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EMPIRICAL RELATION BETWEEN SPECIFIC ABSORPTION RATE AND DISTANCE FROM MOBILE PHONES

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ABSTRACT

Mobile phone usage continues to expand, and its applications keep evolving. However, recent research suggests possible radiofrequency health concerns associated with the long-term mobile phones use, making exposure reduction measures key to mitigating potential risks. The study investigated the empirical relationship between the head's Specific Absorption Rate (SAR) and the separation distance from regulatory-compliant and non-compliant mobile phones using a ComoSAR measuring system. The SAR of both phone categories was below the recommended limits. The regulatory-compliant phones' SAR values decreased regularly with increasing phone distance. However, SAR levels of the regulatory non-compliant phones were inconsistent, where instead of a reduction in SAR levels, an increase in phone distance resulted in an over 70% rise in SAR level, potentially creating localised hotspots and the possibility of localised tissue heating. An exponential decay and single-phase exponential functions were formulated to estimate the SAR of the regulatory non-compliant and regulatory-compliant phones, respectively. The study provided simplified mathematical relations which relate SAR to phone distance. Additionally, the results highlighted the need to tighten controls over the illegal sale of non-compliant phones and their usage by the unsuspecting public. The study outcome also provided the need to consider incorporating SAR-level trends in the regulatory testing regime for mobile phones.

Keywords: Specific absorption rate, regulatory-compliant phones, regulatory non-compliant phones, electromagnetic fields, radiofrequency radiation.

INTRODUCTION

Applications involving radiofrequency (RF) electromagnetic radiation are constantly emerging as well as evolving. One such evolving application is the widely used mobile phone (MP) for communication. It plays a critical role in the individual's daily life, from education, commerce, health, emergency as well as security, just to mention a few. However, concerns about potential health implications associated with RF radiation keep growing.

The outcomes of the study of long-term exposure by the United States Toxicology Program (NTP, 2018a; NTP, 2018b; NTP; 2018c) and the Ramzzini Institute of Italy (Falcioni *et al*., 2018), where they exposed rats and mice to RF fields over their entire life span until natural death, suggest RF fields demonstrated carcinogenicity in the male rats only. The exposure guideline of the International Commission on Non-Ionizing Radiation (ICNIRP, 2020) pointed out some limitations with these studies, including a lack of blinding, challenges with interpreting statistical analysis, and the absence of provision for chance.

Beard *et al*. (2006) reported that near-field SAR simulation is influenced by the distribution of RF current density on the source, the spatial separation between the mobile phone and the head, and the geometry of the source. A small change in the separation distance can alter the SAR significantly. Some precautions recommended to reduce RF field exposure to the user include reducing call time as well as keeping a separation between the head and the mobile phone when in use.

Public and worker health concerns about exposure to RF radiation continue to grow (Osei *et al*., 2022; Deatanyah *et al*., 2020; Azah *et al*., 2018). To provide further baseline data concerning mobile phone-related RF emissions in Africa, this research investigated the nature of the relationship between separation distance and the Specific Absorption Rate (SAR) resulting from radiofrequency radiation exposure to the phone user, adding to scarce data from developing countries, and providing critical data on the potential adverse effects related to increased use of unregulated MP devices.

Derived Theoretical Function of Sar and Distance

The definition of SAR (Wkg^{-1}) can be written as in Equation 1 (ICNIRP, 2020), where E (Vm^{-1}) refers to the root-mean-square electric field strength within biological tissue of density ρ (kgm^{-3}) and conductivity σ (Sm^{-1}).

$$SAR = \frac{\sigma |E|^2}{\rho} \quad (1)$$

According to Coulomb's law (Equation 2), the electric force F is determined by the interaction between a charge Q and a test charge q, separated by a distance r - representing the gap between the phone and the phantom head (Giancoli, 2009). Here, ε denotes the permittivity of the medium, which characterizes its electric properties. The same force is related to the electric field strength by Equation 3 (Giancoli, 2009), which is the Lorentz force when the velocity of the charge is zero. The charge Q is related to the current I and time t by Equation 4. Putting the four equations together produce Equation 5 which shows an inverse power relation between SAR and separation distance, r.

$$F = \frac{1}{4\pi\varepsilon}\frac{Qq}{r^2} \quad (2)$$

$$E = \frac{F}{q} \quad (3)$$

$$Q = It \quad (4)$$

$$SAR = \frac{1}{16\pi^2\varepsilon^2\rho}\frac{I^2t^2}{r^4} \quad 5$$

MATERIALS AND METHODS (METHODOLOGY)

Materials

A fully integrated ComoSAR twin bench system (Figure 1), manufactured in France by the Microwave Vision Group and compliant with IEC/IEEE 62209-1528, FCC OET Bulletin 65 (Ed. 97-01) Supplement C, EN 50361:2001, and EN 50383 standards, was used to measure SAR. The video positioning system (VPS) and the 3-dimensional specific anthropomorphic mannequin (SAM) head phantom of the bench are also shown in Figure 1. The bench and its components are placed in a Faraday cage but integrated with a controlling central computer system installed with the OpenSAR software as indicated in Figure 2. The Faraday cage is an electromagnetic shielded room which prevents interference from ambient sources and prevents multipath effects from the set-up.

