Health implications of Non-Ionizing Radiation from the home appliances in Dhaka City

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A thesis submitted to the Department of Mathematics and Natural Sciences in partial fulfillment of the requirements for the degree of Ms in Biotechnology

Department of Mathematics and Natural Sciences

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Declaration

It is hereby declared that:

1. The thesis submitted is my own original work while completing a degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Abstract

Modern science gave rise to the invention of various technologies and incorporated several electronics, electrical appliances, and devices into our daily lives, leaving us exposed to non-ionizing radiation (NIR). Despite a large number of studies on NIR, limited work has been done to examine its effects from home appliances in Dhaka city. Hence, this study aims to bridge that gap by measuring various Electromagnetic fields (EMF) sources from the domestic environment, focusing on magnetic fields, electric fields, and radio frequency. The study also focused on health issues and awareness among 67 households. Measurements were taken for 1009 appliances and devices. And the health outcomes were assessed through a well-structured questionnaire. The results showed that magnetic field exposure was highest near fans and iron machines, while electric field levels peaked around microwaves, multiple plugs, and refrigerators. Radio frequency exposure was dominated by Wi-Fi routers, mobile phones, and laptops. However, all the values remained well below the international safety threshold. There were some common health issues reported, which are stress, mental health problems, vision problems, cognitive issues, cancer, etc. Even though there was not much conclusive evidence, as no lab tests were done to confirm the relation between biological issues and non-ionizing radiation, it can be inferred that there are some connections between constant exposure to EMF and issues such as cancer, stress, and psychological problems. Public education, safe appliance design, further experiment, and longitudinal research are recommended.

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INTRODUCTION

Without the slightest hint of doubt, the advent of modern science gave us the wondrous gift of electricity and hence such a technological revolution. Being the source of energy and power, electricity gave us the ease and comfort of various electronics, electrical devices, and appliances. These appliances, equipment, wiring used at home, etc., use electricity and so contain electric and magnetic fields or EMF (Electromagnetic Field). Electromagnetic fields can occur both naturally and in man-made ways, constantly exposing us to this invisible field from different sources. The natural EMF comes in a variety of frequencies, ranging from low frequencies (0e50 Hz) up to high levels at 5 GHz (wireless LAN). Apart from this, in the 20th century, various new sources of EMF started emerging due to new electricity supply grids, becoming the source of extremely low-frequency EMF. [1] Compared to natural sources, human sources result in way more EMF through the generation, distribution, transmission, and application of electricity in workplaces and at home.

The perpendicular oscillations of the electric and magnetic fields give rise to electromagnetic waves. Electromagnetic waves can be distinguished as ionizing radiation (IR) or non-ionizing radiation (NIR). Ionizing radiation, such as X-rays and Gamma rays, can cause ionization in cells, whereas non-ionizing radiation, like ultraviolet radiation, visible light, infrared radiation, microwaves, and radio waves, cannot ionize cells. These rather cause biological effects, such as heating, inducing electrical currents in tissues and cells, and possibly damage to DNA molecules [2]. NIR or Non-Ionizing radiations have a few categories depending on their frequency and

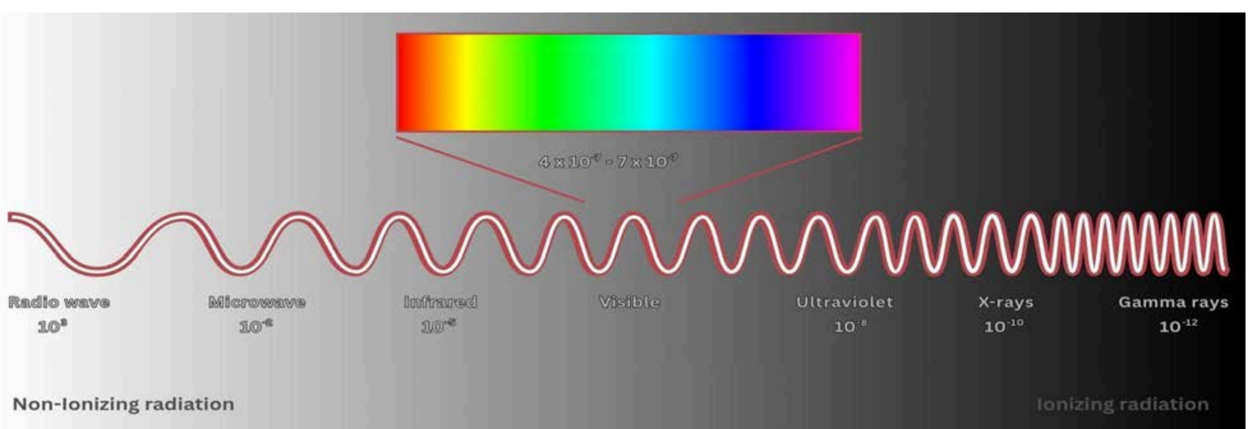


Figure 1: Electromagnetic Field Spectrum

wavelength, these are: radiofrequency (RF) radiation (30 kHz), microwave radiation (300 MHz to 300 GHz), infrared radiation (300 GHz to 400 THz), visible light (400 to 800 THz), and ultraviolet radiation (800 THz to 30 PHz) [3] Even when NIR seems comparatively harmless, it is essential to be careful of the detrimental impacts of radiation from the EMF or nonionizing radiation (NIR) emitting from high power transmission lines, video display unit, computer, laptop, fridge, router, and many other home appliances, office equipment, Telecommunication equipment, Laboratory equipment in schools, colleges and university.[4-7].

When it comes to debating the health impacts of non-ionizing radiation, two distinct sets of beliefs prevail. One belief is inclined to the fact that NIR can only dislodge electrons and hence cannot cause cancer. It is believed that RF and MW radiation only cause heating and are safe below thermal guidelines. This is because the scientific evidence regarding adverse health impacts due to NIR is inconclusive. Another group believes numerous evidence of biological concerns documented in several studies and concluded that the NIR is harmful even below the thermal guidelines, causing health issues like cancer, reproductive complications, and others. [8]

Despite the debate, it is reported that the high-frequency, low-frequency, and extremely low-frequency EMF instruments have harmful effects on the human body and low-level animals. As the magnetic field (MF) is more harmful than the electric field (EF), it is called 'the silent killer' by scientists. Short-term exposure to high EMF or EMR (Electromagnetic radiation) may result in an effect on the central nervous system or can produce muscle or nerve stimulation. [8-12]. On the other hand, long-term continuous exposure to EMF or EMR causes the risk of childhood leukemia, cancer in adults, psychological issues, cardiovascular diseases, reproductive malfunction, developmental disorders, impact on the immune system, and neurodegenerative issues. The radiation (EMR) from the EMF has been declared to be possibly carcinogenic in 2011 by the WHO [13-20]. The rising issue about EMF and NIR drove scientists all over the world towards a lot of research.

Investigation of RF and EM radiation has been done in various locations around the world. Even though there is insufficient data that reflects health impacts from day-to-day exposure, there has been data signifying the intense effect of RF-EMF [21]. Even in Bangladesh, several studies were also done, especially in its capital, Dhaka, due to the rising use of electronics, appliances, and electrical devices as the people keep up with the rest of the world.

Even though more attention is usually paid to high-powered EMF sources in labs and work environments, electrical appliances at home often are the source of the highest magnetic field levels experienced. [22]. At home, one can get electromagnetic field exposure from various internal and external sources. Internal sources include electrical wiring, televisions, computers, mobile phones, vacuum cleaners, refrigerators, washing machines, microwave ovens, food processors, etc., whereas the external ones include high-voltage power transmission lines, electric vehicles, transformers, substances, cell towers, etc. This, often termed as 'electromagnetic pollution' or 'electrosmog', spreading huge amounts of radiation has become a source of great public concern [23-24]. For this reason, it is becoming a very important task to assess the level of EMR exposure to humans from various sources found at home. These studies will help to develop steps and measures focusing on reducing the risk of EMF to human health. [25]

Just like all the other developing nations, Bangladesh is gradually adopting modern technology and advanced electronic features. Cities like Dhaka are constantly getting dense in electromagnetic fields due to the rise in the use of mobile phones, wireless appliances, and technology. Yet, government directives, public policy, and awareness levels are underdeveloped and almost non-existent. There is not even any consistent monitoring of EMF or the barely prevailing regulations. Even though multiple studies and a huge amount of data can be found for EMF all over the world, for laboratories and occupational environments, not much research has been done regarding the EMF sources from home appliances in Bangladesh. Moreover, even fewer studies properly describe whether the appliances at home are under the safety threshold limit. There is also a lack of assessment of the proper health issues posed by NIR from home appliances. Because of this issue, the general public, regulatory bodies, and health workers remain mostly oblivious or unaware of the health concerns and safety limits.

So, the major questions remain hanging in the air- what are the levels of EMF emission from common household appliances and electronic devices, and do these comply with the limits set by international safety guidelines? What are the potential biological impacts of constant or prolonged exposure to the non-ionizing electromagnetic field radiation coming from these sources? What can the general public do to be aware of and conscious of the health implications of non-ionizing radiation? This research aims to answer these questions with a focus on the EMF exposure in Dhaka city.

Hence, in this study, we primarily aim to measure and evaluate various EMF sources from the domestic environment in Dhaka city. We will also compare the measured values with the safety threshold limit guided by the ICNIRP. Furthermore, we intend to assess several potential health impacts associated with prolonged exposure to non-ionizing radiation. This also calls for understanding how well-informed and aware people are about the presence and potential health issues from NIR exposure. Finally, we aim to make people constantly exposed to non-ionizing radiation from home appliances aware of the health implications and, in extension, help them prevent further health deterioration.

This thesis is organized into 6 sections. The introduction is followed by a detailed review of already existing literature in Section 2, to understand the current standpoint of studies regarding non-ionizing radiation. Section 3 includes the materials and methodologies used for conducting this research. Section 4 presents the detailed results of our study, while the next section explains the major findings, research gaps, prospects, and discussion. And the last section will summarize the study and include recommendations for further research.

LITERATURE REVIEW

Over the past few decades, wireless communication technologies have spread widely and progressed rapidly, increasing human exposure to various Electromagnetic fields (EMF), especially non-ionizing radiation (NIR). The sources of NIR range from household appliances, microwave ovens, to mobile phones and wifi routers. They have become deeply integrated in today's world, giving rise to public concern about the potential health issues and dangers associated with prolonged or repeated exposure to these fields.[26]

Non-ionizing EMF does not have sufficient energy like the ionizing radiation to cause direct DNA damage or disruption to cellular structures. However, many studies have suggested that biological effects can be achieved even with very low energy under certain conditions, and the mechanisms for these effects include oxidative stress, cellular dysfunction, and DNA damage. These findings created ongoing controversies regarding the EMF interactions with biological systems and the need for thorough research.

This literature review aims to explore and analyze the current studies regarding the biological and physiological effects of non-ionizing radiation (NIR). It reviews studies about various NIR, like- extremely low frequency (ELF), radiofrequency (RF), and microwave radiation, etc. to understand their mechanisms of action, as well as health impacts. The review also identifies common EMF sources in the household environment, summarizes findings from epidemiological and in vivo studies, and discusses existing international safety threshold limits and guidelines. It stresses the importance of more research involving multidisciplinary fields to determine the long-term health implications of prolonged EMF exposure and to initiate public policies.

1. Understanding Electromagnetic Radiation

Radiation can be divided into two types based on the energy of the radiated particle and its ability to penetrate. They are ionizing and non-ionizing radiation [27]. There are also three different forms of radiation, depending on different penetrating abilities, namely alpha, beta, and gamma, produced from processes like radioactive decay or nuclear systems. [28]

While ionizing radiation is capable of easily removing electrons from an atom, non-ionizing energy lacks that kind of energy. [29]. Ionizing radiation can cause DNA damage and mutation, which can ultimately lead to cancer or other issues like tissue damage and burns [30]. It includes various forms such as alpha and beta particles, gamma rays, and others, coming from natural and artificial sources. Apart from these, ionizing radiation sources also include photons (X-rays and gamma rays) and particles (alpha, beta, and neutrons). Medical procedures are the most common source of ionizing radiation exposure for most people [27]. Also, X-rays, gamma rays, neutrons, radon isotopes, and thorium dioxide are the five types of ionizing radiation identified as human carcinogens by The Report on Carcinogens [27,31]. The human body is especially sensitive to ionizing radiation, and its effects can differ greatly from person to person, depending on factors like how much radiation a person is exposed to and how it is distributed across the body. [32]

On the other hand, non-ionizing radiation (NIR) is an electromagnetic field radiation lacking sufficient energy for ionizing atoms or molecules. Still, they can have biological effects. NIR can cause excitation of electrons but does not produce any charged ions. [33]. The NIR spectrum can be divided into two: optical radiation and electromagnetic fields. This further includes ultraviolet, visible light, infrared, microwaves, and radio waves. [33-34]. NIR is known to cause

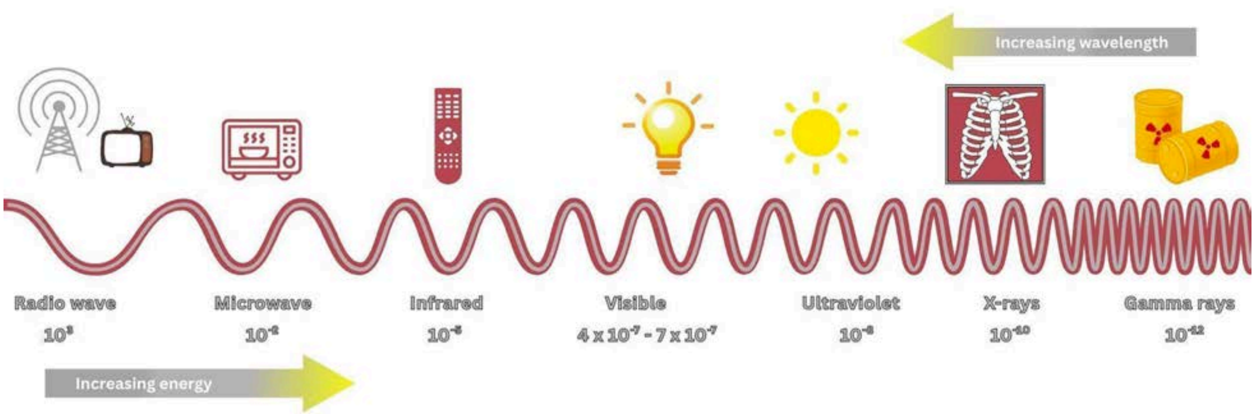


Figure 2: Several Electromagnetic Field Sources

several biological effects. It interacts with matter without causing strong conformational changes, but only by transferring the electrons to higher energy levels. [35] The impacts depend on factors like dose, duration, strength, and tissue characteristics. [35] This damage from thermal effects and increased body temperature induced by NIR can easily be repaired and coped with by the body's natural mechanisms. [35] However, prolonged exposure is what may pose health risks, making proper dosage and precautions necessary. [34] Even when non-ionizing radiation can cause burns, erythema, and lesions, the biological effects coming from it are still currently under study.[36]) Moreover, it also has numerous medical applications in surgery, dermatology, and diagnostics [34]. Hence, public concern is growing regarding the potential long-term impacts of the use of NIR in various fields like telecommunications and medical imaging. [37]

2. Common appliances

Non-ionizing radiation is known to be emitted from various electronic devices and appliances in both occupational settings and public environments. However, this emission from households has been raising concerns about health implications. Several forms of electromagnetic fields, e.g., microwave radiation, infrared, radio frequency, etc., are emitted from the devices in our homes. [38] Even when this emission is considered to be at a safe level, growing concern is spreading about its constant, combined, and prolonged use. [39] There are also some studies that suggest that mobile phones, laptops, smartwatches, etc., can emit both ionizing and non-ionizing radiation. And this shows potential to contribute to several adverse health impacts, such as cancer. [40]

From studies and research, we now know that household appliances emit non-ionizing radiation. However, the biological impact of it is still a topic of debate. [41] People are constantly exposed to low-level non-ionizing radiation as our homes nowadays are getting densely equipped with various sources and electronics. Examples of some common non-ionizing radiation sources include:

- Mobile Phones: They emit radiofrequency (RF) radiation. This falls within the radio waves and microwave part of the electromagnetic spectrum. [42,26] Specifically, GSM systems. For sending, it utilizes 890-915 MHz and 960 MHz. On the other hand, GSM 1800 uses 1785 MHz, and for receiving, it uses 1880 MHz frequencies. [26]
- Radio and TV Broadcasting Transmitters: Emit radio waves. [42,26]
- RF Diathermy, RF Welding, and RF-Brazing Equipment: These are examples of sources emitting radio-wave radiation. [42]

- Electronic-Communication Gadgets and Home Appliances: Generally, these are sources of electromagnetic wave radiation. [42]
- Air Conditioners and Switchboards: These devices emit electromagnetic fields (EMF) containing both electric and magnetic fields. [43]
- Household Appliances: Several household appliances were found to be emitting EMF and exceeded safety threshold limits for electric and magnetic fields. [44] Some examples include:
    - Refrigerators and Freezers: Emit electric and magnetic fields. [44]
    - Microwave Ovens: They emit microwave radiation. [42] These devices typically operate at 2.45 GHz. They can also leak radiation if the shielding or door seal is damaged. However, under normal conditions, leakage is very minimal. [26]
    - Dishwashers: Emit electric and magnetic fields. [44]
    - Luminaire (Lighting Fixtures): Emit electric fields. [44]
    - Multicookers: Emit electric fields, and while in use, also emit magnetic fields. [44]
    - Washing machines: Emit electric fields. [44]
    - Bread Makers: Emit electric and magnetic fields, with higher values in standby mode for magnetic induction. [44]
    - Radio Receivers: Emit electric and magnetic fields. [44]
    - Laptops: Emit electric fields and also magnetic fields during use. [44]
    - Hairdryers: Emit electric and magnetic fields. [44]
    - Sewing Machines: Emit electric fields. [44]
    - Monitors (Computer): Emit electric fields. [44]
    - Nettops: Emit electric fields. [44]
    - Electric Irons Emit electric fields. [44]

Additionally, Extremely Low Frequency (ELF) EMFs are emitted from structures like power line networks, electrical substations, and power cables. [26,42,45] Although these sources of non-ionizing radiation operate at and emit low frequencies, prolonged and constant exposure may lead to long-term health impacts.

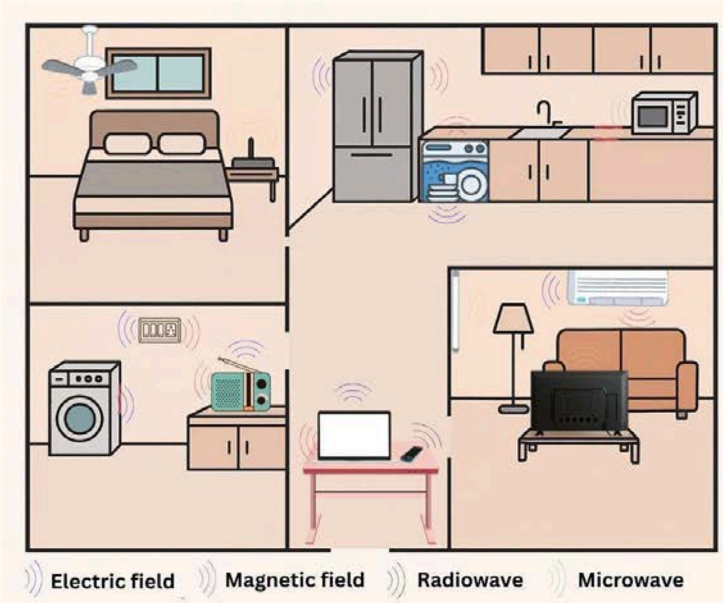


Figure 3: Sources of EMF in household

3. Biological and Physical Effects Mechanism

The everlasting debate about the biological health impacts of non-ionizing radiation remains constant and ongoing to this date. Even when some researchers argue about the lack of energy of non-ionizing radiation and its incapability of causing cancer, several studies go against it and suggest otherwise. Several studies indicate that NIR can still cause oxidative stress and DNA damage by increasing the number of free radicals.[8] There have also been studies that show the potentially harmful impacts of non-ionizing electromagnetic field radiation on cell function and division. [46] People getting exposed to non-ionizing radiation from sources like mobile phones or radio stations were also deemed to be susceptible to diseases like cancer or other biochemical issues. [47]

Despite these growing concerns, the health risks imposed by low-frequency electromagnetic radiation exposure have not been completely addressed by international organizations. [48] These effects caused by non-ionizing radiation on biosystems depend on dose duration and strength, as well as cell type, nature, physicochemical features, depth in biosystems, etc. [35]

Biosystems are affected by non-ionizing radiation in several mechanisms, including thermal and non-thermal processes

Thermal Mechanisms of Action

The thermal mechanisms are a major way in which non-ionizing radiation can affect biological systems. Even though non-ionizing radiation cannot ionize atoms or molecules, it certainly can excite the electrons, which can induce reactivity and cause potential thermal effects on body tissues. [35] This effect, caused by NIR, causes the body temperature to increase.

The thermal mechanism is classified depending on the increase of temperature or the rate of increase, with even a subtle amount of thermal effect possible. [49] And this heating can lead to various molecular disorganization with varying effects. The effects also depend on field strength, frequency, and exposure length. [50] Even though thermal factors are primary, studies have observed non-thermal impacts as well. [51]

Non-Thermal Mechanisms

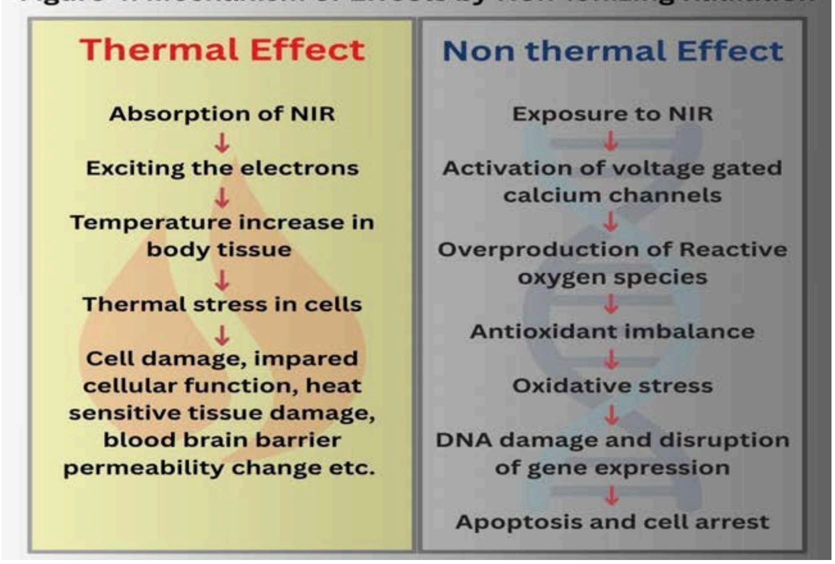
Attention has significantly increased on non-thermal effects of non-ionizing radiation since the 1970s, when Addy discovered that extremely low-frequency EMFs can affect calcium ion efflux from cells. Research studies also suggest that non-ionizing radiation can exert stimulatory and inhibitory effects on various physiological and cellular processes. [52] It can interact with the mammalian central nervous system, and that too without producing heating. This impacts the electrical signaling in tissues. Measurements prove that these fields are effective even with a minimum temperature change. ($<0.1°C$). [53] Hence, biological systems can be affected by non-ionizing radiation through various non-thermal mechanisms as well. This includes inducing reactive oxygen species, alteration of gene expression, DNA damage via epigenetic and genetic processes, etc. [48]

Oxidative stress: The primary method by which non-ionizing radiation affects biological systems is by the production of reactive oxygen species and by causing a deficiency in antioxidants in the oxidative repair mechanism, and hence damaging DNA. [54] They also cause disruptions with the normal cellular processes. [8] . One key mechanism for doing this is its involvement in the activation of voltage-gated calcium channels. This channel is particularly sensitive to low-intensity non-thermal electromagnetic field radiation exposures. [55] Various downstream effects are noticed from this activation, like elevated nitric oxide, calcium signaling, free radical formation, etc. [35] Even when biosystems carry inherent capability to repair this damage and cope with the stress, the major problem lies within the combined impact of exposure to NIR, which can lead to several biological responses that include DNA damage, infertility, and even cancer. [55,8]

DNA Damage: DNA strand breaks are usually caused when electromagnetic fields trigger the voltage-gated ion channel and cause dysfunction. [56] DNA breaks can also be caused by oxidative stress, even though the primary cause of DNA damage in the non-thermal mechanism is due to ultrasound. There is also a radio frequency field that can impact the cellular system in the same way as other chemical mutagens. [51]

Apoptosis and Cell Arrest: Non-ionizing radiation can also induce apoptosis and cell cycle arrest. This is done by mechanisms like membrane modulation, biomolecular resonance, structure resonant energy transfer, etc. [58] Even when this does not directly cause genetic mutation, it can inhibit cell division or even slow down the growth in eukaryotic cells. [58] However, these effects have emerging applications in cancer therapy and are very frequency-specific and dose-dependent. [59]

Figure 4: Mechanism of Effects by Non-ionizing Radiation



4. Biological effects on cells and animals

Numerous in vitro studies have explored how NIR affects cells and microorganisms. In bacterial models, for example, in a study, Strains of Salmonella were exposed to 15 or 30 mT magnetic fields at 0.3 Hz, 1-10 µT sinusoidal magnetic fields at 50 Hz applied in 2 µs pulses, or to a wide range of radio frequency and microwave fields. This displayed zero increase in mutational frequency. However, when exposed to Fields (0.2 mT) at 60 Hz, a 14% increase in azide-induced mutations was found in Salmonella after 48 h exposure [60]

Another study investigates how non-ionizing radiation affects microbial growth. A significant number of samples were collected from various sources, including mice, cell phone cases, and cell phone screens. However, it was found that the samples from these sources did not grow. This indicates an impact of non-ionizing radiation on microbial viability. It rendered microbial samples non-viable even in favorable conditions. [61]

Further results from a study on hybrid human-hamster cells showed that radiofrequency radiation might be causing numerical or chromosomal aberrations. Studies were also done using the µTEM cell, and they showed similar effects to spindle disturbance caused by chemical agents. [62] Although individual exposure to extremely low-frequency magnetic fields and radiofrequency had a very little effect on the cell culture, a significant outcome was observed from combined exposure with other stressors.[63]

Another noteworthy study was on *E. coli*. The use of microwave radiation caused a significant inhibition of cell growth in *Escherichia col*i. In particular, the effect was prominent during the lag phase, where cells did not divide, and also in the log phase, where cells divide only once. This inhibition is not because of heating. The increase in temperature was less than 1°C, indicating a non-thermal effect. The findings showed a reversible blockage of cell division or growth upon removing them from the microwave field. [64]

Several studies were also done on animals. Research using Wistar rats exposed to 2450 MHz microwave radiation (5–15 mW/cm^2, 2 hours/day, 5 days/week) over 30 days was found to have altered immune cell profiles. [65]

Apart from this, the EMF radiation is evident in affecting the lower-level animals. Animals like rats were seen to be living, or observed to be living, far away from the electric field. Some reports suggested that animals like rats and bees that are highly sensitive tend to cover up the sides of their hives if they are vulnerable or exposed to EMF. This is because the radiation from

EMF may cause Sudden Infant Death Syndrome (SIDS). This is making the scientists more aware and concerned about the effects of EMF exposure. [66-72]

In addition, there were three large-scale carcinogenicity studies done on rodents. They were exposed to levels of radiofrequency radiation mimicking lifetime human exposures. This study has shown a significant increase in the rates of Schwannomas and malignant gliomas. Apart from this, chromosomal DNA damage was also observed. [73] These findings are, however, still deemed inconclusive. The variation in outcomes in the studies shows the need for further systematic research to understand the underlying mechanisms and also determine safe exposure guidelines [35]

5. Effect on human health

Primarily, non-ionizing radiation is associated with health impacts like an increase in free radicals, disruption of the blood-brain barrier, and decreased cognitive functions etc. These kinds of radiation are also linked with genotoxic effects, cancer, decreased fertility, hypersensitivity, etc. [74]

Various studies suggest that non-ionizing radiation, and in particular radiofrequency and extremely low-frequency electromagnetic fields, can induce oxidative stress in biological systems. It can lead to cellular component damage, and this damage has been proposed as a key mechanism for carcinogenicity and other health issues. [8] However, specific health concerns linked with EMF exposure, though debated, include:

- Cancer: Even when some studies state that non-ionizing radiation is not capable of causing cancer due to the lack of energy, there have been arguments regarding various mechanisms that provide ways for causing cancer. Various epidemiological studies showed possible associations of various cancers, like testicular cancer, breast cancer, brain tumor, and leukemia, with exposure to radiofrequency and magnetic wave fields. Likewise, low-frequency EMF has also been linked with childhood leukemia. [8] Radiofrequency radiation has been classified as a possible human carcinogen (Group 2B) by the International Agency for Research on Cancer (IARC). [8,26] Apart from this, being exposed to mobile phone frequencies for a long time can also increase the risk of brain cancer in humans and animals. [48] Research also found various examples of acute myeloid leukemia among people who work near telecommunication areas. Moreover, cancerous thyroid tumors, etc., may also arise in individuals who are exposed to NIR. [75]

- Reproductive Effects: Studies have indicated potential impacts on the reproductive systems. For example, in a study, rats were exposed to 900 MHz EMF. This led to alterations in sperm motility and vitality and also caused changes in the structure of the testicles. [26] When mice were exposed to 1800 MHz mobile phone radiation, results showed adverse effects on the ovaries and uterus. There was also a reduction in follicle numbers and disruptions in hormone levels. [26] Additionally, impaired sperm function was also linked with EMF exposure in several studies. [8] These negative impacts on male and female reproduction systems were noted to be caused by reactive oxygen species. Several effects of exposure to non-ionizing electromagnetic radiation have been found on oocytes, estrous cycle, endometrial tissue, reproductive endocrine hormones, ovarian follicles, developing embryo, and fetal development in animal models. [48] The free radical load is increased by NIR exposure in the uterus and ovary, which then leads to the decline of cell growth and disruption of DNA. It can also cause changes in both germ cells and their nourishing environment, further affecting the female reproductive system and may ultimately lead to infertility. [76] Apart from this, a huge portion of pregnant women using electric blankets, electric waterbeds, or computer monitors were observed or documented to have had miscarriages. [75]

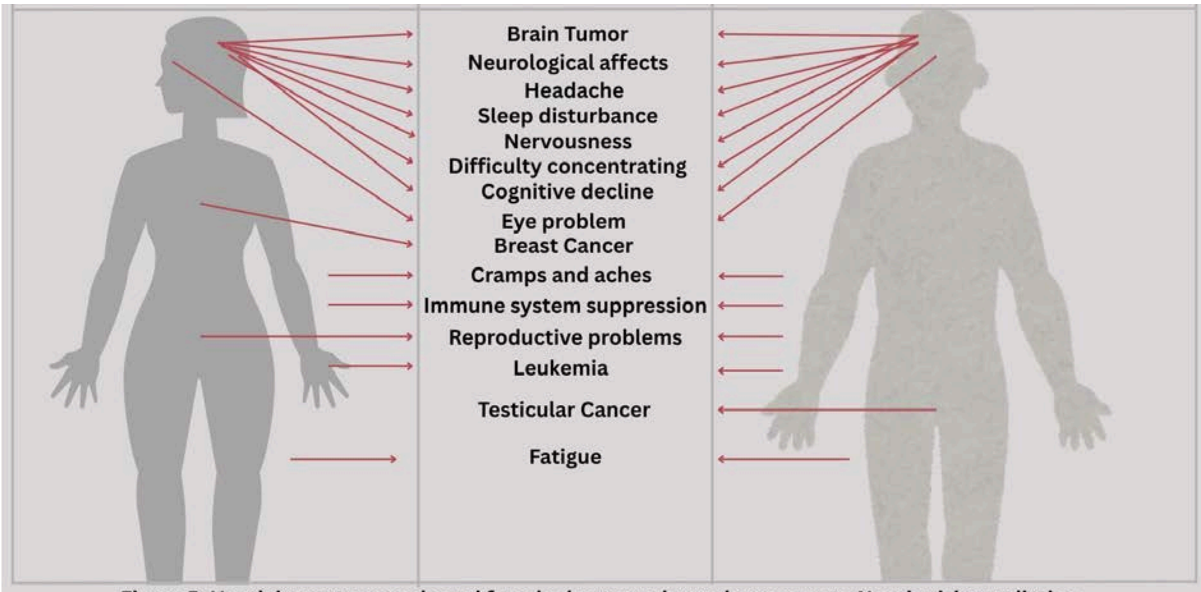


Figure 5: Heath impacts on male and female due to prolonged exposure to Non-ionizing radiation

- Neurological and Cognitive Impairments: Non-ionizing radiation is also linked to disruptions of the blood-brain barrier and decreased cognitive function. Other neurological effects include altered calcium signaling, increased blood-brain barrier permeability, and both single- and double-strand DNA breaks [8].
- Immune System and Psychological Impacts: Studies suggest that NIR can influence immune function by altering immune cell responses and reducing antioxidant enzyme activity. [8,43] The suppression of T- T-lymphocyte cells, cancerous thyroid tumors, etc., may rise in individuals exposed to NIR. [75] Some findings also point to connections between NIR exposure and psychological health, including associations with suicidal tendencies and clinical depression near power lines [77].
- Acute Symptoms: Symptoms such as fatigue, headaches, sleep disturbances, nervousness, and difficulty concentrating have been frequently reported among individuals exposed to EMF sources [73,78]. Other clinical symptoms include heat sensation, vertigo, neuropathy, and burns, particularly when an individual is in contact with conductive materials within the EMF fields [79]. This burning sensation can be induced by the currents in the body produced by magnetic field exposure. This can happen especially in places with a lower cross-sectional area, for example, the ankle. [79] Apart from this, there is insufficient data that reflects health impacts from day-to-day exposure [21], and there has been data signifying the intense effect of RF-EMF released by Universal Mobile

Telecommunication Systems. 40 teenagers aged between 15-16 years old and 40 adults between the ages of 25 and 40 years were exposed to continuous waves at 2140 MHz, a signal at 2140 MHz modulated as UMTS, and UMTS at 2140 MHz, and then they were studied for possible health impacts. [78] Immense health issues have also been seen, from long-term exposure to microwave radiation coming from TV and FM towers, cell phone towers, etc. [78]

An important thing to keep in mind is that a huge portion of this research on non-thermal effects was conducted by using animal models (in vivo) or cell cultures (in vitro). Hence, directly applying these findings to humans and drawing similar conclusions can be problematic. [26] Epidemiological studies on humans are ongoing, but differences in the methodologies and findings continue to create controversies about the precise health risks associated with exposure to non-ionizing radiation. [8,26]

6. Regulatory standards

The International Commission on Non-Ionizing Radiation Protection (ICNIRP), is a non-governmental body recognized by the World Health Organization (WHO). They play a leading role in the development of international exposure limits for non-ionizing radiation. [80] ICNIRP's objective is to establish a unified safety threshold throughout the electromagnetic spectrum. So, they base their principles for protection against negative health impacts on those that are developed for ionizing radiation. [81] These guidelines indicate limits for both occupational and public exposure and usually set stricter thresholds for the general population. [82] They also engage in various activities by maintaining a close connection with other international bodies. These include collaboration with the WHO on EMF projects and the establishment of standing committees. and the development of protection systems. [80]

There is also the UK's National Radiological Protection Board. They have adopted the ICNIRP guidelines even though there are many controversies about long-term EMF exposure effects on biological systems. [82] On top of that, critics argue that the 2020 guidelines by ICNIRP do not completely address the harmful non-thermal effects of non-ionizing radiation. Instead, they mainly focus on thermal damage. There have also been concerns about the lack of representation from scientists in ICNIRP committees, indicating the possibility of bias in their recommendations. [83]

In collaboration with ICNIRP through the International EMF Project, the WHO suggests that non-ionizing radiation poses no known health hazards when exposed below the ICNIRP's standard limit. Despite this, they acknowledge some research gaps. [75] Critics still indicate a conflict of interest within the WHO's core group for radiofrequency radiation assessment, because most of its members are affiliated with ICNIRP. [83] Even when the International Agency for Research on Cancer, IARC, classified radiofrequency radiation as a possible human carcinogen in 2011, little to no public awareness was seen, and limited action was taken by most countries. [84]

In the past, only thermal injury and neural stimulation prevention were considered while setting the safety threshold for EMF exposure. In case of RF radiation, Specific Absorption Rate (SAR) and induced current densities are counted to set the exposure limit. This was designed for preventing tissue heating above 10 MHz and nerve/muscle cell stimulation below 100 kHz. [85] On the other hand, occupational exposure guidelines are often set to keep bulk tissue current densities below 10 mA/m^2. [86] The IEEE Std C95.1™-2019 standard sets the comprehensive safety standard ranging from 0 Hz to 300 GHz. [87] Current studies seem to be considering the non-thermal effects on biological systems. This prompted them to make propositions for limits such as 6 V/m for exposure to radio frequency EMF. They also seem to be taking long-term exposure into account while making these propositions. [88]

Magnetic fields are generally regarded as more biologically disruptive and damaging than electrical fields. Hence, the internationally accepted exposure limit for magnetic field strength is between 0.2 to 0.3 μT (2.5 mG). For electric field strength, this threshold value is below 25 V/m in both residential and occupational fields. Apart from this, there is a threshold value for radiation intensity absorbed by the human body, and this should not exceed 10 mW/cm^2 or 195 V/m in the USA, and 0.1 mW/cm^2 or 20 V/m in CIS countries. [89-91, 102]

There is a huge amount of evidence from various experimental studies and epidemiological data that connects long-term exposure to low-intensity microwave radiation with an increasing cancer rate. This connection is seen in both the human population living near the communication towers and the rodent model used in those studies. [92] Various studies are also identifying the metabolic changes in cells, which to some extent, indicate a stress response in living tissues. Hence, this calls for a reassessment of the safety threshold limit. As research grows, safety regulations shall also continue to evolve to balance health protection with technological advancement.

