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Assessment of Radio-Frequency Radiation Levels from Cellular Base Transceiver Stations in Residential Areas and Their Potential Health Effects on Humans

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Abstract
The exponential growth in need for cellular mobile communication has resulted in a significant increase in the number of base transceiver stations across the country. These base transceiver stations are known to emit electromagnetic radiations and some are located very close to residential areas. This proximity to residential areas has prompted a heightened public and scientific concern over the potential health hazard of electromagnetic radiations from base stations on human body. This research work has carried out experimental investigations aimed at estimating levels of radiations from selected base stations and evaluate their potential health risk associated with the exposure. A handheld transmogmeter was used to measure power densities across selected base transmitter stations within some densely populated areas in Ikorodu area of Lagos State. Results of our investigation show an average measured values within the ranges of 0.0064w/m² to 0.0187w/m². This is considered extremely low when compared with exposure safety level as recommended by International Commission on Non Ionizing Radiation Protection. From our results, it can be inferred that no significant health hazard may arise as a result of radiation exposure on human body within the limit of our experimental data.

Keywords: *Base Transceiver Station (BTS), Electromagnetic Radiation, Power Density, Specific Absorption ratio (SAR).*

1.0 Introduction

The rapid expansion and widespread adoption of wireless communication technologies across the globe have significantly increased human exposure to electromagnetic (EM) fields generated by various radiofrequency (RF) sources. Among the most prominent of these sources are cellular Base Transceiver Stations (BTSs), which constitute the backbone of modern mobile communication networks. Due to the increasing demand for seamless network coverage and high-speed data services, BTS installations have proliferated in both urban and rural environments, with many facilities situated in close proximity to residential buildings, educational institutions, hospitals, marketplaces, and other public spaces.

Base Transceiver Stations emit radiofrequency electromagnetic radiation within frequency bands allocated for mobile communications. The operation of these installations is governed by internationally recognized safety standards established by organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the World Health Organization (WHO), which prescribe maximum permissible exposure limits for electromagnetic radiation to ensure public and occupational safety.

Despite compliance with these regulatory guidelines, public concern regarding the potential health implications of prolonged exposure to RF electromagnetic fields continues to increase. The scientific community has extensively investigated the possible biological and physiological effects associated with long-term exposure to non-ionizing radiation; however, the findings remain inconclusive and, in many cases, contradictory. Several epidemiological and experimental studies have reported associations between RF exposure and symptoms such as fatigue, sleep disturbances, headaches, reduced cognitive performance, and other nonspecific health complaints, whereas numerous other investigations have found no statistically significant evidence linking exposure from BTSs to adverse health outcomes [1–9].

Unlike ionizing radiation, such as X-rays and gamma rays, radiofrequency electromagnetic radiation does not possess sufficient photon energy to ionize atoms or molecules or directly break chemical bonds within biological tissues. Consequently, RF radiation is generally not considered capable of causing direct DNA damage through ionization mechanisms. Nevertheless, its potential biological effects, including both thermal and possible non-thermal interactions with living systems, remain subjects of ongoing scientific research and international debate.

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According to the guidelines established by ICNIRP, exposure in excess of $50w/m^2$ power density for occupationally exposed individuals and $10w/m^2$ for general public may increase the likelihood of adverse biological effects. These effects may include alterations in sleep patterns, changes in blood–brain barrier permeability, tissue heating, and other physiological responses associated with excessive radiofrequency energy absorption. Therefore, continuous monitoring and assessment of electromagnetic radiation levels around BTS installations are essential to ensure compliance with established safety standards and to address public health concerns.

Since the adoption of GSM in Nigeria in 2001, there has been a remarkable increase in the number of BTS across the country. This expansion has been driven by urbanization, population growth, increase in demand for mobile access and internet services etc. Lagos State, being the commercial hub centre has the highest concentration of BTS installations compared to other states. According to NCC data fact [11], Lagos accounts for 10-15% of total BTS installations in the country see figure 1.0. Between the year 2001 and 2020, total BTS installations in Nigeria was put at 36,998 out of which Lagos has a fraction of 6,500. An explosive densification phase was witnessed between years 2021 to 2024 wherein Nigeria recorded 145,141 BTS installations across the country with Lagos state accounting for 20,000 out of the total figure. A total of 67.7% growth was experienced between years 2020 to 2021. This was tagged as explosive growth possibly due to rollout of 5G infrastructure, 4G densification and increased demand for data access.