The research employed the SSE5 and SSE2 probes which had 5mm and 2 mm tip diameter and a dynamic range of 0.01-100 W/kg. They have spherical isotropy and linearity are greater than 0.25 dB and axial isotropy greater than 0,50 dB.

The probes are made up of loops linked to special Schottky diodes with low detection thresholds, or orthogonal dipoles. They are available with a frequency range of 30 MHz to 6 GHz. Because the probes are made with materials of high permittivity, it minimizes disturbance of associated of electric fields. The research utilized mobile phones drawn from two categories of phones used in Ghana. The first category has phones that have gone through regulatory requirements and tested for public use by the regulator, the National Communications Authority (NCA), which are referred to in the work as regulatory-compliant phones. NCA keeps an updated register of these regulatory-compliant phones (NCA, 2010). The second group consisted of phones that were not compliant with regulations; these mobile devices were sold illegally as they had not undergone the required regulatory approval procedures and not listed in the NCA register. Two phones from each category were used in the research. All phones used in the study were had a brick structure. The tests were done with the GSM technology in the 1800 MHz band and a constant phone power of 2 W, and 25 min measurement time-period were maintained.

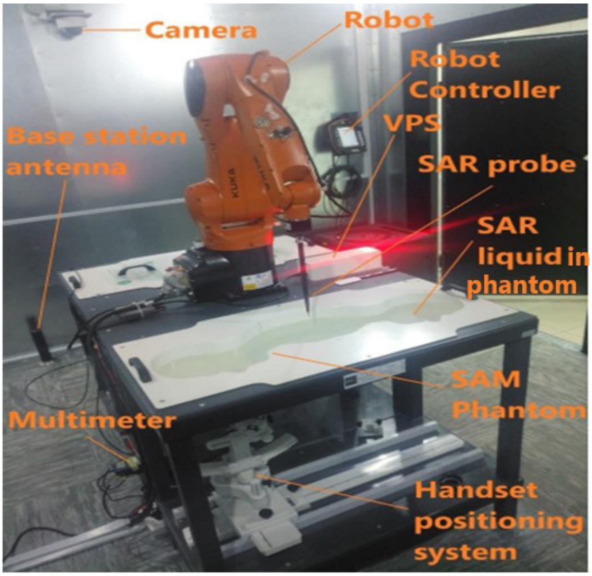

Figure 1: Labelled picture of ComoSAR Bench (Courtesy National Communications Authority)

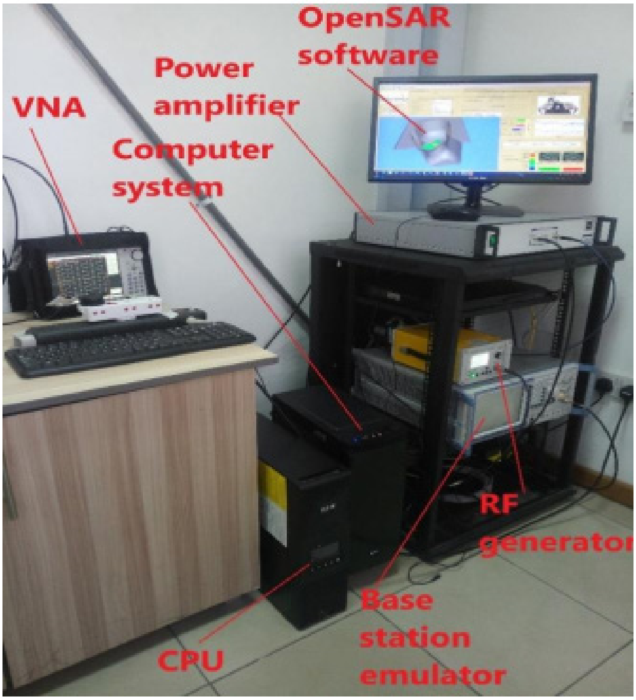

Figure 2: OpenSAR Central Controlling Computer System (Courtesy National Communications Authority)

Method

Following IEC 62209 (2020) recommendations, the two tests, comprising the liquid dielectric property test (within ±10% or ±5% of the standard) of the tissue equivalent liquid (1800 MHz) used in the phantom and dipole system evaluation test, were done as pre-requisites to the SAR measurements. The depth of the tissue equivalent liquid within the SAM phantom was 15 mm.