7. Research in Bangladesh

The research that was conducted in Bangladesh was particularly based in Dhaka. They have studied the intensity and occurrence of non-ionizing radiation (NIR) that is emitted from common electronic devices and infrastructure. Since electronic appliances and devices started to deeply integrate into our lives, exposure to electromagnetic fields (EMF) has become a growing concern. This prompted multiple studies on non-ionizing radiation.

There have been several studies that were done on the Electromagnetic field radiation exposure in Bangladesh. The studies researched the health implications and environmental effects posed by EMF exposure. These studies include epidemiological surveys on people working in high-frequency EMF areas. [94] There were also studies of EMF levels from photocopy machines in Dhaka [95]; measurements of EMF values from CRT monitors [96]; and studies on lab equipment and air conditioners used in academic settings like a university. [97-99]

Many researchers also measured the high magnetic field values near high-voltage transmission lines [100], while others worked on the health issues caused by mobile phones or cell towers [101]. EMF exposure from individual mobile phone usage was also a matter of study [102]. These studies highlight that the density of Electromagnetic radiation is increasing day by day in the urban areas of Bangladesh. These also emphasize the necessity for risk assessments and awareness campaigns in local areas.

A survey was done on 20 Base Transceiver Stations sites in Joypurhat district. It was found that electric field (EF) strengths ranged from 0.093–1.378 V/m and magnetic field (MF) is up to 0.79 μT. The highest power density measured was 1.01 mW/cm^2, which exceeded the safety thresholds recommended by ICNIRP [106].

A survey of 33 residents aging from 16–60 found that 87.9% reported symptoms like headache, joint pain, and insomnia after four years of exposure. [106]

Several studies were also done to measure the EMF emissions in laboratories and classrooms of universities. One study done on the lab equipment of the CSE laboratory at Daffodil International University showed the measured magnetic values to range between 15.9 mG and 98.2 mG. This higher reading came especially from power supplies and personal computers. [45] This suggests the necessity and requirement for special precautions, considering that the value is much higher than the threshold limit for the magnetic field, which is at 2.5 mG. Other than that, the air conditioners used in this laboratory also showed a significant amount of magnetic field emission. [45]

Another study conducted at Southeast University (SEU) showed magnetic-field emissions from classroom switchboards and ACs reaching as high as 190 mG, way beyond the WHO limit of 0.2–0.3 µT. These levels were attributed to faulty wiring and close proximity of equipment [107].

Apart from this, in their CSE labs, air-conditioners emitted magnetic fields of up to 65.1 µT, and switchboards recorded 1.4 µT at close range—both of which exceeded WHO/ICNIRP thresholds [108]

The Pharmacy labs in the South East University also showed high EMF levels. Certain appliances such as centrifuges and binders emit magnetic fields above 200 mG. This raised the possibility of persistent student exposure [109]

In the work place, there have been reports of over-exposure to EMF. Field measurement in a Dhaka case study found that the strength near an 11kV transmission line could be up to 48.9 mG. Office workers claimed to experience symptoms such as headaches and depression, which disappeared after moving. This indicates that short-term effects can be reversible, although long-term risks are not yet clear. [100]

An investigation on CRT computer monitors concluded that magnetic field exposure was frequently much higher than health-based guidelines of WHO/ICNIRP (2013). Symptoms reported by users included indigestion and mental fatigue, as well as insomnia. [96]

An epidemiological survey of photocopy machine operators in Dhaka revealed similar symptoms like cataracts, musculoskeletal pain. The magnetic field measured exceeded recommended exposure limits. The study emphasized minimizing exposure time and keeping field intensity below 10 mW/cm^2. [95]

A 2014 review categorized EMR from mobile devices and BTSs as a Group 2B carcinogen per IARC, suggesting possible links to brain tumors, Parkinson's, Alzheimer's, and childhood radiation absorption [101]

Studies were also done on cell phone usage in Dhaka city. This research revealed that cell phones are emitting a large amount of magnetic field that often exceeds the international safety threshold. [93] This value was compared against the ICNIRP guidelines, as Bangladesh has currently adopted this. The recommended value is 0.475 mW/cm^2 at 950 MHz and 0.925 mW/cm^2 at 1850 MHz. The measured limits were seen to be surpassed by a lot in daily life. [93] The naturally occurring electromagnetic fields are also significantly lower than these measured values. This finding stressed that these levels usually contradict naturally occurring electromagnetic fields, which are significantly lower. We can see a very concerning trend of non-ionizing radiation in urban settings, breaking the safety threshold limit from these studies. This pattern raises concerns about the long-term health issues in the people of the country. [93]

8. Methodologies used for EMF measurement:

For measuring the electromagnetic field from various devices and appliances, several kinds of meters are used. In one study for the measurement of magnetic field, the cornet ED78S EMF RF meter was used. In other studies, meters like the Coghill Field Mouse for Biohazard Awareness were used for the measurement of electric and magnetic field threshold values. [43] Another study used a Magnetic Science International MF meter, a single-axis Gauss meter for measuring the magnetic field from AC, wiring, and other appliances. The readings were then taken from all around the appliances, including the center, right, left, etc. [43,93]

9. Controversies and research gap

Several controversies are going around about the health implications of non-ionizing radiation on human beings. On one hand, NIR is perceived to not have enough energy for dislodging or removing electrons. This idea is accepted by many physicists and health agencies; hence, they conclude that non-ionizing radiation does not have the capacity to cause cancer. [8] On the other hand, this view is challenged by several pieces of evidence that suggest that non-ionizing radiation can interfere with the oxidative stress mechanism, and this can, in the long run, cause damage to the DNA and hence contribute to cancer development. [8] There is also another debate about whether NIR is dangerous at levels below the thermal guidelines. Some believe that this can cause several issues, like reproductive problems, cancer, or symptoms classified as electrohypersensitivity, even at levels below the guidelines. (EHS). [8]

The current studies suggest that there are no known health consequences from exposure to electromagnetic fields below the recommended limit. However, they also acknowledge that knowledge gaps exist and call for further research to improve risk assessment. [75] Apart from this, there is also a need for a study on the issues non-ionizing radiation causes from the combined effects. [103] This highlights the importance of acknowledging the effects of non-ionizing radiation. Other researchers like Hansson emphasize the necessity for evidence-based and clear information from reliable sources in order to improve the knowledge of healthcare professionals regarding the risk and safety measures of non-ionizing radiation. [103] These gaps highlight the ongoing need for better, organized and comprehensive research on the health implications of non-ionizing radiation

In Bangladesh, we lack extensive and complete studies on electromagnetic field radiation. This lack is particularly evident in the case of studies regarding EMF from air conditioners and switchboards. [43,93,104,]. On top of that, there is also a need for research to improve the quality and functionality of measurement tools to estimate the EMF exposure over many years. [105] Apart from this, the potentially harmful effects that may arise from the EMF emission from Wi-Fi, 5G networks, etc., have not been tested enough in biological settings. This indicates the requirement for further research in these areas. [8]

The literature review discusses several health complications that may arise from exposure to non-ionizing radiation. There are several studies that have already explored the impact of non-ionizing electromagnetic field radiation emitted from various technologies. Several studies were also done based on occupational or academic settings. However, there remains a significant lack of studies focused on the domestic environment. In this era of rapid technological development, it is crucial to understand the biological and physiological impacts of prolonged exposure to low-level non-ionizing radiation. This is particularly important to raise public awareness and ensure policies to protect the people in urban areas that are mostly exposed to such radiation. So, this study proceeds with the objective of bridging that gap by evaluating the exposure to non-ionizing radiation in everyday life and its potential health implications.

Here, several past studies have been discussed to understand non-ionizing radiation, identify the common sources in households, and also assess the imposed related health issues. Here, several mechanisms were also discussed in which non-ionizing radiation might cause health impacts. Even though the current regulatory threshold provides the baseline for safe exposure, most do not comply with this, especially in countries like Bangladesh. Apart from this, there is growing concern regarding the non-thermal effects and long-term health implications of non-ionizing radiation. These unsolved issues need to be addressed in a more comprehensive manner to understand domestic NIR exposure and its potential health consequences.

MATERIALS AND METHODS

This chapter outlines the research designs, materials used, sampling method, and data analysis techniques used in this research. The objective was to identify the potential sources of EMF emission to measure the values for comparing them with ICNIRP threshold limits and assess the related biological issues and awareness level of individuals. This study used quantitative research design with a structured questionnaire survey. Field data was collected by measuring the EMF value of several household appliances.

The study was conducted in several residential areas of Dhaka city. Data was collected from 62 households in various places, including Uttara, Mohakhali, Mirpur, Mohammadpur, Bashabo, Khilkhet, Lake city, Shanti Nagar, Mogbazar, Sobhanbag, Nakhalpara, Mugda, Khilgaon etc. A variety of appliances, such as television, refrigerator, air conditioner, switchboards, light, fan, microwave oven, electric iron, computer, laptop, monitor, multiplug, power outlets, Wi-fi router, etc., were selected carefully and measured.

Figure 6: Some of the measure appliances

An EMF meter with a magnetic field triple-axis sensor was used for measuring the magnetic field (MF), electric field (EF), and RF strength values of the home appliances. The MF, EF, and RF strength values for various Wi-Fi routers and mobile phones were also taken in the same way.

The values were taken with the equipment from all around the electronics and electrical devices, from the center/ front, right side, left side, and back side (when possible).

Figure 7: An EMF Meter

Figure 8: Measuring the EMF (Electrical field, Magnetic field and Radiofrequency Strength) of an appliance from four sides

Then a standard question set was developed and used. The structured questionnaire includes 4 sections: demographics (age, gender, occupation, information of any child or old people in the household), related health symptoms (of the individual, their family and pets (if any), types and brands of electronic appliances and devices used (including their EMF values) and their awareness level (about safety guidelines, studies and general comments). This survey was done to understand and analyze the potential connection of any possible health issues with the EMF coming from the home appliances, and to get a picture of the general awareness level.

The questionnaire form is as follows:

Questionnaire Form

Effect Of Non-Ionizing Radiation (NIR) on Home Appliances

Date: – – 2023

The individual agreed to participate on a voluntary basis in the NIR survey. The participant hereby provides permission for obtaining his/her information on the topic of ionizing radiation. I have explained to the participant that his/her identity will remain confidential. This questionnaire survey will be used for scientific research purposes only. All information provided here is all true to the best of my knowledge.

Name of the Data collector____________

Signature_________________

Date______________

Personal Questions:

1. How old are you?
    - less than 15 years
    - 15-30 years
    - 30-45 years
    - more than 45 years
2. Profession

Answer: ____

3. Education:

Answer: ____

4. Gender
    - Male
    - Female
    - Other
    - Prefer not to say
5. Where do you live?

    Answer:____
6. How long have you been living in this area or village?
    - Less than 2 years
    - 2-5 years
    - 5-10 years
    - Native
7. Are there any old people or children living with you?
    - Yes
    - No
    - Prefer not to say
8. What is the age range of the older people?
    - 60-65
    - 66-70
    - 71-80
    - Above 80
    - Not applicable
9. What is the age range of children?
    - 0-2 years old

- 2-4 years old
- 4-7 years old
- 7-9 years old
- 10-12 years old
- Not applicable

10. Do you have a pet/domestic animal at home?
    - Yes
    - No
11. What is your pet/domestic animal?
    - Cat
    - Dog
    - Domestic animals like Cow, Goat
    - Other
    - Not applicable
12. How old is the pet?

    Answer: ____________________________________
13. How long has it been living with you?

    Answer: ____________________________________

Health related personal questions:

14. Do you have any disabled or special or special needs people living with you?
    - Yes
    - No
15. Type of special need or disability.

Answer: ________________________________

16. How long are they living with you?
    - Less than 1 year.
    - 1-5 years.
    - 5-10 years.
    - More than 10 years.
17. Do any of your family members have or had diseases like Cancer?
    - Yes
    - No
18. How long have they been suffering from it?
    - Less than 1 year.
    - 1-3 years.
    - 3-6 years.
    - More than 6 years.
    - Not applicable.

Questions about symptoms:

19. Have you observed any health effects as a result of using the phone for a long time?
    - Yes
    - No

20. Have you observed any health effects as a result of using the laptop for a long time?
    - Yes
    - No

21. Is there any problem in the body as a result of using the tv for an extended period of time, 4-8 hours?

    - Yes
    - No

22. Have you observed any health effects as a result of using the ac for a long time? Please define AC.

    - Yes
    - No

23. To your knowledge, do you or any of your family members suffer from stress, anxiety, depression or other mental health issues?

    - Yes
    - No
    - Prefer not to say

24. The type of mental or psychological issue faced.

    Answer: ____

25. To what extent do you feel stress in your daily life?

    - Barely
    - 1-2 days a week.
    - 2-4 days a week.
    - More than 4 days.
    - Prefer not to say.
    - Not applicable.

26. Have you ever experienced eye discomfort or vision problems after using an electrical device for a long time?

    - Yes
    - No

27. Have you noticed any cognitive effects such as difficulty in concentrating or having a hard time remembering something?

    - Yes.
    - No.

28. Have you or any of your family members experienced any health issues after using an electrical appliance?

    - Yes
    - No.

29. Have you observed that the use of home appliances has any effect on the health of your pets?

    Answer: ____

30. Have you observed any detrimental effects on the children, older people, disabled or special need people, as a result of using electrical appliances?

    Answer:
    ____
    ____
    ____

31. Have you observed that the use of home appliances has any effect on the health of your pets?

    Answer: ____

Questions of effects:

32. Do you have any problems regarding the location of houses, cell phone towers, high voltage transformation or distribution of electric power lines, TV/radio stations or TV dish antennas?

    - Yes
    - No

33. Did your body show any unusual symptoms after using the cell phone, high voltage transfer lines, TV/radio stations or TV dish antennas?

    Answer: ____

34. Do you have multiple electronics and electrical home appliances at home?

- Yes
- No

35. How often do you use your home appliances?

Answer:
____
____
____
____
____
____

Home appliance survey

Serial no.	1	2	3	4	5	6
Name						
Model						
When purchased						
MF (mG) (Vertically Back)						

MF (mG) (Vertically Right)						
MF (mG) (Vertically Left)						
MF (mG)(Average)						
EF (V/m) (Vertically Front)						
EF (V/m) (Vertically Back)						
EF (V/m) (Vertically Right)						
EF (V/m) (Vertically Left)						
EF (V/m)(Average)						
RF Strength (μW/m2) (Vertically Front)						

RF Strength (µW/m2) (Vertically Back						
RF Strength (µW/m2) (Vertically Right)						
RF Strength (µW/m2) (Vertically Left)						
RF Strength (µW/m2) (Average)						

Serial no.	7	8	9	10	11	12
Name						
Model						
When purchased						

MF (mG) (Vertically Back)						
MF (mG) (Vertically Right)						
MF (mG) (Vertically Left)						
MF (mG)(Average)						
EF (V/m) (Vertically Front)						
EF (V/m) (Vertically Back)						
EF (V/m) (Vertically Right)						
EF (V/m) (Vertically Left)						
EF (V/m)(Average)						

RF Strength (µW/m2) (Vertically Front)						
RF Strength (µW/m2) (Vertically Back						
RF Strength (µW/m2) (Vertically Right)						
RF Strength (µW/m2) (Vertically Left)						
RF Strength (µW/m2) (Average)						

Serial no.	13	14	15	16	17	18
Name						

Model						
When purchased						
MF (mG) (Vertically Back)						
MF (mG) (Vertically Right)						
MF (mG) (Vertically Left)						
MF (mG)(Average)						
EF (V/m) (Vertically Front)						
EF (V/m) (Vertically Back)						
EF (V/m) (Vertically Right)						
EF (V/m) (Vertically Left)						

EF (V/m)(Average)						
RF Strength (µW/m2) (Vertically Front)						
RF Strength (µW/m2) (Vertically Back						
RF Strength (µW/m2) (Vertically Right)						
RF Strength (µW/m2) (Vertically Left)						
RF Strength (µW/m2) (Average)						

Awareness based question:

36. How informed do you feel about the potential health risks of EMF exposure from home appliances for humans?

Answer: ____

37. Do you think use of these electrical appliances can pose a potential threat to health?

Answer: ____

38. Are you aware of any scientific studies that have been conducted on the effects of Non-Ionizing Radiation (EMF) on humans?

- Yes
- No

39. On a scale of 1-10, how concerned are you about the potential health risks associated withEMF (NIR) on home appliances?

Answer: ____

40. Do you think that there is a need for further research on the potential health effects of Non-Ionizing Radiation (EMF) on humans?

Answer: ____

41. Do you have any other concerns or comments regarding the potential health effects of Non-Ionizing Radiation (EMF) on humans?

Answer: ____

42. Are you aware of the safety guidelines and regulations regarding NIR radiation exposure from home appliances?

Answer: ____

43. Would you be interested in knowing more about NIR exposure and ways to reduce it?

Answer: ____

44. Are there any steps that you think individuals or communities can take to reduce the potential harm of Non-Ionizing Radiation (EMF) on humans?

Answer: ____

General comments:

The data collected were then compiled systematically for analysis with SPSS software.

The data collection involved informed consent from the participants with assurance of confidentiality, before EMF measurement and survey conduction. The participation was voluntary as well.

Results and Analysis:

The results and analysis part include the findings of the study in three main sections. The first section presents the demographic information of respondents, household characteristics, and the presence of pets, children, or the elderly. The second section summarizes exposure-related variables, including device-wise MF, EF, and RF levels. The third section focuses on health outcomes and awareness, with tables, charts, and statistical tests showing the relationship between exposure factors, symptoms, awareness levels, and concern ratings.

Section 1: Demographics

Age

	Frequency	Percent
Less than 15	1	1.5
15-30 years	26	38.8
30-45 years	24	35.8
More than 45	16	23.9
Total	67	100.0

Gender

	Frequency	Percent
Male	12	17.9
Female	55	82.1
Total	67	100.0

Figure 9: Frequency of Age and Gender among the participants

Highest education level

	Frequency	Percent
S.S.C	3	4.5
H.S.C	10	14.9
Honours	34	50.7
Masters	20	29.9
Total	67	100.0

Profession

	Frequency	Percent
Businessman	3	4.5
Homemaker	29	43.3
Service holder	17	25.4
Student	18	26.9
Total	67	100.0

Figure 10: Frequency of highest level of education and Profession

The majority of the 67 houses were surveyed during the weekends or in the evening, when the participants were in the house using multiple devices. Four major individual demographics were looked into in the questionnaire. These are Age, gender, the highest level of education and their profession. Among 67 participants, the highest number of participants were from the age group 30-45 years, accounting for 35.8% of the total. As for the gender, 55 were female and only 17.9% of the participants were male. The highest level of education for the majority of the participants was Honours. 34 participants accounted for 50.7% of the participants. Whereas only 4.5% of the people had their highest level of education as Secondary School. The last part is the profession, where the majority, that is 29 (44.6%) participants, were homemakers, followed by 18 (26.9%) students, 17 (25.4%) service holders, and only 3 (4.5%) businessmen.

Age of old people

	Frequency	Percent
60-65	9	13.4
66-70	5	7.5
71-80	5	7.5
Above 80	5	7.5
Not applicable	43	64.2
Total	67	100.0

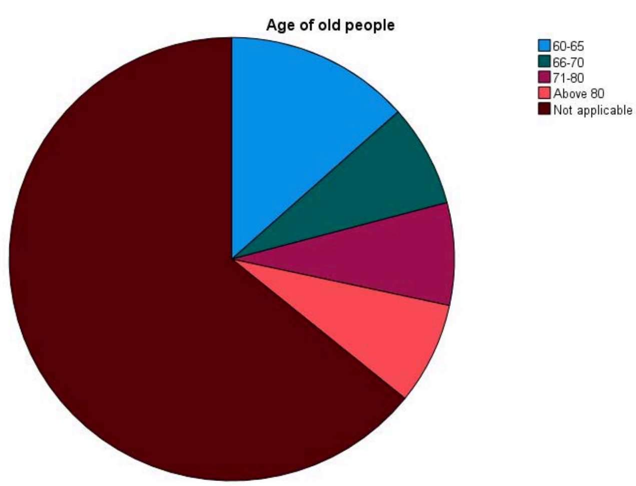


Figure 11: Frequency and pie chart of the age of old people

Age of Child

	Frequency	Percent
0	1	1.5
0-2	2	3.0
2-4	6	9.0
4-7	7	10.4
7-9	7	10.4
9-12	8	11.9
Not applicable	36	53.7
Total	67	100.0

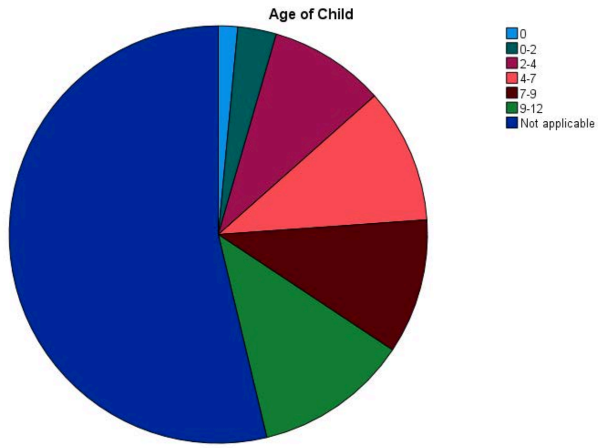
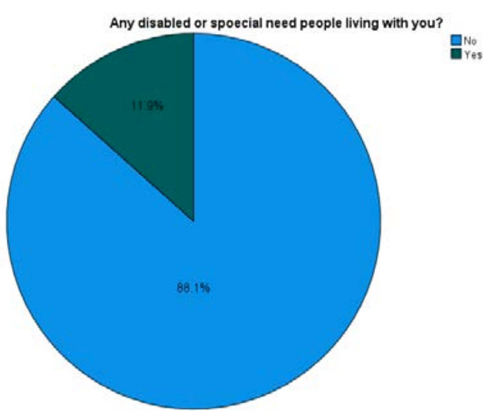


Figure 12: Frequency and pie chart of the age of children

Along with the individual demographic of the respondents, the household profile was also checked in terms of the presence of old people, children, disabled or special needs people, and the presence of any pets. This was done to find any sort of correlation among the more vulnerable members of the family, any symptoms displayed, and the magnetic field, electric field, and radiofrequency value.

Among the participants, only 24 people mentioned having older members in their family living in the household. 5 of them had family members aged above 80, 5 between the ages of 71-80, 5 aged between 66-70, and 13.8% (9) had members aged between 60-65 years. Apart from this, 46.3% of the respondents mentioned having children living in the house, the majority (22 children) of them aged between 4-12 years old.



Type of special need or disability?

		Frequency	Percent
Valid		59	88.1
	Autism	1	1.5
	Paralysis	3	4.5
	Preferred not to say	1	1.5
	Slow brain development	1	1.5
	Speech disability	2	3.0
	Total	67	100.0

Figure 13: Frequency and pie chart of the presence of disabled or special needs people

Among the respondents, 11.9% mentioned having a family member with disability or requiring special needs. Among them, two households have members with speech disabilities. Other houses have members with autism, paralysis, and slow brain development. One respondent preferred not to mention the type of disability or special need. The total number of households with special needs members was 8.

Pet

	Frequency	Percent
No	55	82.1
Yes	12	17.9
Total	67	100.0

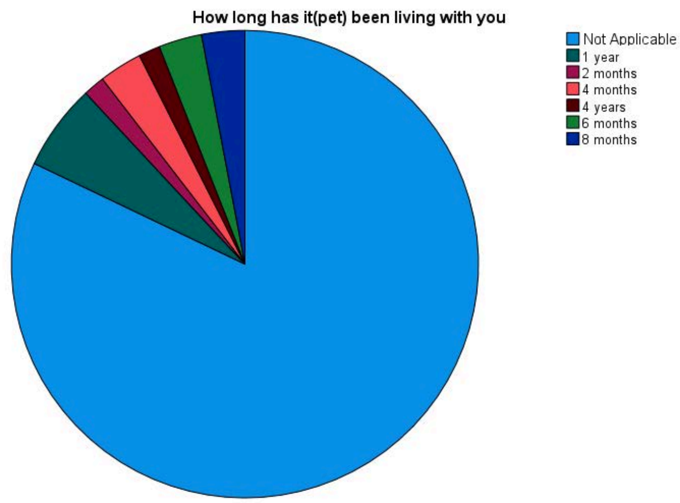


Figure 14: Frequency of the presence of pet and pie chart of the duration of their stay

Presence of pets in the households, their age and the duration of their inclusion into the households were also considered to look for any possible health effects observed. In total, 12 out of 67 households, comprising only 17.9%, mentioned having pets like cats, rabbits, fish, birds, ducks, and hens. The pets were living in the houses for about 2 months to 4 years.

Section 2: Data statistics and graphical analysis

2.1: Number of appliances:

The number of electrical and electronic appliances per household ranged from 10 to 18, with an average of 15 appliances per household. The total number of appliances and devices measured for magnetic field, electric field and radio frequency strength is 1009.

The most prevalent appliances that were measured were phones (109), fans (97), and switchboards (96). Other frequently measured devices and appliances are Power outlet, refrigerator, AC, Light, TV, Laptop, etc., while appliances like Air fryer, electric comforter, speaker, UPS, Camera, etc. were less widely found and measured. The distribution of appliance types is shown in the figure.

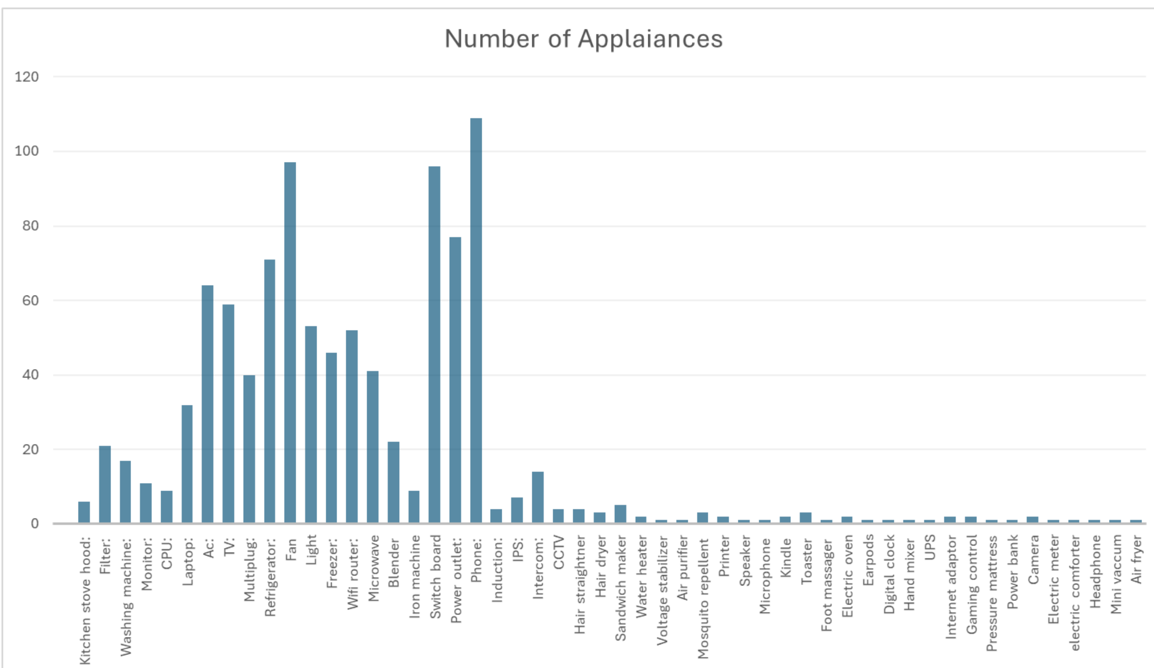


Figure 15: Bar chart for the number of appliances

2.2: Average Magnetic field per appliance:

The average magnetic field strengths varied considerably across appliances, as we observe in the figure. The highest values were observed near Iron machines (69.2 mG) and Fans (50.9 mG), crossing the threshold value significantly. Moderate levels were recorded around refrigerators, AC, Switchboards, and Microwaves (around 5-10 mG), while most other household appliances, such as phones, laptops, televisions, washing machines, power outlets, freezers, blenders, etc., produced relatively low magnetic field strengths (<5 mG). This indicates that while Magnetic Field exposure from most devices and appliances was minimal, a few appliances contributed noticeably higher magnetic field levels.

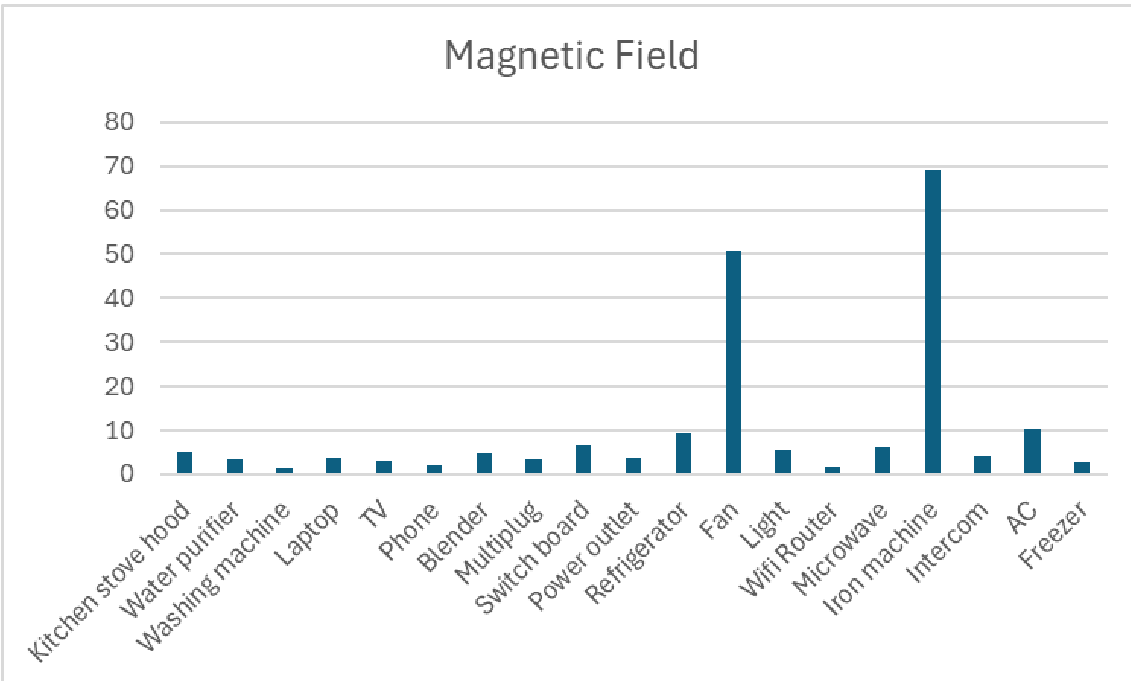


Figure 16: Average magnetic field per appliances

2.3: Average Electric field per appliance:

Electric field strengths also showed marked variation. The greatest values were recorded around multiplugs (437.5 V/m) and microwaves (436.8 V/m), followed by Iron machines (412.92 V/m), Televisions (~350 V/m), and refrigerators (324.8 V/m). Intermediate levels were observed for appliances such as Blenders, freezers, washing machines, power outlets and Wi-Fi routers (200–300 V/m). In contrast, some devices like phones and intercoms emitted very low electric field strengths (<50 V/m). Other appliances like kitchen stove hoods, air purifiers, laptops, lights and ACs have electric field value between 50 and 200 V/m. These results suggest that kitchen and large electronic appliances tend to contribute more strongly to electric field exposure compared to smaller devices, like phones and intercoms.