Figure 1: Growth of BTS since 2001 till 2024). Source: NCC

These densifications have raised concerns among residents, policymakers and researchers about environmental aesthetics, potential health hazards, regulatory compliance and infrastructure congestion. Another major concern is the clustering of these BTS around residential areas, schools, market places, hospitals etc.

1.1 Theoretical framework

A base transceiver station (BTS) is an integral part of Cellular network that involves in radio interface within the network. This BTS infrastructure houses an antenna that radiates em energy with output power in the range of $20w$. Deployment condition of BTS is 24m minimum height and a minimum of 10m setback distance as stipulated by National Environmental Standards and Regulation Enforcement Agency (NESREA).

From Maxwell's analysis, electrical and electronics equipment have tendencies of radiating electromagnetic energy as a result of movement of electrons (charges) from current displacement. This em energy, when interacted with body tissue of living organism, can change the body chemistry and results in adverse effects. A metric that is used to determine this is the Specific Absorption Rate (S.A.R). This (SAR) is a measure of the rate in which human body absorbs RF energy upon exposure. This (SAR) can be expressed mathematically in relations to Electric Field (E),

$$S.A.R = \frac{\sigma E^2}{\rho} \quad (1)$$

where σ = tissue conductivity (Sm^{-1}), E = electric field strength (vm^{-1}) and ρ = tissue mass density (kgm^{-3}). Factors that determine exposure rate are radiation frequency, power and distance from radiation source.

The behaviour of em fields generated by BTS is governed by Maxwell's Equations which encompasses Ampere's law, Faraday's law and Gauss's law for both electric and magnetic fields.

$$\oint \overline{H}\,.dx = \int \left(\overline{J_{con}} + \frac{\partial \overline{D}}{\partial t}\right).ds \quad (2)$$

$$\oint \bar{E}\ .dx\ =\ -\int \frac{\partial \bar{B}}{\partial t}.ds \qquad (3)$$

$$\oint \bar{D}\ .ds\ =\ \int \rho.dv \qquad (4)$$

$$\oint \bar{B}\ .ds\ =\ 0 \qquad (5)$$

where

E = Electric field intensity (v/m), H = Magnetic field intensity (A/m), D = Electric flux density (C/m^2)

B = Magnetic flux density (T or Wb/m^2), Jcon = Conduction current density (A/m^2),

ρ = Volume charge density (C/m^3) ,

These equations describe the relationship between electric fields, magnetic fields, current and charge densities. From Faraday and Ampere's laws, a wave equation can be obtained. This wave equation shows that em field propagates at the speed of light and that it follows a transverse pattern of propagation. The solutions of all these equations form the basis for predicting field strength distributions around BTS. The predicted field distributions are used to estimate power density and SAR within biological tissues. It is thus inferred that the integration of maxwell's analysis with tissue-specific parameter (SAR) can enable accurate evaluation of human exposure to BTS radiation.

Conclusively, maxwell's theory explains the generation and propagation of RF waves, while SAR provides biologically relevant metric for exposure assessment.

