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Research Article

RF-EMR pollution levels near kindergartens due to mobile communication towers and Wi-Fi sources

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Abstract

Wireless communications play a crucial role in human lives. The introduction of cellular network systems, broadband internet services and public Wi-Fi services increase the connectivity between people exponentially. These wireless networks require antenna structures to propagate carrier waves through space and these waves are located within the Radiofrequency (RF) region in the electromagnetic spectrum. The effects of these RF waves on people, especially children, and pregnant women cannot be neglected. According to the researchers, there are some adverse health issues related to thermal and non-thermal effects due to exposure to these non-ionizing radiations. In this study, RF exposure levels within the proximity of 21 selected kindergartens in the Colombo and Kandy districts were evaluated by using a high-frequency spectrum analyzer. Results of the study show a nearly 251 % increase in the RF exposure levels in the kindergartens located in Colombo district relative to the kindergartens in Kandy district. As well as GSM900, GSM1800 and UMTS cellular communication bands show a higher contribution to background RF exposure than the other wireless networks. However, measured maximum electric fields and calculated specific absorption rate (SAR) values are well below the maximum permissible levels published by International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Keywords: Radiofrequency Radiation, Health effects, Kindergartens

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1. INTRODUCTION

1.1 Overview

Currently, there are more than 5000 communication towers in Sri Lanka and this number is increasing year to year, as well as Wi-Fi hotspots. These communication towers and Wi-Fi hotspots emit Radio Frequency Electromagnetic Radiation (RF-EMR) as the carrier of data. There are many benefits of these networks but overexposure to these radiations would be harmful. Especially children and pregnant women are more vulnerable. This study is mainly focused on the RF -EMR levels emitted by cellular towers and Wi-Fi hotspots in the proximity of kindergartens located in Colombo and Kandy districts in Sri Lanka.

1.2 Background

At the present day in Sri Lanka as well as in the world, an exponential increase of cellular network operators and cellular tower structures can be observed. The increase in mobile device users is the main reason for this. When increasing the number of mobile device users, the service providers must increase the number of cell towers to make sure stable, high-quality service. When the above networks are expanding, the background radiation levels due to the non-ionizing electromagnetic waves become higher and this may lead to higher personal exposure levels to the public. According to the present studies children and pregnant women are more vulnerable to these radio waves and continuous monitoring of these RF levels at the places where children and pregnant women live is a must. Personal exposure to non-ionizing radio waves could be in many forms. Living close to a mobile communication base station or TV/Radio transmission tower, when operating a mobile phone, sitting close to a microwave oven when it is operating as well as hi-tech devices such as smart meters and wireless multimedia devices would lead to the high exposure of RF-EMR. To regulate these exposures, international organizations such as ICNIRP (International Commission on Non-Ionizing Radiation Protection) and FCC (Federal Communication Commission) have published some guidelines for exposure to these non-ionizing radiations. Table 1 shows the reference levels published by ICNIRP [1].

Table 1: ICNIRP reference levels for RF exposure, averaged over 30 min and the whole body, to electromagnetic fields from 100 kHz to 300 GHz (unperturbed RMS values)

Exposure Type	**Frequency Range**	**Incident E-Field Strength (V $\mathbf{m^{-1}}$)**	**Incident B-Field Strength (A $\mathbf{m^{-1}}$)**	**Incident Plain Wave Power Density (W $\mathbf{m^{-2}}$)**
Occupational	0.1-30 MHz	$660/f_M^{0.7}$	$4.9/f_M$	NA
	>30-400 MHZ	61	0.16	10
	>400-2000 MHz	$3f_M^{0.5}$	$0.008f_M^{0.5}$	$f_M/40$
	>2-300GHz	NA	NA	50
General Public	0.1-30 MHz	$300/f_M^{0.7}$	$2.2/f_M$	NA
	>30-400 MHZ	27.7	0.073	2
	>400-2000 MHz	$1.375f_M^{0.5}$	$0.0037f_M^{0.5}$	$f_M/200$
	>2-300GHz	NA	NA	10

A conventional cellular device uses different frequency bands when it is operating, Table 2 shows the cellular frequency bands and wireless fidelity (Wi-Fi) frequency band considered for the study and their operating frequency ranges.