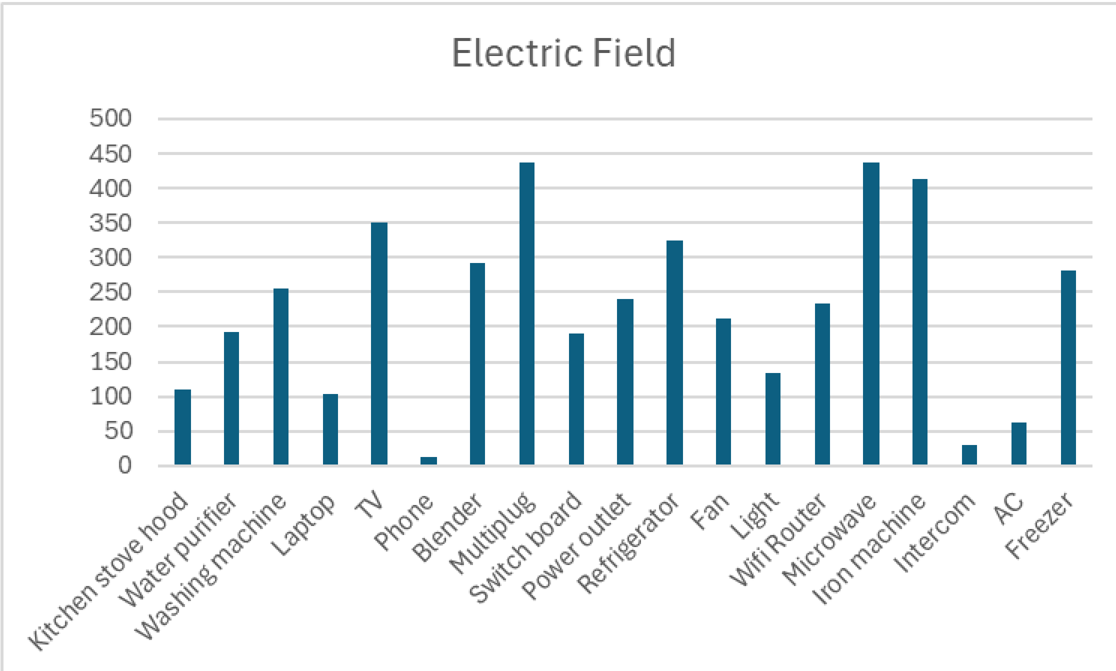


Figure 16: Average electric field per appliance

2.4: Average Radio Frequency Strength per appliance:

Radiofrequency (RF) exposures displayed a distinct pattern compared to the Magnetic field and Electric field. The highest average RF strength was associated with Wi-Fi routers, followed by mobile phones, both of which are designed to transmit RF signals. Laptops also showed elevated RF values, though not as significant as Phones and wifi routers. By contrast, appliances such as kitchen stove hood, water purifiers, washing machines, TVs, multiplugs, switchboards, power outlets, refrigerators, fans, lights, microwave, iron machines, intercoms, and ACs contributed negligible RF exposure, remaining close to background levels. This reflects the functional design of these devices, as only communication and heating technologies intentionally emit RF radiation. However, all the appliances emitted Radiofrequency within the threshold value of 0.1 mW/cm² or 1,000,000 µW/m².

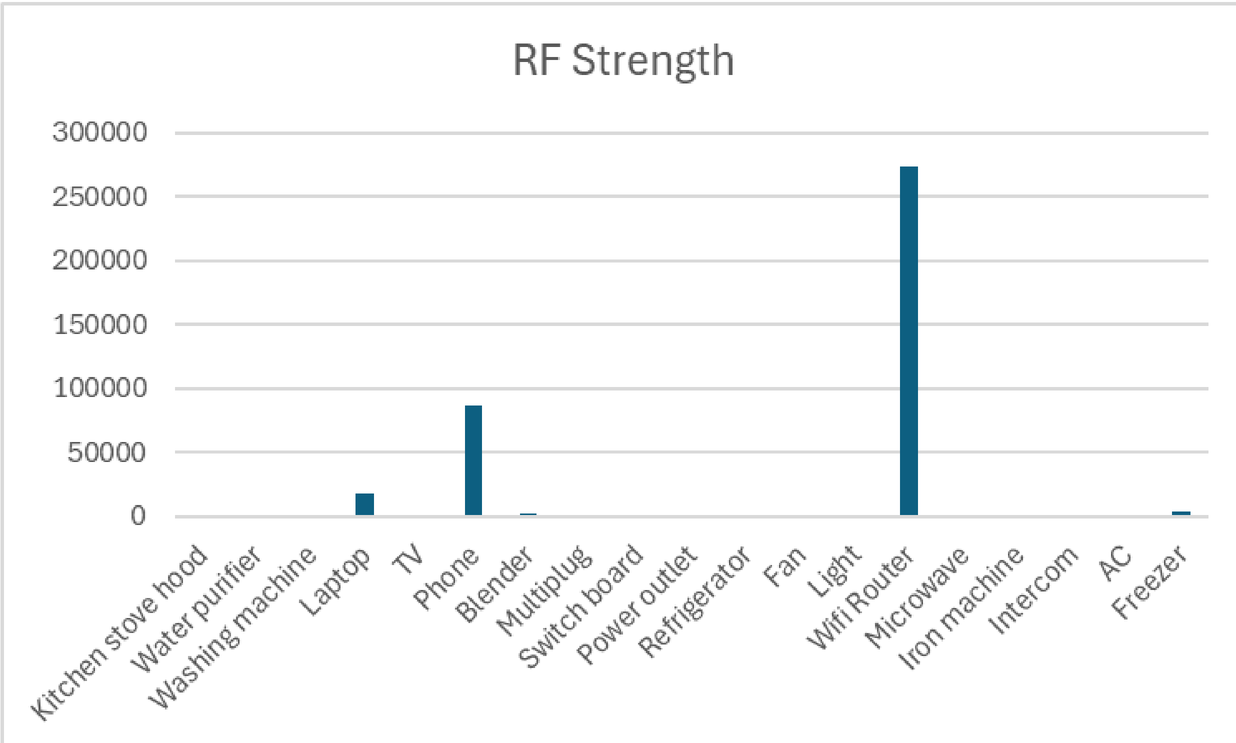


Figure 18: Average radiofrequency strength per appliances

Overall, magnetic field exposures were highest near iron machines and fans, with moderate levels around refrigerators, ACs, switchboards, and microwaves, while most other appliances contributed minimally. Electric fields peaked for multiplugs, microwaves, irons, and televisions, with kitchen and large appliances generally showing stronger emissions than smaller devices. Radiofrequency exposures were dominated by Wi-Fi routers and mobile phones, with laptops showing moderate levels and all other appliances contributing negligible RF emissions. Importantly, all RF exposures remained well below the reference threshold of 0.1 mW/cm^2

2.5: Comparison of Background and Household EMF Levels

To understand the natural background levels of electromagnetic fields (EMF), measurements were taken in an empty open field where no home appliances or power sources were nearby. These readings provided the baseline exposure values, which were found to be 0.64 mG for magnetic field (MF), 2 V/m for electric field (EF), and 225.58 µW/m² for radiofrequency (RF). These baseline values served as reference points against which household appliance emissions were compared.

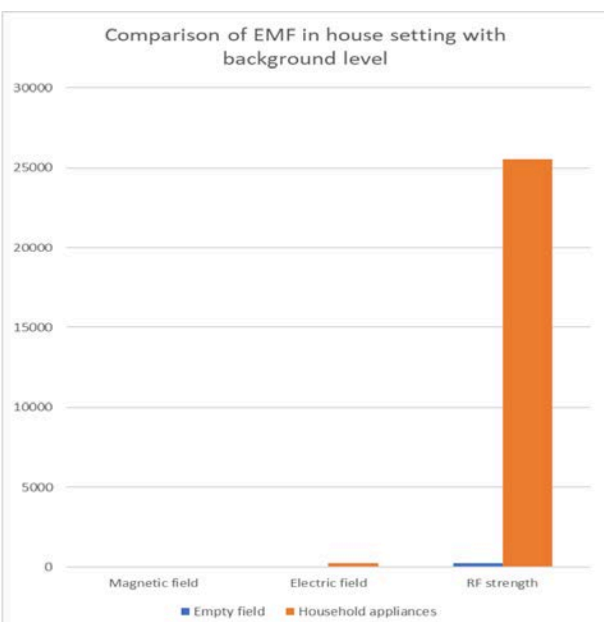
Figure 19: Measuring EMF at background levels

When compared with this baseline, the values recorded inside households were much higher. For example, the average magnetic field (MF) from household appliances was 12.44 mG, which is about 19.5 times greater than the background level. Similarly, the electric field (EF) was 222.68 V/m in the house and radiofrequency (RF) strength was 25553.88 µW/m² measured indoors, which were several times higher than those recorded in the open field. This shows that appliances are a major contributor to EMF exposure in daily life.

EMF in:	Magnetic Field (mG)	Electric Field (V/m)	RF strength (µW/m²)
Open field (Background level)	0.64	2	225.58
Household environment	12.44	222.68	25553.88

Table 1: Magnetic field, Electric field, and RadioFrequency strength value in the household environment and open field.

The differences are further illustrated in bar charts, which clearly demonstrate the stark contrast between background exposure and household appliance emissions. These findings confirm that domestic environments are associated with considerably higher EMF levels than naturally occurring background fields. The elevated indoor exposure levels may contribute to the variety of health complaints reported by participants, particularly in relation to devices with consistently higher emissions, such as mobile phones, Wi-Fi routers, and certain large household appliances.



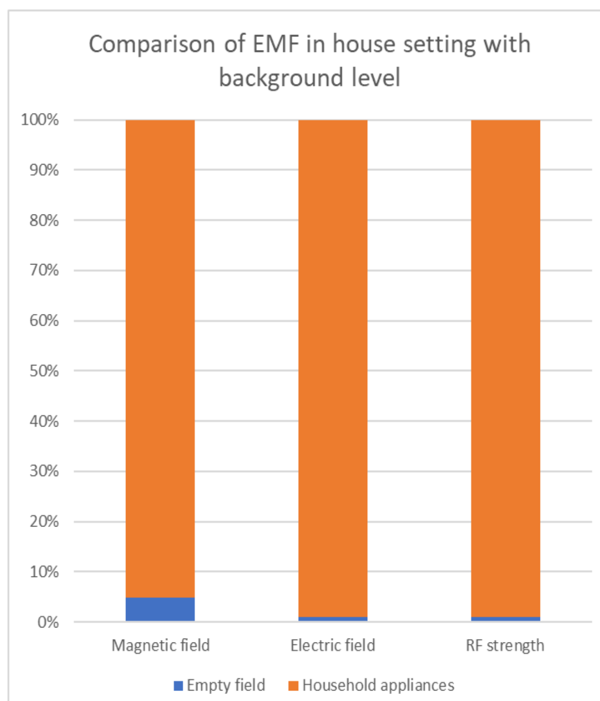


Figure 20: Comparison of EMF in house setting with the background level

2.6: Magnetic field, Electric field, and Radiofrequency strength per household:

Household-wise measurements of electromagnetic fields are presented in the following figures. Magnetic field strengths varied across households, ranging from 0.67 mG (house 61) to 74.5 mG in house 31. Electric field strengths also showed variability, with values between 46.1 to 810.6 V/m. In case of radiofrequency exposure, while most households recorded values near background levels, some households showed elevated RF strengths. On average, RF exposure ranges from 64316.17 to 2547.3 μW/m².

Overall, these results indicate that MF and EF exposures differed considerably between households depending on appliance use and household setup, while RF exposures were more localized and strongly influenced by communication devices.

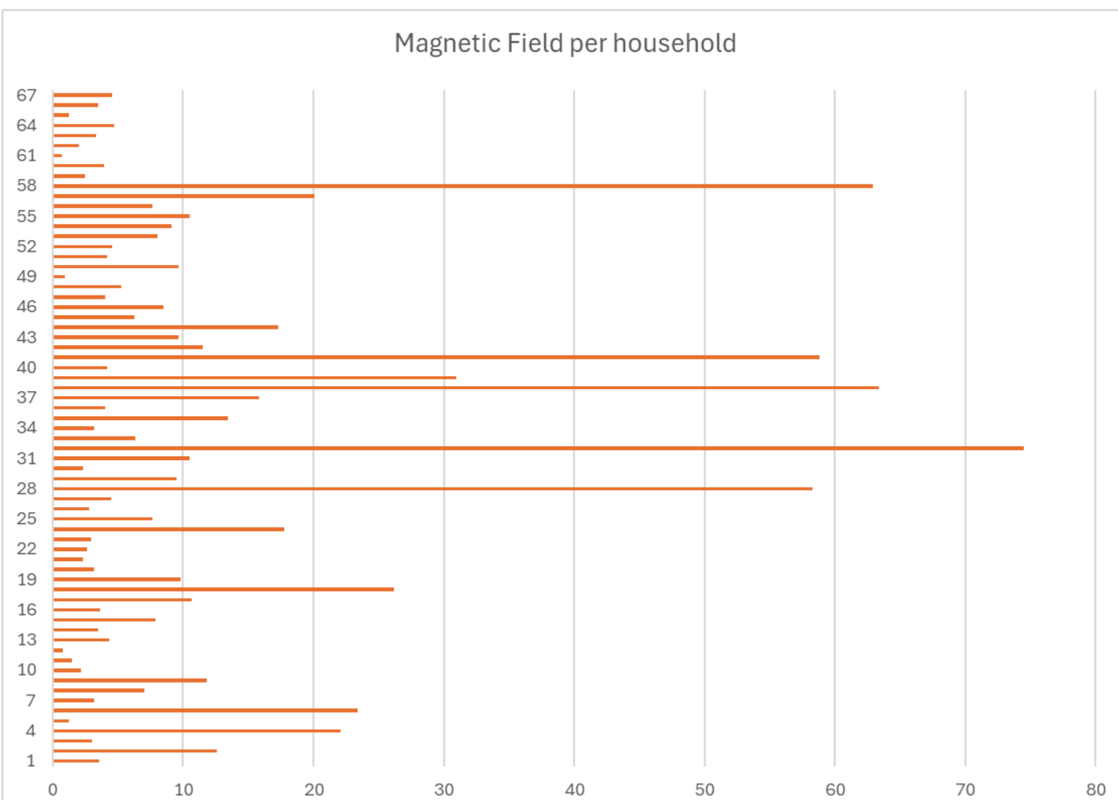
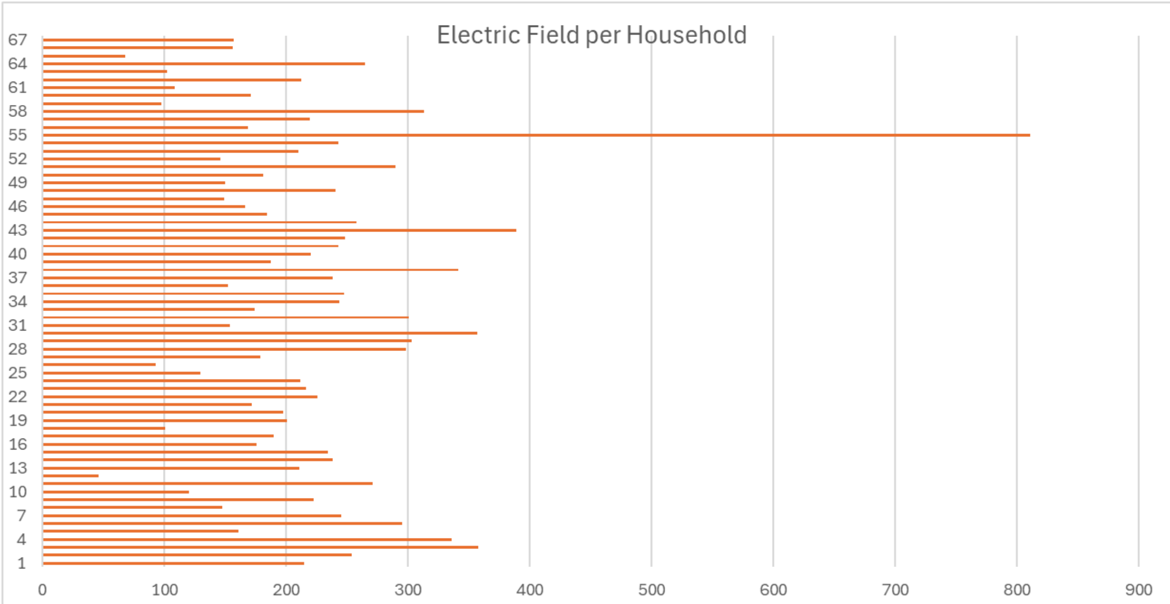
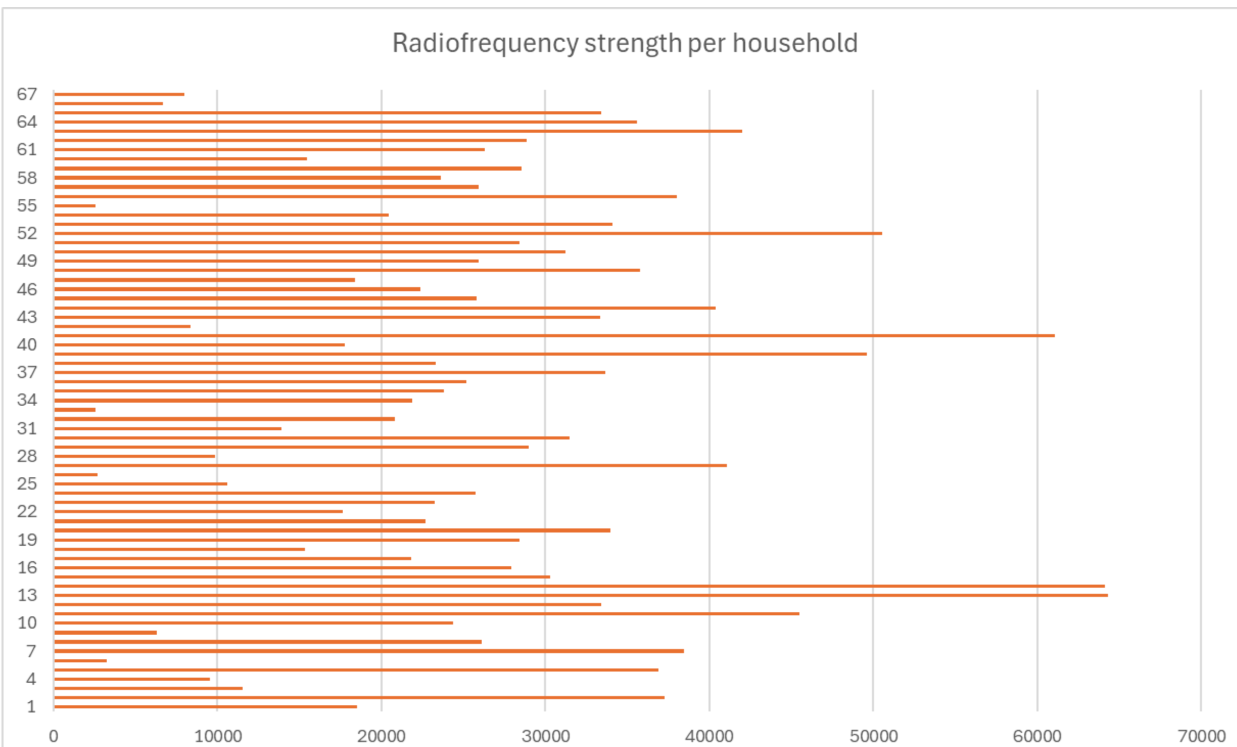


Figure 21: Average magnetic field per household



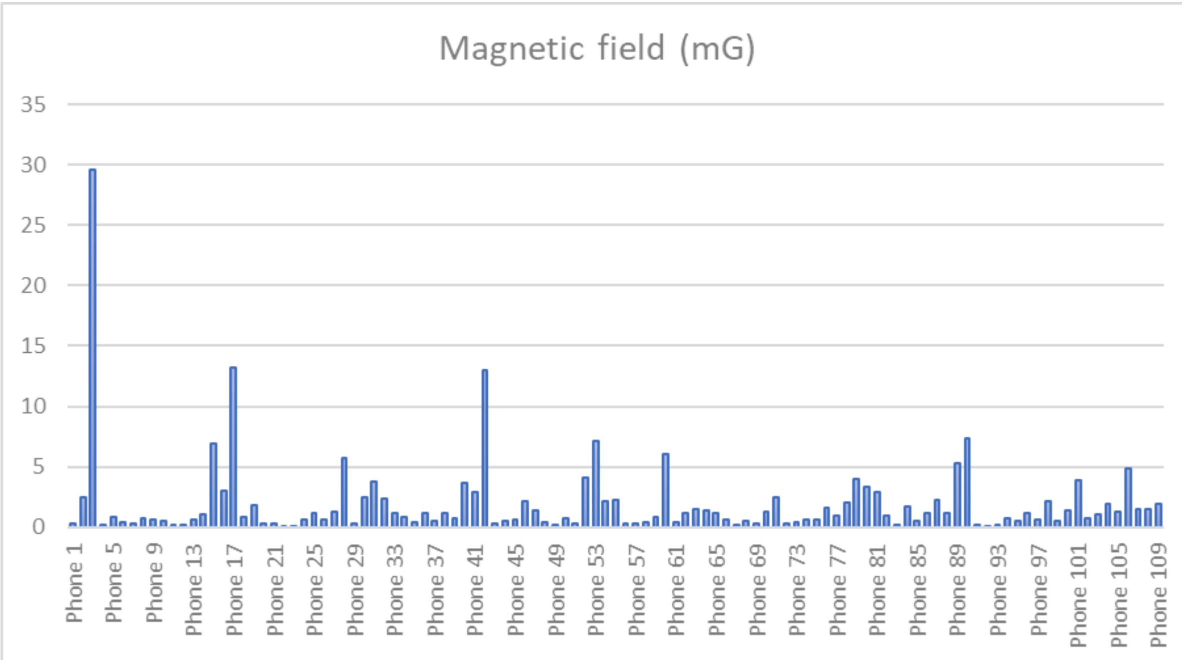
<u>Figure 22: Average electric field per household</u>



<u>Figure 23: Average RF strength per household</u>

2.7: Graphical analysis of the devices:

Cell phone:



<u>**Figure 24: Magnetic field values found in cell phones**</u>

A total of 109 phones were measured, and a bar chart was used to assess the magnetic field. The majority of the phones measured were below the accepted safety threshold limit of 2.5 mG, although a few cell phones exceeded this limit by a lot, like the one reaching 29.6 mG magnetic field strength.

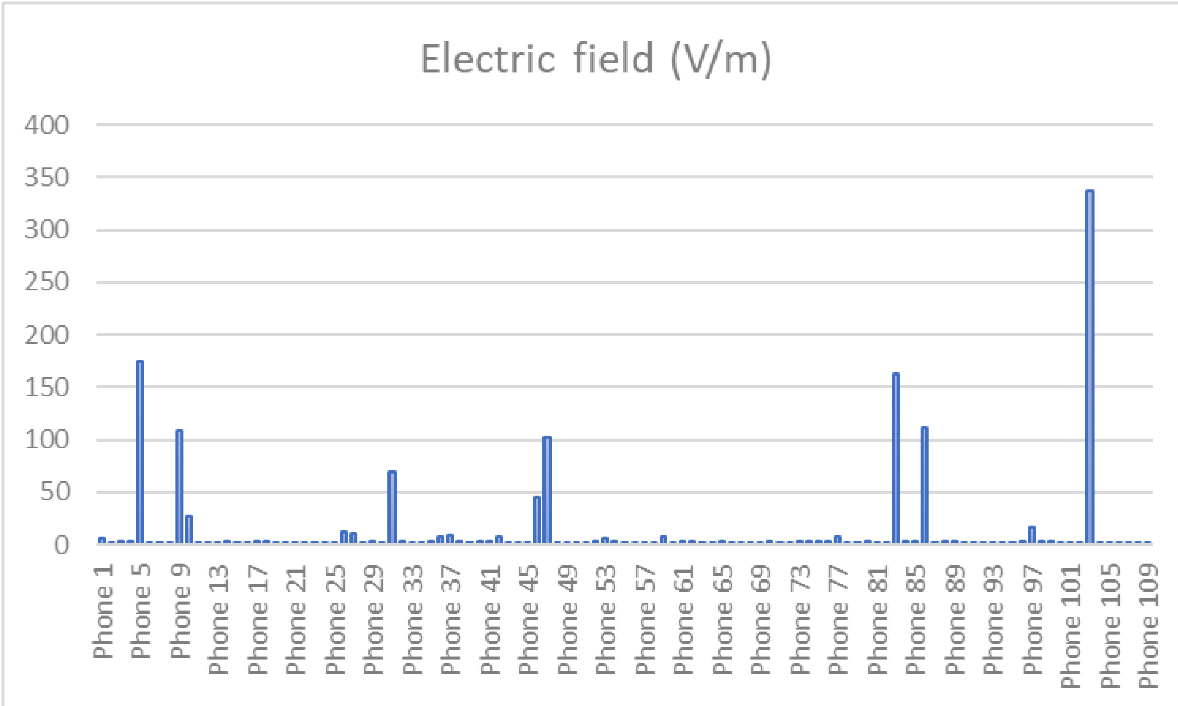


Figure 25: Electric field values found in cell phones

For assessing the Electric field 109 phones were measured with the E.M.F meter. Among them only phone numbers 5, 9, 11, 31, 47, 83, 86 and 103 showed elevated levels of Electric field value. The other cell phones had their exposure level below 25 V/m, well below the acceptable limit.

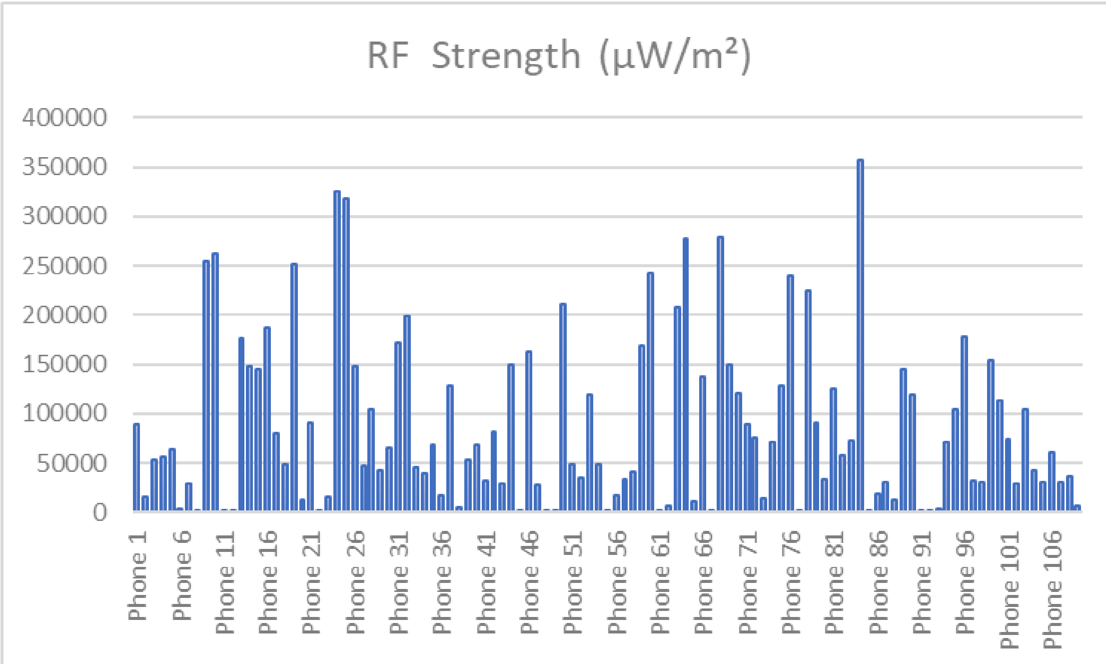


Figure 26: RF Strength values found in cell phones

All of the 109 phones measured showed radiofrequency strength well below the acceptable threshold value of 1,000,000 µW/m². Even though the RF strength varied widely across the cell phones till 357,000 µW/m², none of them crossed the safety threshold.

Power outlet:

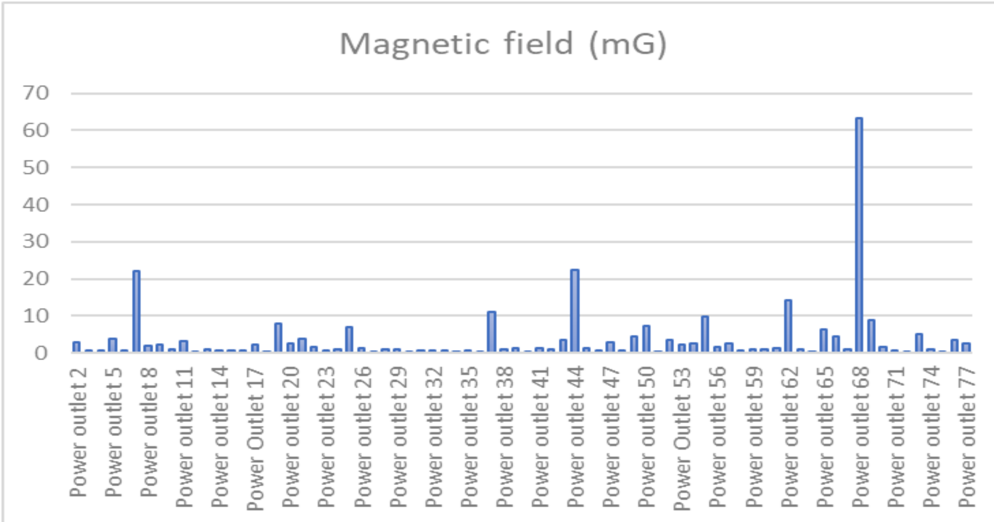


Figure 27: Magnetic field values found in power outlets

In total 77 power outlets were measured for assessing the magnetic field strength. Almost all the power outlets stayed well below the safety threshold limit of 2.5 mG. Only a few were seen to be exceeding this limit, and the highest value was found in Power Outlet No. 68, which is 63.22 mG.

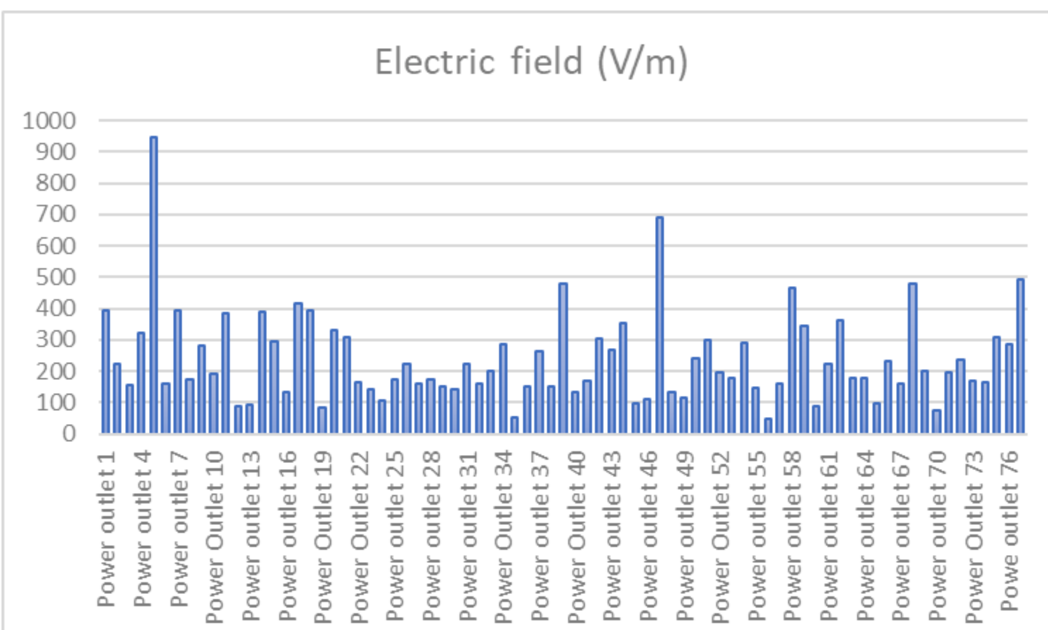


Figure 28: Electric field values found in power outlets

As for the electric field, all the power outlets crossed the safety threshold value by a lot. The highest was found to be 947.25 V/m in Power Outlet No. 5, and the lowest was found in Power Outlet No. 56, which is 46.25 V/m. Apart from this, the majority of the power outlets displayed electric field values up to 300 V/m.

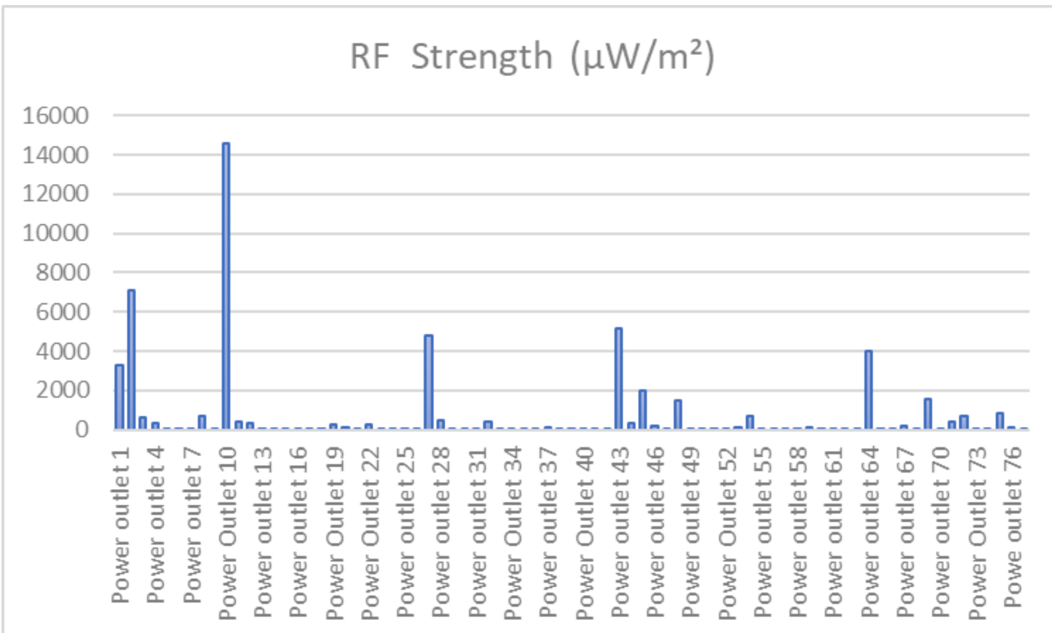


Figure 29: RF Strength values found in power outlets

As for the RF strength, none of the power outlets exceeded the safety threshold limit. The majority of them stayed below 300 µW/m². The highest value was found in Power Outlet No. 10. Apart from this, all the other power outlets were seen to be way below the accepted value.

