialing the network. Such radiation levels have been found to vary with handset model and decrease during conversation.

The use of anti-radiation filters in abating RF radiation has been found effective. Amongst the three anti-radiation filters used, "EM Wave Protection Sticker" from LG (Korea) was the most effective (44.4%). The efficiencies of "Sage guard" and "Wave Scrambler" were 34.8% and 23.2% respectively. However, none of the filters was 99% effective as asserted by respective manufacturers.

Radiation levels from a handset were affected by its physical condition. Radiation intensity accruing from the use of a naked handset, for instance, was found to be higher than the normal radiation level as well as the intensity from a cased handset. Handset with metallic casing such as TV22i was found to attenuate much radiation than plastic-cased handsets such as Nokia 1202.

Most of the branded handsets under test were not compliant to the IMEI standards. Only, Blackberry 7290, Tecno T780, Nokia 2626 and 1661were adhered to such regulations. This constitutes of 20% of the assessed mobile phones.

References

Anita, G. G. (2005). Genetic damage in mobile phone users: Some preliminary findings. *Indian Journal of Medical Genetics* , *11*(2), 99-103.

ATMR. (2009). *Africa Telecom Market Report*: 2008-2009. Dublin,Ireland:Research and Markets Ltd..

AWC. (2010). *African Wireless Communications Yearbook*.. Kadium Publishing (Pty) Ltd. 41.

Barnes, H. J. (1999). Cell Phones: Are they Safe? *American Society of Safety Engineers*, December Edition, 21.

CCK. (2010). *Quaterly Sector Statistics Report*: 2nd Quarter, Oct-Dec 2009/2010. Communications Commission of Kenya, Nairobi.

Damir, K., KreSimir, M., & Tomislav, M. (2004). Measurement of mobile phone radiations in respect to human exposure standards. 46th *International Symposium on Electronics in Marine, ELMAR-PW4* (pp. 515-519). Zadar, Croatia: IEEE Xplore.

Frey, A. (1998). Headaches from cellular telephones: Are they real and what are the implications? *Environmental Health Perspectiv*e , *106*, 101-103.

Hyland, G. J. (2000). Physics and biology of mobile telephony. *Lancet* , *356*, 1833-1836.

ICNIRP. (1998). Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz). *Health Physics Society*, *74*(4), 494-522.

ITU. (2009). *ITU Report for 2009: Kenya poised for huge growth in mobile services.* International Telecommunications Union.

KIA. (2000).Information and communication technology. *Monthly Review (January Edition)*. Nairobi, Kenya: Kenya Investment Authority Ltd.

Krewski, D., Barry, W. G., Riadh, W. Y., Brian, H., Lotz, W. G., & Rosemonde, M. (2007). Recent advances in research on radiofrequency fields and health: 2001-2003. *Journal of Toxicology and Environmental*

Health , 10, 287–318.
Maneesh, M., Anil, P. K., Jayalekshmi, H., Bhargav, K., & Rohith, V. (2009). Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. *ClinicalScience*, *64*(6), 561-565.
RPB. (2008). *Export/Import control procedures.* Nairobi, Kenya: Radiation Protection Board of Kenya.
Sandström, M., Mild, K. H., Wilén, J., & Oftedal, G. (1998). Symptoms associated with mobile phone use: Results of the Swedish-Norwegian Survey. *Occupational Medicine* , *48*, 357-360.
Stewart. (2000). *Mobile phones and health* Independent Export Group on Mobile Phones Londonl
Usikalu, M., & Akanyemi, M. (2007).Monitoring of radiof requency radiation from selected mobile phones. *Journal of Applied Sciences Research, 3*(12), 1701-1704
WHO. (2000). Electromagnetic fields and public health:mobile telephones and their base stations. *Fact Sheet No. 193* . Geneva, Swizerland: World Health Organization..
Yoshihiro, S., & Takahashi, S. (2008). Material design of functionally graded plates with the function of electromagnetic noise suppression (Quantitative evaluation of the effect of electromagnetic noise suppression). *Journal of Solid Mechanics and Material Engineering*, *2*(7), 912-920.

BIOCONTROL POTENTIAL OF SELECTED PLANT ESSENTIAL OIL CONSTITUENTS AS FUMIGANTS OF INSECT PESTS ATTACKING STORED FOOD COMMODITIES.

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Abstract

Laboratory space fumigation studies were conducted to evaluate the fumigant toxicity of selected essential oil terpenoids against adult *Sitophilus oryzae* L., *Rhyzopertha dominica* F., *Tribolium castaneum* (Herbst), *Oryzaephilus surinamensis* L. and *Callosobruchus chinensis* F. Five essential oil constituents, alpha humulene, caryophyllene oxide, myrcene, R-(+)-alpha pinene and R-(+)-beta pinene were each evaluated at four rates (0, 1, 5 and 10 µl/L air) in space fumigation chambers with four replicates per concentration. Results showed strong dose-, insect species- and time-dependent fumigant toxicity in which caryophyllene oxide, myrcene, α- humulene, R- (+)-α- pinene and R- (+)-β- pinene caused 18- 100, 49- 100, 55- 100, 47- 100 and 33- 100% kill of all test insects, except the most tolerant species, *T. castaneum*, at 10 µl/L air 168 h after treatment. Except *T. castaneum*, end-point LC50 values of 0.03- 8.5, 0.03- 7.0, 0.01- 4.82, 0.01- 8.20 and 0.03- 6.5 µl/L air were obtained for the five terpenoids, respectively. The varied toxicities could be explained by the compound structure-insecticidal activity relationships that influence their degree of penetration into the insect cuticle and neurotoxicity. These findings provide the scientific basis for using essential oils as fumigants against storage insects and hence, potential alternative fumigants in both subsistence and commercial agriculture. Further studies are recommended to evaluate the grain fumigation potency, biosafety and broad spectrum bioactivity of these essential constituents against insect pests of stored food commodities.

Key words: *Callosobruchus chinensis*, *Oryzaephilus surinamensis*, *Rhyzopertha dominica*, *Sitophilus oryzae*, *Tribolium castaneum*, Essential oil constituent, Fumigant toxicity.

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Introduction

Poor storage and post-harvest handling practices remain major challenges facing mankind today. The food situation is made worrisome in the tropics where insect pests cause up to av. 40% pre- and post-harvest food grain losses. Grain storage and post-harvest handling plays a key