Table 2: Different cellular network bands and Wi-Fi frequency band with the corresponding frequency ranges

Network Band	**Frequency Range (MHz)**
GSM900	890-915 (up link) /935-960 (down link)
GSM1800	1710-1785 (up link)/1805-1880 (down link)
UMTS	1885-2025 (up link)/2110-2200 (down link)
LTE2.6	2500-2570 (up link)/2620-2690 (down link)
Wi-Fi 2.4 (802.11 b/g/n)	2401-2484

An increase in background RF pollution levels under certain levels may not cause any direct harm, but radiation-sensitive people such as children and pregnant women may have some effects due to these RF radiation levels. According to the international agency for cancer

research, the RF EMRs are possibly carcinogenic and they have classified radio frequency radiation as Group 2B [2].

In this study background RF pollution levels due to different cellular network bands and wi-fi hotspots were evaluated in the proximity of 21 kindergartens in two main districts of Sri Lanka. A total number of 16 kindergartens were selected in Colombo district and 5 kindergartens were selected in Kandy district.

1.3 Radio frequencies

The Radiofrequency region is classified within the frequency range of 100 kHz to 300 GHz in the electromagnetic spectrum. This region is very important because nowadays most of the cellular communication systems, tv, radio, radar systems and other wireless communication systems use different frequency bands within the above frequency range as the carrier.

1.4 Energy carried by an electromagnetic wave

The simple type of electromagnetic waves are called sinusoidal electromagnetic waves and in a sinusoidal EM wave the electric field vector($\vec{E}$) and magnetic field vector ($\vec{B}$) follows a sinusoidal function with time. Spatial variation of the fields are also sinusoidal at any instant of time. Equation 1 and 2 show the variation of the magnitude of electric and magnetic fields with time for a simple electromagnetic wave propagating in the +x direction.

$$E = E_0 \sin(\omega t - kx) \quad (1)$$

$$B = B_0 \sin(\omega t - kx) \quad (2)$$

In the above equations E_0 and B_0 represent the magnitude of peak electric field and peak magnetic field of the sinusoidal electromagnetic wave respectively. When an electromagnetic wave is propagating through a given space it carries a certain amount of energy. Equation 3 shows an expression for the energy density (ψ) associated with a unit volume of free space when an electromagnetic wave is propagating through that space [3].

$$\psi = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2\mu_0} B^2 \quad (3)$$

Here ε_0 is the permittivity of free space and μ_0 is the permeability of free space. By using above expression and the relationship shown in Equation 4 and Equation 5, an expression can be obtained for the electromagnetic power per unit area or plane wave power density (S) measured in W/m^2. Equation 6 shows the relationship with plane wave power density, ε_0, μ_0 and E.

$$E = c\,B \quad ---------- (4)$$

In Equation 4, 'c' is the speed of light in vacuum and *E*, *B* represent the instantaneous values of $\vec{E}$ and $\vec{B}$ fields at a certain instant of time.

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \quad ---------(5)$$

$$S = \sqrt{\frac{\varepsilon_0}{\mu_0}} E^2 \quad ---------(6)$$

For a time-varying field *S* also varies with time, therefore having an average value for *S* is more convenient. When considering a sinusoidal wave average value of E^2 could be given by Equation 7.

$$E^2 = \frac{E_0^2}{2} \quad ---------- (7)$$

Equation 8 shows the average plane wave power density for a simple electromagnetic wave.

$$S = \frac{1}{2}\sqrt{\frac{\varepsilon_0}{\mu_0}} E_0^2 \quad ---------(8)$$

1.5 RF-EMR field measurements and exposure compliance

The electric field intensity (*E*), magnetic field strength (*B*) and plane wave power density (*S*) are the basic measurements of radio frequency electromagnetic waves at a particular point of space and these could be measured by using a suitable measuring instrument such as a high frequency spectrum analyser. When considering exposure compliance, Specific Absorption Rate (SAR) can be used. It measures the rate of energy absorbed by a unit mass of a particular type of tissue of a human or animal. More generally SAR value could be used

to evaluate thermal losses in human or animal body tissues. This value depends on various properties such as water content, the geometry of the particular type of tissue, the frequency of the incident wave, and the size of the tissue [10].