2.0 Literature Review

A large number of studies have been conducted over the last decade to assess whether radiations from BTS pose a potential health risk to humans. From all, there are conflicting research findings on potential health effects of RF exposure on human body. Some studies [7-10] have postulated that exposure of human body to RF radiation (Non-Ionizing) can cause adverse biological effects such as perturbations in biochemical reactions, increase in reaction rates, hemolysis etc. On the other hand, some other results have postulated that no visible health hazard was recorded upon exposure of human body to RF radiation. This was attributed to the low level of radiation from the BTS. [1] carried out an assessment of RF level from BTS in kebbi State-Nigeria. Three major operators MTN, GLO and Airtel BTS's were used for the investigations. Their results show that the measured field strength and power density were found to be below maximum ranges as stipulated by ICNIRP and IEEE safety standards. Hence, no potential threat to human health. Also, [2] carried out experimental investigations on selected BTS in Kaduna State aimed at assessing their levels of RF radiation. Their measured values ranges between $9.29\text{n}w/m^2$ to $58.08\text{n}w/m^2$. These values are obviously below ICNIRP standard limits and that it cannot pose any health risk. [3] carried out experimental investigations in Lagos State to determine the levels of electric field strength intensities emanating from some selected BTS in Ikoyi area. From their results, average values of between 0.0000309v/m to 0.0123v/m were recorded which are considered to be within the limit of ICNIRP exposure level. A spatial variation in measured data values were observed during their experimentation which is attributed to obstructions of line of sights due to immobile objects. [4] Conducted an investigation to assess level of RF radiation within the health facilities at Obafemi Awolowo University, Osun State, Nigeria. Measurements were conducted in an indoor and outdoor environment using a portable electrosmogmeter with frequency range of 10MHz and 8GHz. Their results show that the measured radiated power at various locations was below the maximum limit as stipulated by federal ministry of environment. Also, [5] investigated the radiation levels of some selected BTS in Akpor/Obio local government area of Rivers State. Apart from measuring electric field intensities on each BTS, they have also used SAR and power density to assess radiation effects on human body. At each experimentation site, measurements were taken to cover a distance of 300m from the BTS. For SAR, their average measured values were within 0.003w/kg to 0.0084w/kg. While for power density, average values within the range of $1.5183w/m^2$ to $9.5083w/m^2$ were measured. These values are far below ICNIRP recommended limits. The authors concluded that radiations from selected BTS are not likely to cause any harms to humans. In a similar manner, [6] carried out a research work to assess electromagnetic field radiation from BTS. In their investigation, a hand-held R-F meter in the range of 50MHz to 3.5GHz was used to take measurement across ten (10) selected BTS in Ijebu-Igbo, Ogun State. Their results show maximum measured values of power density between $0.0001188w/m^2$ to $0.0217359w/m^2$ which indicates that the measured values cannot constitute any health hazard to human beings.

On the contrary to the above findings, it was reported in [7] that a survey conducted in France revealed that people living at close proximity to BTS reported cases of fatigue, headache, sleep-disruption and memory loss. Following a similar trend, [8] conducted an investigation to determine possible health effect of RF radiation from BTS on an albino mice. Results show a slight tissue deformities in the kidneys of the mice. The author concluded that further research is still needed in this area to determine varying biological effects that have been reported in the literature. A study conducted by [9] on people living near base station location revealed possible physiological and psychological reactions upon continuous exposure to RF radiation. Their findings revealed some of these people showed symptoms of dizziness, discomfort, nervousness, depression and sleep-disturbance. This was however likened to continuous and long-term exposure.

Obviously, there are conflicting research findings on possible health effects of RF exposure on human body. It therefore becomes imperative to carry out further research findings on the subject matter.

3.0 Methodology

Radiofrequency (RF) electromagnetic field exposure measurements were conducted around selected Base Transceiver Stations (BTSs) located across various parts of Lagos State, Nigeria. The selection of the BTS sites was based on several criteria, including accessibility, proximity to residential buildings and other public facilities, and the availability of technical personnel responsible for site operations. The inclusion of site engineers in the selection process was particularly important, as it facilitated unrestricted access to the facilities, minimized potential interference or apprehension from nearby residents, and ensured that all measurements were conducted under appropriate operational conditions.

Furthermore, the site engineers provided valuable site-specific technical information, including antenna configuration, tower orientation, operating frequencies, and transmission characteristics, which significantly enhanced the planning and execution of the measurement campaign. The selected BTS sites comprised installations belonging to major telecommunications service providers, including MTN and GLO, with several locations consisting of co-located base stations where multiple network operators share the same tower infrastructure.

Field measurements were performed using a hand-held Transmogmeter (Figure 2.0), a broadband electromagnetic field meter capable of detecting radiofrequency signals within the frequency range of 800 MHz to 8 GHz. To simulate the average height of human exposure, the instrument was securely mounted on a tripod stand and positioned at a height of 1.5m above ground level throughout the measurement process.

At each BTS location, measurements were carried out along predetermined radial axes extending outward from the base station in a straight-line trajectory. To capture representative exposure levels under maximum network utilization, the measurement campaign was conducted predominantly during peak traffic periods, when transmission power and network activity were expected to be highest.