Switch board:

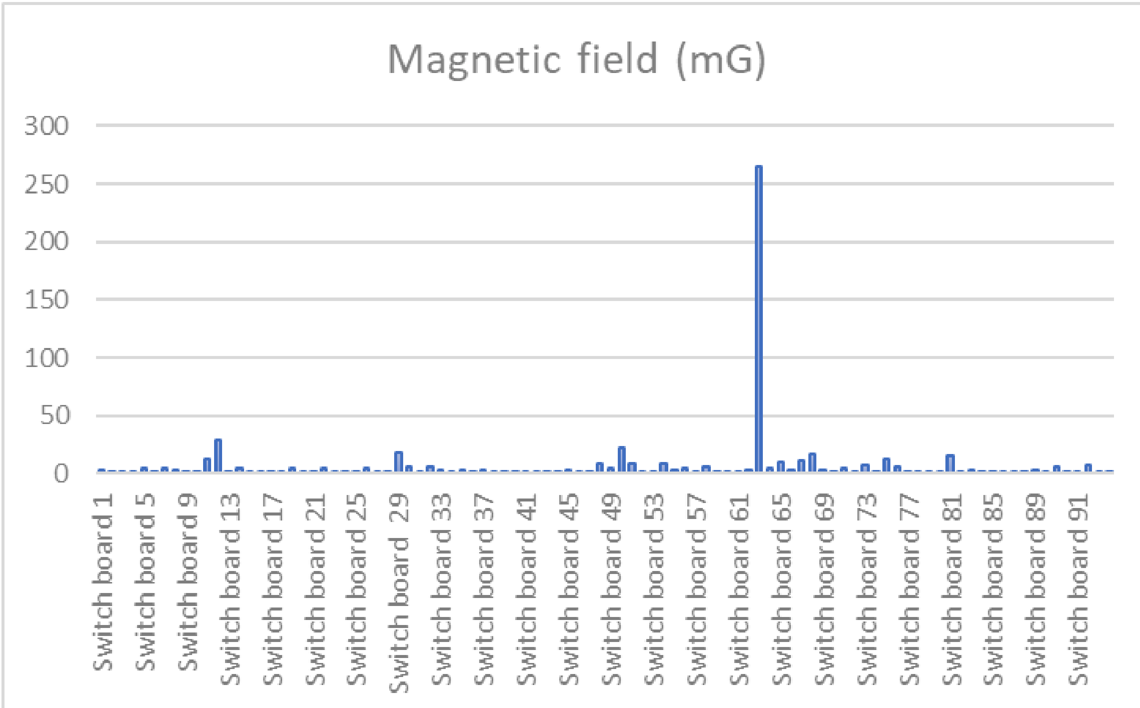


Figure 30: Magnetic field values found in Switchboards

Among the 94 switchboards measured, the highest magnetic field strength was recorded in Switchboard No. 63, with a value of 265.37 mG, which is well above the safety threshold limit of 2.5 mG. The majority of switchboards were within the 0–5 mG range, and most of these remained below the 2.5 mG limit. However, a few switchboards, including No. 11, 12, 29, 50, 63, 67, 68, 75, and 81, exceeded 10 mG.

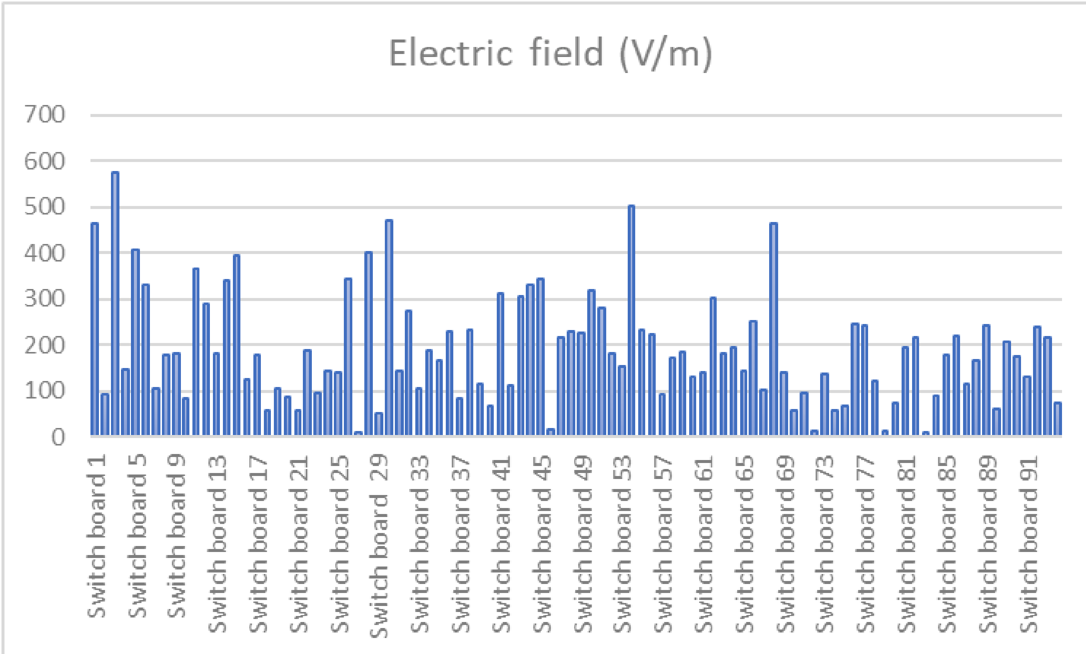


Figure 31: Electric field values found in Switchboards

As for the electric field intensity, almost all switchboards measured values well above the acceptable limit of 25 V/m. Only a few were found below this threshold, while the majority exceeded it significantly. The highest value was observed in Switchboard No. 3 (575.75 V/m), whereas the lowest was recorded in Switchboards No. 27 and 83 (9.75 V/m).

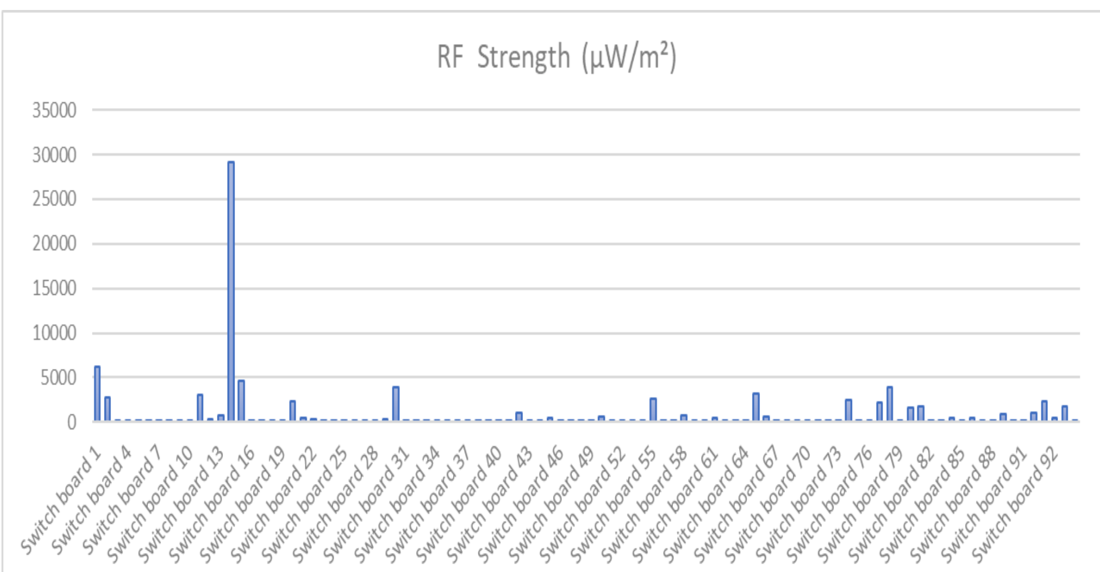


Figure 32: RF Strength values found in Switchboards

In the case of radio frequency (RF) strength, none of the switchboards surpassed the safety threshold. RF levels were negligible in most cases, with the highest recorded in Switchboard No. 14 (291.25 µW/m²). All the values remained far below the accepted limit and close to background levels.

Fan:

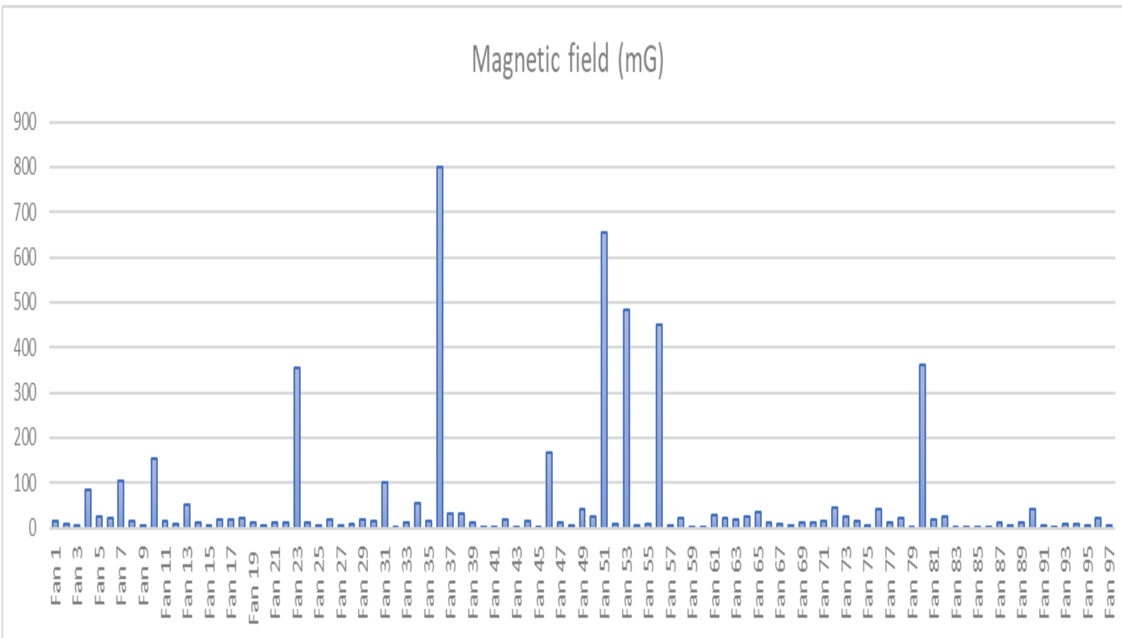


Figure 33: Magnetic field values found in Fans

Among the 97 fans measured, the highest magnetic field strength was recorded in Fan No. 36, with a value of 800.69 mG, which exceeded the safety threshold limit of 2.5 mG. The majority of fans exceeded this range, and most remained beyond the safety threshold.

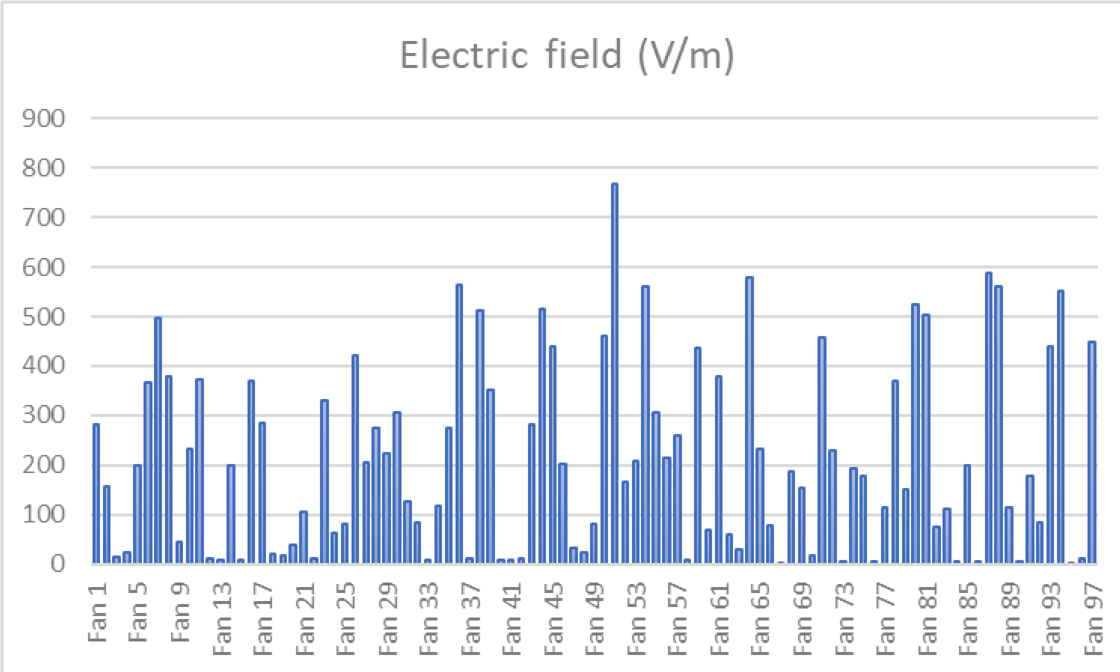


Figure 34: Electric field values found in Fans

For the electric field intensity, most of the fans recorded values above the acceptable limit of 25 V/m, while only a few stayed below the threshold. The highest value was observed in Fan No. 51 (765.75 V/m), whereas the lowest was found in Fan No. 67 (2 V/m).

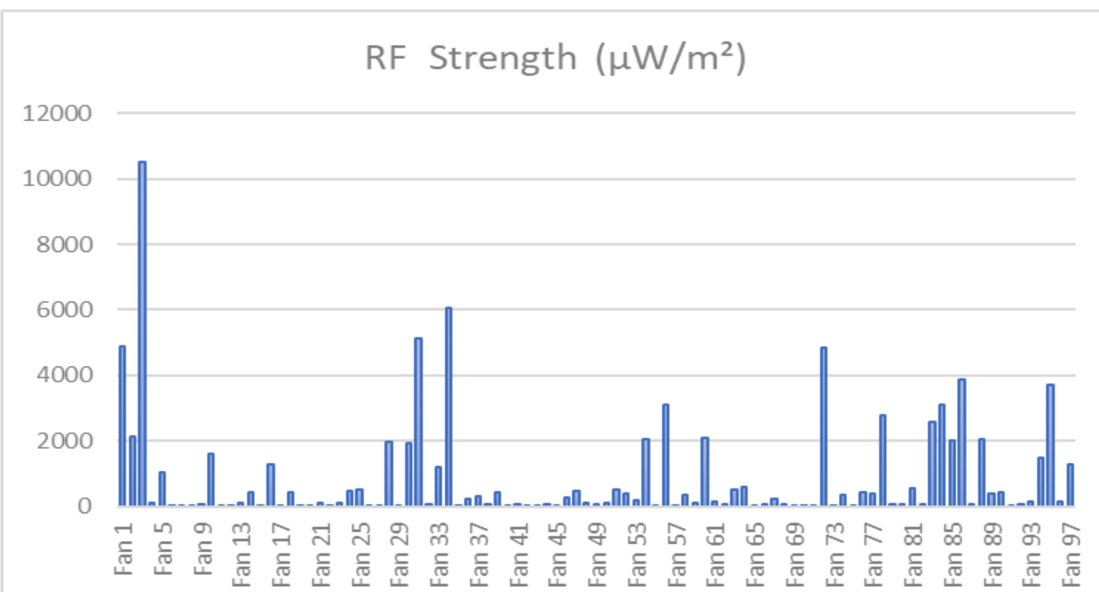


Figure 35: RF strength values found in Fans

Regarding radio frequency (RF) strength, none of the fans crossed the safety threshold. RF levels were generally negligible, with the highest value recorded in Fan No. 3 (10510 µW/m²). All other readings remained far below the limit and close to background levels.

Light

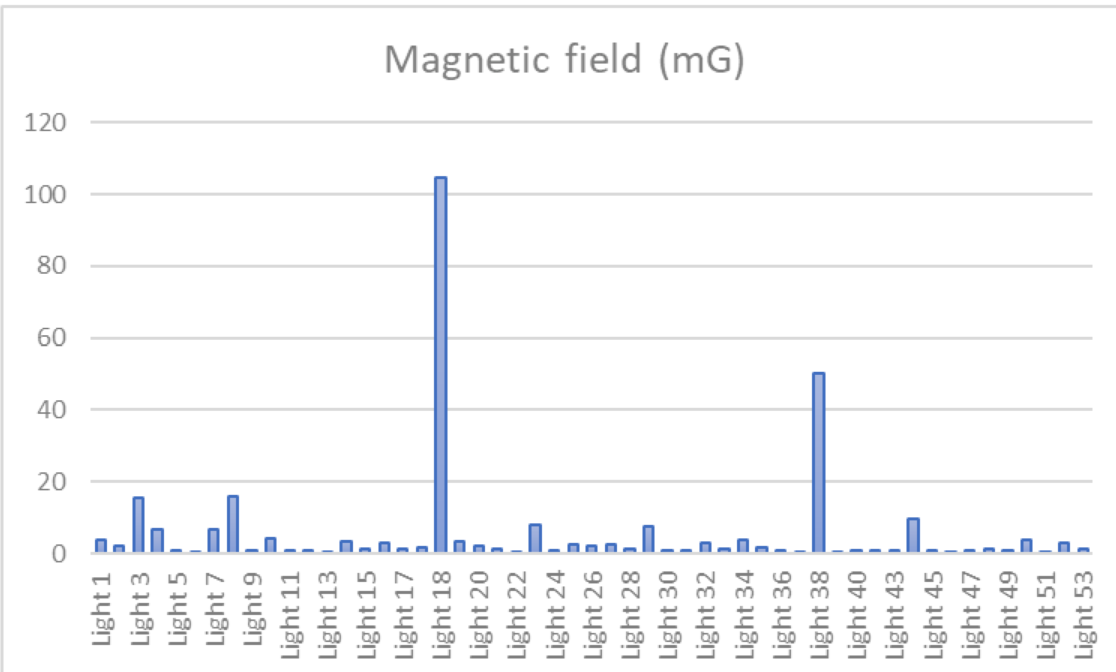


Figure 36: Magnetic field values found in lights

Among the 53 lights measured, the highest magnetic field strength was observed in Light No. 18, with a value of 104.43 mG, which exceeded the safety threshold limit of 2.5 mG by a significant margin. The majority of lights, however, were found within the 2.5 mG range, and most of them stayed below the threshold. Only a few lights recorded values higher than this limit, with some even crossing 10 mG, indicating higher field emissions.

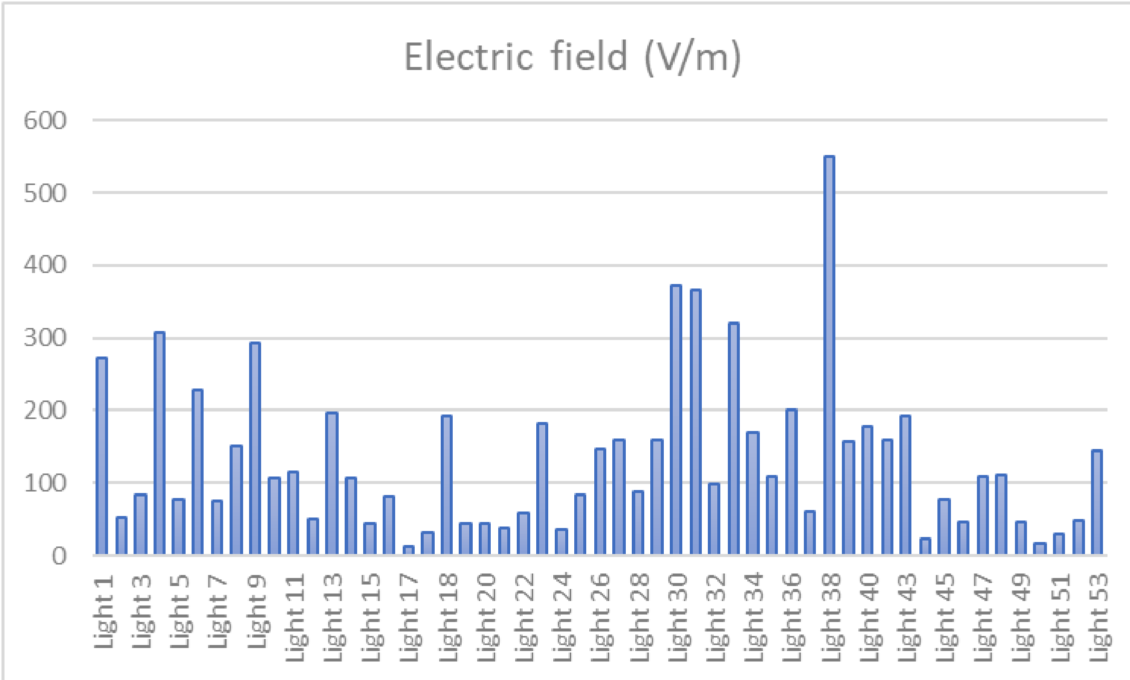


Figure 37: Electric field values found in lights

In terms of the electric field intensity, most lights exceeded the acceptable limit of 25 V/m, while only a small number of them were found to be below this threshold. The highest electric field was detected in Light No. 38, reaching up to 550.5 V/m, which was well above the safety standard. On the other hand, the lowest value was measured in Light No. 17, which was 11.75 V/m. This shows a wide variation across the lights, though the majority clearly exceeded the recommended limit by a considerable amount.

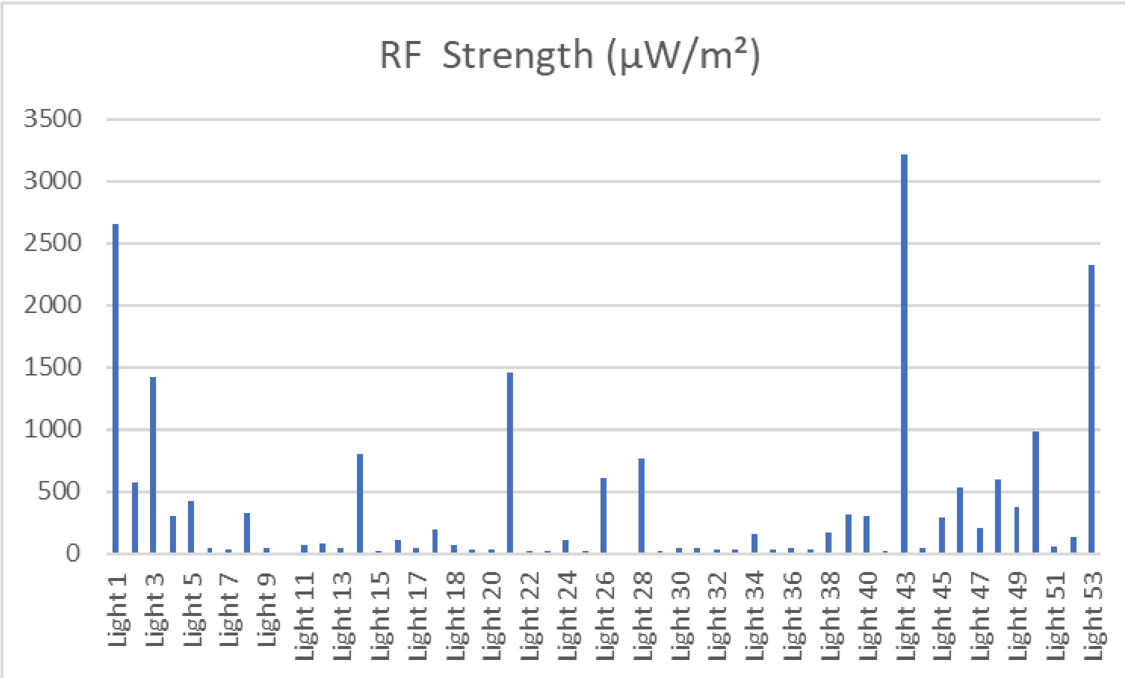


Figure 38: RF strength values found in lights

When assessing the radio frequency (RF) strength, none of the lights surpassed the safety threshold. The RF values in most cases remained negligible and close to background levels, with only slight variations across different lights. The highest RF measurement was found in Light No. 43, which recorded 3214.75 µW/m², remaining well below the safety threshold. All the other lights showed values much lower than this, confirming that RF radiation from lights was not a concern in this assessment.

Kitchen hood:

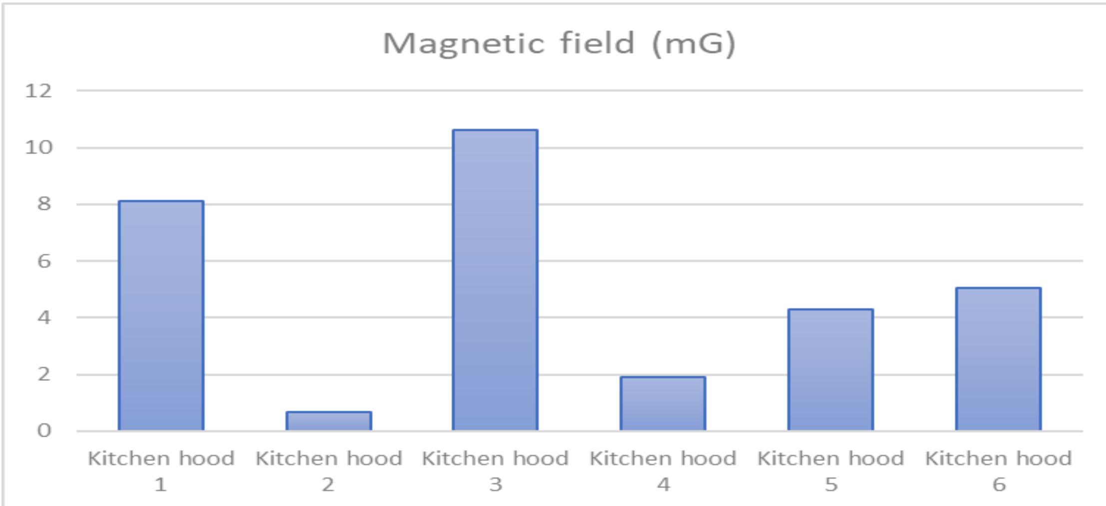


Figure 39: Magnetic field values found in kitchen hoods

Among the 6 kitchen stove hoods measured, the highest magnetic field strength was observed in Hood No. 3, with a value of 10.63 mG, which exceeded the safety threshold limit of 2.5 mG. The lowest was in hood 2 (0.655 mG). The majority of the hoods recorded values above the safety threshold, although a couple were found to be below the limit.

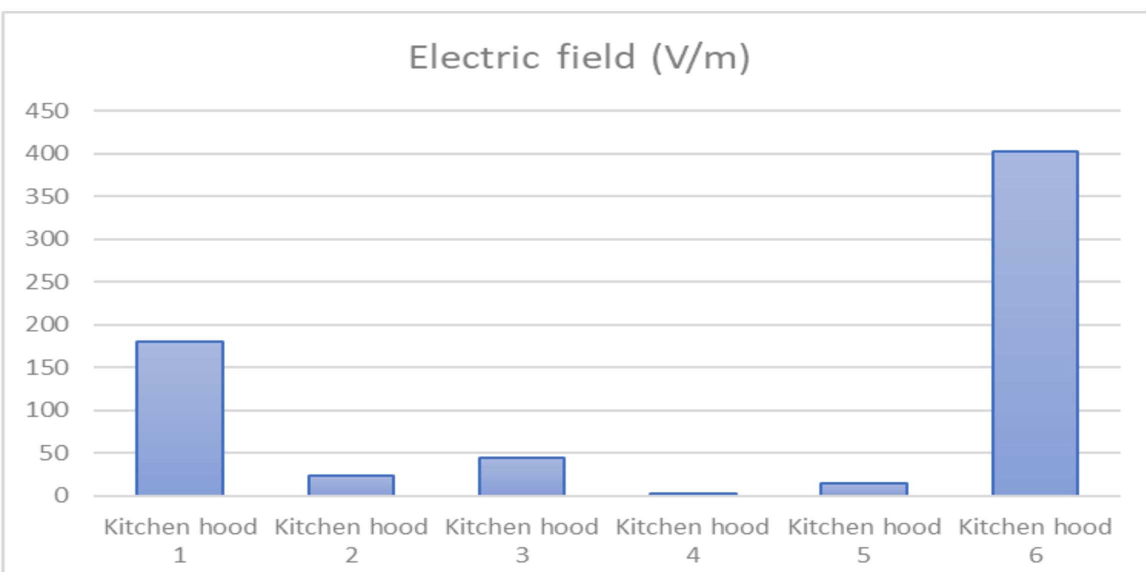


Figure 40: Electric field values found in kitchen hoods

As for the electric field intensity, half of the hoods were measured to be above the acceptable limit of 25 V/m, while the other half were close to or below this value. The highest electric field was found in Hood No. 6 (401.65 V/m), whereas the lowest was observed in Hood No. 4 (2 V/m). This indicates that, similar to other household appliances, the stove hoods generally exceeded the threshold by a considerable margin.

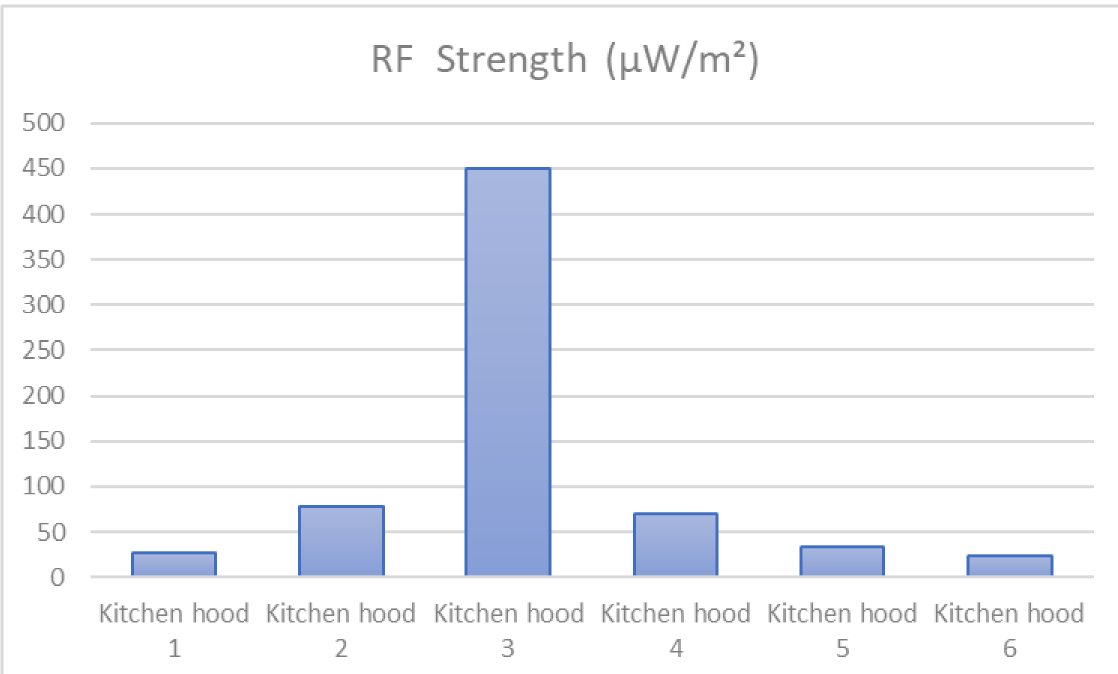


Figure 41: RF Strength values found in kitchen hoods

In the case of radio frequency (RF) strength, none of the stove hoods exceeded the safety threshold. The measured RF values remained negligible, with the highest recorded in Hood No. 3, and all of them stayed within 450 µW/m². All others were far below the accepted limit, remaining close to background levels.

Water Purifier/ Filter:

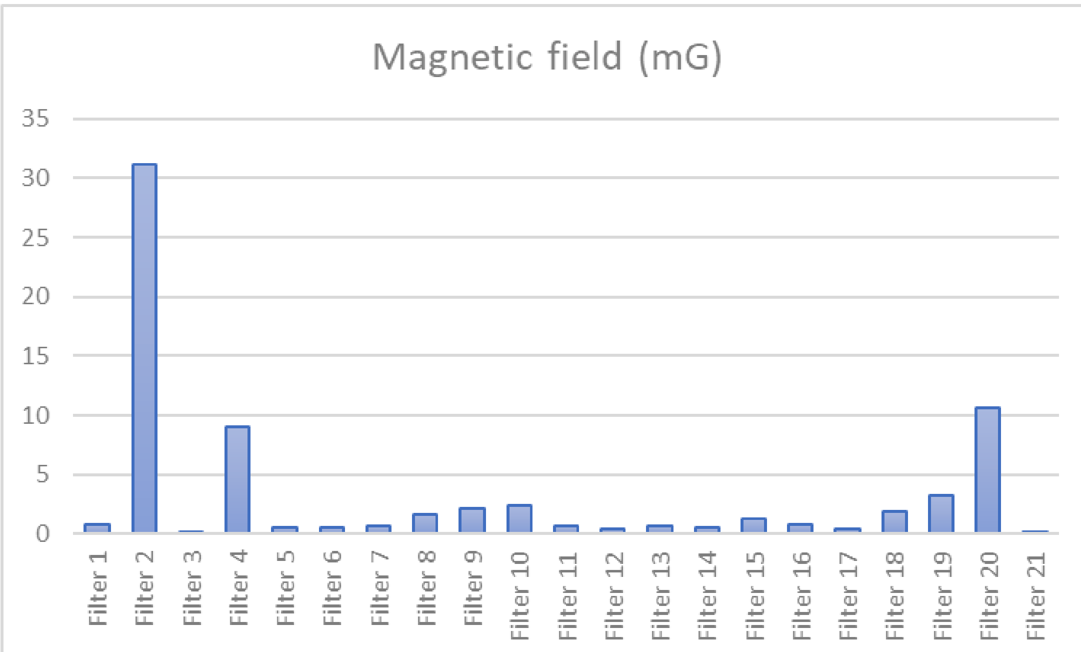
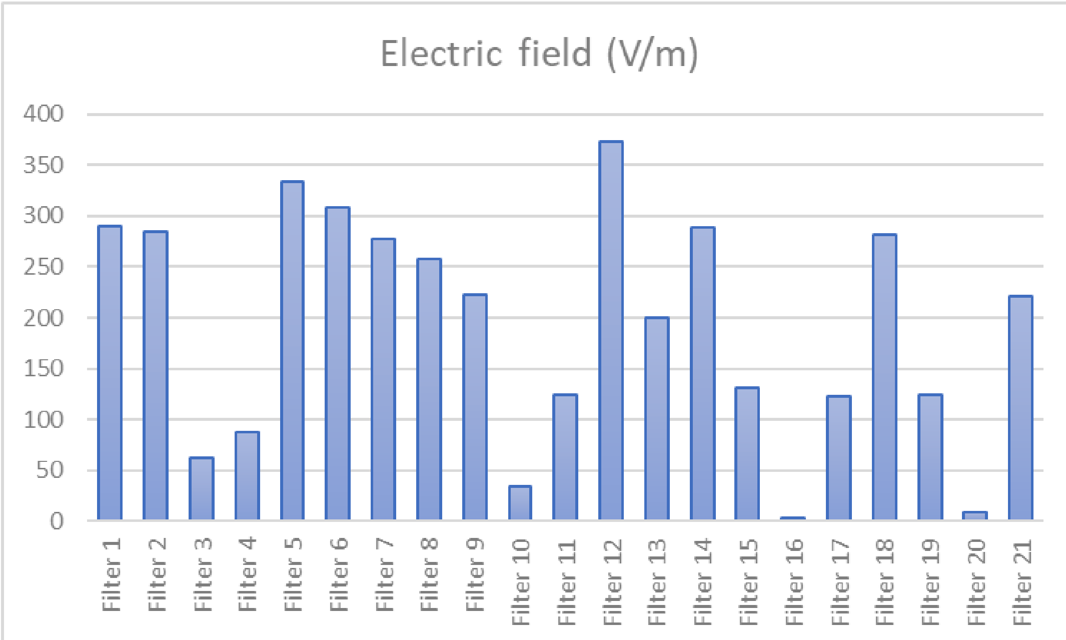


Figure 42: Magnetic field values found in Filters

Among the 21 water purifiers measured, the highest magnetic field strength was recorded in Purifier No. 2, with a value of 31.18 mG, which exceeded the safety threshold limit of 2.5 mG. Most of the purifiers, however, fell within the 2.5 mG range. Only a few, like water purifier/ filter numbers 2, 4, 19, and 20, showed elevated values, with some crossing beyond the threshold value, indicating localized higher emissions.