SAR value for a specific type of tissue can be calculated by measuring the peak value of the electric field inside the tissue [4]. SAR value for a particular type of tissue with electrical conductivity σ and mass density ρ can be found by using Equation 9.

$$SAR\ Value = \frac{\sigma\ E_0^2}{\rho} - - - - - - - - (9)$$

Here, E_0 is the peak value of the electric field intensity of the electromagnetic wave to which the tissue is exposed.

1.6 Literature on the effects of RF radiation on children

Many studies have been conducted around the globe regarding the effect of nonionizing radiofrequency radiation on children and radiation levels within the proximity of kindergartens. However, in Sri Lanka, no such studies were conducted up to date.

When compared with the brain of an adult, the absorption of RF EMR energy becomes high in the brain of a child [11]. A study conducted to evaluate the health effects of electromagnetic fields on children shows that the developing brain of a child is vulnerable to radiofrequency electromagnetic radiation. As well as the nervous system of children is at a higher risk due to these electromagnetic waves than adults [5]. A group of researchers conducted a transverse study including 3102 children aged five years who lived in Amsterdam in the Netherlands to study emotional and behavioural problems due to the exposure to radiofrequency electromagnetic radiation emitted by cellular base stations, codeless phone base stations, and Wi-Fi sources [6]. Another group of researchers conducted research about mobile tower radiation and its impacts on child health in an ecologically sensitive area of Western Ghats, India. Results of the study showed a close relationship with bone weakness, rheumatic pain, headaches, sleeping quality and hearing of children under 15 years with RF-EMR exposure [7]. A review study was carried out by the Tunisian researcher to find the perspectives and risks of Wi-Fi and health. According to their work, the biological effects of RF-EMR in different frequency ranges were found in vitro and in vivo experiments. However, their study was insufficient to justify the direct effects of the impact [8]. A study designed to observe radiofrequency electromagnetic field exposure in kindergarten children in Melbourne, Australia shows GSM900 cellular communication

band is the largest contributor to personal and total environmental RF-EMR exposure. They have also found that Wi-Fi exposure is lower when compared with cellular base station exposure and according to their results exposure levels due to a cellular base station are higher in the kindergartens located less than 300 m from the towers and the values are lower when the distance to the tower is more than 300 m [9].

2. METHODOLOGY

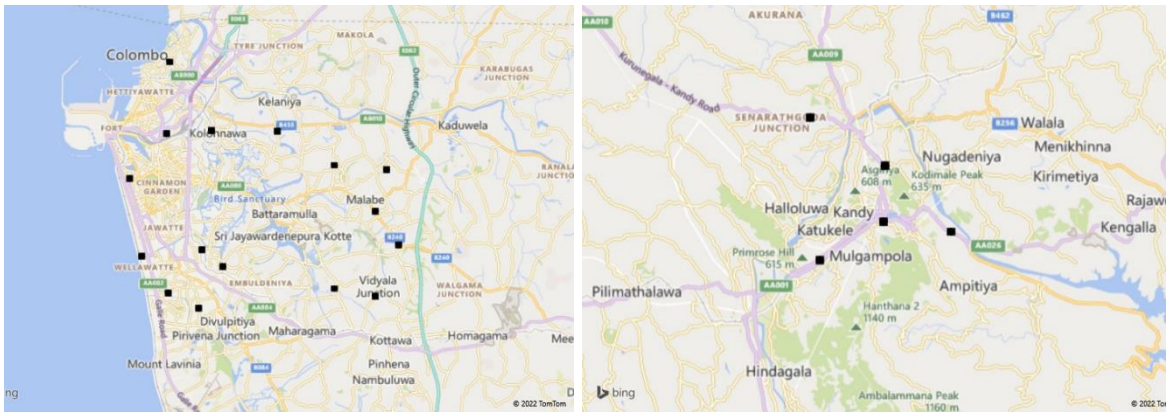
When selecting kindergartens for the study, the number of cell towers in proximity, and radiation barriers such as large buildings and metal structures were considered. Measurements were taken at the places having at least one visible cellular tower structure close to the kindergartens and having a smaller number of radiation barriers. The peak value of the electric field intensity was measured at the selected locations for the downlink of the cellular frequency bands GSM900, GSM1800, UMTS, LTE2.6 and the peak electric field intensity due to Wi-Fi (WLan2.4) hotspots. At a selected kindergarten, five readings were collected within the open areas of the kindergarten for the peak electric field strength in the selected frequency band by using SPECTRAN HF6065 spectrum analyser. Nowadays most children and kindergarten teachers prefer open areas to do their activities and this is the reason for selecting open areas for the measurements.