A controlled temperature range of 18-25°C was maintained during SAR testing. Measurements were made at 1800 MHz, using the global system for communication (GSM) technology, with a fixed 2W phone power, and within a time interval of 25 minutes. Tilt and Cheek measurement positions are demonstrated in Figure 3. Four separation distances of 0 cm to 3 cm (in 1 cm increments) between the mobile phones and the phantom head were assessed. Both 1 g SAR and 10 g SAR were measured. Measurements were repeated twice for each of the phones and for each 12 measurement reference positions.

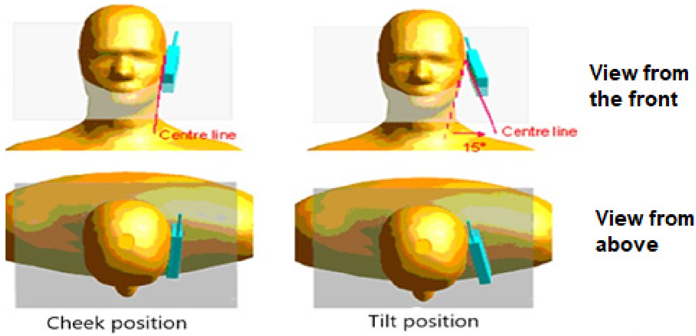

Figure 3: Typical Phone Orientation showing typical Tilt and Cheek Phone Positions (Courtesy of National Communications Authority)

Data Processing

The 12 measurement reference positions of the phone on the phantom and applicable frequency channels are coded as LCH, LCL, LCM, LTH, LTL, LTM, RCH, RCL, RCM, RTH, RTL, and RTM. The first letter of the three-letter code indicates the side of the thead that the phone is placed - left (L) or right (R) ear. The second letter shows the inclination of the phone, whether cheek (C) or tilt (T). The last letter indicates the frequency channel – high (H), middle (M) or low (L). The low channel (Channel 512) had a frequency of 1710 MHz, the middle channel (Channel 698) had a frequency of 1747 MHz, and the high channel (Channel 884) had a frequency of 1784 MHz. The 1 g SAR (SAR_{1g}) and 10 g SAR (SAR_{10g}) are average local head SAR defined as the power absorbed over 1g or 10g of cubic volume, respectively, capped at 1.6 W/kg and 2.0 W/kg (ICNIRP, 2020).

Measurement Uncertainty

The OpenSAR software evaluates and reports uncertainty for both the SAR1g and SAR10g. For the SAR1g and SAR10g, combined standard uncertainties of 20.32% and 20.06%, respectively, were obtained from predefined measurement system parameters, test sample-related parameters, dipole parameters, phantom and tissue equivalent liquid parameters and applied to all measured SAR levels. Table 1 demonstrates the evaluation.

Table 1: Uncertainty Budget of the SAR Measurements

Uncertainty Component	Tol (±%)	Prob. Dist.	Div.	Ci (1g)	Ci (10g)	1g Ui (±%)	10g Ui (±%)	Vi
a	c	d	e= f(d,k)	f	g	h= c*f/e	i= c*g/e	k
Measurement System								
Probe Calibration	5.8	N	1	1	1	5.80	5.80	∞
Axial Isotropy	3.5	R	√3	1	1	2.02	2.02	∞
Hemispherical Isotropy	5.9	R	√3	0	0	0.0	0.0	∞
Boundary Effect	1.0	R	√3	1	1	0.58	0.58	∞
Linearity	4.7	R	√3	1	1	2.71	2.71	∞
System Detection Limits	1.0	R	√3	1	1	0.58	0.58	∞
Modulation response	0.00	N	√3	0	0	0.00	0.00	∞
Readout Electronics	0.50	N	1	1	1	0.50	0.50	∞
Response Time	0.0	R	√3	0	0	0.00	0.00	∞
Integration Time	1.4	R	√3	0	0	0.0	0.0	∞
RF Ambient Conditions - Noise	3.0	R	√3	1	1	1.73	1.73	∞
RF Ambient Conditions - Reflections	3.0	R	√3	1	1	1.73	1.73	∞
Probe Positioner Mechanical Tolerance	1.4	R	√3	1	1	0.81	0.81	∞
Probe Positioning with respect to Phantom Shell	1.40	R	√3	1	1	0.81	0.81	∞
Extrapolation, interpolation and integration Algorithms for Max. SAR Evaluation	2.3	R	√3	1	1	1.33	1.33	∞
Dipole								
Deviation of experimental source from numerical source	5.00	N	1	1	1	5.00	5.00	∞
Input Power and SAR drift measurement	0.50	R	√3	1	1	0.29	0.29	∞
Dipole Axis to Liquid Distance	2.00	R	√3	1	1	1.15	1.15	∞
Phantom and Tissue Parameters								
Phantom Shell Uncertainty - Shape, Thickness and Permittivity	4.00	R	√3	1	1	2.31	2.31	∞
Uncertainty in SAR correction for deviation in permittivity and conductivity	2.00	N	1	1	0.84	2.00	1.68	∞
Liquid Conductivity - Temperature Uncertainty	2.50	R	√3	0.78	0.71	1.13	1.02	∞
Liquid Conductivity Measurement	4.00	N	1	0.78	0.71	3.12	2.84	5
Liquid Permittivity - Temperature Uncertainty	2.50	R	√3	0.23	0.26	0.33	0.38	∞
Liquid Permittivity Measurement	5.00	N	1	0.23	0.26	1.15	1.30	5
Combined Standard Uncertainty		RSS				10.16	10.03	

