

2023-12-02

Assessment of public awareness on the effects of exposure to non-ionizing radiation sources in Tanzania

Nyakyi, Christina

Elsevier B.V.

<https://doi.org/10.1016/j.jrras.2023.100770>

Provided with love from The Nelson Mandela African Institution of Science and Technology



Assessment of public awareness on the effects of exposure to non-ionizing radiation sources in Tanzania

Christina P. Nyakyi^{a,*}, Saul C. Mpeshe^b, Mussa A. Dida^a

^a School of Computational and Communication Science and Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

^b Department of Mathematics, University of Iringa, Iringa, Tanzania

ARTICLE INFO

Keywords:

Non-ionizing radiation
Electromagnetic radiation
Exposure
Public awareness
Chi square

ABSTRACT

Devices, equipment and facilities producing Non-Ionizing Radiation (NIR) are all around human environment. Exposure to NIR has effects to humans. Humans need to be aware of such effects as they are working with NIR sources and are working and living close to them. The objective of this research was to study public awareness on possible effects of exposure to NIR. The research was conducted in Mwanza, Dodoma and Dar es Salaam regions in Tanzania. Through survey, respondents were approached and voluntarily requested to complete a structured questionnaire. Descriptive statistics was employed in data analysis and frequencies were computed to determine the counts and their percentages, and Chi-Square test of independence determined the existence of significant relationship between awareness statements and demographic variables. The research involved 600 respondents (314 (52.3%) males, 286 (47.7%) females). Results show that most respondents were aware of the effects of exposure to NIR and females were more aware than males. Awareness did not differ across education levels and respondents with no/low education showed the same level of awareness as those with higher education. Based on age, respondents of all age groups demonstrated awareness of NIR effects. However, some practices like mobile phone use, watching TVs, conducting activities or living near NIR sources, are exposing people to NIR. To make people more aware of NIR exposure effects, it is recommended awareness campaigns and training be provided to the public; to minimize NIR exposure, policies, regulations and guidelines be enforced by regulatory bodies and be observed by organs owning sources producing NIR. The essence is to ensure cases of effects due to NIR exposure are minimized.

1. Introduction

Non-ionizing radiation (NIR) refers to electromagnetic radiation and fields with a photon energy lower than 10 eV, corresponding to frequencies lower than 300 GHz (3×10^{15} Hz) and wavelengths longer than 100 nm (ICNIRP, 2020). It is grouped into six different frequency or wavelength bands: ultraviolet (UV) radiation (wavelengths 100–400 nm), visible light (wavelengths 400–780 nm), infrared radiation (wavelengths 780 nm - 1 mm), radiofrequency electromagnetic fields (frequencies 100 kHz - 300 GHz), low frequency (frequencies 1 Hz –100 kHz) and static electric and magnetic fields (0 Hz) (ICNIRP, 2020), as shown in Fig. 1.

Sources of NIR are naturally occurring and manmade (Ng, 2003). Natural occurring are unregulated sources, such as sunlight, lightning discharges, cosmic rays etc. Manmade are most regulated sources, found in a controlled and manageable areas, can be seen in wireless

communications, transport industry, scientific research and medical applications. Some manmade sources which are daily and frequently used by humans are electrical and electronic devices and tools producing low frequency radiation such as cordless phones, mobile networks, microwave ovens, computers, hair dryers and wireless switches (Syaza et al., 2017).

People are exposed to NIR in different ways. People are carrying devices producing NIR e.g. mobile phones; are living/working near high voltage power lines, transmitters and base transceivers; are operating or working on/with NIR sources (e.g. hair dryer, microwaves); are watching screens with cathode ray tube such as TVs, desktop computers and oscilloscope; and are being diagnosed by magnetic resonance imaging and ultrasound. The longer and close one stays close to the source, the more s/he is exposed to NIR.

Exposure to high level NIR sources without proper protection or precaution may be harmful and can cause health effect to people in

* Corresponding author.

E-mail addresses: christinan@nm-aist.ac.tz (C.P. Nyakyi), saul.mpeshe@uoi.ac.tz (S.C. Mpeshe), mussa.ally@nm-aist.ac.tz (M.A. Dida).

<https://doi.org/10.1016/j.jrras.2023.100770>

Received 18 July 2023; Received in revised form 30 October 2023; Accepted 18 November 2023

Available online 2 December 2023

1687-8507/© 2023 The Authors. Published by Elsevier B.V. on behalf of The Egyptian Society of Radiation Sciences and Applications. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

different ways. Scholars have reported different cases of health effects to humans due to NIR exposure. Agarwal et al. (2008), Wang et al. (2017) and Kesari et al. (2018) linked NIR exposure to the effects on human health issues such as headache, sleep disturbance and male infertility. Belpomme et al. (2018) linked the NIR exposure to cancer risks and noted that people using mobile phones held to their head for extended period of time run a higher chance of acquiring brain cancer. The electromagnetic radiation from mobile phone and mobile towers has been found to be a potential cause of health problem including the possibility of brain tumors, eye cancer, leukemia and salivary gland tumors (Tambe, 2015). There is increased risk of miscarriage associated with high NIR exposure during pregnancy (Chen et al., 2017). A study done by Yu et al. (2021) found that the sperm quality is much affected by the radiations from the mobile phones. Also, a recent study by Chu et al. (2023) showed the effect of radio frequency to sperms in motility and viability is critical when the exposure increases i.e. time increases and distance decreases.