SPECTRAN HF6065 analyser is a selective high-frequency electromagnetic wave meter, and it can be used to measure RF EMR within the frequency range 10 MHz to 6 GHz with an accuracy of ± 0.001 V/m and for this study a compatible broadband directional antenna (Hyperlog7060) was used with the device. The selected antenna can be used to measure electromagnetic waves within the frequency range of 700 MHz to 6 GHz.

When measuring the peak electric field at a particular place, the directional antenna was rotated by an angle of 360^0 while keeping it on the same horizontal plane about 1 m of hight from the ground level for each frequency band and all the data were recorded during the daytime in between 8 am to 11 am on the month of January 2022. The reason for selecting the above time interval is most of the kindergartens operate within this time interval of the day. Figure 1 shows the instrumentational setup used for the study.

Figure 1 Instrumental Setup

Colombo district has the highest population density in Sri Lanka as well as Kandy district also has a moderate population density. When the population density gets higher the wireless network providers have to increase the number of sources (antenna structures) to maintain uninterrupted service. As well as most of the environmental pollutants are found within these two districts in recent years and these are the main reasons for selecting Colombo and Kandy districts in this study. Figure 2 (a) shows the locations of the selected kindergartens in Colombo district and Figure 2 (b) show the locations of the selected kindergartens in Kandy district.



(a) (b)

Figure 2 (a) Locations in Colombo district and Figure 2 (b) Locations in Kandy district.

3. RESULTS AND DISCUSSION

Table 3 and Table 4 show the RF levels at the selected kindergartens in Colombo district.

Table 3 Measured peak electric field intensity for different cellular bands and Wi-Fi 2.4 network in Colombo district.

No.	Location of the Kindergarten		Peak Value of the Electric Field Intensity (V/m)				
	Latitude	Longitude	GSM900	GSM1800	UMTS	LTE 2.6	WLAN 2.4
01	6.862772°	79.958231°	0.059	0.045	0.018	0.022	0.004
			0.062	0.053	0.026	0.024	0.003
			0.055	0.043	0.038	0.021	0.003
			0.061	0.036	0.016	0.019	0.006
			0.056	0.053	0.017	0.033	0.003
02	6.884720°	79.968189°	0.015	0.119	0.033	0.032	0.011
			0.026	0.116	0.168	0.031	0.004
			0.015	0.262	0.022	0.116	0.01
			0.013	0.07	0.032	0.076	0.004
			0.016	0.087	0.046	0.075	0.006
03	6.916654°	79.962931°	0.04	0.11	0.1	0.014	0.004
			0.04	0.076	0.087	0.014	0.003
			0.043	0.073	0.042	0.026	0.018
			0.043	0.051	0.033	0.015	0.004
			0.037	0.05	0.089	0.022	0.018
04	6.899009°	79.958219°	0.031	0.019	0.01	0.014	0.005
			0.025	0.013	0.014	0.012	0.007
			0.022	0.018	0.006	0.011	0.007
			0.018	0.013	0.01	0.009	0.007
			0.025	0.021	0.015	0.007	0.004
05	6.918654°	79.940482°	0.119	0.041	0.023	0.03	0.016
			0.093	0.043	0.035	0.038	0.008
			0.062	0.035	0.042	0.028	0.005
			0.052	0.027	0.015	0.019	0.009
			0.097	0.06	0.023	0.015	0.016
06	6.912973°	79.852778°	0.04	0.152	0.104	0.034	0.012
			0.032	0.174	0.218	0.038	0.007
			0.048	0.235	0.251	0.024	0.009
			0.06	0.119	0.105	0.027	0.024
			0.041	0.135	0.088	0.013	0.021
07	6.857559°	79.882300°	0.106	0.156	0.077	0.043	0.01
			0.068	0.438	0.162	0.021	0.011
			0.079	0.446	0.112	0.036	0.005
			0.067	0.428	0.106	0.056	0.006
			0.057	0.173	0.083	0.064	0.008
08	6.932154°	79.868626°	0.353	0.263	0.336	0.384	0.02
			0.435	0.604	0.577	0.064	0.017
			0.41	0.33	0.604	0.231	0.014
			1.143	0.526	0.222	0.333	0.015
			0.507	0.393	0.44	0.752	0.02