<u>Figure 43: Electric field values found in Filters</u>

For the electric field intensity, the majority of purifiers recorded levels above the acceptable limit of 25 V/m, while only 2 stayed within the safe range. The highest electric field was observed in Purifier No. 12 (372.25 V/m), whereas the lowest was found in Purifier No. 16 (3.5 V/m). This suggests a wide variation across devices, though the general trend showed values surpassing the safety threshold considerably.

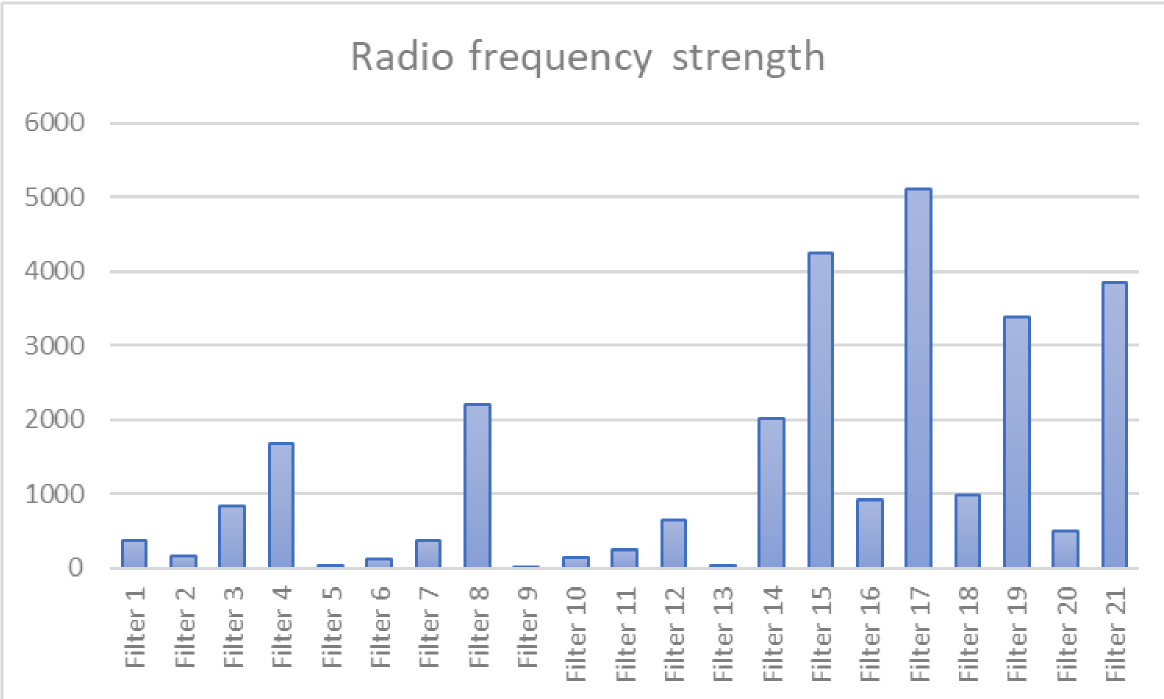


Figure 44: RF strength values found in Filters

In the case of radio frequency (RF) strength, none of the purifiers exceeded the threshold. RF emissions were negligible across almost all measurements, with the highest detected in Purifier No. 17 (5113.8 µW/m²). The rest remained far below the accepted limit, close to background levels. The lowest was found in number 9 with only 11.64 µW/m².

Washing machine:

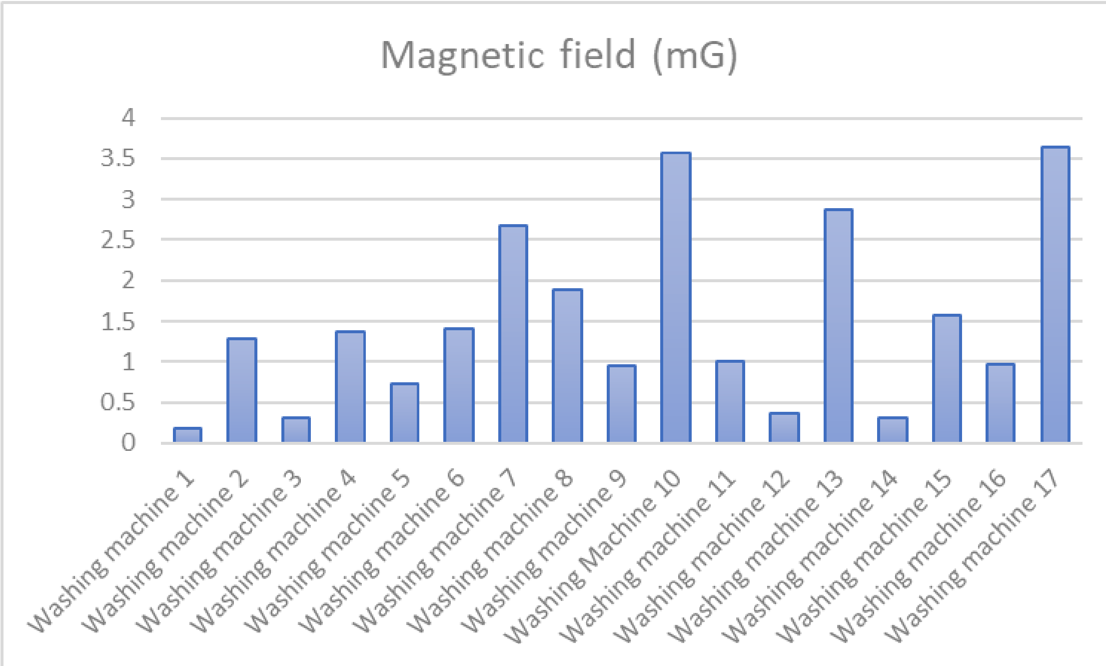


Figure 45: Magnetic field values found in washing machines

The washing machines exhibited a range of magnetic field emissions, with the majority staying within the 0–2.5 mG range. Most readings were found below the safety threshold of 2.5 mG, but a few machines exceeded this level. The maximum magnetic field was observed in Machine No. 17, reaching 3.65 mG, while the lowest remained near background levels with 0.19 mG.

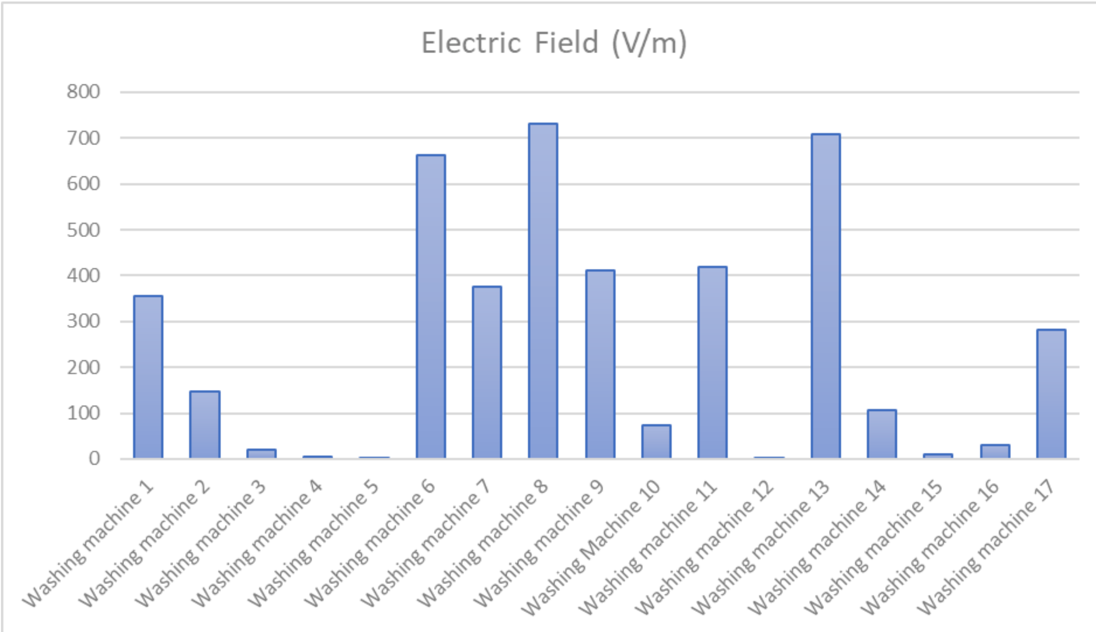


Figure 46: Electric field values found in Washing machines

In terms of electric fields in the 17 washing machines, they consistently produced values higher than the 25 V/m safety limit, except for a few. The range was quite broad, with the highest reading recorded at 730.25 V/m and the lowest at 2 V/m. This shows that washing machines, due to their motorized function, tend to contribute significantly to electric field exposure. Only five washing machines were found to be within the safety threshold limit.

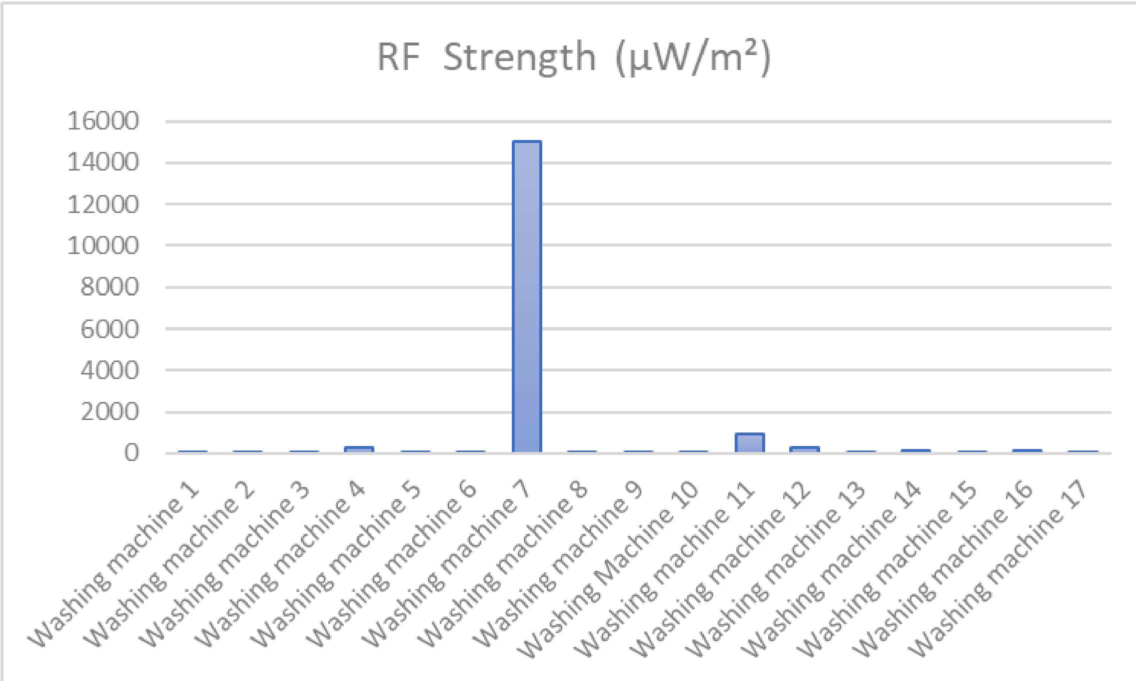


Figure 47: RF strength values found in washing machines

With respect to radio frequency (RF), emissions were negligible. None of the machines came close to the safety threshold, and the maximum, found in Machine No. 7, was 15008 µW/m², with all others staying close to background radiation levels.

Monitor:

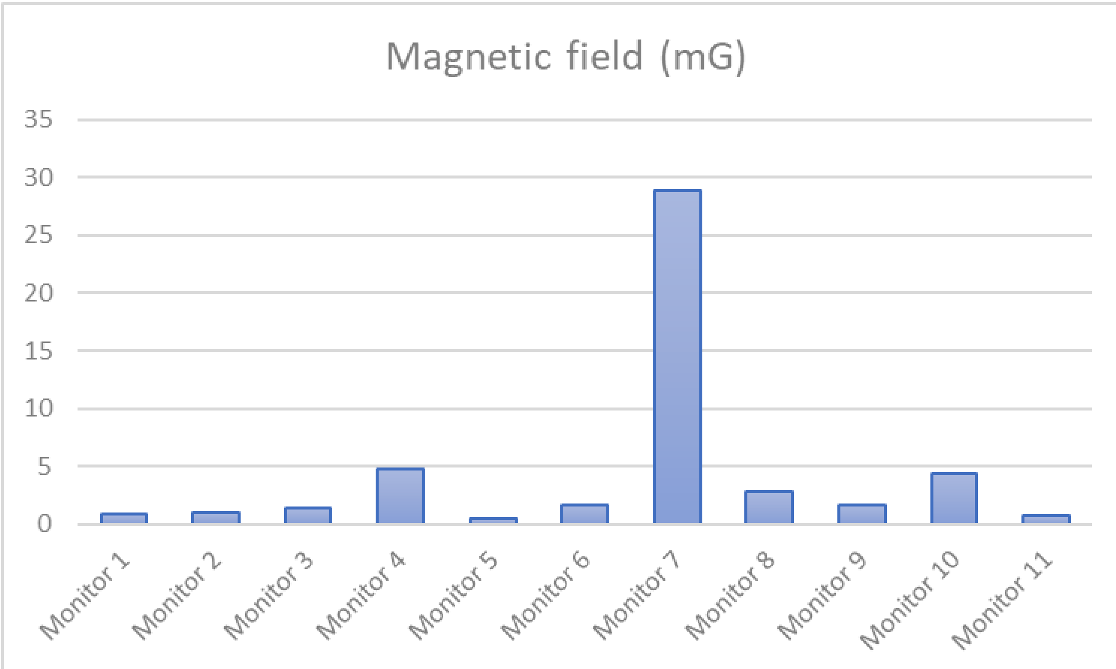


Figure 48: Magnetic field values found in Monitors

A total of 11 monitors were measured. The monitors generally produced very low magnetic fields, with nearly all devices remaining below the 2.5 mG threshold. Only isolated cases showed higher values, such as Monitor Numbers 4, 7, 8 and 10 which registered magnetic fields above the accepted limit, though still not alarmingly high. The highest recorded was monitor number 7 with 28.88 mG.

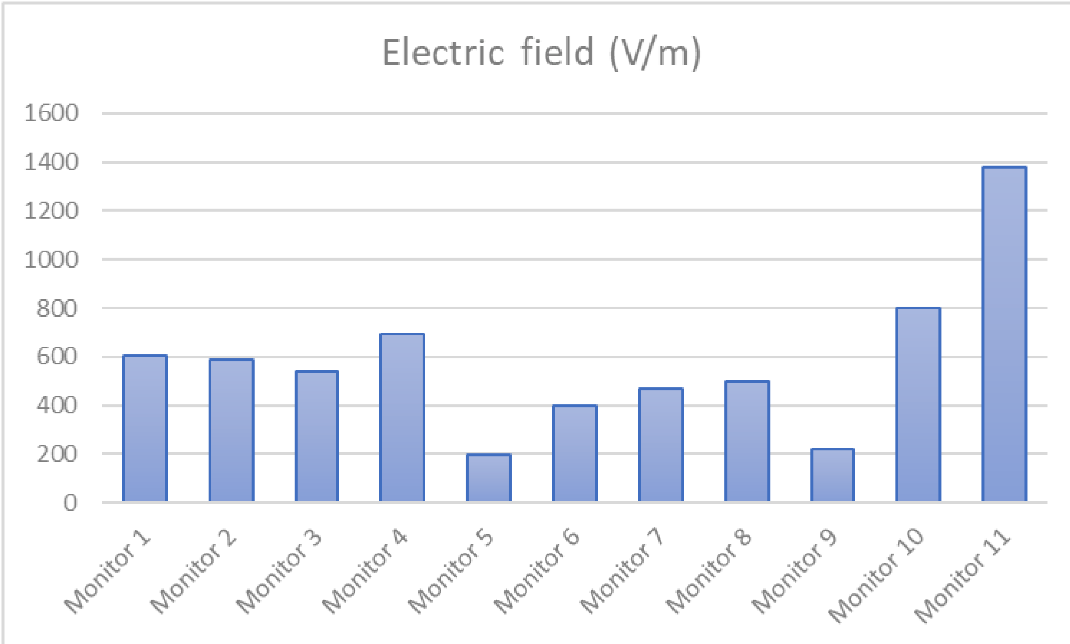


Figure 49: Electric field values found in Monitors

The electric field values, on the other hand, were much more significant. Most monitors exceeded the 25 V/m limit, reflecting their continuous operation and display-based circuitry. The highest was found in Monitor No. 11, at 1379.5 V/m, while the lowest, in Monitor No. 5, measured 197.75 V/m.

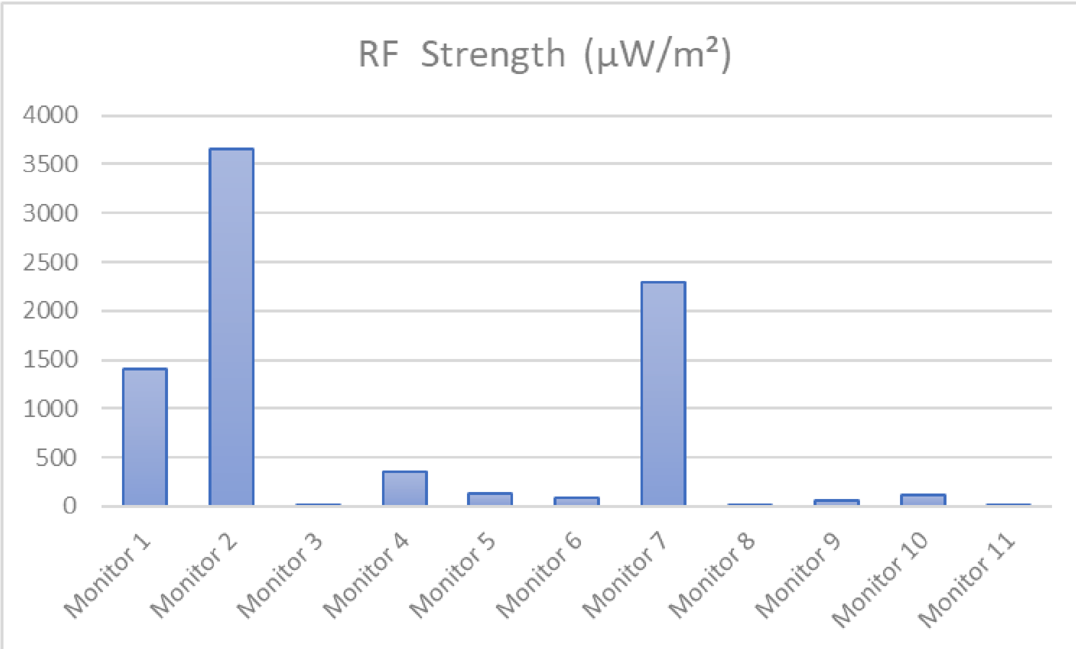


Figure 50: RF strength values found in Monitors

For RF strength, the monitors displayed no concerning values. The majority stayed at background levels, with the maximum recorded being 3660.73 µW/m² in monitor 2, still well under the threshold.

Laptop:

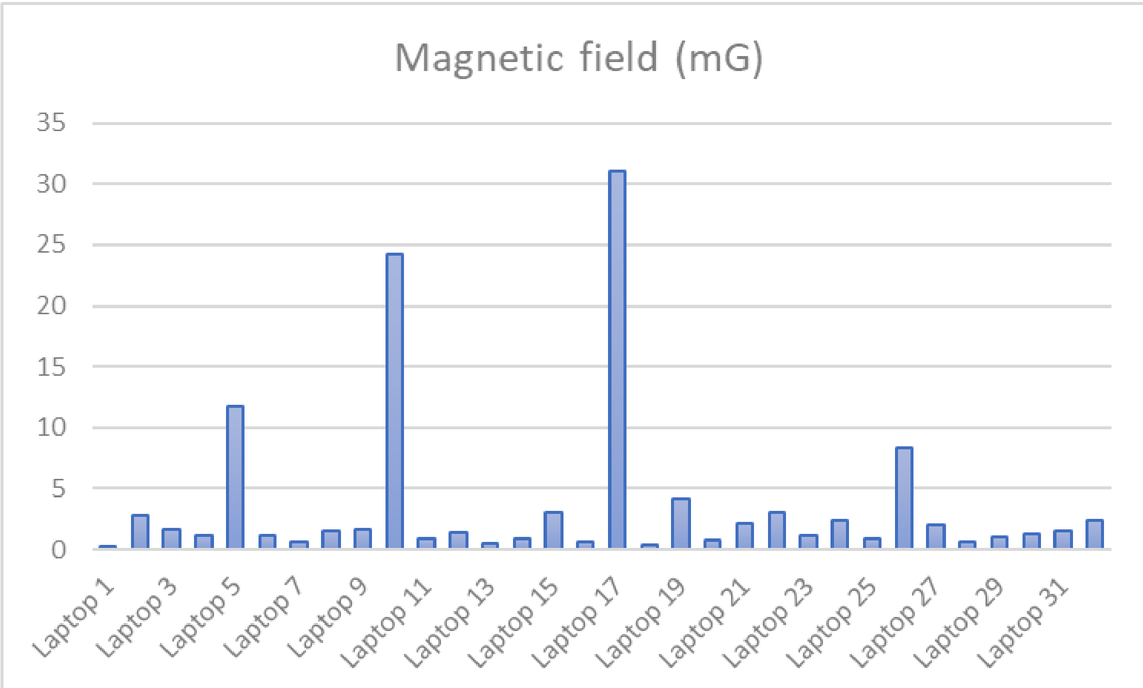


Figure 51: Magnetic field values found in Laptops

The laptops showed greater variability in their emissions compared to desktop monitors. Magnetic fields were usually confined to the 0–2.5 mG range, but a few exceeded the threshold, likely influenced by battery charging or internal component activity. Only 8 laptops out of the 32 measured showed a higher magnetic field value than the safety limit. The highest was seen in Laptop No. 17, with 31.09 mG, while the lowest remained below detection limits.

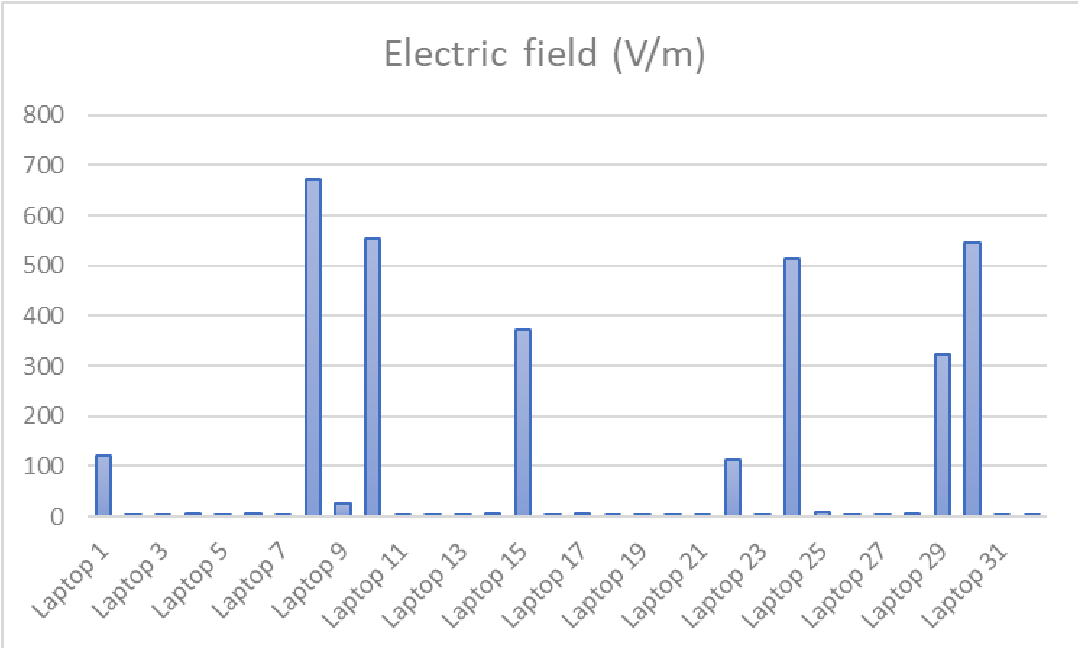


Figure 52: Electric field values found in Laptops

The electric field strength was consistently higher, with 9 laptops surpassing the 25 V/m safety margin. Maximum values climbed as high as 673 V/m, and even the lowest readings were 2 for many laptops. This indicates that laptops, though portable, can be a notable source of electric field exposure, especially when connected to a charger.

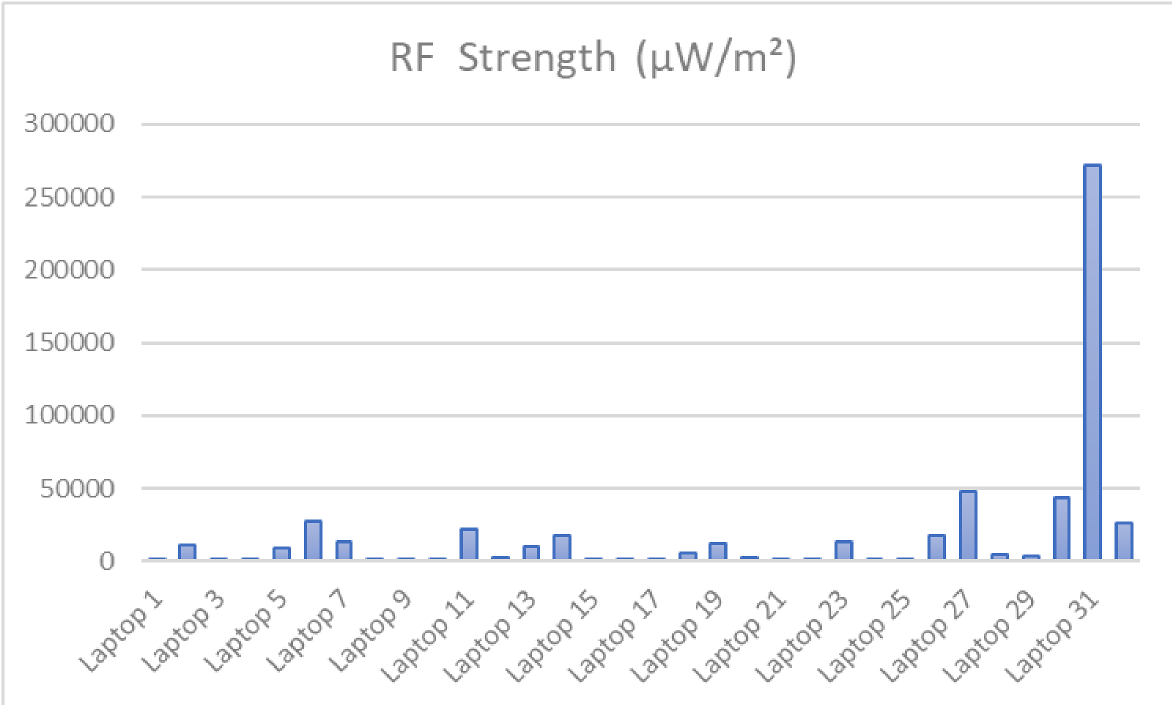


Figure 53: RF Strength values found in Laptops

For RF strength, laptops recorded comparatively higher values than most other appliances, due to Wi-Fi and Bluetooth transmissions. Nevertheless, even the strongest emission, 271771 µW/m² in Laptop No. 30, stayed well below the international safety guideline.

Ac:

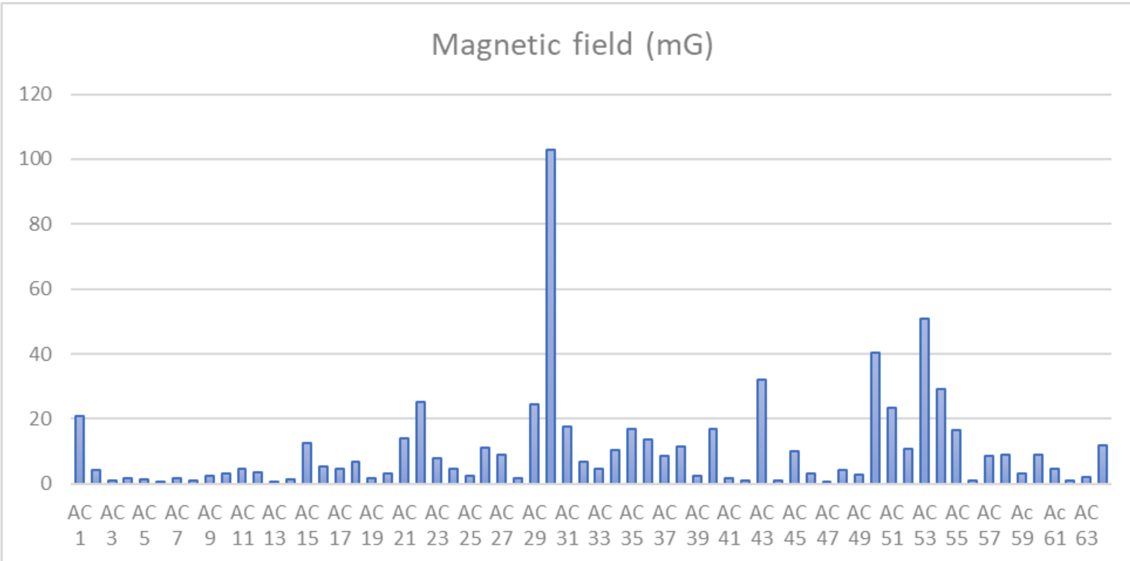


Figure 54: Magnetic field values found in ACs

A total of 64 ACs were measured to assess the magnetic field values. The air conditioners generally produced low magnetic field levels, but not below 2.5 mG. A lot of ACs measured values higher than the safety threshold. Only a handful stayed below this threshold, the lowest being 0.61 mG in AC No. 47..

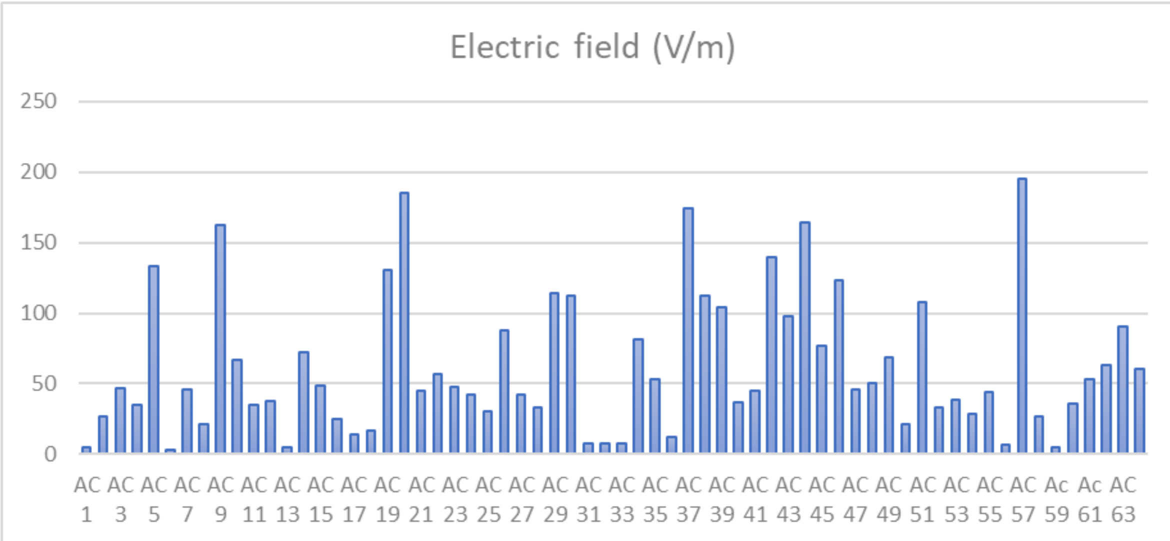


Figure 55: Electric field values found in ACs

Their electric field intensity was noticeably higher, with the majority surpassing the 25 V/m limit. Readings varied a lot, from a minimum of 3.5 V/m to a maximum of 195 V/m, reflecting variations in power usage and design.