To ensure NIR exposure to humans is reduced and NIR is kept at minimum level which is safe to humans, different strategies have been adopted. The public is made aware of the negative impacts of NIR exposure. Témaugee et al. (2014) recommended that training be given to the public regarding the consequences of radiation after examining the level of awareness of those effects in Nigeria. Geofery et al. (2015) concluded that there was insufficient knowledge about NIR when analyzing the knowledge and awareness of NIR exposure among medical students at Maiduguri University, Nigeria. They suggested that the curriculum be revised to incorporate studies of NIR and its effects. A research to gauge Saudi Arabian practicing physicians' awareness of radiation exposure revealed that there was a low degree of familiarity with NIR effective doses (Abuelhia, 2016).

Some NIR sources are operated by specialized personnel from controlled locations. Dielectric heaters and sealers, which are frequently sources of NIR, ought to be used by trained personnel from safe distances or locations (Sirav et al., 2010). Patients are prevented from carrying ferromagnetic materials into the MRI facility (Hansson Mild et al., 2019). There are guidelines and standards that describe the distances from the NIR sources where the public can safely live or conduct their activities (Sharma & Lamba, 2017; Usikalu, 2014). Sharma and Lamba (2017) advised cell phone users to have brief calls and to use hand-free devices like earphones and bluetooth. Therefore, humans should keep a distance from the radiation source as well as avoiding staying too long close to it.

NIR sources are everywhere around the globe and humans are exposed to radiation from them. Our economies, social lives and health depend on the application of devices producing NIR. Since exposure to NIR can cause health effects, high levels of exposure need to be avoided to reduce health effects. The public need to be aware of possible health

effects due to excessive exposure to NIR as a strategy of minimizing cases of its effects. Thus, the objective of this study was to assess public awareness on the effects of exposure to NIR sources in Tanzania.

2. Controlling NIR exposure

Different national and international organizations have been established to regulate proper use of NIR. International Commission for Non-Ionizing Radiation Protection (ICNIRP) offers recommendations on how to protect ourselves against the harmful effects of NIR, including advice on how to restrict NIR exposure (ICNIRP, 2009; Ziegelberger et al., 2020). ICNIRP creates awareness of the dangers of NIR exposure and provides training on radiation protection procedures (ICNIRP, 2009). Institute of Electrical and Electronics Engineering (IEEE) sets standards to provide exposure limits to protect humans against adverse effects induced by exposure to NIR sources over the frequency range of 3 kHz–300 GHz (Lin, 2006). In Tanzania, the government adopted European Standards of ICNIRP to control and monitor the exposure limits (Nyakyi et al., 2013).

Occupational workers on NIR sources are trained to be aware of potential risk of NIR effects and to take appropriate precautions, but members of the public are not trained on NIR health effects (ICNIRP, 2009). Scholars are yet to study the public awareness on NIR exposure effects, but much have been published on awareness of the public on ionizing radiation effects. A study by Ribeiro et al. (2020) revealed that patients were generally lacking awareness about radiation exposure. In Nigeria, Nwodo et al. (2020) revealed poor level of knowledge and awareness of radiation hazards and protection among patients' caregivers.

Within the general public in United States, Evans et al. (2015) argued that there were many misperceptions of actual risks of exposure to ionizing radiation, particularly of medical imaging tests. In Turkey, a study by Yurt et al. (2014) demonstrated insufficient knowledge among health professions in relation to radiation, radiation protection, health risks and doses used for radiological applications in their work. Geofery et al. (2015) revealed poor knowledge on non-ionizing radiation among final year students of college of medical sciences at Maiduguri, Nigeria.

Many researches have explored the knowledge and awareness of professionals working in ionizing radiation and their patients. Results revealed that both professionals and patients are unaware of effects of radiation exposure. Scholars have not explored much on the knowledge and awareness of the public on the effects of exposure to ionizing radiation as well as NIR exposure. Thus, this study aims to bridge the gap by assessing the public awareness on the effects of exposure to NIR.

In Tanzania, ownership and use of digital devices producing NIR have increased. People are using mobile phones in the daily activities, people are watching TVs and using computers. In hospitals, medical

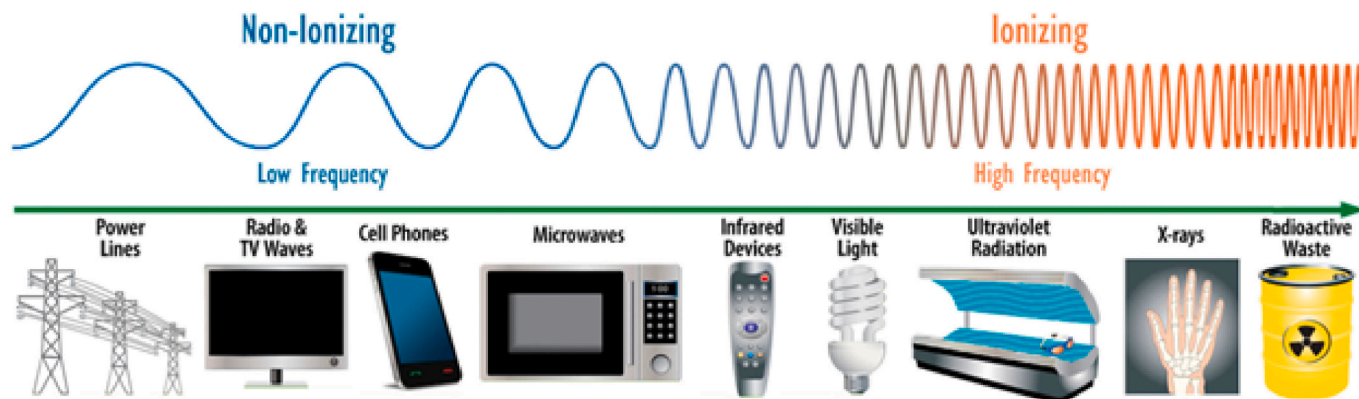


Fig. 1. Electromagnetic Spectrum (source: <https://deq.utah.gov/waste-management-and-radiation-control/non-ionizing-radiation> = date accessed 10th March 2023).