Power density measurements were recorded at successive observation points spaced at 2m intervals along the selected measurement paths. At each sampling location, the Transmogmeter was allowed to operate continuously for an averaging period of approximately two minutes before a reading was recorded. The mean power density value obtained during this interval was used as the representative measurement for that location, thereby reducing the influence of short-term fluctuations in RF emissions and improving the accuracy and reliability of the collected data.

In accordance with NESREA, telecommunications operators are required to maintain a minimum setback distance of 10m between BTS infrastructure and adjacent residential buildings to minimize public exposure to radiofrequency electromagnetic fields and ensure environmental safety. During our measurement campaigns, the degree of compliance with this regulatory setback requirement was systematically assessed and documented at each BTS site included in the study.

In addition, the research team adhered to all relevant ethical and safety protocols throughout the experimental campaign. To ensure the integrity of the study and the safety of all parties involved, no physical contact was made with any BTS infrastructure during the measurement process. At each measurement location, the team engaged a small number of randomly selected residents to explain the purpose of the study and provide assurances that the activities posed no risk to their safety or property.

In several instances, the presence of the tripod-mounted measurement equipment generated concern among local residents, who initially presumed that the team represented the Ministry of Lands or another governmental agency. To address these concerns, we presented our official means of identification and clarified our status as independent researchers conducting an academic field study. These interactions helped to foster community trust and facilitated the successful completion of the measurement exercise.

Figure 2: Electromagnetic Radiation Tester. (EMF02R)

(a) (b)

(c) (d)

Figure 3: (a-d). Pictures at experimental sites

4.0 Results and Discussion

The average dataset from each of the experimental sites is as presented in Table 1.0.

Table 1: Dataset from experimental sites

Distance (m)	Site1 Exposure Value(m/w^2) x10^{-3}	Site2 Exposure Value(m/w^2) x10^{-3}	Site3 Exposure Value(m/w^2) x10^{-3}	Site4 Exposure Value(m/w^2) x10^{-3}	Site5 Exposure Value(m/w^2) x10^{-3}	Site6 Exposure Value(m/w^2) x10^{-3}
2	12.60	15.40	15.50	14.50	17.20	15.55
4	13.50	16.00	16.50	14.00	15.70	15.90
6	14.40	15.60	16.90	14.40	16.30	15.37
8	14.17	15.87	15.60	14.50	16.530	14.83
10	13.93	16.13	14.30	14.60	16.77	14.30
12	13.70	16.40	13.00	14.70	17.00	14.63
14	13.73	16.73	12.93	14.03	17.03	14.97
16	13.77	17.07	12.87	13.37	17.07	15.30
18	13.80	17.40	12.80	12.70	17.10	15.93