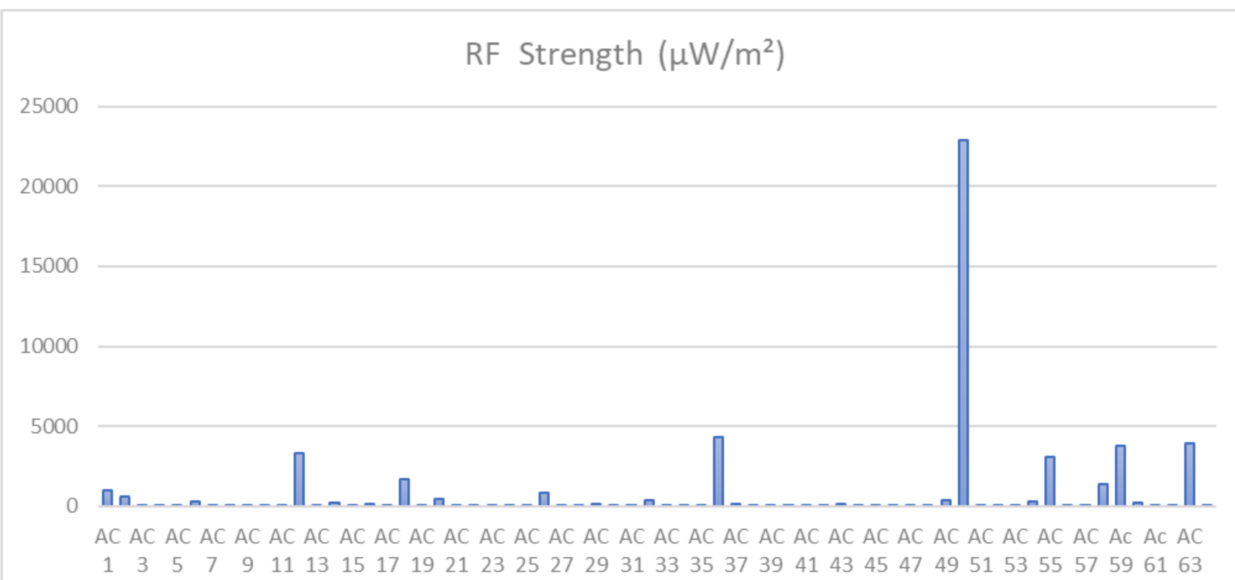


Figure 56: RF strength field values found in ACs

RF strength from AC units was negligible, as expected, with all readings remaining far below the threshold. The maximum recorded was 22914 µW/m² in AC 50, while most stayed at background levels.

TV:

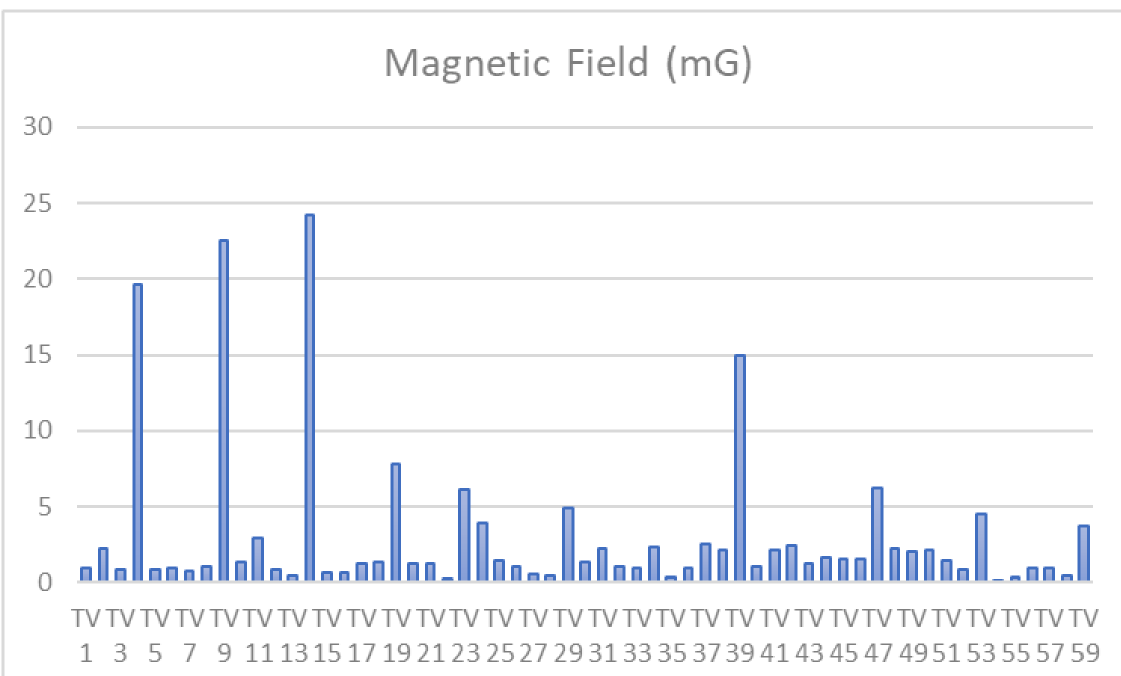


Figure 57: Magnetic field values found in TVs

The televisions displayed mixed magnetic field outputs. A majority of the total of 59 televisions measured, stayed within the 2.5 mG range, but several crossed the threshold, the highest being 24.235 mG in TV No. 14.

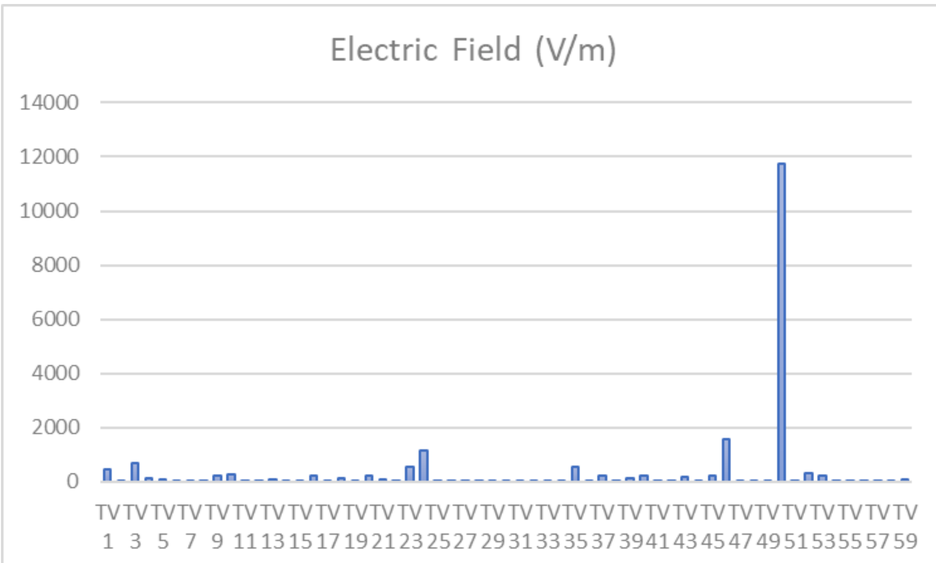
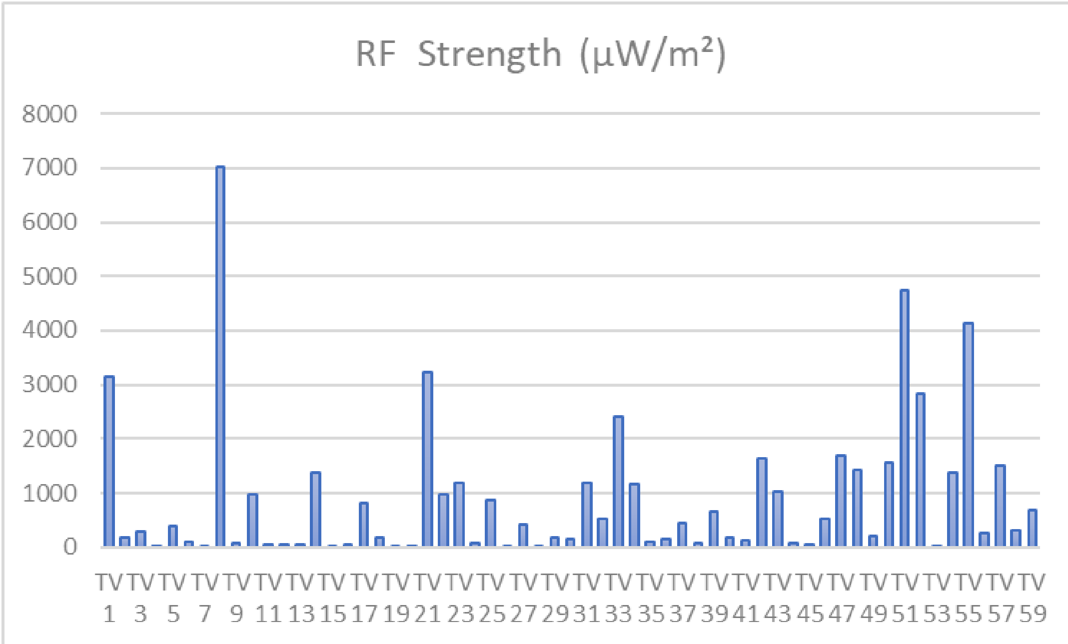


Figure 58: Electric field values found in TVs

For the electric fields, nearly all TVs produced values above the 25 V/m acceptable limit. The difference in the values ranged greatly. The highest was measured at 11751.25 V/m, and the lowest being 2 V/m, showing the significant influence of display and power circuits.



<u>Figure 59: RF strength values found in TVs</u>

When assessing RF emissions, televisions were found to be relatively safe, with the maximum being 7023 µW/m² and all other readings far below the safety margin.

Multiplug:

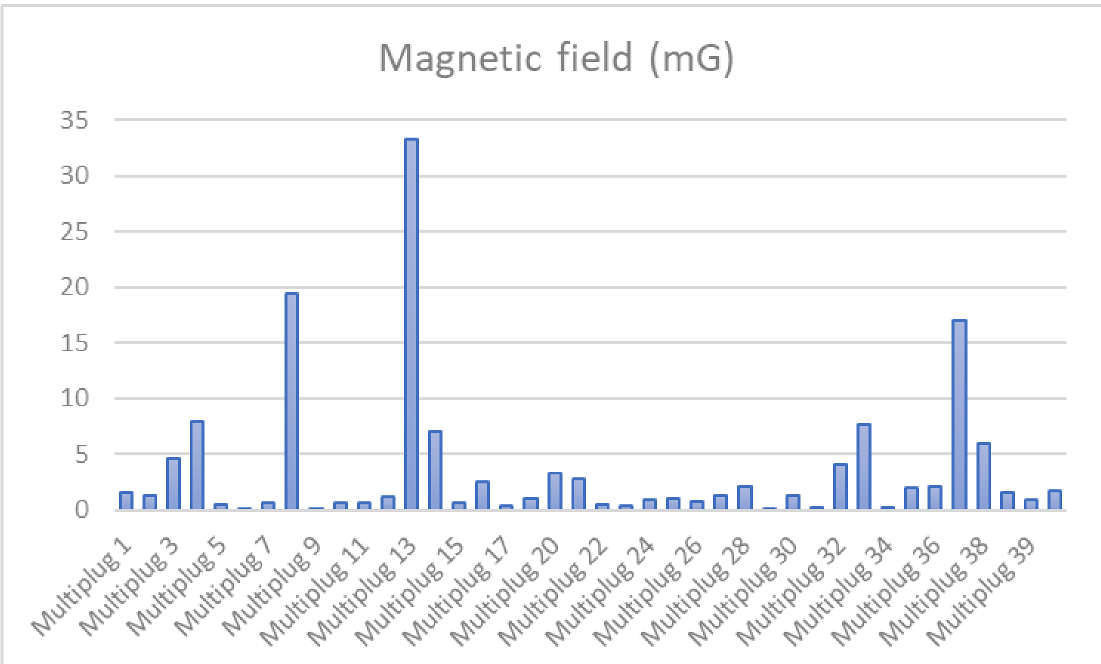


Figure 60: Magnetic field values found in Multiplugs

40 multiplugs were measured in total for the assessment of EMF value. The multiplugs showed a wide range of magnetic field values, highly dependent on the number of devices connected and the power outlets in them. Most stayed below the 2.5 mG limit, while some went far beyond it, with the highest recorded at 33.3 mG in multiplug number 13.

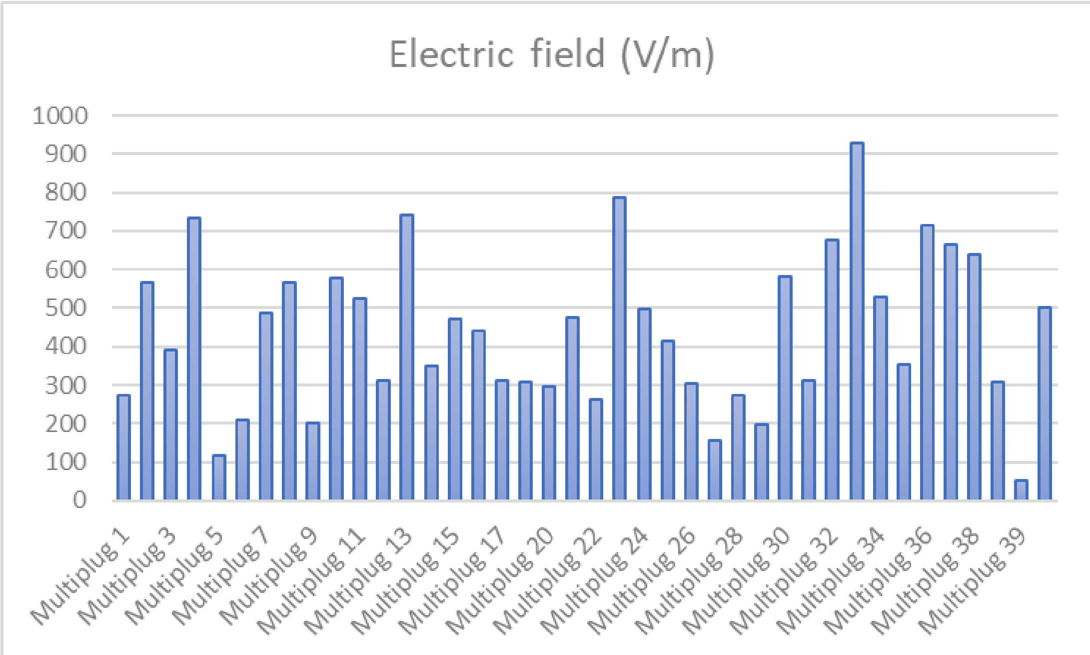


Figure 61: Electric field values found in Multiplugs

Their electric fields were above the 25 V/m threshold in every case. The value was highest, particularly when fully loaded or having more power outlets, with the maximum reaching 928.5 V/m and the lowest being 52.25 V/m.

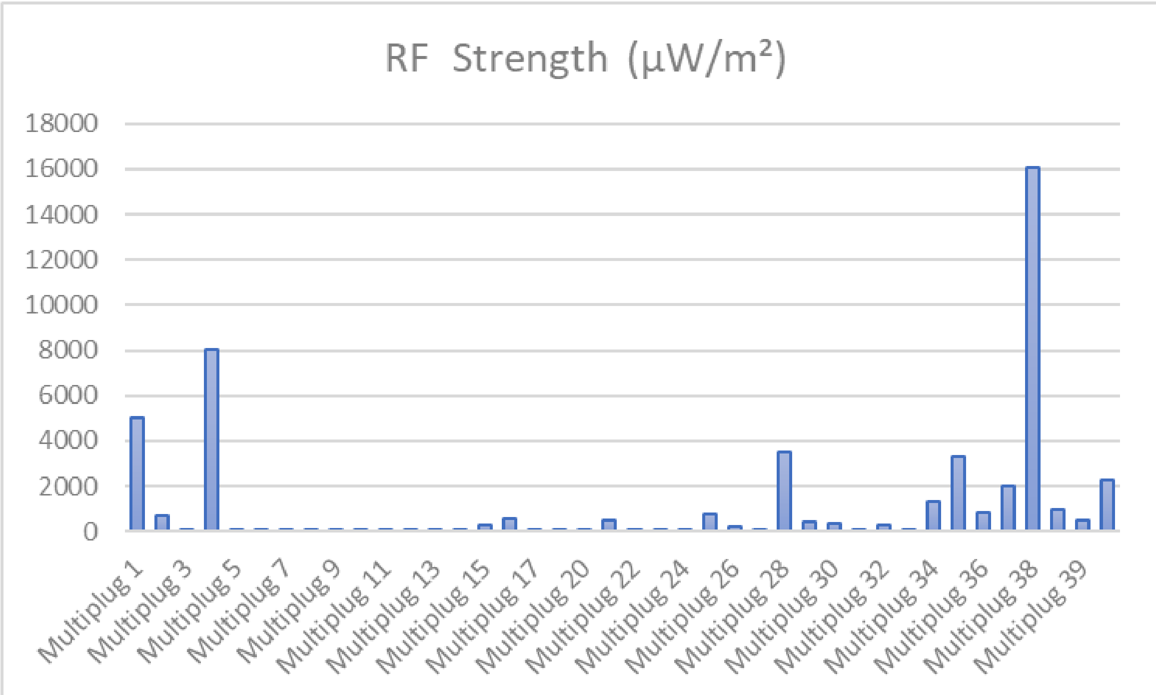


Figure 62: Electric field values found in Multiplugs

RF emissions were negligible, and the highest value detected was in multiplug number 38 with 16037.6 µW/m².

Refrigerator:

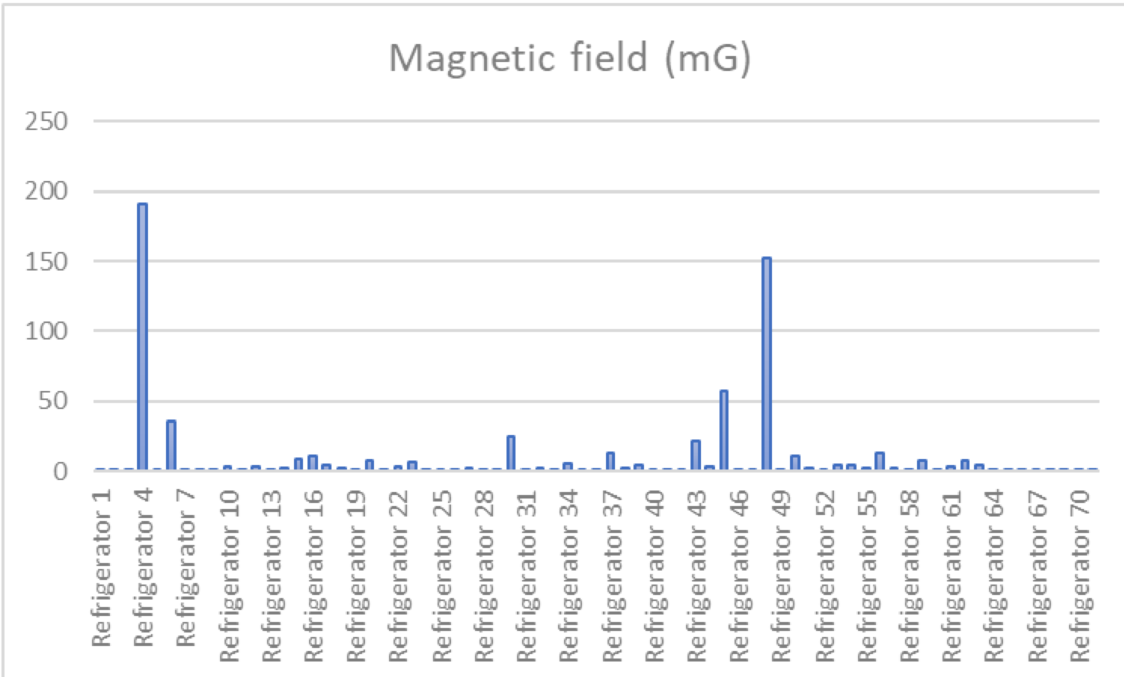


Figure 63: Magnetic field values found in refrigerators

The refrigerators generally recorded low magnetic field strengths, most of them falling below the 2.5 mG threshold. Only a few exceeded this limit, with Refrigerator No. 4 reaching the highest with 191.53 mG.

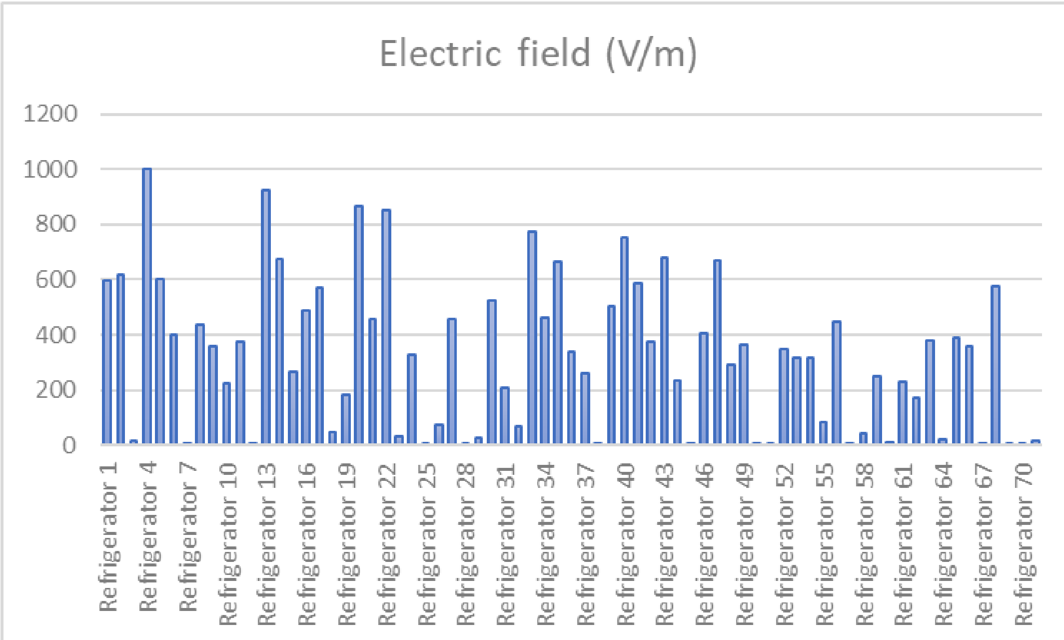


Figure 64: Electric field values found in refrigerators

For the electric field intensity, however, a different pattern emerged. Almost all of the 70 refrigerators measured crossed the 25 V/m safety limit, with the highest value at 1003.75 V/m and the lowest at 2.75 V/m. This reflects the continuous operation of compressors and electronic components.

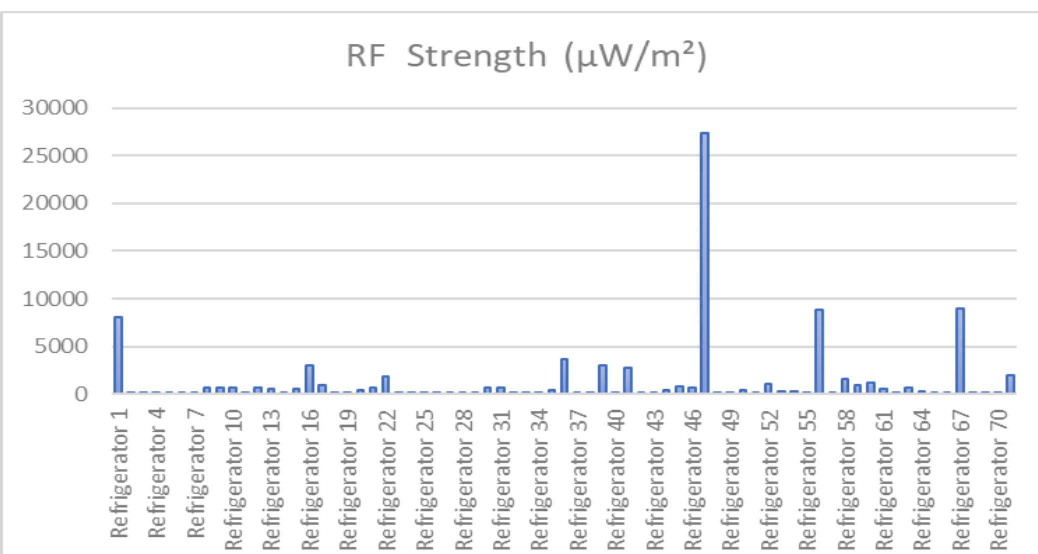


Figure 65: RF strength values found in refrigerators

The RF strength was negligible in all units. Even the highest, 27423.72 µW/m², measured in Refrigerator No. 47, was far below the accepted safety level.

Freezer:

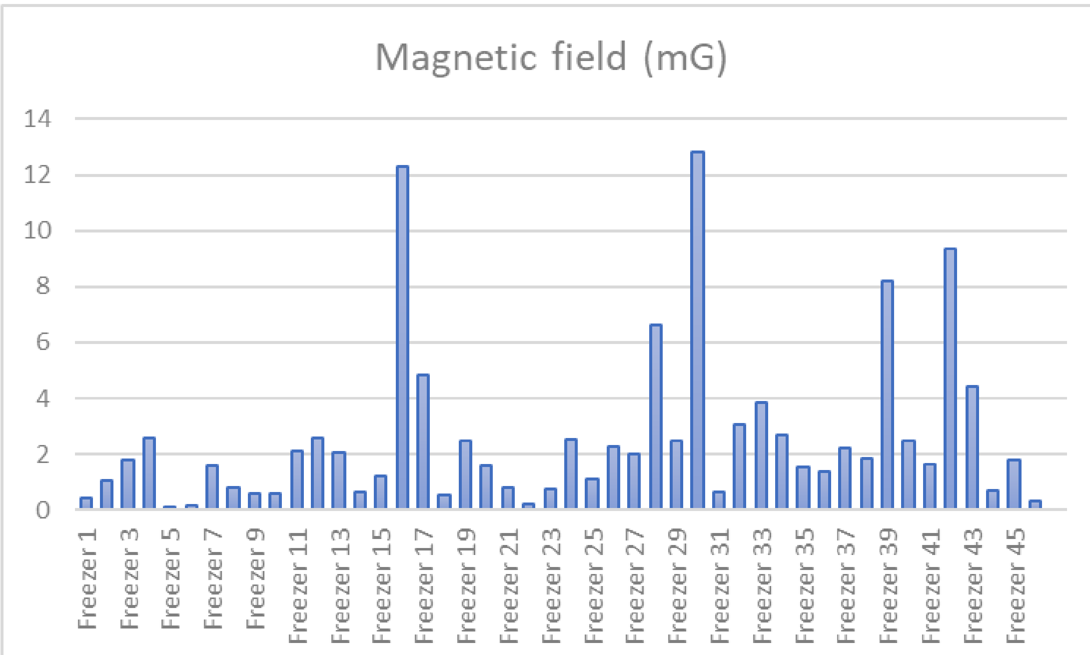


Figure 66: Magnetic field values found in Freezers

The freezers followed a similar pattern to refrigerators. Magnetic field values were mostly between 0 and 5 mG, with the majority below 2.5 mG, except for a few units, such as Freezer No. 16 and 30, which recorded 12.3 and 12.7 mG.

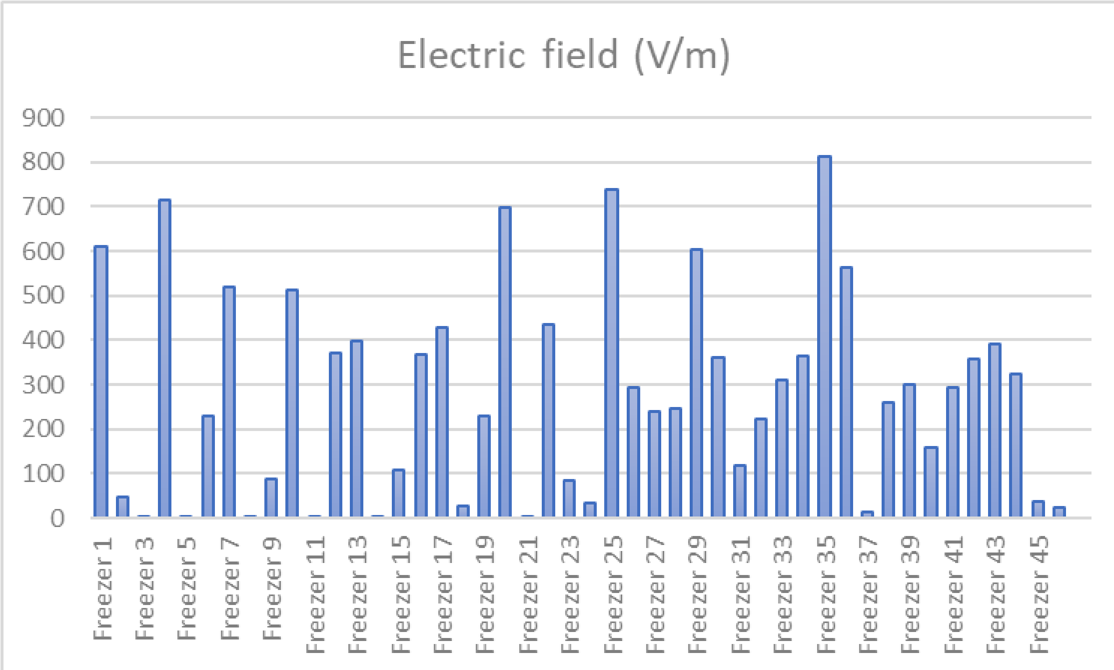


Figure 67: Electric field values found in Freezers

Electric field strengths were concerning, with almost every freezer exceeding the 25 V/m standard. The highest was 813.25 V/m.

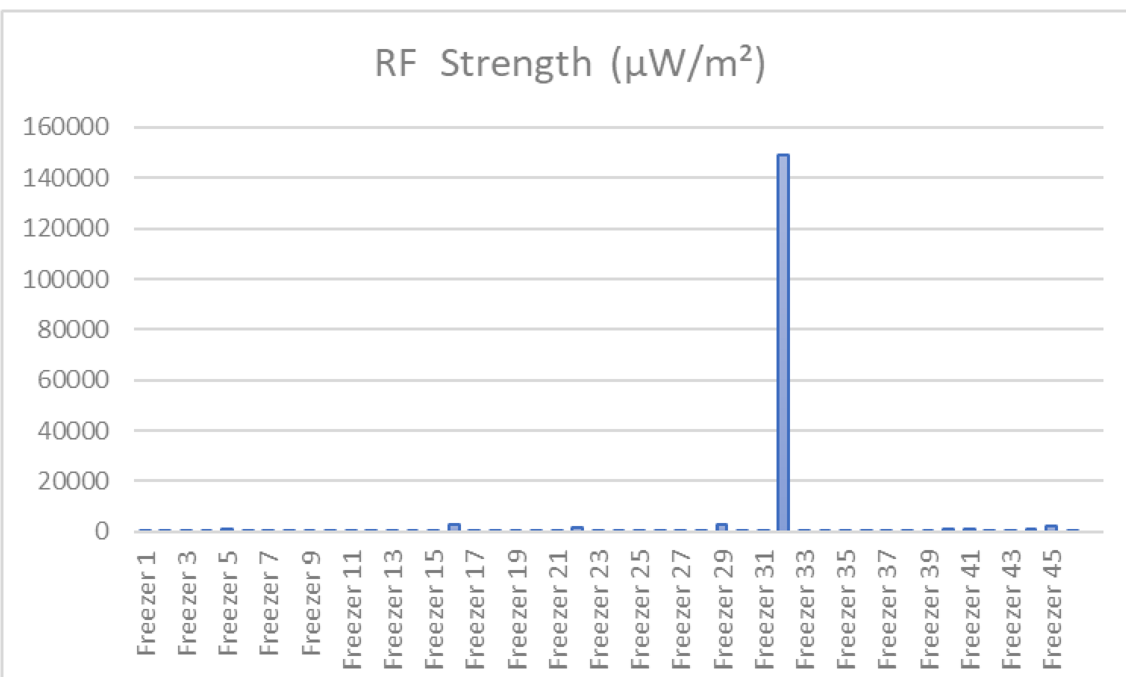


Figure 68: RF strength values found in Freezers

For RF strength, the freezers showed no significant emissions. The maximum was 149250 µW/m² in freezer 32, and the rest stayed close to background values.

Wifi Router:

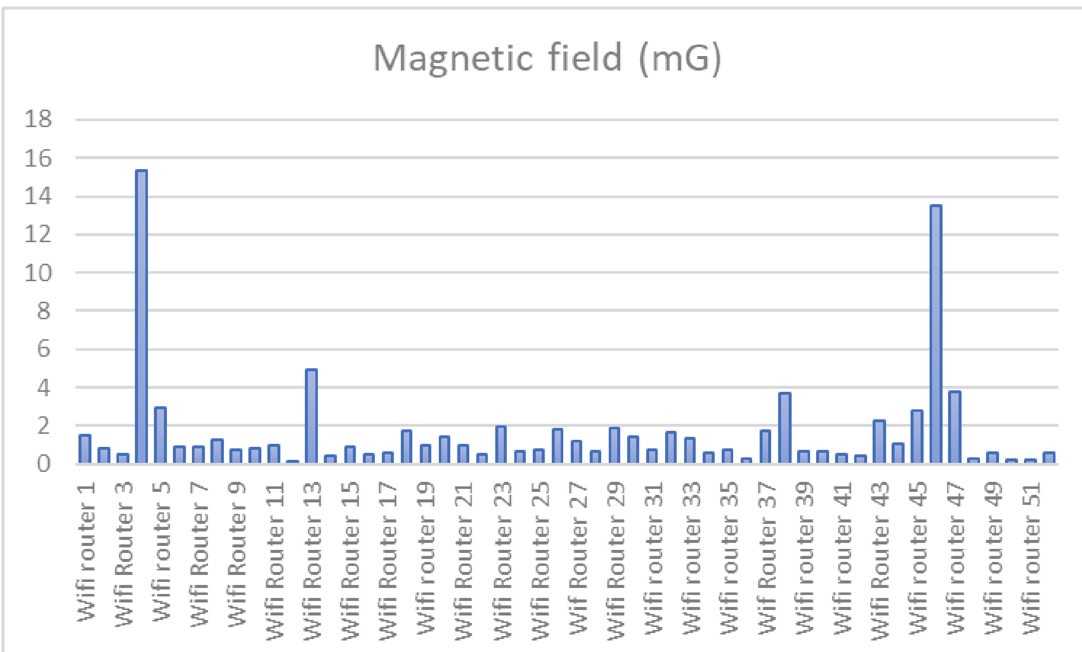


Figure 69: Magnetic field values found in Wifi routers

The Wi-Fi routers presented a distinct profile. Magnetic field levels were almost negligible, all staying well under 2.5 mG, with the highest being 15.29 mG in Wifi router 4.