diagnoses are being carried out by devices producing NIR such as MRI and ultrasound. In some areas, people are passing near or under power lines, or are conducting their social and economic activities (e.g. farming) near power lines. Cellular towers and transmitters can be found close to human habitats. All these expose humans to NIR and thus require studying the awareness of the public on health effects of NIR exposure.

3. Research methodology

3.1. Method

The study involved six (6) districts randomly selected from three (3) regions in Tanzania. These districts were Ilemela and Nyamagana in Mwanza region, Ipagala and Chamwino in Dodoma region, and Ilala and Temeke in Dar es Salaam region. A survey research method was adopted and the researcher with the assistance of ward leaders visited the respondents to request them to participate in the study. Participation was voluntarily, respondents participated based on their availability and readiness. The research used a structured questionnaire as a tool for data collection. The questionnaire had statements measured on 5-point Likert scale (1- strongly agree, 5- strongly disagree) to assess the (un)awareness of participants on health effects of NIR exposure.

3.2. Data analysis

The research employed descriptive statistics in analyzing data collected using SPSS v.28. Frequencies were computed to determine the counts and their percentages. Chi-Square test of independence was used to determine if there was a significant relationship between awareness statements and demographic variables. Results were presented in tables.

4. Results

4.1. Demographic data

The study involved 600 respondents, where 314 (52.3%) were males and 286 (47.7%) were females as shown in Table 3. Based on education level (Table 4), 34 (7.2%) had not attended to school, 183 (30.5%) had primary education, 261 (43.5 %) had secondary education and 113 (18.8%) had university education. Age groups of respondents in years are shown in Table 5. 186 (31.0%) were 25 years or below, 268 (44.7%) were between 26 and 40 years inclusive, 130 (21.7%) were between 41 and 60 years inclusive and 13 (2.2%) were above 60 years.

4.2. Awareness of respondents on NIR exposure

Results in Table 1 indicated that majority of respondents (380 (63.3%)) had access to NIR exposure effects information. Also, a good

Table 1
NIR awareness information.

a) Whether received NIR effects information		
Response	n	% n
Yes	380	63.3
No	217	36.2
Missing	3	0.5
Total	600	100
b) Source of NIR effect information		
Source	n	% n
TV	217	36.2
Radio	58	9.7
Magazine	40	6.7
Internet	151	25.2
Other sources	43	7.2

Table 2
Assessing awareness of respondents on NIR exposure effects.

Statements	Aware		Unaware	
	n	%n	n	%n
It is fine to sleep with mobile phone ON and close to my body	515	85.83	84	14.00
I can use the mobile phone (e.g. calling) while charging without any problem	509	84.83	90	15.00
I can use the mobile phone with low charge without any problem	407	67.83	191	31.83
I can talk over the mobile phone for long time (e.g. some hours) without any problem	451	75.17	148	24.67
Use of voice call to communicate is better than texting	337	56.17	262	43.67
It is fine to use mobile phone while the signal strength is poor	463	77.17	136	22.67
It is fine to talk over the mobile phone without using hand free speaker, earphone or headphone	452	75.33	147	24.50
It is fine to provide a mobile phone to child under sixteen years old	559	93.17	40	6.67
Using a microwave oven while standing in front of it is fine.	388	64.67	197	32.83
Using a leaking or damaged microwave oven it is fine.	457	76.17	130	21.67
It is fine to operate a microwave cooker without putting on a protective gear.	434	72.33	153	25.50
It is fine to watch a TV while sitting straight in front of it	431	71.83	168	28.00
It is fine watching TV without put on sunglasses	407	67.83	191	31.83
It is fine watching TV or desktop screen without screen protector	433	72.17	165	27.50
It is fine for child to watch TV more than 5 h a day	544	90.67	55	9.17
Is fine to make hair style on hairdryer more than one per week.	432	72.00	155	25.83
Is fine with me to use hairdryer without ear protective gear	477	79.50	111	18.50
It is fine to work on hairdryer without any precaution	506	84.33	82	13.67
It is fine to construct building for social activities such as schools, market and hospital at the proximity of tower/transmitters for TV and Radio	511	85.17	89	14.83
It is fine to conduct social activities such as schools, market and hospital at the proximity of tower/transmitters for TV and Radio	532	88.67	68	11.33
Living near a tower or transmitter is fine.	506	84.33	94	15.67
It is okay to fix a tower/transmitter at the top of a roof.	536	89.33	64	10.67
It is fine to work near the tower/transmitter without putting on protective gears.	547	91.17	53	8.83
It is fine to conduct social activities such as church, schools, market, hospital, playgrounds at the vicinity of High Voltage Transmission Lines	519	86.50	81	13.50
Living near a High Voltage Transmission Lines is safe.	540	90.00	60	10.00
I can work at High Voltage Transmission Lines without putting on electric protective tools	547	91.17	53	8.83
It is safe to work on substations without protective gears	553	92.17	47	7.83
It is ok to stay at substation more than 5 h a day	527	87.83	73	12.17

number of respondents i.e. 217(63.3%) had no access to information about NIR. Respondents received NIR effects information from different sources as indicated in Table 1. Most respondents (36.2%) received information through the TVs, 25.2% accessed the information from the Internet and others received information by listening radios, reading magazines and other sources.