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Distance (m)	Site1 Exposure Value(m/w^2) x10^{-3}	Site2 Exposure Value(m/w^2) x10^{-3}	Site3 Exposure Value(m/w^2) x10^{-3}	Site4 Exposure Value(m/w^2) x10^{-3}	Site5 Exposure Value(m/w^2) x10^{-3}	Site6 Exposure Value(m/w^2) x10^{-3}
20	14.03	17.83	13.17	12.77	16.90	16.57
22	14.27	18.27	13.53	12.83	16.70	17.20
24	14.50	18.70	13.90	12.90	16.50	15.33
26	14.97	18.20	15.00	14.10	17.07	13.47
28	15.43	17.70	16.10	15.30	17.63	11.60
30	15.90	17.20	17.20	16.50	18.20	10.47
32	15.23	17.23	17.23	15.87	18.37	9.33
34	14.57	17.27	17.27	15.23	18.53	8.20
36	13.90	17.30	17.30	14.60	18.70	7.90
38	14.63	17.00	17.00	13.93	17.43	7.60
40	15.37	16.70	16.70	13.27	16.17	7.30
42	16.10	16.40	16.40	12.60	14.90	7.55
44	15.07	16.07	16.07	12.27	14.70	7.80
46	14.03	15.73	15.73	11.93	14.50	8.05
48	13.00	15.40	15.40	11.60	14.30	8.90
50	10.80	16.37	16.37	11.67	13.67	9.75
52	8.60	17.33	17.33	11.73	13.03	10.60
54	6.40	18.30	18.30	11.80	12.40	11.37
56	9.10	18.30	18.30	11.63	12.57	12.13
58	11.80	18.30	18.30	11.47	12.73	12.90
60	14.50	18.30	18.30	11.30	12.90	12.47
62	14.73	18.43	18.43	11.20	12.83	12.03
64	14.97	18.57	18.57	11.10	12.77	11.60
66	15.20	18.70	18.70	11.00	12.70	10.70
68	15.87	18.17	18.17	11.20	13.30	9.80
70	16.53	17.63	17.63	11.40	13.90	8.90
72	17.20	17.10	17.10	11.60	14.50	8.33
74	17.13	15.47	16.03	12.27	14.40	7.77
76	17.07	13.83	14.97	12.93	14.30	7.20
78	17.00	12.20	13.90	13.60	14.20	7.83
80	16.63	11.87	13.53	13.27	14.60	8.47
82	16.27	11.53	13.17	12.93	15.00	9.10
84	15.90	11.20	12.8	12.60	15.40	8.93
86	15.53	12.10	12.63	12.50	15.8	8.77
88	15.17	13.00	12.47	12.40	16.20	8.60
90	14.80	13.90	12.30	12.30	16.60	9.30
92	15.43	14.13	12.17	12.73	16.60	10.00
94	16.07	14.37	12.03	13.17	16.60	10.70
96	16.70	14.60	11.90	13.60	16.60	15.55
98	16.70	14.77	11.40	13.17	16.87	15.90
100	16.70	14.93	10.90	12.73	17.13	15.37

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Table 2: Statistical Parameters (mean, standard deviation, and RMS values) for All Sites ($\times 10^{-3}$ W/m²)

Site	Mean Value ($\times 10^{-3}$ W/m²)	Standard Deviation ($\times 10^{-3}$ W/m²)	RMS Value ($\times 10^{-3}$ W/m²)
Site 1	14.5902	2.1705	14.7476
Site 2	16.1196	2.0329	16.2448
Site 3	15.1863	2.3726	15.3669
Site 4	12.9824	1.3218	13.0482
Site 5	15.6137	1.7946	15.7145
Site 6	11.3960	3.1909	11.8257