Table 4 Measured peak electric field intensity for different cellular bands and Wi-Fi 2.4 network in Colombo district.

No.	Location of the Kindergarten		Peak Value of the Electric Field Intensity (V/m)				
	Latitude	Longitude	GSM900	GSM1800	UMTS	LTE 2.6	WLAN 2.4
09	6.933069°	79.915971°	0.099	0.033	0.068	0.026	0.022
			0.066	0.028	0.094	0.019	0.025
			0.057	0.038	0.062	0.025	0.009
			0.062	0.055	0.054	0.054	0.011
			0.062	0.108	0.025	0.077	0.025
10	6.866006°	79.940670°	0.026	0.201	0.203	0.052	0.004
			0.032	0.223	0.133	0.047	0.014
			0.023	0.094	0.101	0.163	0.032
			0.023	0.106	0.1	0.236	0.004
			0.034	0.4	0.052	0.172	0.004
11	6.879901°	79.857731°	0.069	0.28	0.29	0.015	0.011
			0.047	0.28	0.21	0.036	0.016
			0.046	0.1	0.043	0.045	0.012
			0.04	0.103	0.224	0.084	0.006
			0.042	0.432	0.221	0.021	0.004
12	6.962760°	79.869977°	0.167	0.12	0.407	0.14	0.009
			0.094	0.132	0.178	0.177	0.014
			0.095	0.207	0.358	0.125	0.038
			0.091	0.362	0.234	0.026	0.039
			0.122	0.4	0.174	0.073	0.038
13	6.875337°	79.892562°	0.256	0.132	0.209	0.097	0.031
			0.097	0.159	0.33	0.128	0.012
			0.241	0.371	0.262	0.211	0.016
			0.137	0.203	0.366	0.167	0.014
			0.106	0.14	0.304	0.139	0.036
14	6.882711°	79.883768°	0.072	0.132	0.068	0.053	0.006
			0.089	0.087	0.144	0.066	0.004
			0.078	0.097	0.141	0.073	0.009
			0.104	0.088	0.08	0.045	0.007
			0.061	0.095	0.113	0.069	0.006
15	6.864107°	79.869355°	0.082	0.208	0.184	0.143	0.006
			0.08	0.236	0.159	0.119	0.013
			0.092	0.76	0.222	0.303	0.018
			0.09	0.545	0.12	0.158	0.012
			0.113	0.255	0.16	0.094	0.014
16	6.933630°	79.887744°	0.424	0.329	0.128	0.203	0.019
			0.117	0.359	0.094	0.336	0.014
			0.093	0.421	0.137	0.343	0.01
			0.087	0.138	0.205	0.08	0.02
			0.334	0.093	0.429	0.066	0.016

Table 5 shows the measured RF EMR values at the selected kindergartens in Kandy district.

Table 5 Measured Peak electric field intensity for different cellular bands and Wi-Fi 2.4 network in Kandy district.