Expanded Uncertainty (95% Confidence interval)	k	20.32	20.06

RESULTS AND DISCUSSIONS

Sar Levels at Different Phone Distances

A detailed examination of the average 10 g and 1 g SAR levels for regulatory-compliant phones across reference positions reveals consistent trends at distances of 1.0 cm, 2.0 cm, and 3.0 cm. Specifically, SAR levels are generally higher on the right ear compared to the left, as illustrated in Figures 4 and 5. Generally, for the regulatory-compliant phones, SAR levels of 0.0 cm at all positions are the highest (except RCL position for the SAR_{10g}) and decrease in the order of 1.0 cm, 2.0 cm and 3.0 cm. This observation aligns with Equation 5 and the findings of Musiige *et al*. (2012), Beard *et al*. (2006), and Sole *et al*. (2013), all of which report that head SAR decreases exponentially with increasing distance. However, as shown in Figures 6 and 7, the SAR levels of the regulatory non-compliant phones exhibited an irregular pattern, with SAR increasing with distance in several cases. There are very few similarities between the SAR trends of different distances. The irregular results of the regulatory non-compliant phones make their SAR difficult to predict.

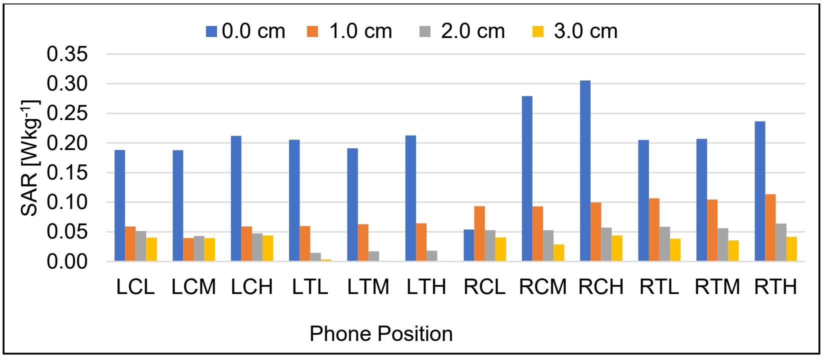

Figure 4: Levels of regulatory-compliant phones average SAR_{10g} at distances

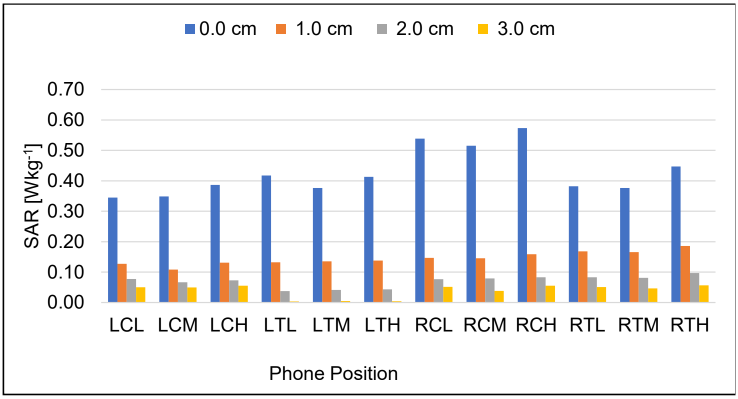

Figure 5: Levels of regulatory-compliant phones average SAR_{1g} at distances

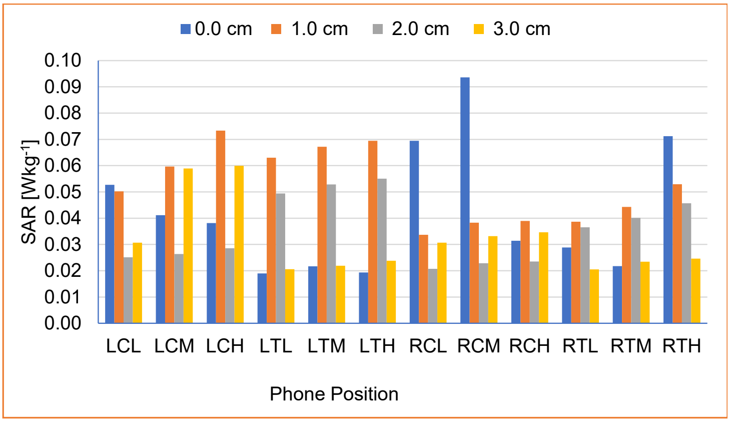