To assess the awareness of respondents on NIR exposure, their use of mobile phones, microwave ovens, TVs and hair dryers, and activities they conduct near cellular towers, radio and TV transmitters, power lines and substations, were assessed. Respondents were considered to be aware if they either answered strongly disagree or disagree; neutral, agree or strongly agree responses were considered to be not aware.

Table 3
Awareness Among Respondents based on gender.

Statement	Response	Gender				p
		Male N = 314		Female (N = 286)		
		n	n%	n	n%	
Sleeping with mobile phone turned ON is fine	Aware	266	84.7	249	87.1	0.485
	Not aware	47	15.0	37	12.9	
Using mobile phone while in charging socket is fine	Aware	263	83.8	246	86.0	0.503
	Not aware	50	15.9	40	14.0	
Using mobile phone with lower power or battery is fine	Aware	203	64.6	204	71.3	0.104
	Not aware	109	34.7	82	28.7	
Making calls for longtime is fine	Aware	231	73.6	220	76.9	0.428
	Not aware	82	26.1	66	23.1	
Making more calls than texting is good	Aware	173	55.1	164	57.3	0.556
	Not aware	140	44.6	122	42.7	
Using mobile-phone with inadequate signal strength is fine	Aware	242	77.1	221	77.3	0.634
	Not aware	71	22.6	65	22.7	
Using mobile-phone without header-phone, earphone or loudspeaker is fine	Aware	236	75.2	216	75.5	0.633
	Not aware	77	24.5	70	24.5	
Standing front of microwave while operating is fine	Aware	194	61.8	194	67.8	0.217
	Not aware	110	35.0	87	30.4	
Is good to operate the defective and leakage microwave oven	Aware	235	74.8	222	77.6	0.415
	Not aware	70	22.3	60	21.0	
Watching TV while standing front of it is fine	Aware	216	68.8	215	75.2	0.155
	Not aware	97	30.9	71	24.8	
Keeping kids watching TV more than 5 h is fine	Aware	224	71.3	209	73.1	0.888
	Not aware	89	28.3	76	26.6	
Using hairdryer more than 30 min a day is fine	Aware	207	65.9	230	80.4	0.000
	Not aware	98	31.2	53	18.5	
Using hairdryer more than once a week is OK	Aware	207	65.9	225	78.7	0.001
	Not aware	97	30.9	58	20.3	
Using hairdryer without putting ear-protector is fine	Aware	235	74.8	242	84.6	0.009
	Not aware	70	22.3	41	14.3	
Using hairdryer without following protective procedure is fine	Aware	246	78.3	260	90.9	0.000
	Not aware	59	18.8	23	8.0	
Conducting social activities proximity towers is OK	Aware	280	89.2	252	88.1	0.682
	Not aware	34	10.8	34	11.9	
Living proximity to cellular tower, radio and TV transmitters is fine	Aware	268	85.4	238	83.2	0.473
	Not aware	46	14.6	48	16.8	
Working on towers without putting personal protective equipment (PPE) is OK	Aware	289	92.0	258	90.2	0.431
	Not aware	25	8.0	28	9.8	
Constructing building at HVPL is fine	Aware	275	87.6	244	85.3	0.417
	Not aware	39	12.4	42	14.7	
Working on HVPL without PPE is fine	Aware	294	93.6	253	88.5	0.026
	Not aware	20	6.4	33	11.5	
Working on Power Substation without putting PPE is fine	Aware	294	93.6	259	90.6	0.162
	Not aware	20	6.4	27	9.4	
Stay more than 5 h a day at Power Substation is fine	Aware	279	88.9	248	86.7	0.423
	Not aware	35	11.1	38	13.3	

Descriptive statistics analysis was conducted to determine the frequencies (n) and percentages (%n) of (un)awareness and results are depicted in [Table 2](#).

Results in [Table 2](#) show that most respondents are aware of the effects of exposure to NIR sources and can use and conduct activities near the NIR sources safely. Over 50% of respondents indicated they can use the mobile phones, microwave ovens, TVs and hair dryers safely. Also, over 50% of respondents indicated that they can conduct their economic and social activities daily near the NIR sources such as transmitters and power lines safely. However, in some cases, a good percentage of respondents indicated they are not aware of effects of NIR. 31.83% indicated they can use the mobile phone with low charge, 24.67% can talk over the mobile phone for long time, 43.67% agreed that it is better to use voice call than texting and 24.50% agreed to talk over the mobile phone without using hand free speaker, earphone or headphone. On microwave oven use, 32.83% can operate while standing in front of it and 25.5% can operate it without putting on a protective gear. On television use, 28% accepted watching while sitting straight in front of it, 31.83% accepted watching it without put on sunglasses and 27.5% accepted watching TV or desktop screen without screen protector. On hair dryer use, 25.17% indicated that it is fine to stay on it for more than 30 min and 25.83% indicated that it is fine to dry hair more than once per week. In all aspects, less than 14% of respondents indicated that they can conduct their daily and social activities near the NIR sources such as transmitters and power lines.