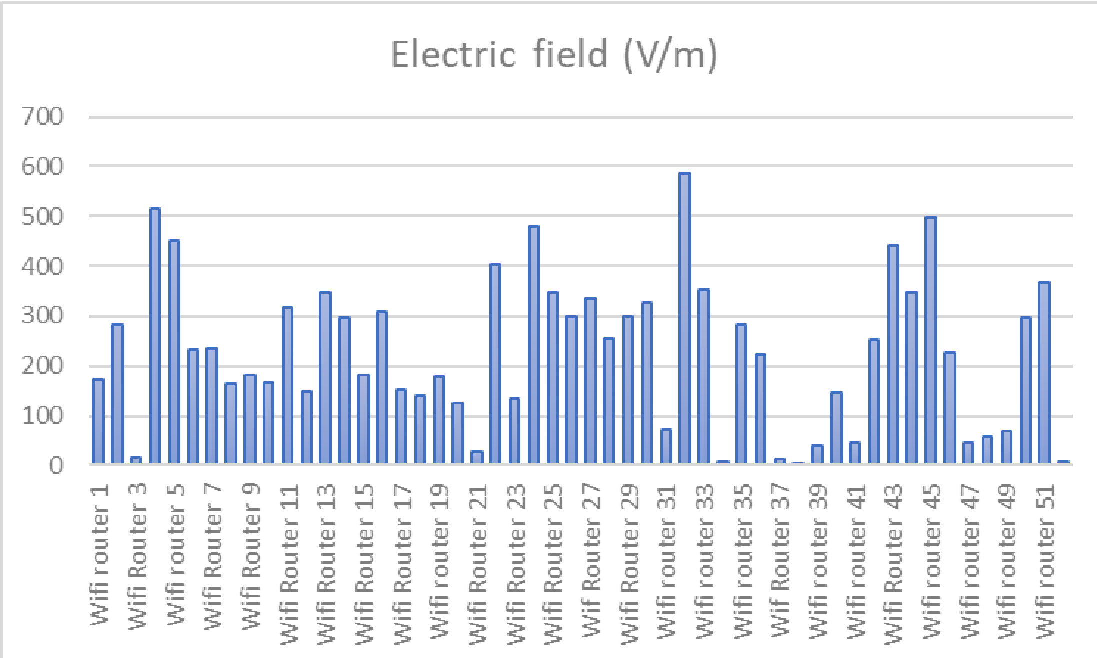


Figure 70: Electric field values found in Wi-Fi routers

Most of the 51 Wi-Fi routers measured presented higher electric field values. The highest was 586.25 V/m in router number 32, while the lowest was 5 V/m.

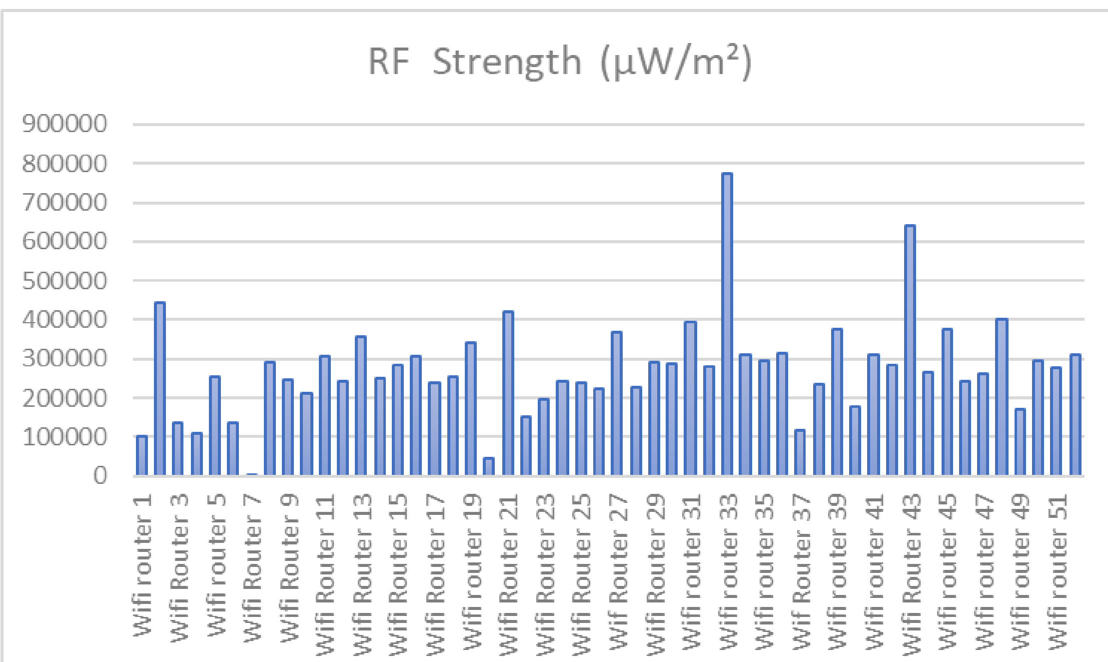


Figure 71: RF strength values found in Wifi routers

As expected, RF strength was more prominent compared to other appliances. Routers operate using continuous RF signals, but the highest measurement, 775950 µW/m² in router 33, still falls under the recommended safety limit.

Microwave:

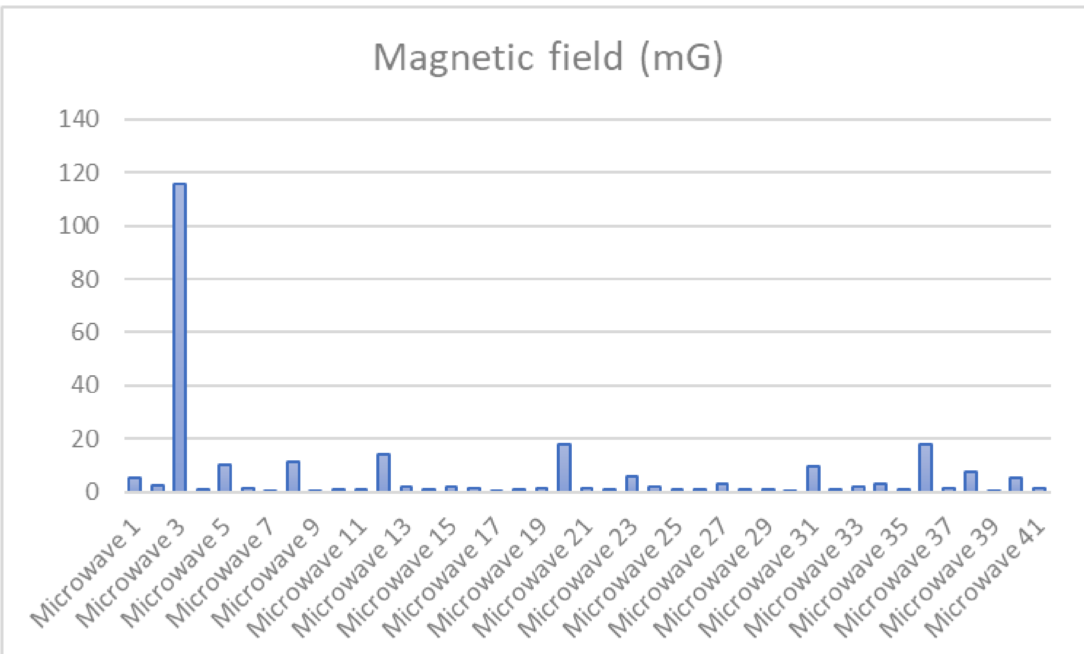


Figure 72: Magnetic field values found in Wi-Fi microwaves

The microwave ovens generally have higher magnetic field emissions. However, this value is higher when the appliance is at work. All the values here were taken when the microwave was plugged in and not in use. Several recorded magnetic field strengths exceeded the 2.5 mG threshold, with Microwave No. 3 reaching as high as 115.6 mG.

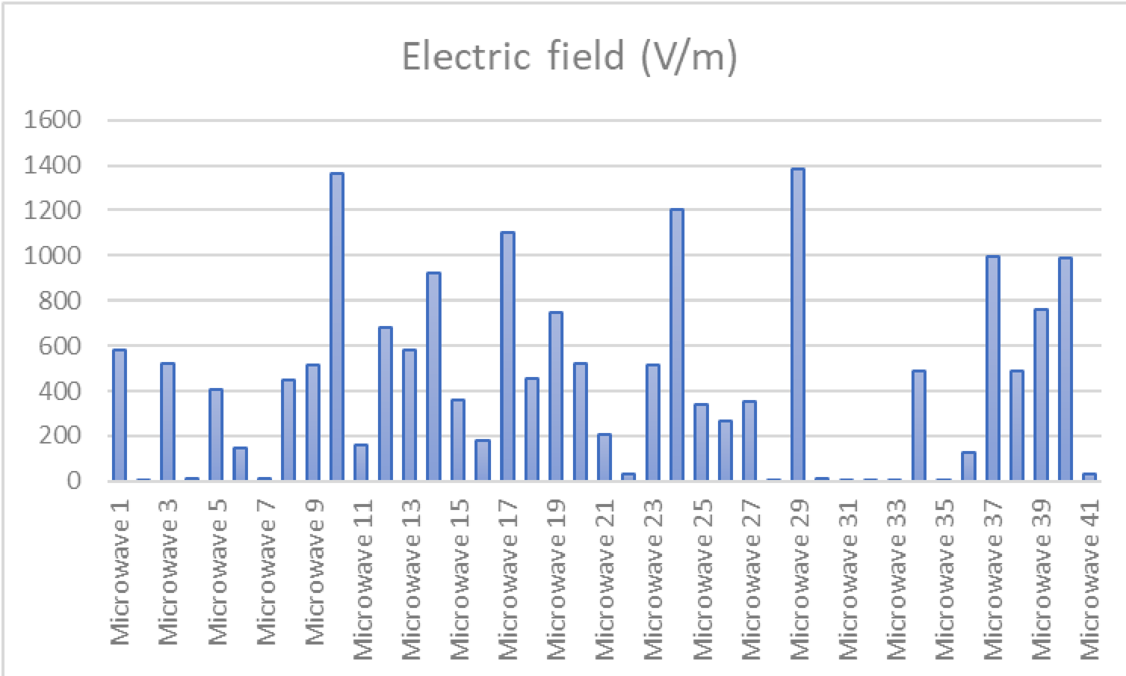


Figure 73: Electric field values found in Wi-Fi microwaves

The electric field intensity was also considerably strong, with readings way above 25 V/m. The highest measure was 1384 V/m, reflecting the appliance's high-voltage operation.

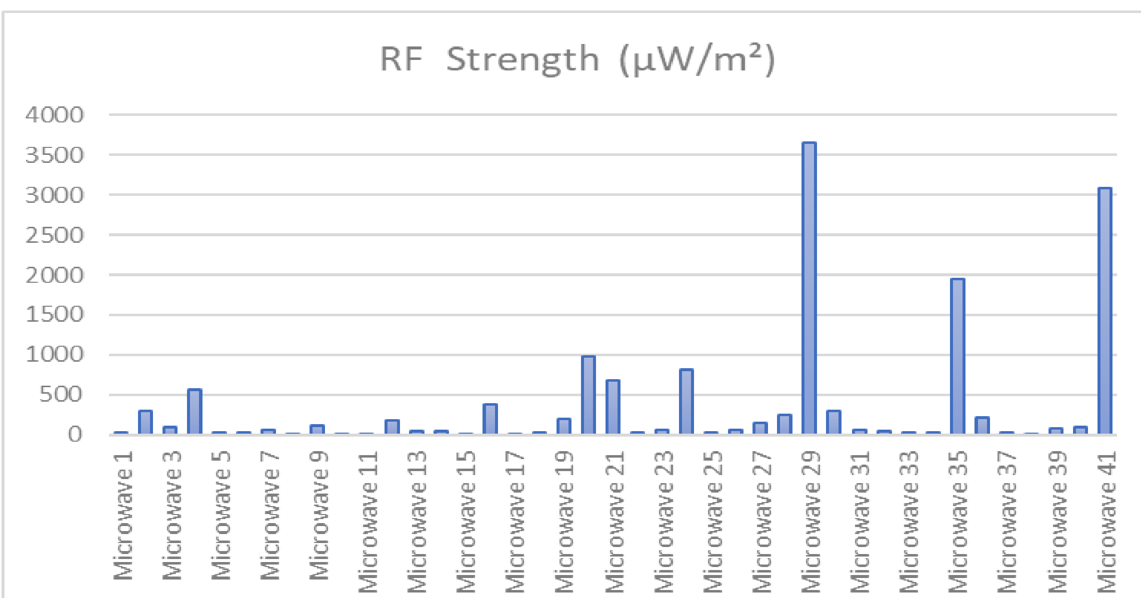


Figure 74: RF strength values found in Wi-Fi Microwaves

As expected, RF strength was not as pronounced, since they were not in function when measured. Even so, the maximum detected, 3469 µW/m², remained below the internationally accepted safety limit.

Blender:

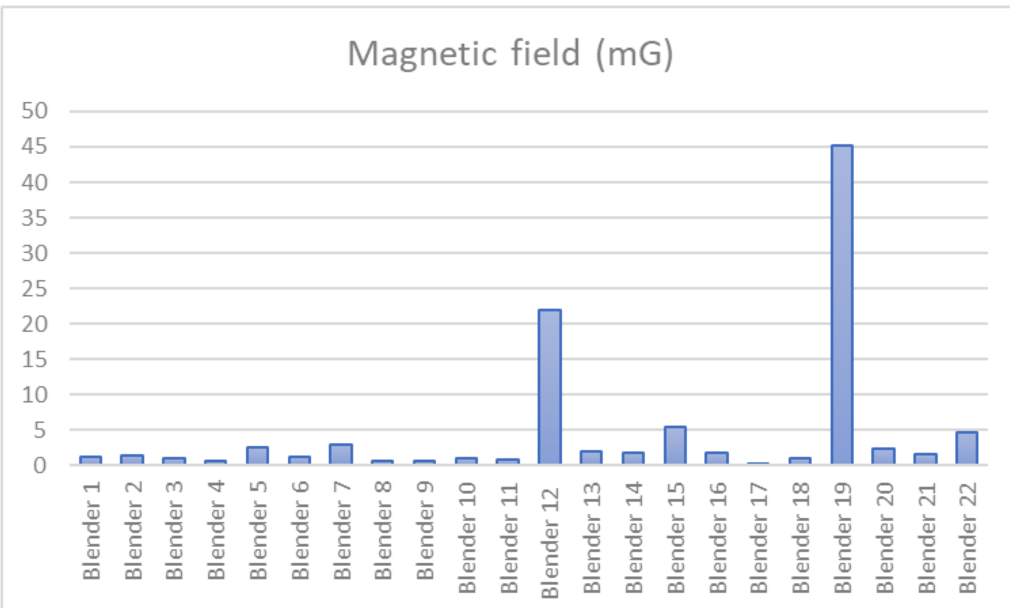


Figure 75: Magnetic field values found in Blenders

The blenders did not generate strong magnetic fields, as they were not in operation while being measured. The majority stayed within the safety limit of 2.5 mG. The maximum recorded was 40.09 mG in blender 19, while the lowest remained within acceptable levels.

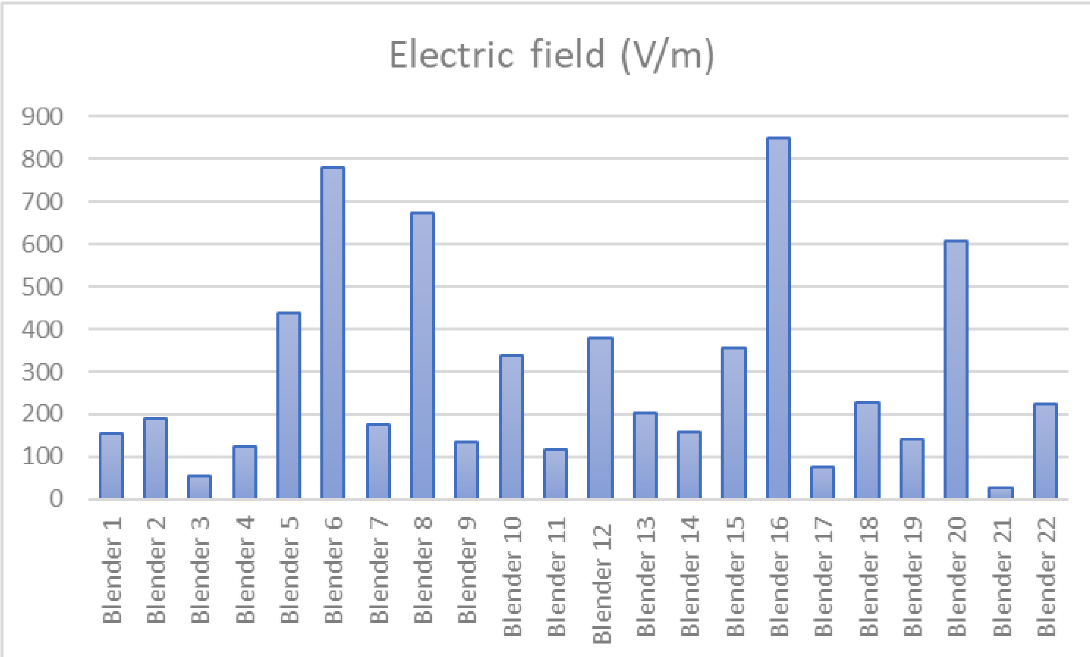


Figure 76: Electric field values found in Blenders

For electric fields, nearly all exceeded 25 V/m, with a peak reading of 848.5 V/m. This is expected due to the high-speed motor mechanism.

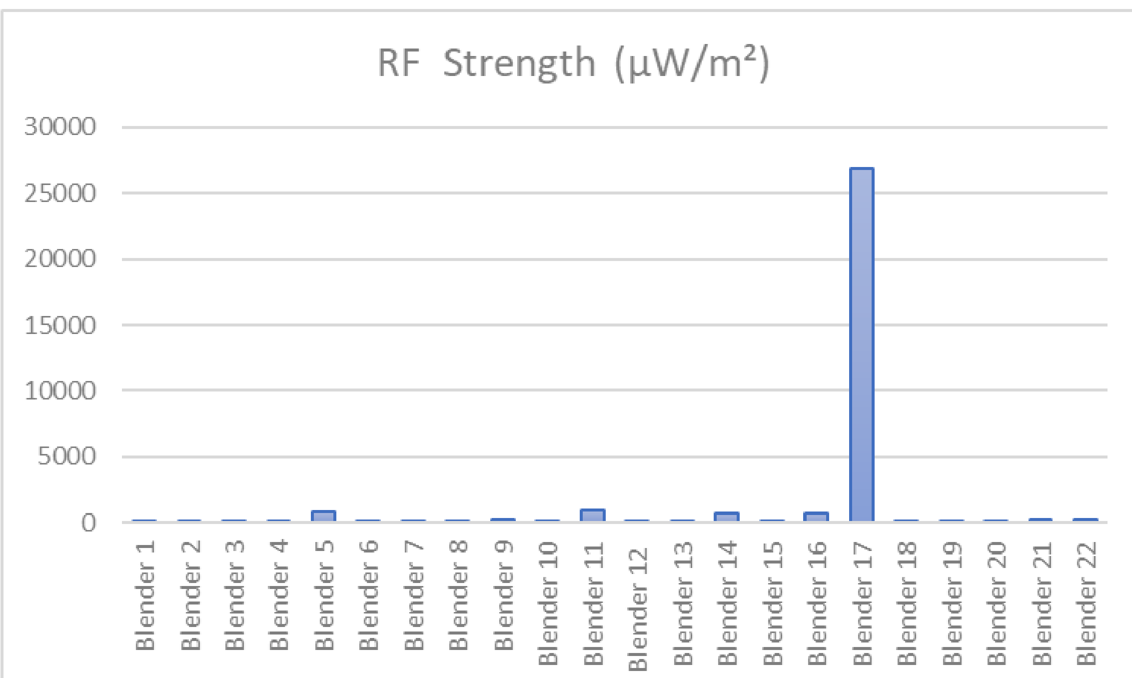


Figure 77: RF strength values found in Blenders

RF emissions were negligible, with the highest recorded at 26903.4 µW/m², well below the threshold.

Iron machine:

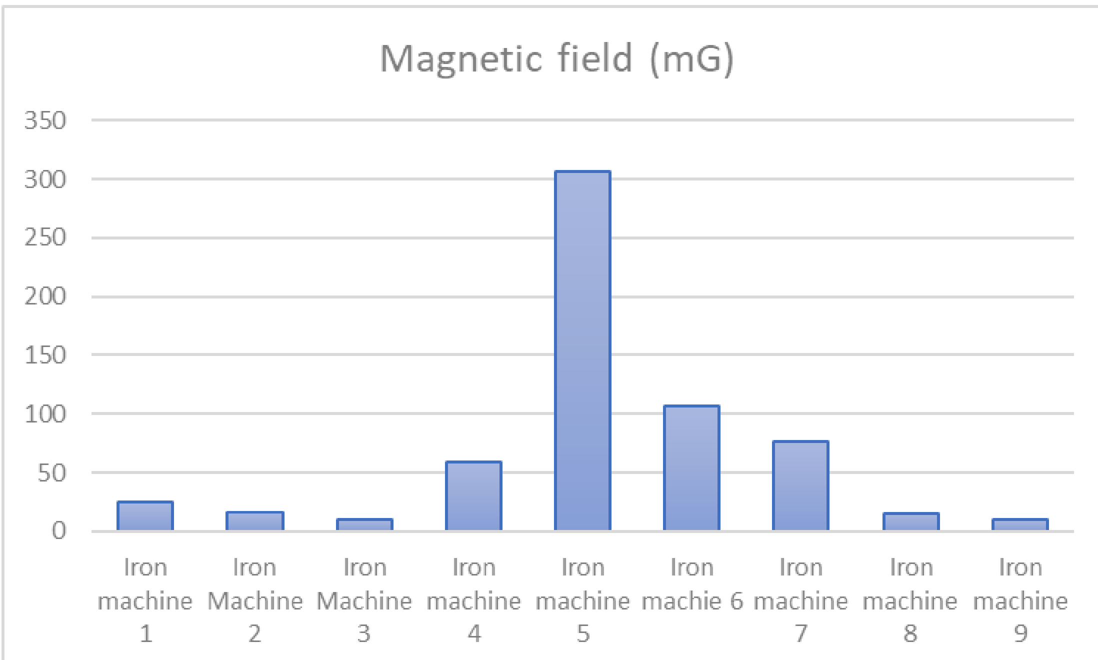


Figure 78: Magnetic field values found in Iron machines

The iron machines produced noticeable magnetic fields when active, with all units well above the 2.5 mG limit. The maximum was 305.62 mG, while the lowest was 9.68 mG, crossing the threshold limit.

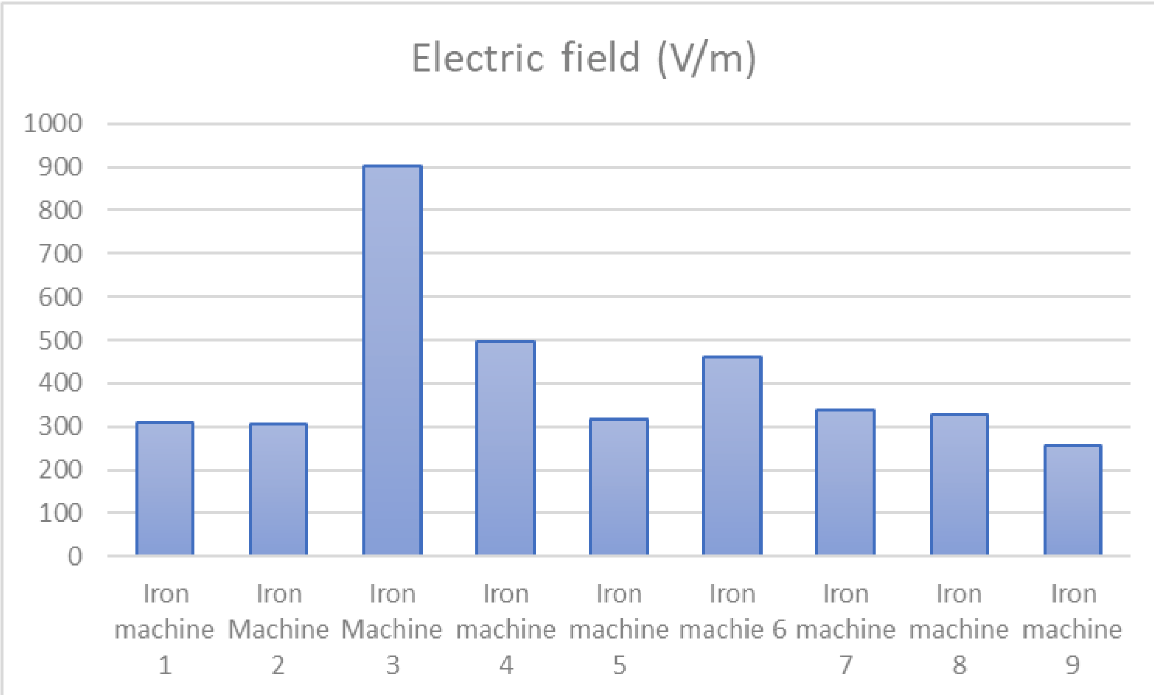


Figure 79: Electric field values found in Iron machines

In terms of electric fields, the readings were consistently high, with all of them exceeding 25 V/m. The highest registered was 901.75 V/m in iron machine 3, which reflects the strong power draw of heating coils.

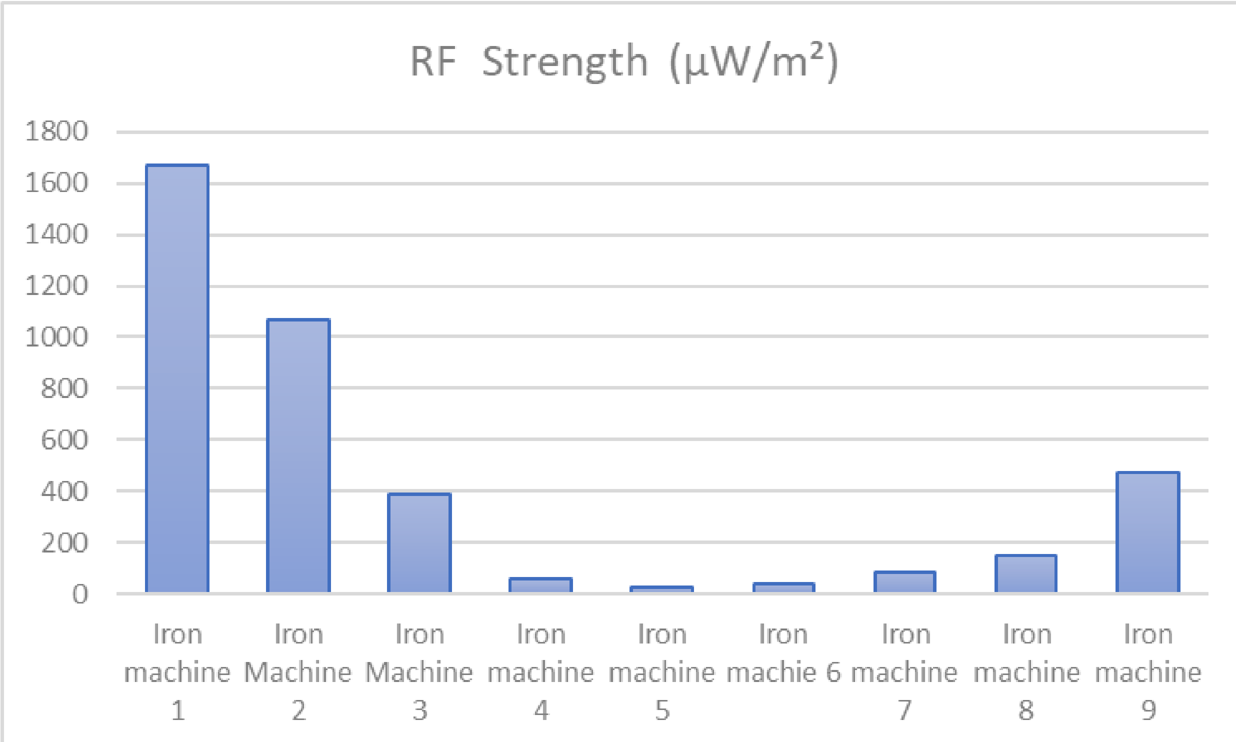


Figure 80: RF strength values found in Iron Machines

RF values were negligible across all machines, with the maximum being 1670.3 µW/m² and lowest being only 28.9 µW/m².

Intercom:

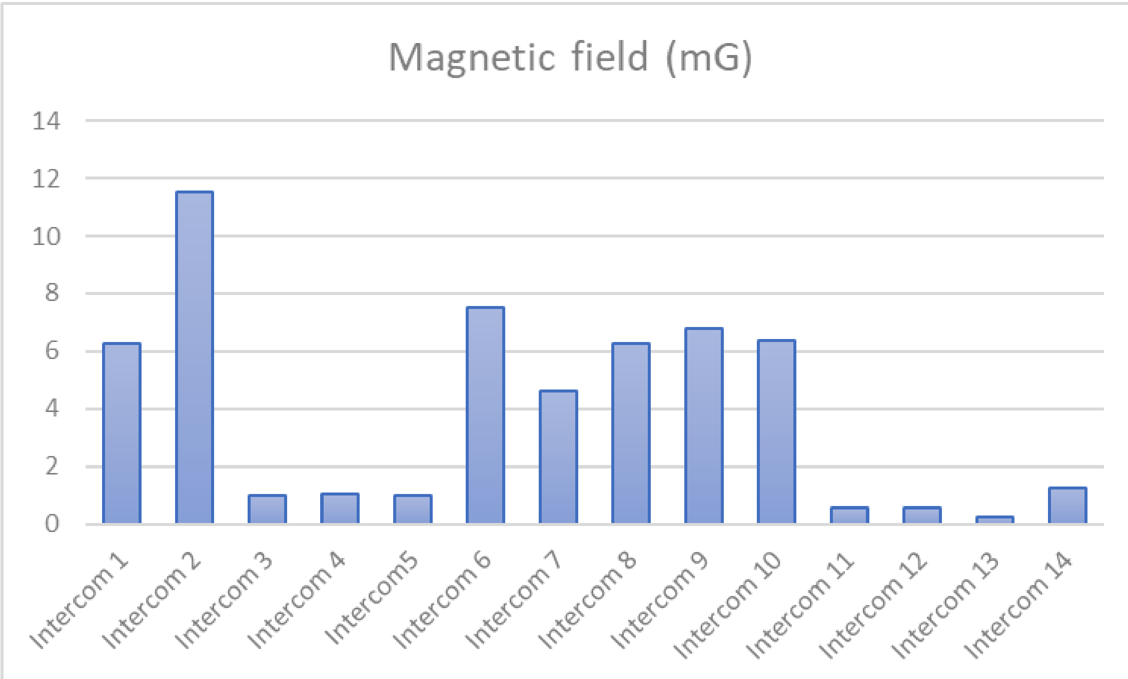


Figure 81: Magnetic field values found in Intercoms

The intercom systems generally emitted low magnetic fields, even though not always below 2.5 mG. Half of the readings were below the safety threshold limit, while the other half was slightly above, with the highest being 11.52 mG in intercom number 2.

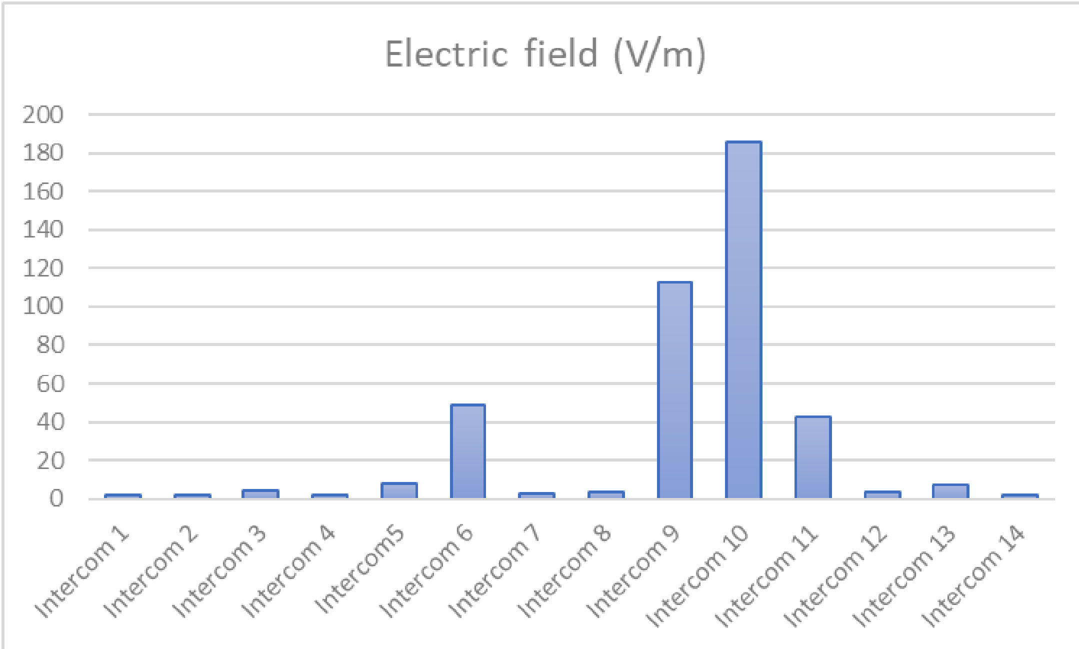


Figure 82: Electric field values found in Intercoms

The majority of the intercoms showed electric field values lower than 25 V/m, with only a few like, intercom numbers 6, 9, 10 and 11 exceeding this value.

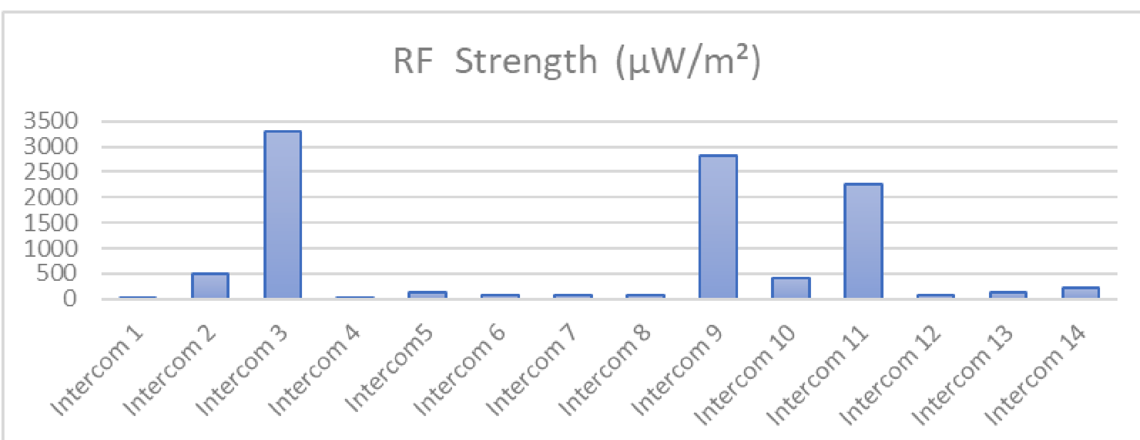


Figure 83: RF Strength values found in Intercoms

For RF strength, minor emissions were recorded, though none approached concerning levels. The highest, 3297.625 µW/m², was still well within the safe zone.