No.	Location of the Kindergarten		Peak Value of the Electric Field Intensity (V/m)				
	Latitude	Longitude	GSM900	GSM1800	UMTS	LTE 2.6	WLAN 2.4
01	7.286478°	80.660109°	0.04	0.038	0.033	0.021	0.019
			0.029	0.034	0.026	0.012	0.006
			0.026	0.042	0.033	0.032	0.01
			0.028	0.051	0.032	0.037	0.013
			0.032	0.086	0.033	0.042	0.006
02	7.276901°	80.615399°	0.079	0.074	0.094	0.027	0.015
			0.035	0.12	0.037	0.028	0.01
			0.047	0.14	0.058	0.045	0.007
			0.048	0.08	0.119	0.035	0.032
			0.096	0.088	0.111	0.033	0.008
03	7.289850°	80.636996°	0.029	0.028	0.023	0.021	0.006
			0.031	0.022	0.044	0.012	0.003
			0.029	0.065	0.048	0.016	0.003
			0.035	0.03	0.044	0.061	0.003
			0.039	0.022	0.026	0.062	0.004
04	7.308773°	80.637603°	0.037	0.01	0.012	0.013	0.013
			0.041	0.016	0.018	0.01	0.032
			0.037	0.015	0.02	0.014	0.009
			0.027	0.03	0.024	0.015	0.01
			0.032	0.031	0.015	0.016	0.011
05	7.325125°	80.612108°	0.037	0.012	0.007	0.011	0.003
			0.037	0.006	0.015	0.018	0.005
			0.02	0.005	0.021	0.011	0.006
			0.032	0.006	0.015	0.017	0.006
			0.032	0.013	0.009	0.012	0.006

Based on the above data, average values of the measured peak electric field intensities were calculated and Table 6 shows the average values of the measured peak electric field intensities of all the kindergartens.

Table 6 Average values of the peak electric field intensities measured for each network band at each kindergarten.

	Location Coordinates		**Average Values of the Peak E-Field Intensities (V/m)**				
No.	**Lat**	**Long**	**GSM900**	**GSM1800**	**UMTS**	**LTE 2.6**	**WLAN 2.4**
1	6.862772°	79.958231°	0.059	0.046	0.023	0.024	0.004
2	6.884720°	79.968189°	0.017	0.131	0.060	0.066	0.007
3	6.916654°	79.962931°	0.041	0.072	0.070	0.018	0.009
4	6.899009°	79.958219°	0.024	0.017	0.011	0.011	0.006
5	6.918654°	79.940482°	0.085	0.041	0.027	0.026	0.011
6	6.912973°	79.852778°	0.044	0.163	0.153	0.027	0.015
7	6.857559°	79.882300°	0.075	0.328	0.108	0.044	0.008
8	6.932154°	79.868626°	0.570	0.423	0.436	0.353	0.017
9	6.933069°	79.915971°	0.069	0.052	0.061	0.040	0.018
10	6.866006°	79.940670°	0.028	0.205	0.118	0.134	0.012
11	6.879901°	79.857731°	0.049	0.239	0.198	0.040	0.010
12	6.962760°	79.869977°	0.114	0.244	0.270	0.108	0.028
13	6.875337°	79.892562°	0.167	0.201	0.294	0.148	0.022
14	6.882711°	79.883768°	0.081	0.010	0.109	0.061	0.006
15	6.864107°	79.869355°	0.091	0.401	0.169	0.163	0.013
16	6.933630°	79.887744°	0.211	0.268	0.199	0.206	0.016
17	7.286478°	80.660109°	0.031	0.050	0.031	0.029	0.011
18	7.276901°	80.615399°	0.061	0.100	0.083	0.034	0.014
19	7.289850°	80.636996°	0.033	0.033	0.037	0.034	0.004
20	7.308773°	80.637603°	0.035	0.020	0.018	0.014	0.015
21	7.325125°	80.612108°	0.032	0.008	0.013	0.014	0.005

Based on the values in Table 6 the maximum value of the average electric field intensities can be compared. Figure 3 shows the bar graph for the average values of the peak electric field intensities measured for each cellular network band and Wi-Fi network.