4.3. Awareness based on demographic data

Based on gender, results in [Table 3](#) show that females were more aware on NIR effects than males. Of the 22 statements, females had greater percentages in 15 statements. In dealing with the correlation of outcomes with the demographic data, 5 statements were of significance since the significance level were below 5%. Statements such as *using hair dryer more than 30 min is fine* ($\chi^2[2, N = 600] = 16.350; P < .000$); *using hair dryer more than once a week is ok* ($\chi^2[2, N = 600] = 13.054; P = .001$); *using hair dryer without putting ear-protector is fine* ($\chi^2[2, N = 600] = 9.393; P = .009$); *using hair dryer without following protective procedure is fine* ($\chi^2[2, N = 600] = 17.925; P < .000$); *working on HVPL without PPE is fine* ($\chi^2[1, N = 600] = 4.966; P = .026$) show that females were more aware than males.

The assessment of awareness of NIR effects based on education level is presented in [Table 4](#). Results show that 6 statements were significant: *sleeping with mobile phone turned ON is fine* ($\chi^2[8, N = 591] = 15.879; P = .044$); *using mobile-phone without header-phone, earphone or loudspeaker is fine* ($\chi^2[8, N = 591] = 16.075; P = .041$); *is good to operate the defective and leakage microwave oven* ($\chi^2[8, N = 591] = 32.522; P < .000$); *keeping kids watching TV more than 5 h is fine* ($\chi^2[8, N = 591] = 19.723; P = .011$); *using hair dryer more than 30 min is fine* ($\chi^2[8, N = 591] = 16.180; P = .040$); and *constructing building at High Voltage Power Lines (HVPL) is fine* ($\chi^2[4, N = 591] = 10.268; P = .036$).

[Table 5](#) presents the assessment of awareness of exposure to NIR on effects based on age, categorized into four groups. 5 statements were significant and showed the association between awareness and age: *using mobile phone with lower power or battery is fine* ($\chi^2[8, N = 597] = 16.645; P = .034$); *using hair dryer more than 30 min is fine* ($\chi^2[8, N = 597] = 19.124; P = .014$); *using hair dryer more than once a week is ok* ($\chi^2[8, N = 597] = 19.878; P = .011$); *using hair dryer without putting ear-protector is fine* ($\chi^2[8, N = 597] = 19.838; P = .011$); and *using hair dryer without following protective procedure is fine* ($\chi^2[8, N = 597] = 19.236; P = .014$).

5. Discussion

Results have shown that most respondents are aware of the effects of exposure to NIR. This suggests that people know how to operate devices

Table 4
Output against education level.

Statement	Responses	Education Level								P
		None (N = 34)		Primary (N = 183)		Secondary (N = 261)		University (N = 113)		
		n	%n	n	%n	n	%n	n	%n	
Sleeping with mobile phone turned ON is fine	Aware	24	70.6	150	82.0	228	87.4	105	92.9	0.044
	Not aware	10	29.4	32	17.5	33	12.6	8	7.1	
Using mobile phone while in charging socket is fine	Aware	28	82.4	157	85.8	230	88.1	86	76.1	0.160
	Not aware	6	17.6	25	13.7	31	11.9	27	23.9	
Making calls for longtime is fine	Aware	24	70.6	137	74.9	207	79.3	75	66.4	0.220
	Not aware	10	29.4	45	24.6	54	20.7	38	33.6	
Making more calls than texting is good	Aware	18	52.9	107	58.5	154	59.0	52	46.0	0.348
	Not aware	16	47.1	75	41.0	107	41.0	61	54.0	
Using mobiles with inadequate signal strength is fine	Aware	26	76.5	136	74.3	211	80.8	83	73.5	0.669
	Not aware	8	23.5	46	25.1	50	19.2	30	26.5	
Use mobile without header-phone, earphone or loudspeaker is fine	Aware	23	67.6	127	69.4	215	82.4	79	69.9	0.041
	Not aware	11	32.4	55	30.1	46	17.6	34	30.1	
Allow child <10 years to possess and or use mobile-phone is fine	Aware	32	94.1	170	92.9	251	96.2	98	86.7	0.084
	Not aware	2	5.9	12	6.6	10	3.8	15	13.3	
Is good to operate the defective and leakage microwave oven	Aware	26	76.5	129	70.5	175	67.0	51	45.1	0.000
	Not aware	6	17.6	49	26.8	79	30.3	61	54.0	
Watching TV while standing front of it is fine	Aware	25	73.5	132	72.1	198	75.9	72	63.7	0.351
	Not aware	8	23.5	46	25.1	57	21.8	40	35.4	
Keeping kids watching TV more than 5 h a day is fine	Aware	26	76.5	118	64.5	196	75.1	61	54.0	0.011
	Not aware	8	23.5	64	35.0	65	24.9	51	45.1	
Using hairdryer more than 30 min a day is fine	Aware	23	67.6	133	72.7	200	76.6	72	63.7	0.040
	Not aware	10	29.4	43	23.5	58	22.2	40	35.4	
Using hairdryer without putting ear-protector is fine	Aware	25	73.5	135	73.8	221	84.7	87	77.0	0.071
	Not aware	8	23.5	41	22.4	37	14.2	25	22.1	
Using hairdryer without following protective procedure is fine	Aware	26	76.5	145	79.2	232	88.9	96	85.0	0.139
	Not aware	7	20.6	31	16.9	26	10.0	16	14.2	
Conduct social activities proximity to transmitters is OK	Aware	28	82.4	158	86.3	240	92.0	97	85.8	0.126
	Not aware	6	17.6	25	13.7	21	8.0	16	14.2	
Living proximity to cellular tower, radio and TV transmitters is fine	Aware	28	82.4	153	83.6	225	86.2	93	82.3	0.824
	Not aware	6	17.6	30	16.4	36	13.8	20	17.7	
Putting cellular tower at top floor of building is fine	Aware	30	88.2	162	88.5	230	88.1	105	92.9	0.530
	Not aware	4	11.8	21	11.5	31	11.9	8	7.1	
Working on towers without putting PPE is OK	Aware	29	85.3	162	88.5	242	92.7	106	93.8	0.302
	Not aware	5	14.7	21	11.5	19	7.3	7	6.2	
Constructing building at HVPL is fine	Aware	29	85.3	163	89.1	230	88.1	88	77.9	0.036
	Not aware	5	14.7	20	10.9	31	11.9	25	22.1	
Conducting social activities proximity to HVPL is well	Aware	30	88.2	164	89.6	239	91.6	98	86.7	0.523
	Not aware	4	11.8	19	10.4	22	8.4	15	13.3	
Working on HVPL without PPE is fine	Aware	29	85.3	160	87.4	246	94.3	103	91.2	0.072
	Not aware	5	14.7	23	12.6	15	5.7	10	8.8	
Working on Power Substation without putting PPE is fine	Aware	31	91.2	164	89.6	246	94.3	104	92.0	0.493
	Not aware	3	8.8	19	10.4	15	5.7	9	8.0	
Stay more than 5 h a day at Power Substation is fine	Aware	27	79.4	157	85.8	234	89.7	101	89.4	0.400
	Not aware	7	20.6	26	14.2	27	10.3	12	10.6	