Figure 6: Levels of regulatory non-compliant phones average SAR_{10g} at distances

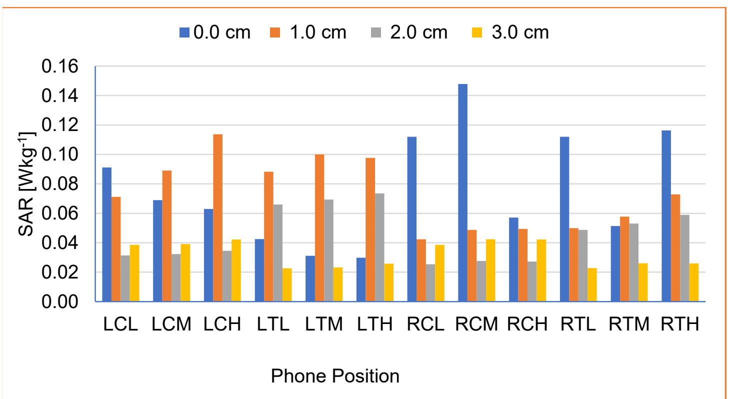

Figure 7: Levels of regulatory non-compliant phones average SAR_{1g} at distances

Altering the distance between the phone and the phantom head leads to a change in SAR levels, as described by Equation 5. The behaviour of SAR level changes is described in Figures 8 and 9 for the regulatory-compliant and regulatory non-compliant phones respectively. Table 2 gives the value of the SAR change. Unlike the regulatory non-compliant handsets, there was a regular reduction in SAR of the regulatory-compliant phones in almost all cases when the phone distance from the phantom head was increased. Two exceptions were observed: the right-cheek low-frequency (RCL) position during the transition from 0.0 cm to 1.0 cm, and the left-cheek middle-frequency (LCM) position when the distance increased from 1.0 cm to 2.0 cm, as illustrated in Figure 8.

A detailed analysis of the magnitude of SAR reduction with increasing distance from the phantom head highlights a clear divergence in the performance of the GSM phones. Unlike the regulatory-compliant phones, the regulatory non-compliant phones exhibit highly inconsistent SAR reductions, as illustrated in Figure 9 and Table 2, with SAR levels sometimes increasing instead of decreasing as the phone-to-head distance grows. An increase in SAR levels was consistently observed across all cheek positions on both ears.