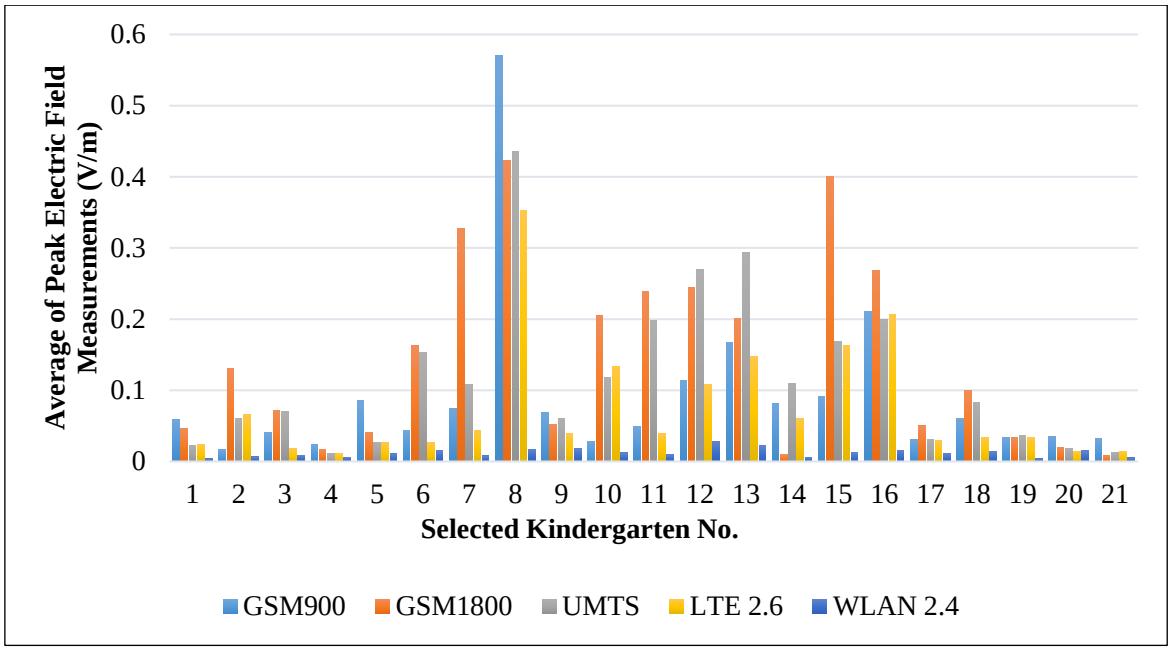


Figure 3 Average of the peak electric field measurements of each kindergarten for each network band.

According to the above chart, GSM900, GSM1800 and UMTS network bands contribute more for the background exposure levels among the selected frequency bands. Moreover, the selected kindergartens in Kandy District show comparatively low exposure levels for all the selected network bands than the selected kindergartens in Colombo district and the reasons for this could be comparatively larger number of cell towers in Colombo district than Kandy district and terrain characteristics.

Table 7 shows the calculated maximum permissible plane wave power density levels to the general public for the selected frequency bands. These values were calculated based on the centre frequency of each network band and based on the guidelines given in Table 1.

Table 7 Calculated maximum permissible plane wave power densities corresponding to each frequency band.

Network Band	**Centre Frequency (MHz)**	**Permissible Plane Wave Power Density (W/m^2)**
GSM900	974.5	4.87
GSM1800	1842.5	9.21
UMTS	2155.0	10.00
LTE2.6	2655.0	10.00
WLan 2.4	2442.5	10.00

Among all the kindergartens, Kindergarten number 8 shows the highest exposure levels for the selected cellular network bands and kindergarten number 12 shows the highest WLan 2.4 exposure level. Main reason for these elevated RF levels is the number of RF emitting sources within the proximity. Table 8 shows the calculated plane wave power density levels corresponding to each maximum electric field intensities of each band.

Table 8 Calculated maximum plane wave power density levels corresponding to the peak electric field intensity of each band.

Network Band	**Peak Electric Field Intensity (V/m)**	**Calculated Maximum Plane Wave Power Density (W/m^2)**
GSM900	0.570	4.31×10^{-4}
GSM1800	0.423	2.38×10^{-4}
UMTS	0.436	2.52×10^{-4}
LTE2.6	0.353	1.65×10^{-4}
WLan 2.4	0.028	1.04×10^{-6}

Figure 4 shows the comparison of the above-calculated plane wave power densities with the maximum permissible levels calculated in Table 7.