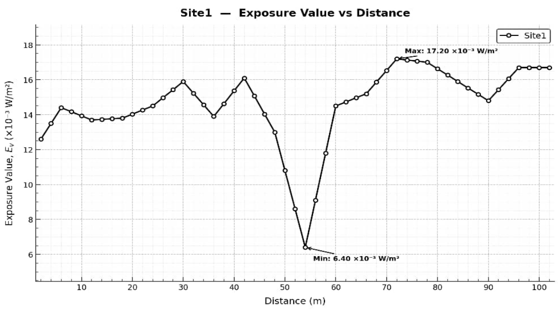

Figure 4: Exposure value versus distance for site 1

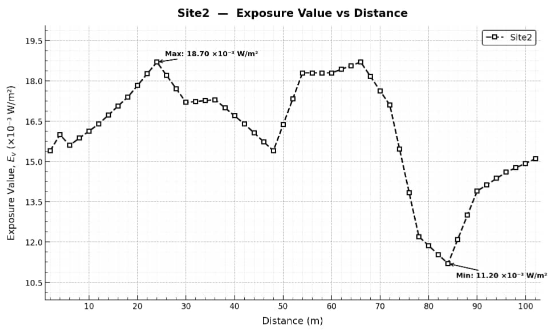

Figure 5: Exposure value versus distance for site 2

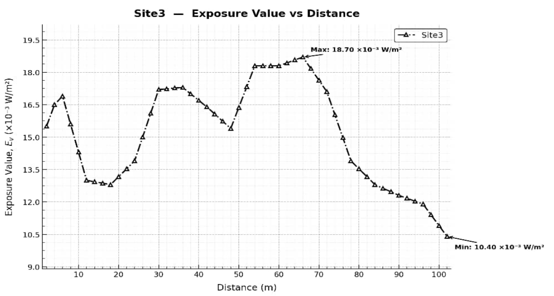

Figure 6: Exposure value versus distance for site 3

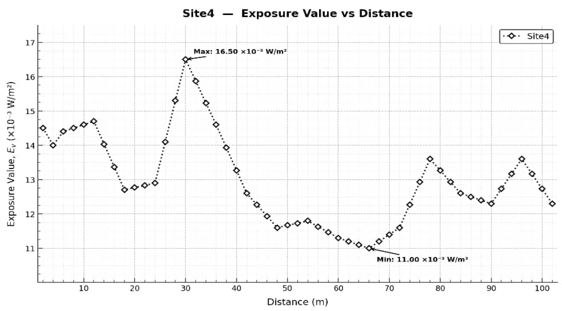

Figure 7: Exposure value versus distance for site 4

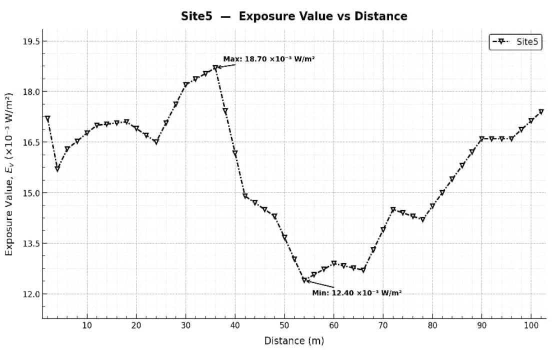

Figure 8: Exposure value versus distance for site 5

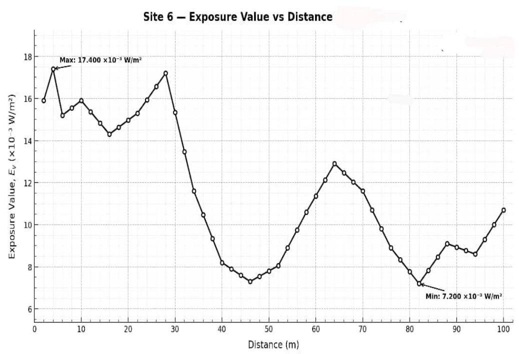

Figure 9: Exposure value versus distance for site 6

On a site to site basis, the plots of exposure values against distance show a clear inverse relationship. As the distance from the BTS increases, exposure value shows a slowly decreasing trend. At some instances, a spatial variation in radiation level was observed during our measurement campaigns and this is attributed to environmental obstructions and terrain irregularities. Though, this is not too significant as can be seen in the standard deviation values.

The measured values ranges between $0.0064w/m^2$ and $0.0187w/m^2$ across all surveyed sites. These values constitute only a small fraction of the permissible limit by ICNIRP. With this substantial safety margin, it clearly suggests that the RF emissions from the surveyed sites will not pose any significant health risks to human inhabitants. When compared with results of other researchers in the field, our results show statistical adherence with most postulations in the literature, which posited that RF exposure from cellular infrastructure remains well below international safety thresholds. This consistency is therefore reinforcing the reliability of our findings and supports the conclusion that current telecoms infrastructure is safe for public exposure.

In addition, it was observed that all the sites visited complied with 10m setback distance from residential building and most of the sites carries safety charts for public information and awareness.

While this study provides evidence of safety for inhabitants of BTS infrastructure, certain experimental limitations are recognized. For instance, measurements were conducted on only few selected sites which may limit generalization of findings. Also, inability to isolate emissions from individual operators at co-located sites.

5.0 Conclusion

This research work has evaluated RF radiation emitted from cellular BTS located in residential areas and examined their potential health implications for the nearby residents. Measurements were taken across selected sites and the recorded power density values were compared against internationally accepted safety benchmarks. Our findings revealed that measured RF values from all surveyed locations remained significantly below the exposure limit recommended by ICNIRP. This therefore provides empirical evidence that in the immediate term, radiations emitted from BTS may not pose any significant health risks to residents within BTS proximity.

From a public health perspective, our findings in this investigations will provide reassurances to communities living near BTS installations. Often, there is a public perceptions that associate BTS proximity with increased health risks, this study has therefore demonstrated that such concerns may not be supported by empirical data.

Conclusively, this study has affirmed that RF radiation from BTS in the investigated residential areas is within safe exposure limits and may not constitute any significant health hazard based on the current evidence. However, further research work is suggested to monitor long term exposure in order to completely address the ongoing public concern.

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