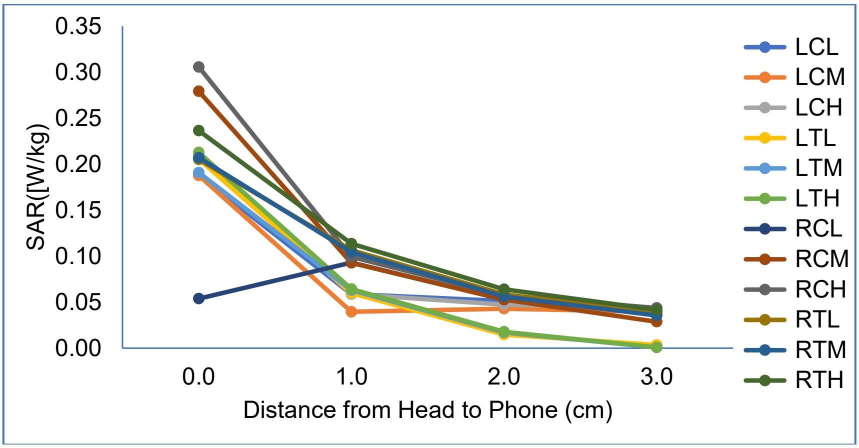

Figure 8: Reduction trend of regulatory-compliant phones' average SAR_{10g}

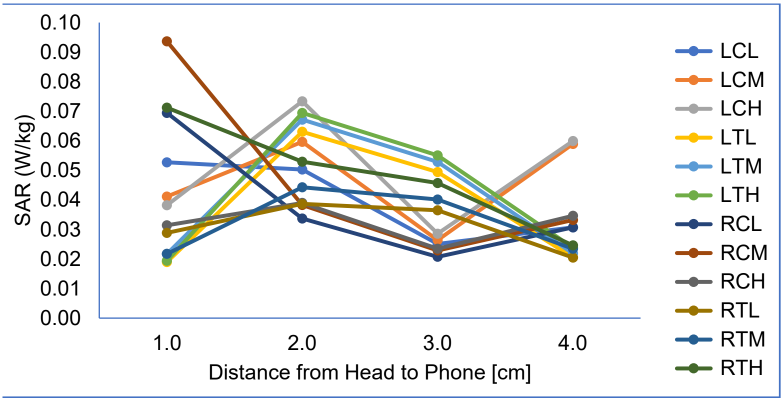

Figure 9: Reduction trend of regulatory non-compliant phones' average SAR_{10g}

Table 2: Average Percentage Reduction of SAR with Distance

Phone	Average SAR reduction from 0.0 to 1.0 cm	Averaged SAR reduction from 1.0 to 2.0 cm	Average SAR reduction from 2.0 to 3.0 cm
Regulatory-compliant Phones' average SAR_{10g}	53 % reduction	42 % reduction	42 % reduction
Regulatory non-compliant Phones' average SAR_{10g}	71 % increase	31 % reduction	8 % increase
Regulatory-compliant Phones' average SAR_{1g}	65 % reduction	52 % reduction	49 % reduction
Regulatory non-compliant Phones' average SAR_{1g}	35 % increase	36 % reduction	11 % reduction

The irregular increases in SAR observed in the regulatory non-compliant phones with greater separation distances are inconsistent with the findings of Krstić et al. (2011), Musiige et al. (2012), and Morega et al. (2010), where SAR consistently decreased with each increase in distance. Krstić et al. They all employed numerical methods or actual measurements to determine the SAR of model human heads from mobile phones. Stimulations in this respect have shown to be very accurate (Musiige et al.). Krstić et al. relied on the finite integration technique (FIT) as the numerical approach to compute induced SAR for two mobile phones with different types of antennas in the 900 MHz transmission band over the phone distance from 0 to 16 cm from the ear. The SAR levels of the phone with a quarter wavelength monopole antenna increased with the range of about 2 to 5 cm. This may appear to have some similarity with the SAR levels of the regulatory non-compliant phones but less rampant erratic behaviour.

The phone with a planer inverted-F antenna (PIFA) had its SAR levels decreasing consistently with distance. Using a numerical approach, Mussige et al. employed finite-difference time-domain (FDTD) to compute 10g SAR at five distances from 5 to 25 mm.

The SAR values increased consistently with distance, agreeing with the results from the regulatory-compliant phones. In Morega et al., the authors presented both the SAR measurement method and a numerical approach. They used the ComoSAR system, and the OpenSAR software, and followed the IEC 62209 and IEEE 1528 protocols for the SAR measurement, just like in the case of this study. They used the finite element method for the numerical approach. Both measured and computed SAR decreased consistently with distance over the range of 0 to 3 cm, agreeing with the results of the regulatory-compliant phones.

The irregular SAR reduction nature of the regulatory non-compliant phones may create potential high SAR levels hotspots that can lead to possible localised tissue heating and exposure risks. It can also result in potential effects on nearby devices due to the erratic electromagnetic fields. In addition, this behaviour makes accurate prediction of its SAR values a challenge, hence undermining safety. Power management issues, design flaws and challenges in the positioning of the phone antenna may contribute to irregular results of the regulatory non-compliant phones.

Empirical Distance-SAR Predictive Model

Using the measured data, mathematical models were developed to estimate head SAR. An RStudio fitting curve for the plots of SAR levels and distance is given in Figures 10 and 11. The RStudio program compares and tests multiple regression models to derive the best fitting model. Hence, several candidate models were evaluated to determine the best functional form most appropriately describing the SAR-distance relationships of the compliant and non-compliant phones separately.

Although the SAR of the two categories of mobile phones exhibited a decaying trend with distance, the compliant phones demonstrated a more consistent and smoother decline as evident in Figures 10 and 11.