producing NIR such as mobile phones, microwaves, hair dryer and televisions. People can also safely conduct their economic and social activities daily near NIR sources such as power lines, substations and transmitters. As ownership and use of devices producing NIR increase, people can take precautions on how to operate them. Infrastructure producing NIR are also extending within human vicinity; people can safely conduct their economic and social activities daily close to them.

For cases where awareness statements associate with education level ($p < .05$), respondents with no formal education and with lower education level demonstrated the same level of awareness as those with higher education level. In some cases, higher percentages of respondents with university education were not aware of NIR effects. For example, 54.0% of respondents with university education were not aware that it is not safe to operate a defective and leaking microwave oven. In some cases, a slightly higher percentage demonstrated awareness of NIR effects. For example, 54.0% of respondents with university education were aware that keeping kids watching TVs more than 5 h five hours is not safe.

Also, cases where awareness on NIR health effects associate with age ($p < .05$), respondents of all age categories demonstrated awareness of NIR effects. Respondents with ages between 41 and 60 years inclusive

had almost the same percentage of responses on awareness statements. Respondents with 40 years and below had varying percentages of awareness and those with greater than 60 years had low and varying percentages of awareness.

However, in countries like Tanzania we can observe practices that are exposing people to NIR. People are more accustomed to calling than texting. You may find an individual spending a considerable time on mobile phone calling without aid of devices like earphones. Also, you may find an individual sleeping with his/her mobile phone ON close to his/her body and sometimes talking over the phone with low charge battery. Elders are allowing children to talk over the phone for some time and use mobile phones for watching videos and playing games.

Use of televisions is also exposing individuals to NIR. People are watching televisions while sitting in front and close to them, endangering their health. Also, people spend much time more than 5 h watching their favorable programs in televisions. In streets, one can observe cellular towers installed close to buildings where people live. People are conducting their activities near transmitters and power lines. One can see farms near transmitters, cattle are being grazed near transmitters or even below power lines. In some cases, people are doing businesses near substations like transformers, children are also playing

Table 5
Output against age.