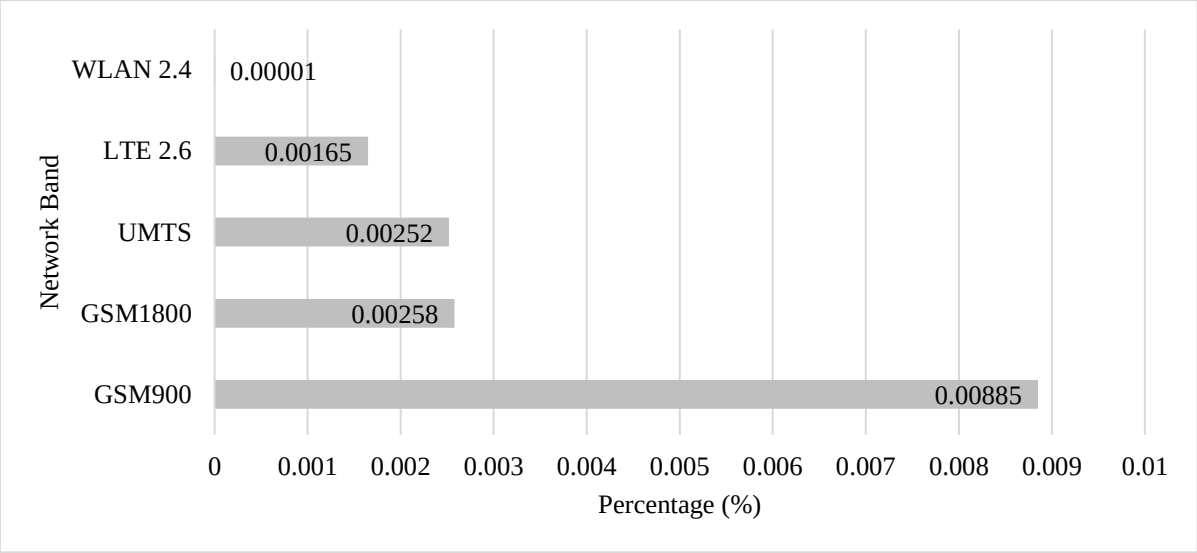


Figure 4 Percentages of the calculated maximum plane wave power densities for each network band when compared to the maximum permissible levels.

Figure 4 reveals that the maximum exposure levels are well below the maximum permissible levels. But It should be noted that above maximum permissible levels were given for the average over 30 min duration.

The specific absorption rate is another important measure used to evaluate the rate of energy absorption per unit mass of a given tissue. To calculate SAR values for the human brain, the electrical conductivity of the human brain for different frequencies should be known. Table 9 shows the average electric conductivity for the selected frequency bands in this study [12].

Table 9 Average electrical conductivity of the human brain for different frequency bands.

	Frequency (MHz)				
	900	1800	2100	2400	2600
Electrical Conductivity (S/m)	0.77	1.15	1.31	1.48	3.2

By assuming a negligible decrease in the electric field strength due to the other layers of the head, SAR values can be calculated for the maximum electric field intensities with the data in Table 9 and by taking the average density of the human brain as 1030 kg m^{-3}. Table 10 shows the calculated peak SAR values corresponding to the peak electric field strengths.

Table 10 Calculated peak SAR values for the human brain for the different network bands based on the peak electric field measurements.

Network Band	**Peak E Field (V/m)**	**Calculated SAR (W/kg)**
GSM900	0.570	2.43×10^{-4}
GSM1800	0.423	2.00×10^{-4}
UMTS	0.436	2.42×10^{-4}
LTE2.6	0.353	1.79×10^{-4}
WLan 2.4	0.028	2.44×10^{-6}

According to the international guidelines, the peak SAR limitation for the human head is 2 W/kg [12] and according to Table 10, the GSM900 band shows a maximum peak SAR value and this value is 0.012% of the maximum permissible SAR level.

4. CONCLUSION

According to this study, all the measured electric field strengths and calculated SAR values are well below the maximum permissible exposure levels. But the measured RF Levels in Colombo district show comparatively greater levels than that of Kandy district and this can not be neglected. However, children spend approximately 3 hours in their kindergartens. Therefore, If they are staying in a kindergarten having considerably higher RF exposure levels, then they might have some adverse effects due to this long period of exposure. Therefore, proper care must be taken to shield these kindergartens to avoid unnecessary RF exposure. Currently, there are no rules and regulations to measure the RF-EMR level at the site when approving a place for a kindergarten in Sri Lanka. But more prominent care should be given to these invisible RF-EMRs since the adverse effects of these radiations are currently not proven well and most of the effects are still under research.

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