The equation established between head SAR and the phone-to-head distance, X followed a single-phase (one-phase) exponential decay model for the phones that met regulatory standards. However, the SAR levels of the non-compliant devices exhibited an exponential decay model. These patterns are represented by Equations 6 and 7, respectively.

$$SAR = (\beta - \tau)\, e^{-\alpha x} + \tau \qquad 6$$

$$SAR = \beta\, e^{-\alpha x} \qquad 7$$

In these equations, β denote the intercept, τ refers to the SAR plateau value, and α represent the decay rate constant. For the regulatory-compliant phones, the one-phase exponential model (Equation 6) yielded high average regression coefficients of 0.96 for the SAR_{10g}, but 0.99 for the SAR_{1g}. These values indicate that the exponential model (Equation 6) explains a large proportion of the variance in the SAR measurement for regulatory compliant phones, hence pointing to a strong predictable relationship. Conversely, application of the exponential decay model (Equation 7) to the non-compliant phones produced lower decay coefficients, with values of 0.72 for the SAR_{10g} and 0.85 for the SAR_{1g}. Hence, exhibiting a high variance and statistically inconsistent behaviour.

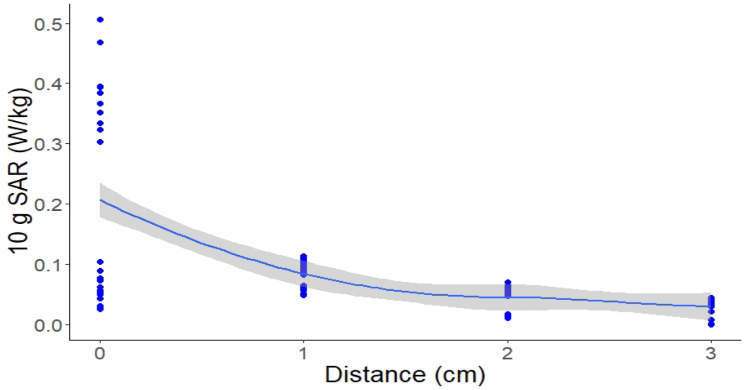

Figure 10: Regulatory-compliant Phones' SAR_{10g} and Distance Fitting Plot

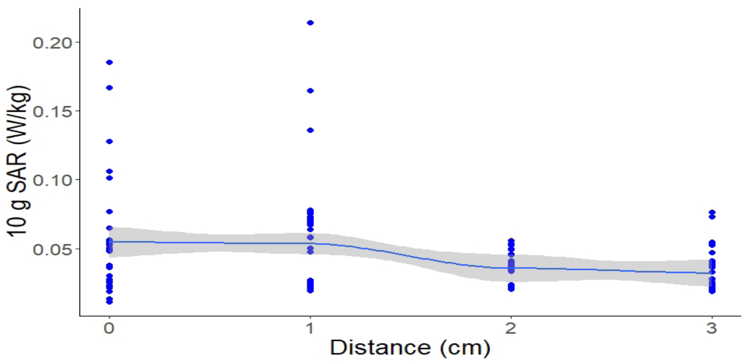

Figure 11: Regulatory non-compliant Phones' SAR_{10g} and Distance Fitting Plot

This study has presented simplified mathematical SAR predictive models. The derivation of different SAR predictive models for the two groups of phones demonstrates that they follow distinct patterns though both describe exponential SAR change processes.

The one-phase exponential model observed in the regulatory-compliant phones indicates the presence of a uniform influencing factor that is systematically governing the SAR levels.

The non-linear decaying predictive fitting model describing SAR levels with increasing phone distance aligns with the SAR trends reported by Sole *et al*. (2013), which were computed at various power levels over distances ranging from 10 to 100 cm. This is also consistent with the findings of Krstić *et al*. (2011) and Morega *et al*. (2010). Morega *et al*. established a non-linear relationship between SAR and distance. Meanwhile, Khalatbari *et al*. (2006) developed a predictive model showing that local SAR decreases inversely with a power function of the distance. The models reported in these studies showed a consistent reduction in SAR with increasing separation distance, aligning closely with the behaviour observed in the model developed for the regulatory-compliant phones.

Some technical factors may be part of the contributing factors underlining the irregular SAR levels behaviour of the regulatory non-compliant phones.

Antenna design, quality and position in the phone can strongly influence near-field radiation patterns (Das, 2010).

Poorly designed antennas may contribute to uneven field distributions and consequently lead to unstable coupling with tissues. Automatic Power Control (APC) algorithms in mobile phones regulate transmitted power in response to network conditions and ensure only sufficient power levels is transmitted (Das, 2010). Poorly designed phones may cause inefficient power management and lead to unstable transmission power levels, hence resulting in the irregular SAR levels observed with the non-compliant phones. Additionally, impedance mismatches in a poorly designed phone may also alter the efficiency with which RF energy is radiated and contribute to the irregular SAR-distance behaviour.