Statements	Responses	Age								p
		N = 186 (≤25)		N = 268 (26–40)		N = 130 (41–60)		N = 13 (>60)		
		n	%n	n	%n	n	%n	n	%n	
Sleeping with mobile phone turned ON is fine	Aware	163	87.6	231	86.2	108	83.1	11	84.6	0.698
	Not aware	23	12.4	37	13.8	21	16.2	2	15.4	
Using mobile phone while in charging socket is fine	Aware	159	85.5	224	83.6	110	84.6	13	100.0	0.546
	Not aware	27	14.5	44	16.4	19	14.6	0	0.0	
Using mobile phone with lower power or battery is fine	Aware	133	71.5	167	62.3	93	71.5	11	84.6	0.034
	Not aware	53	28.5	101	37.7	35	26.9	2	15.4	
Making calls for longtime is fine	Aware	140	75.3	197	73.5	102	78.5	10	76.9	0.736
	Not aware	46	24.7	71	26.5	27	20.8	3	23.1	
Making more calls than texting is good	Aware	103	55.4	150	56.0	75	57.7	8	61.5	0.793
	Not aware	83	44.6	118	44.0	54	41.5	5	38.5	
Giving child under ten years to possess and or using mobile-phone is fine	Aware	178	95.7	247	92.2	119	91.5	13	100.0	0.695
	Not aware	8	4.3	21	7.8	10	7.7	0	0.0	
Is fine standing front of microwave while is working	Aware	123	66.1	166	61.9	89	68.5	8	61.5	0.740
	Not aware	60	32.3	96	35.8	36	27.7	4	30.8	
Is good to operate the defective and leakage microwave oven	Aware	123	66.1	166	61.9	89	68.5	8	61.5	0.630
	Not aware	60	32.3	96	35.8	36	27.7	4	30.8	
Watching TV or desktop without screen protector is fine	Aware	137	73.7	184	68.7	98	75.4	9	69.2	0.476
	Not aware	49	26.3	84	31.3	31	23.8	4	30.8	
Keeping kids watching TV more than 5 h is fine	Aware	123	66.1	187	69.8	87	66.9	8	61.5	0.961
	Not aware	63	33.9	80	29.9	42	32.3	5	38.5	
Using hairdryer more than 30 min is fine	Aware	141	75.8	191	71.3	94	72.3	9	69.2	0.014
	Not aware	42	22.6	72	26.9	34	26.2	3	23.1	
Using hairdryer more than once a week is OK	Aware	129	69.4	194	72.4	100	76.9	7	53.8	0.011
	Not aware	53	28.5	69	25.7	28	21.5	5	38.5	
Using hairdryer without putting ear-protector is fine	Aware	151	81.2	209	78.0	107	82.3	9	69.2	0.011
	Not aware	32	17.2	54	20.1	21	16.2	3	23.1	
Using hairdryer without following protective procedure	Aware	160	86.0	226	84.3	109	83.8	9	69.2	0.014
	Not aware	23	12.4	37	13.8	19	14.6	3	23.1	
Constructing buildings for churches, schools, hospitals, etc, at proximity towers is fine	Aware	151	81.2	236	88.1	108	83.1	13	100.0	0.119
	Not aware	35	18.8	32	11.9	22	16.9	0	0.0	
Living proximity to cellular tower, radio and TV transmitters is fine	Aware	147	79.0	234	87.3	112	86.2	11	84.6	0.147
	Not aware	39	21.0	34	12.7	18	13.8	2	15.4	
Working on towers without personal protective equipment (PPE) is OK	Aware	172	92.5	244	91.0	115	88.5	13	100.0	0.536
	Not aware	14	7.5	24	9.0	15	11.5	0	0.0	
Working on High Voltage Power Line (HVPL) without PPE is fine	Aware	169	90.9	245	91.4	118	90.8	12	92.3	0.984
	Not aware	17	9.1	23	8.6	12	9.2	1	7.7	
Working on Power Substation without putting PPE is fine	Aware	169	90.9	248	92.5	120	92.3	13	100.0	0.763
	Not aware	17	9.1	20	7.5	10	7.7	0	0.0	
Stay more than 5 hs a day at Power Substation is fine	Aware	159	85.5	238	88.8	115	88.5	12	92.3	0.753
	Not aware	27	14.5	30	11.2	15	11.5	1	7.7	

near transformers. All these expose people to NIR.

Thus, observations reveal that people are exposed to NIR through the devices they own and even through the facilities within their environment. Guidelines, rules and policies are provided. In some places, danger signs are provided.

6. Recommendations

Sources producing NIR have proved to be essential to our daily lives. We always depend on them; they make our lives better. To be aware means to know their possible effects when we are exposed to radiation from them. One can take the precautions to ensure s/he does not absorb radiation from them. Guidelines, rules and policies are provided to ensure we live with sources producing NIR safely. Awareness will enable individuals to observe and follow prescribed guidelines and rules when exposed to NIR. Thus, it is recommended to make the public aware of possible effects when exposed to NIR sources by:

- a. Having awareness campaigns: through these campaigns, public can learn the potential effects of NIR, how safely to operate devices producing NIR and also how safely to conduct their activities close to sources of NIR. Leaflets and brochures campaigns can be promoted,

radio and TV campaigns can be conducted to help raise the awareness.

- b. Providing training: training can be provided in places where the public meet e.g. in schools. Training can also be provided in organized meetings in places where researches can indicate the need to raise the awareness of the risks of exposure to NIR.
- c. The optimal technique can be included in order to minimize the exposure from NIR sources to the society like cellular towers, radio and television transmitter.

The government through the responsible organs, like Tanzania Atomic Energy Commission (TAEC) and Tanzania Communication Regulatory Authority (TCRA) needs to enforce the associated policies by ensuring the guidelines, regulations and rules are observed and followed. For example, mobile phone companies can install their communication towers while observing safety rules. Also, people can no longer establish their settlement close to sources producing NIR and even conduct their economic and social activities close to them. Also, the study suggested to take some measures or controls for optimizing the NIR exposure dose in minimizing the exposure level to the members of the public and environment in large.

7. Conclusion

Result has shown people are aware of the risks of exposure to NIR and the study recommended to raise awareness among more people. Strategies need to be adopted to raise public awareness on matters related to NIR. Policies that guide safe exposure to NIR need to come into operations. People of all sex, age and education level needs to be included as results have shown. Government can invest more in information, communication and education that target raising the awareness. The essence is to minimize the possible risks of exposure to NIR.

Acknowledgments

It is greatly appreciated that this work was supported and funded by the Tanzania Atomic Energy Commission (TAEC) and The Nelson Mandela African Institution of Science and Technology (NM-AIST).