Unlike most previous SAR studies which looked at peak SAR at specific testing positions only, this research focused on analysing SAR as a function of phone separation distance under conditions consistent with IEC recommendations. By showing that the distance-dependent SAR behaviour varies significantly between the compliant and non-compliant phones, this study enhances the body of knowledge on RF exposure assessment. The study presents the stability of SAR-distance trends as a likely additional metric for regulatory screening by deriving simplified empirical models from measured data. The results of the research support the widening of the scope of RF exposure science from merely magnitude-based compliance testing towards behaviour-based assessment. Additionally, the research provides one of the first IEC-compliant SAR-distance dataset from Sub-Saharan Africa on phones used in developing countries where regulatory oversight may not be fully robust. By relating unusual exposure characteristics with regulatory non-compliance, the study extends the global SAR literature into a less characterized area, with direct consequences for end user protection and the international standardization of RF safety.

Furthermore, the study contributes a computationally efficient and simplified predictive models for approximating RF exposure from mobile phones unlike rigorous numerical methods such as Finite-Difference Time-Domian (FDTD), Finite Element Method (FEM), and Finite Integration Technique (FIT). The simplification enhances usability for exposure assessment, preliminary safety evaluations, and regulatory screening, especially in situations where complete numerical stimulations are impractical. Collectively, the findings of this study sort to reframe RF exposure assessment by demonstrating that the predictability of SAR level trends with distance may itself be an indicator of device safely.

Basically, this signifies a potential conceptual shift from static compliance evaluation towards a more dynamic exposure assessment, affecting dosimetry science, regulatory testing approaches, and public health references.

Though the findings of the study provide important insights into the SAR-distance relation, some limitation should be pointed out. The number of mobile phones examined was limited and may not completely represent the wide variability of phone designs available on the Ghanaian market. The study considered only a single operating frequency band and communication technology. Further studies involving a wider and larger number and of mobile phones, multiple frequency bands, and more communication technologies, like LTE and 5G which have different modulation and accessing schemes, will provide further clarifications on the influencing factors on the SAR-distance behaviour.

CONCLUSION

In this paper, the head SAR from regulatory-compliant and non-compliant phones were measured at distances from the mobile phones. The average measured head SAR levels decreased non-linearly with increasing separation over the distance of 0.0 - 3.0 cm. This aligns with the studies by Krstić *et al*. (2011), Sole *et al*. (2013), and Morega *et al*. (2010), who observed inverse exponential relationships. The decrease in SAR with increasing distance for regulatory-compliant phones was consistent and predictable, whereas for regulatory non-compliant phones, the pattern was irregular, inconsistent, and less predictable. For several positions of the regulatory non-compliant phones, an increase in phone separation distance rather increased head SAR. This could be attributed to the phone's characteristics and antenna quality. Rather than decreasing, SAR increased by 70% with a 1.0 cm increase in the phone-to-head distance for regulatory non-compliant phones. This could create high-exposure hotspots at distances that potentially lead to localised heating and the risks of high RF exposure. Additionally, the maximum head SAR levels for regulatory non-compliant phones were observed at a 1.0 cm distance, rather than at 0.0 cm as theoretical predictions suggest. From the measured SAR data, a simplified single-phase exponential model was predicted SAR of regulatory-compliant phones, while an exponential decay model was derived for regulatory non-compliant phones, both relating the phones' phone-to-head separation to the local head SAR.

The SAR measurement results of this study emphasise the necessity for regulatory testing and approval for all mobile phones before they are allowed for public use. It also stresses the urgent need for regulatory authorities to strengthen controls that limit and eliminate the flow of non-compliant phones to the market and their usage by the unaware public. Trends in SAR-distance levels may be incorporated into the regulatory testing regime as an added safeguard. Further investigations are needed to clarify and establish the factors influencing the inconsistent SAR results behaviour of the regulatory non-compliant phones.

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AUTHOR CONTRIBUTIONS

Frederick Sam (Writing-review & editing, Methodology, Formal analysis, Conceptualization), Samuel Osei (Writing-original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization), Philip Deatanyah (Writing-review & editing, Formal analysis) Collins K. Azah (Writing-review & editing, Formal analysis), Joseph K. Amoako (Writing-review & editing, Formal analysis), Roland Y. Kudozia (Writing-review & editing, Methodology, Investigation, Formal analysis), Peter Onyekwere (Writing-review & editing, Methodology, Investigation, Formal analysis, Data curation), Godfred B. Hagan (Writing-review & editing, Formal analysis), Joanna A. M. Hodasi (Writing-review & editing, Formal analysis), and Christiana Subaar (Writing-review & editing, Formal analysis).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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The authors have no funding information to declare.

DATA AVAILABILITY STATEMENT

The authors have nothing to report.

ETHICS APPROVAL STATEMENT

The authors have nothing to report.

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