References

- Abuelhia, E. (2016). Awareness of ionizing radiation exposure among junior doctors and senior medical students in radiological investigations. *Journal of Radiological Protection*, 37(1), 59.
- Agarwal, A., Deepinder, F., Sharma, R. K., Ranga, G., & Li, J. (2008). Effect of cell phone usage on semen analysis in men attending infertility clinic: An observational study. *Fertility and Sterility*, 89(1), 124–128.
- Belpomme, D., Hardell, L., Belyaev, I., Burgio, E., & Carpenter, D. O. (2018). Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environmental Pollution*, 242, 643–658.
- Chen, H., Ferber, J. R., Odouli, R., & Quesenberry, C. (2017). Exposure to magnetic field non-ionizing radiation and the risk of miscarriage: A prospective cohort study. *Scientific Reports*, 7(1), Article 17541.
- Chu, K. Y., Khodamoradi, K., Blachman-Braun, R., Dullea, A., Bidhan, J., Campbell, K., Zizzo, J., Israeli, J., Kim, M., & Petrella, F. (2023). Effect of radiofrequency electromagnetic radiation emitted by modern cellphones on sperm motility and viability: An in vitro study. *European Urology Focus*, 9(1), 69–74.
- Evans, K. M., Bodmer, J., Edwards, B., Levins, J., O'Meara, A., Ruhotina, M., Smith, R., Delaney, T., Hoffman-Contois, R., & Boccuzzo, L. (2015). An exploratory analysis of public awareness and perception of ionizing radiation and guide to public health practice in Vermont. *Journal of Environmental and Public Health*. <https://doi.org/10.1155/2015/476495>, 2015.
- Geofery, L., Basirat, M., Eze, C. U., Chigozie, N. I., Auwal, A., Kalu, O., Bobuin, N. F., Moi, N. M. A. S., & Mathew, A. G. (2015). Evaluation of the knowledge and awareness of non-ionizing radiation among final year students of College of Medical Science University of Maiduguri. *Int Res J Pure Appl Phys*, 3(3), 8–14.
- Hansson Mild, K., Lundström, R., & Wilén, J. (2019). Non-ionizing radiation in Swedish health care—exposure and safety aspects. *International Journal of Environmental Research and Public Health*, 16(7), 1186.
- ICNIRP. (2009). ICNIRP statement on the “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz).” *Health Physics*, 97(3), 257–258.
- ICNIRP. (2020). Principles for non-ionizing radiation protection. *Health Physics*, 118(5), 477–482.
- Kesari, K. K., Agarwal, A., & Henkel, R. (2018). Radiations and male fertility. *Reproductive Biology and Endocrinology*, 16(1), 1–16.
- Lin, J. C. (2006). A new IEEE standard for safety levels with respect to human exposure to radio-frequency radiation. *IEEE Antennas and Propagation Magazine*, 48(1), 157–159.
- Ng, K.-H. (2003). Non-ionizing radiations—sources, biological effects, emissions and exposures. *Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN*, 1–16.
- Nwodo, V. K., Chiaghanam, N. O., Ogolodom, M. P., Ohagwu, C. C., Nwodo, C. U., Agbadaola, O. A., Mbaba, A. N., Ezenma, I. C., & Abubakar, U. (2020). Assessment of knowledge and awareness of radiation hazards and protection among patient's relative in Southeast, Nigeria. *Journal of Clinical and Diagnostic Research*, 14(8).
- Nyakyi, C. P., Kalolo, S., Byanyuma, M., & Sam, A. (2013). Assessment of electromagnetic radiations from communication transmission towers—A case study of Tanzania. *International Journal of Renewable Energy Technology*, 8(2), 349–352.
- Ribeiro, A., Husson, O., Drey, N., Murray, I., May, K., Thurston, J., & Oyen, W. (2020). Ionising radiation exposure from medical imaging—A review of Patient's (un) awareness. *Radiography*, 26(2), e25–e30.
- Sharma, A. B., & Lamba, O. S. (2017). A review: Source and effect of mobile communication radiation on human health. *Advances in Wireless and Mobile Communications*, 10(3), 423–435.
- Sirav, B., Tuysuz, M. Z., Canseven, A. G., & Seyhan, N. (2010). Evaluation of non ionizing radiation around the dielectric heaters and sealers: A case report. *Electromagnetic Biology and Medicine*, 29(4), 144–153.
- Syaza, S. K. F., Umar, R., Hazmin, S. N., Kamarudin, M. K. A., Hassan, A., & Juahir, H. (2017). Non-ionizing radiation as threat in daily life. *Journal of Fundamental and Applied Sciences*, 9(2S), 308–316.
- Tambe, K. M. (2015). Review of Mobile tower radiation effects on Human and Mitigation techniques. *International Journal on Recent and Innovation Trends in Computing and Communication*, 3(2), 622–625.
- Temaagee, S. T., Daniel, T. A., Oladejo, K. O., & Daniel, S. (2014). Assessment of public awareness of the detrimental effects of ionizing radiation in Kontagora, Niger State, Nigeria. *International Journal of Science and Technology*, 4(7), 2224–3577.
- Usikalu, M. R. (2014). Safe distance to extremely low frequency radiation associated with power transmission lines located in Ota, Southwest, Nigeria. *International Journal of Engineering & Technology*, 14(2), 118–121.
- Wang, J., Su, H., Xie, W., & Yu, S. (2017). Mobile phone use and the risk of headache: A systematic review and meta-analysis of cross-sectional studies. *Scientific Reports*, 7(1), Article 12595.
- Yu, G., Bai, Z., Song, C., Cheng, Q., Wang, G., Tang, Z., & Yang, S. (2021). Current progress on the effect of mobile phone radiation on sperm quality: An updated systematic review and meta-analysis of human and animal studies. *Environmental Pollution*, 282, Article 116952.
- Yurt, A., Çavuşoğlu, B., & Günay, T. (2014). Evaluation of awareness on radiation protection and knowledge about radiological examinations in healthcare professionals who use ionized radiation at work. *Mol Imaging Radionucl Ther*, 23(2), 48–53.
- Ziegelberger, G., van Rongen, E., Croft, R., Feychting, M., Green, A. C., Hirata, A., d'Inzeo, G., Marino, C., Miller, S., & Oftedal, G. (2020). Principles for non-ionizing radiation protection. *Health Physics*, 118(5), 477–482.