CPU:

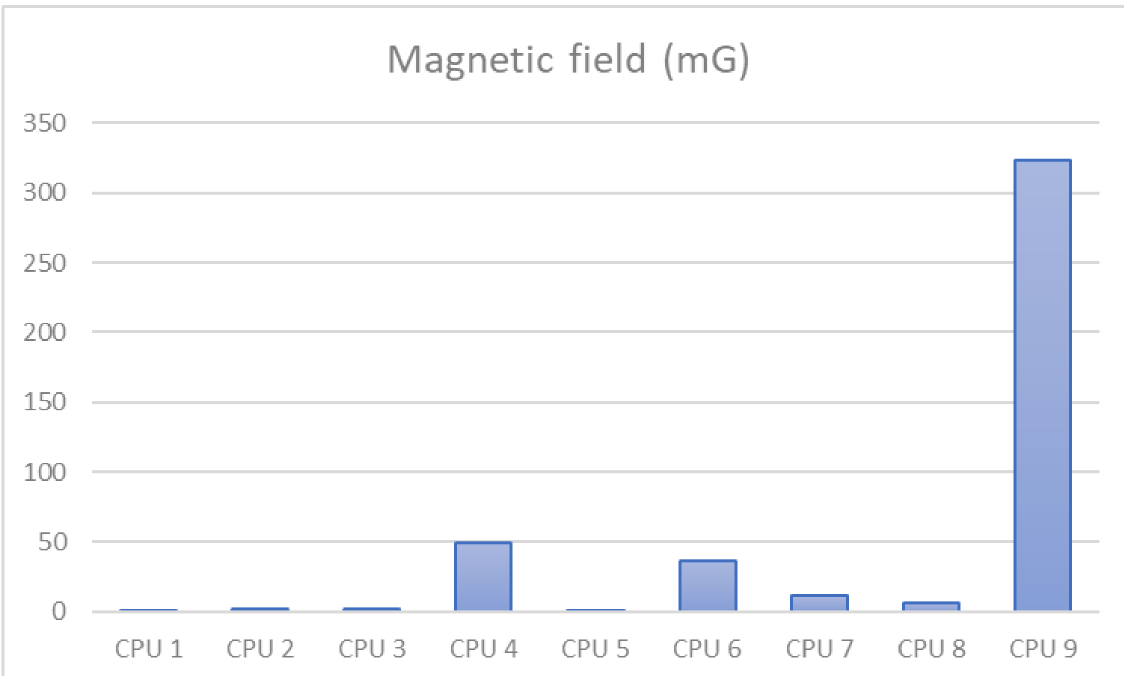


Figure 84: Magnetic field values found in CPUs

Among the 9 CPUs measured, the magnetic field strength was generally low in almost half of them, with most readings falling under the 2.5 mG range. The majority stayed above the safety threshold of 2.5 mG, with the highest being 323.14 mG.

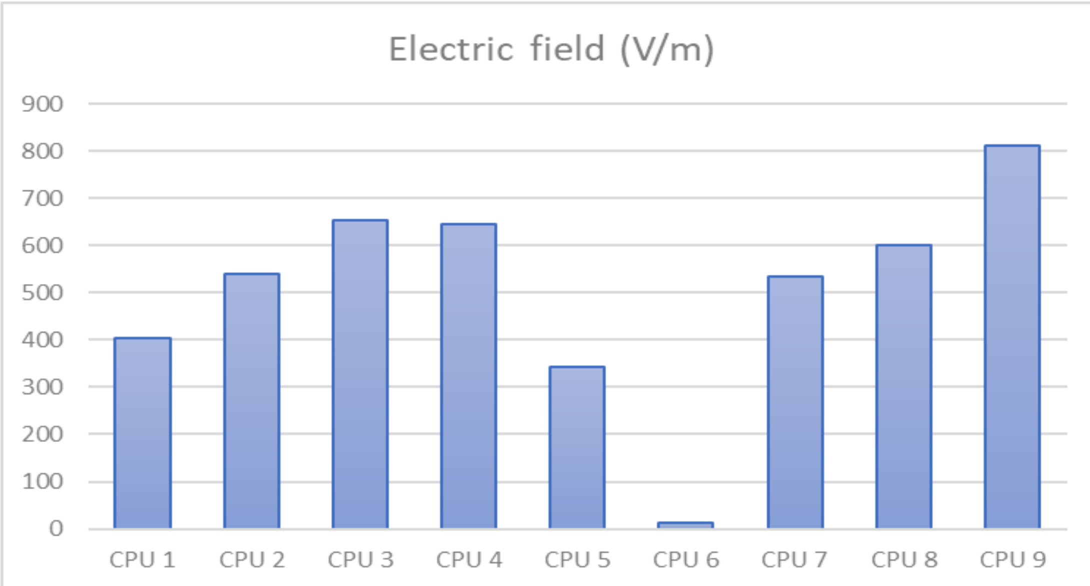


Figure 85: Electric field values found in CPUs

In terms of the electric field intensity, almost all CPUs exceeded the acceptable limit of 25 V/m, in most cases by a considerable margin. The highest value was observed in CPU No. 9, which reached 810.25 V/m, while the lowest and only one within acceptable limit was found in CPU No. 6 (12.5 V/m).

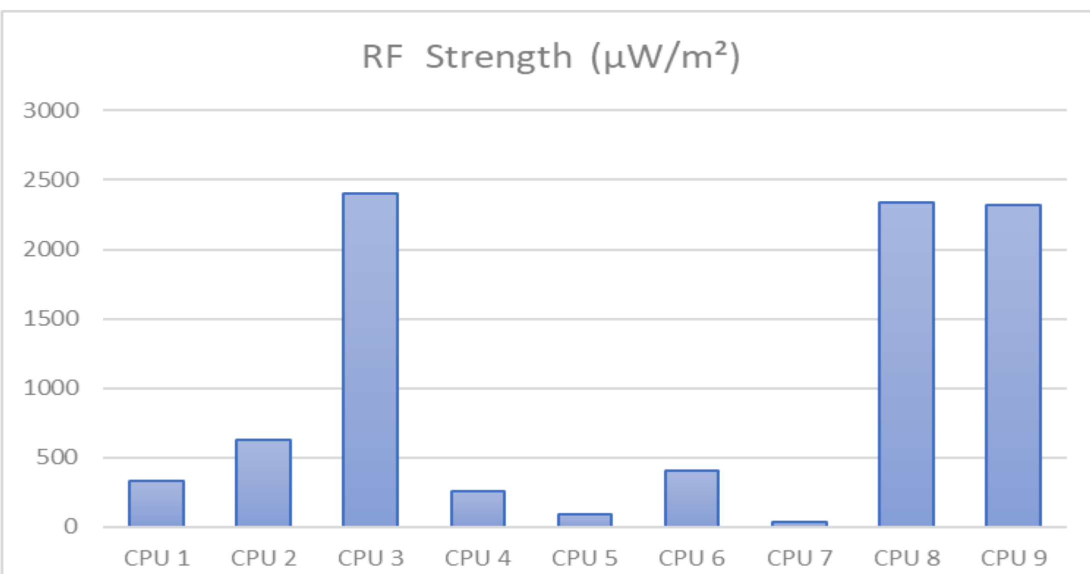


Figure 86: RF Strength values found in CPUs

Regarding RF emissions, no CPU crossed the safety threshold. The measured levels remained negligible, with the highest being 2407.1 μW/m², while most stayed close to background levels

IPS:

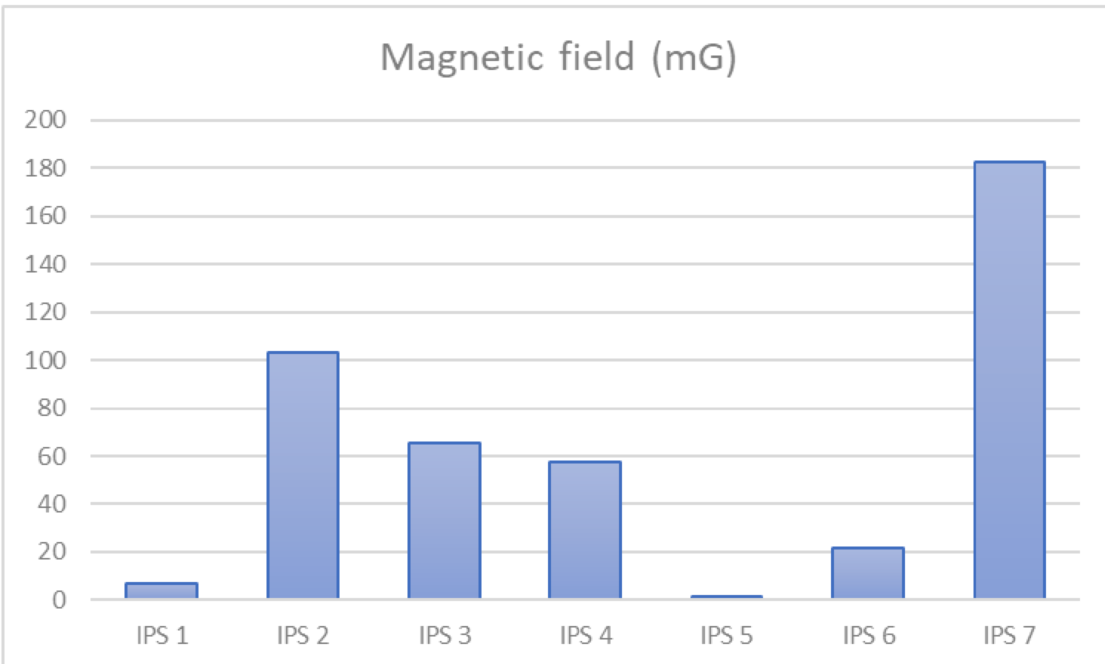


Figure 87: Magnetic field values found IPS

For the 7 IPS units measured, the magnetic field strength varied a lot, and the majority exceeded the safety threshold limit of 2.5 mG. Only one was found to be within the limit. The rest had high magnetic field values, with the highest reaching as high as 182.8 mG in IPS number 7.

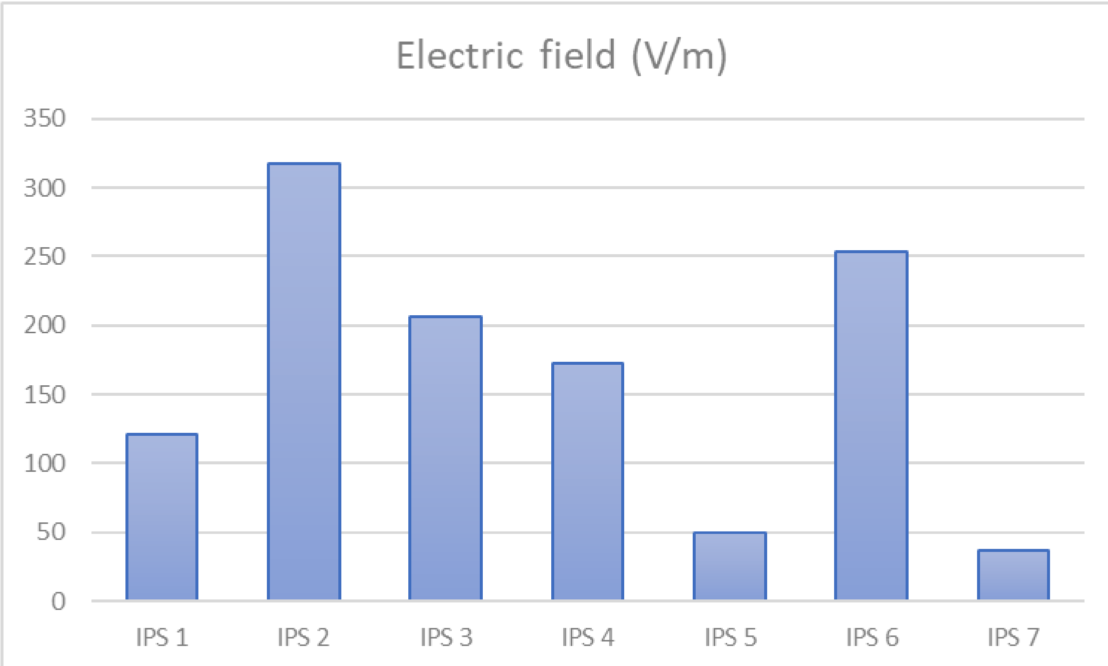


Figure 88: Electric field values found IPS

In the case of the electric field intensity, all IPS devices exceeded the acceptable limit of 25 V/m, with significant variation among them. The highest value reached 316.75 V/m in IPS No. 2, while the lowest was 37 V/m in IPS No. 7.

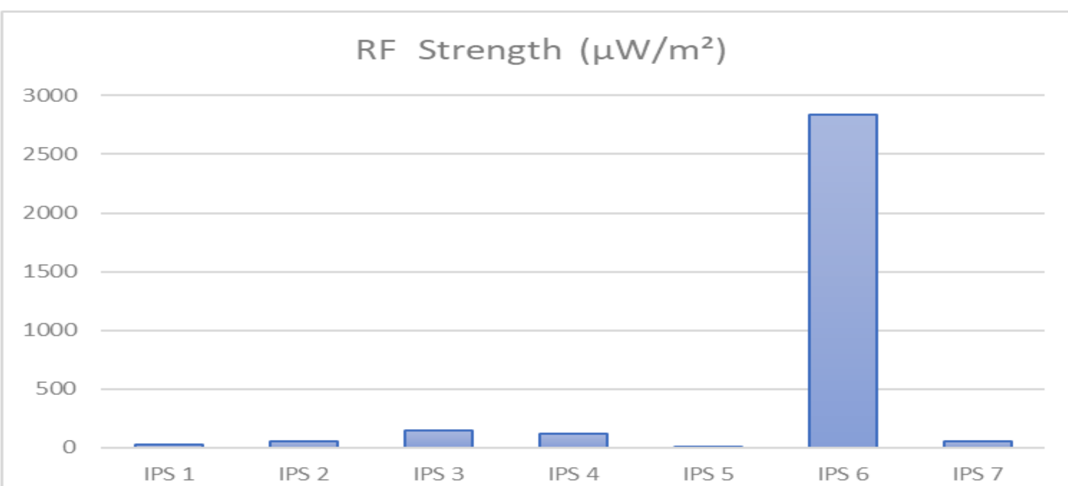


Figure 89: RF Strength values found IPS

As for RF strength, none of the IPS devices exceeded the safety threshold. The measured values remained very low, with the maximum recorded at 2839.8 µW/m², and the rest staying at or near background levels.

Others:

Apart from the major household appliances, a few other devices such as the CCTV, Hair straightener, Hair dryer, Sandwich maker, Water heater, Voltage stabilizer, Air purifier, Mosquito repellent, Printer, Speaker, Microphone, Kindle, Toaster, Foot massager, Electric oven, Earpods, Digital clock, Hand mixer, UPS, Internet adaptor, Gaming console, Pressure mattress, Power bank, Camera, Electric meter, electric comforter, Headphone, Mini vacuum and Air fryer were also measured. Since the number of samples for these devices was limited (1-5 units each), the data provides only a preliminary idea of their field strength levels. In general, the magnetic field measurements for these devices were mostly found to be within the 2.5 mG range, with only occasional readings slightly above the safety threshold of 2.5 mG, especially in the case of hair straightener, hair dryer, voltage stabilizer, earpods, sandwich maker, toaster, pressure mattress, and UPS. For the electric field intensity, most values tended to be higher than the acceptable limit of 25 V/m, though the extent of exceedance varied depending on the device type. As for radio frequency (RF) emissions, the readings were negligible and consistently remained well below the threshold limit, staying close to background levels.

2.8: Hypothesis testing: One-sample T-test:

Hypothesis:

Null hypothesis (H_0): The mean exposure value of Non-Ionizing Radiation is less than or equal to the safety threshold value.

Alternative hypothesis (H_1): The mean exposure value of the Magnetic field, Electric field, and RF strength from various appliances is higher and exceeds the standard/threshold value.

Magnetic fields:

One-Sample Statistics for magnetic fields of common appliances and devices

	N	Mean	Std. Deviation	Std. Error Mean
Phone	109	1.9658	3.47365	.33272
Power Outlet	77	3.5945	8.05803	.91830
Switch board	96	6.6534	27.12386	2.76832
Blender	22	4.6345	10.09872	2.15305
Microwave	41	6.2643	18.11165	2.82856
Wifi router	51	1.7165	2.77150	.38809
Freezer	46	2.5613	2.89746	.42721
Light	53	5.5449	15.66549	2.15182
Fan	97	50.8906	130.00365	13.19987
Refrigerator	71	9.2042	29.36525	3.48501
Multplug	40	3.5456	6.37060	1.00728
TV	59	3.0244	5.03791	.65588
AC	64	10.4828	15.44479	1.93060
Laptop	32	3.6523	6.76017	1.19504
Washing machine	17	1.4790	1.10978	.26916
Kitchen stove hood	6	5.1092	3.74342	1.52824

Figure 90: One-sample statistics for the magnetic field of common appliances

One-Sample Test for the magnetic fields of common appliances and devices

	Test Value = 2.5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Phone	-1.606	108	.111	-.53417	-1.1937	.1253
Power outlet	1.192	76	.237	1.09455	-.7344	2.9235
Switchboard	1.500	95	.137	4.15339	-1.3424	9.6492
Blender	.991	21	.333	2.13455	-2.3430	6.6121
Microwave	1.331	40	.191	3.76427	-1.9525	9.4810
Wifi router	-2.019	50	.049	-.78354	-1.5630	-.0040
Freezer	.143	45	.887	.06125	-.7992	.9217
Light	1.415	52	.163	3.04487	-1.2731	7.3628
Fan	3.666	96	<.001	48.39064	22.1891	74.5922
Refrigerator	1.924	70	.058	6.70415	-.2465	13.6548
Multplug	1.038	39	.306	1.04562	-.9918	3.0830
TV	.800	58	.427	.52445	-.7884	1.8373
AC	4.135	63	<.001	7.98284	4.1248	11.8408
Laptop	.964	31	.342	1.15234	-1.2850	3.5896
Washing machine	-3.793	16	.002	-1.02103	-1.5916	-.4504
Kitchen stove hood	1.707	5	.148	2.60917	-1.3193	6.5376

Figure 91: One-sample Test for the magnetic field of common appliances

The table summarizes the descriptive statistics for magnetic field strengths across common household appliances. The highest average exposure was observed for fans (50.9 mG, SD = 130.0), followed by air conditioners (10.5 mG, SD = 15.4) and refrigerators (9.2 mG, SD = 29.4). These appliances appear to be the major contributors to magnetic field levels in households. Microwaves (6.3 mG), switchboards (6.7 mG), lights (5.5 mG), and kitchen stove hoods (5.1 mG) produced moderate MF values, while most other appliances, including phones (2.0 mG), Wi-Fi routers (1.7 mG), washing machines (1.5 mG), and freezers (2.6 mG), were associated with relatively low magnetic field exposures.

A one-sample t-test was conducted to compare the average magnetic field strength of each appliance against a reference value of 2.5 mG. Results showed that fans ($M = 50.9$ mG, $p < .001$) and air conditioners ($M = 10.5$ mG, $p < .001$) had significantly higher magnetic field strengths than the reference value, indicating that these appliances contribute substantially to household magnetic field exposure. By contrast, Wi-Fi routers (M = 1.7 mG, p = .049) and washing machines (M = 1.5 mG, p = .002) recorded significantly lower magnetic field strengths compared to the test value. For other appliances, including phones, refrigerators, microwaves, lights, and TVs, no significant differences were observed.

Considerable variability between households was evident for several devices, particularly fans, refrigerators, and switchboards, which displayed very high standard deviations. This variability may reflect differences in device models, age of appliances, household wiring, and frequency of use. In contrast, appliances like washing machines and Wi-Fi routers showed very low variability, indicating consistent low-level exposures across households.
These findings highlight that fans and ACs are major sources of elevated MF exposure, while smaller devices such as Wi-Fi routers and washing machines generate minimal levels.

Electric fields:

One-Sample Statistics for Electric Field of common appliances and devices

	N	Mean	Std. Deviation	Std. Error Mean
Phone	109	13.1789	42.46259	4.06718
Power outlet	77	239.7305	146.24732	16.66643
Switchboard	96	190.7935	119.21149	12.16697
Blender	22	292.1409	237.91294	50.72321
Microwave	41	436.7927	399.78175	62.43542
Wifi router	51	233.3152	147.63227	20.67265
Freezer	46	281.8011	229.30205	33.80874
Light	53	134.0330	107.59268	14.77899
Fan	97	210.9894	189.88588	19.27999
Refrigerator	71	324.7136	270.56076	32.10965
Multplug	40	437.6344	202.11312	31.95689
TV	59	349.9025	1534.92430	199.83012
AC	64	61.6693	48.88933	6.11117
Laptop	32	103.8438	200.83776	35.50344
Washing machine	17	255.1647	261.75512	63.48494
Kitchen stove hood	6	111.0000	156.68049	63.96454

Figure 92: One-sample statistics for electric field of common appliances

One-Sample Test for electric field of common appliances and devices

	Test Value = 25					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Phone	-2.906	108	.004	-11.82110	-19.8830	-3.7592
Power outlet	12.884	76	<.001	214.73052	181.5365	247.9246
Switchboard	13.627	95	<.001	165.79354	141.6390	189.9480
Blender	5.267	21	<.001	267.14091	161.6562	372.6256
Microwave	6.595	40	<.001	411.79268	285.6060	537.9794
Wifi router	10.077	50	<.001	208.31520	166.7930	249.8374
Freezer	7.596	45	<.001	256.80109	188.7068	324.8954
Light	7.378	52	<.001	109.03300	79.3768	138.6892
Fan	9.647	96	<.001	185.98943	147.7190	224.2599
Refrigerator	9.334	70	<.001	299.71363	235.6729	363.7543
Multiplug	12.912	39	<.001	412.63438	347.9955	477.2733
TV	1.626	58	.109	324.90254	-75.1009	724.9060
AC	6.000	63	<.001	36.66927	24.4571	48.8815
Laptop	2.221	31	.034	78.84375	6.4340	151.2535
Washing machine	3.626	16	.002	230.16471	95.5826	364.7468
Kitchen stove hood	1.344	5	.237	86.00000	-78.4261	250.4261

Figure 93: One-sample test for electric field of common appliances

Descriptive statistics for the electric field strengths of appliances are shown in the table. The highest average values were recorded for microwaves (M = 436.8 V/m, SD = 399.8), multiplugs (M = 437.6 V/m, SD = 202.1), and televisions (M = 349.9 V/m, SD = 1534.9), although TV values showed extreme variability across households. Other appliances with consistently high EF means included refrigerators (M = 324.7 V/m, SD = 270.6), freezers (M = 281.8 V/m, SD = 229.3), and blenders (M = 292.1 V/m, SD = 237.9). Moderate EF levels were found for fans (M = 211.0 V/m, SD = 189.9), switchboards (M = 190.8 V/m, SD = 119.2), and Wi-Fi routers (M = 233.3 V/m, SD = 147.6). In contrast, phones (M = 13.2 V/m, SD = 42.5) and laptops (M = 103.8 V/m, SD = 200.8) exhibited relatively low EF strengths. Air conditioners (M = 61.7 V/m, SD =

48.9) and kitchen stove hoods (M = 111.0 V/m, SD = 156.7) were also found to contribute only modest levels of EF exposure.

A one-sample t-test was conducted to compare the average electric field strengths of common household appliances to a reference value of 25 V/m. Results indicated that phones (M = 13.2 V/m, $p = .004$) had significantly lower EF strengths than the reference. By contrast, the majority of appliances exhibited EF values significantly higher than 25 V/m, including power outlets (M = 239.7 V/m, $p < .001$), switchboards (M = 190.8 V/m, $p < .001$), blenders (M = 292.1 V/m, $p < .001$), microwaves (M = 436.8 V/m, $p < .001$), Wi-Fi routers (M = 233.3 V/m, $p < .001$), freezers (M = 281.8 V/m, $p < .001$), lights (M = 134.0 V/m, $p < .001$), fans (M = 211.0 V/m, $p < .001$), refrigerators (M = 324.7 V/m, $p < .001$), multiplugs (M = 437.6 V/m, $p < .001$), ACs (M = 61.7 V/m, $p < .001$), laptops (M = 103.8 V/m, $p = .034$), and washing machines (M = 255.2 V/m, $p = .002$).

Among these, microwaves and multiplugs recorded the highest EF strengths (>400 V/m), followed by TVs (~350 V/m), refrigerators (~325 V/m), and freezers (~282 V/m). Although TV EF levels were high, they did not reach statistical significance due to the very large variability across households. The kitchen stove hood (M = 111.0 V/m, $p = .237$) also did not differ significantly from the reference, likely due to the small sample size.

These findings demonstrate that kitchen appliances (microwaves, refrigerators, blenders, freezers, and washing machines) and large electronic devices (TVs, fans, ACs) are major contributors to household EF exposure, while phones contribute negligible EF.

RF strength:

One-Sample Statistics for RF strength of common appliances and devices

	N	Mean	Std. Deviation	Std. Error Mean
Phone	109	86966.2533	85319.63481	8172.13889
Power outlet	77	690.9217	2037.79782	232.22861
Switchboard	96	903.9477	3133.10964	319.77166
Blender	22	1436.1093	5695.93426	1214.37727
Microwave	41	284.1109	647.14478	101.06703
Wifi router	51	274158.4348	128274.6226	17962.03993
Freezer	46	3628.0390	21959.13938	3237.69847
Light	53	351.1410	618.82339	85.00193
Fan	97	871.4730	1623.64064	164.85573
Refrigerator	71	1244.8668	3633.13119	431.17335
Multiplug	40	1218.6205	2895.77663	457.86249
TV	59	896.0895	1330.54721	173.22249
AC	64	796.9651	2983.36542	372.92068
Laptop	32	17666.4244	48013.26811	8487.62687
Washing machine	16	1071.5862	3723.97918	930.99480
Kitchen stove hood	6	113.6250	166.48652	67.96784

Figure 94: One-sample statistics for RF strength of common appliances

One-Sample Test for RF strength of common appliances and devices

	Test Value = 1000000					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Phone	-111.725	108	<.001	-913033.747	-929232.3437	-896835.1497
Power outlet	-4303.126	76	<.001	-999309.078	-999771.6017	-998846.5549
Switchboard	-3124.405	95	<.001	-999096.052	-999730.8794	-998461.2253
Blender	-822.285	21	<.001	-998563.891	-1001089.33	-996038.4549
Microwave	-9891.612	40	<.001	-999715.889	-999920.1532	-999511.6251
Wifi router	-40.410	50	<.001	-725841.565	-761919.3842	-689763.7462
Freezer	-307.741	45	<.001	-996371.961	-1002893.02	-989850.9015
Light	-11760.308	52	<.001	-999648.859	-999819.4279	-999478.2902
Fan	-6060.624	96	<.001	-999128.527	-999455.7631	-998801.2910
Refrigerator	-2316.366	70	<.001	-998755.133	-999615.0814	-997895.1851
Multiplug	-2181.400	39	<.001	-998781.380	-999707.4938	-997855.2652
TV	-5767.749	58	<.001	-999103.911	-999450.6530	-998757.1680
AC	-2679.398	63	<.001	-999203.035	-999948.2574	-998457.8124
Laptop	-115.737	31	<.001	-982333.576	-999644.2047	-965022.9465
Washing machine	-1072.969	15	<.001	-998928.414	-1000912.78	-996944.0453
Kitchen stove hood	-14711.169	5	<.001	-999886.375	-1000061.09	-999711.6581

Figure 95: One-sample test for RF Strength of common appliances

The first table summarizes the descriptive statistics for RF strengths of household appliances. The highest average RF strength was observed in Wi-Fi routers (M = 274,158 µW/m², SD = 128,275), followed by phones (M = 86,966 µW/m², SD = 85,320) and laptops (M = 17,666 µW/m², SD = 48,013). Moderate RF levels were recorded in appliances such as refrigerators (M = 1245 µW/m²), blenders (M = 1436 µW/m²), washing machines (M = 1072 µW/m²), and TVs (M = 896 µW/m²). By contrast, most other household devices, including microwaves (M = 284 µW/m²), lights (M = 351 µW/m²), kitchen stove hoods (M = 114 µW/m²), and ACs (M = 797 µW/m²), contributed only negligible RF exposure. These findings indicate that communication devices (Wi-Fi routers, phones, laptops) dominate household RF emissions, while most conventional appliances emit near-background levels.

A one-sample t-test was conducted using the public exposure reference value of 1,000,000 $\mu W/m^2$. Results showed that all appliances had significantly lower RF strengths compared to the standard ($p < .001$ for all comparisons). The largest differences were observed for Wi-Fi routers ($M = 274,158$ $\mu W/m^2$, $t = -40.41$, $p < .001$) and phones ($M = 86,966$ $\mu W/m^2$, $t = -111.73$, $p < .001$), both of which, despite being the highest RF sources among appliances, remained far below the threshold. Other appliances, including laptops, TVs, refrigerators, and washing machines, also showed significantly lower values than the guideline, typically within a few thousand $\mu W/m^2$.

These results confirm that while certain devices are relatively stronger RF emitters, particularly communication technologies, all measured household appliances remain well within international safety limits.

Section 3: Health outcomes and awareness

3.1: Correlation between the symptoms and magnetic field:

Correlations

		MF Average
Magnetic field (Average)	Pearson Correlation	1
	Sig. (2-tailed)	
	N	67
Symptoms from Phone	Pearson Correlation	.070
	Sig. (2-tailed)	.574
	N	67
Symptoms from Laptop	Pearson Correlation	-.096
	Sig. (2-tailed)	.438
	N	67
Symptoms from TV	Pearson Correlation	-.031
	Sig. (2-tailed)	.805
	N	67
Symptoms from AC	Pearson Correlation	.151
	Sig. (2-tailed)	.222
	N	67
Mental Health problems	Pearson Correlation	-.160
	Sig. (2-tailed)	.196
	N	67
Eyes or Vision problem	Pearson Correlation	.065
	Sig. (2-tailed)	.600
	N	67
Cognitive Issues	Pearson Correlation	.074
	Sig. (2-tailed)	.553
	N	67

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 96: Correlation between magnetic field and several reported symptoms

Pearson correlation analysis was conducted to evaluate the relationship between average magnetic field (MF) exposure and various self-reported health symptoms by the respondents. There were no statistically significant correlations. Specifically, MF exposure was very weakly and positively correlated with symptoms from phone use ($r = 0.070$, $p = .574$) and AC use ($r = 0.151$, $p = .222$). Negative, non-significant correlations were observed with laptop-related symptoms ($r = –0.096$, $p = .438$), TV-related symptoms ($r = –0.031$, $p = .805$), and mental health problems (r = –0.160, p = .196). Similarly, weak and non-significant relationships were found with vision problems (r = 0.065, p = .600) and cognitive issues (r = 0.074, p = .553).

3.2: Correlation between the symptoms and the electric field:

Correlations

		EF Average
Electric field Average	Pearson Correlation	1
	Sig. (2-tailed)	
	N	67
Symptoms from phone	Pearson Correlation	.179
	Sig. (2-tailed)	.147
	N	67
Symptoms from Laptop	Pearson Correlation	-.106
	Sig. (2-tailed)	.395
	N	67
Symptoms from TV	Pearson Correlation	-.063
	Sig. (2-tailed)	.610
	N	67
Symptoms from AC	Pearson Correlation	.115
	Sig. (2-tailed)	.355
	N	67
Mental health problems	Pearson Correlation	.210
	Sig. (2-tailed)	.089
	N	67
Eyes or Vision Problems	Pearson Correlation	-.050
	Sig. (2-tailed)	.687
	N	67
Cognitive Issues	Pearson Correlation	-.036
	Sig. (2-tailed)	.775
	N	67

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 97: Correlation between electric field and several reported symptoms

The relationship between Electric field (EF) exposure and health symptoms was also assessed. None of the correlations reached statistical significance. A small positive correlation was found with symptoms from phone use (r = 0.179, p = .147) and mental health problems (r = 0.210, p = .089), though these were not significant at the 0.05 level. Weak, non-significant negative correlations were found with symptoms from laptop (r = -0.106, p = .395), TV-related symptoms (r = -0.063, p = .610), vision problems (r = -0.050, p = .687), and cognitive issues (r = -0.036, p = .775). Weak and non-significant positive correlations were observed with symptoms from AC (r = 0.115, p = .355). Overall, EF exposure did not significantly predict any health outcomes.

3.3: Correlation between the symptoms and radio frequency strength:

Correlations

		RF Average
Radio frequency Strength Average	Pearson Correlation	1
	Sig. (2-tailed)	
	N	67
Symptoms from Phone	Pearson Correlation	.117
	Sig. (2-tailed)	.345
	N	67
Symptoms from Laptop	Pearson Correlation	-.161
	Sig. (2-tailed)	.192
	N	67
Symptoms from TV	Pearson Correlation	.170
	Sig. (2-tailed)	.170
	N	67
Symptoms from AC	Pearson Correlation	-.098
	Sig. (2-tailed)	.429
	N	67
Mental Health Problems	Pearson Correlation	-.115
	Sig. (2-tailed)	.354
	N	67
Eyes or Vision problems	Pearson Correlation	.049
	Sig. (2-tailed)	.693
	N	67
Cognitive Issues	Pearson Correlation	.156
	Sig. (2-tailed)	.209
	N	67

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 98: Correlation between RF strength and several reported symptoms

Finally, the correlations between average radiofrequency (RF) strength and reported health symptoms were examined. No significant associations were found. Weak positive correlations were observed with phone-related symptoms ($r = 0.117$, $p = .345$), TV-related symptoms ($r = 0.170$, $p = .170$), and cognitive issues ($r = 0.156$, $p = .209$). Weak negative correlations were found with laptop related symptoms ($r = -0.161$, $p = .192$), AC related symptoms ($r = -0.098$, $p = .429$), and mental health problems ($r = -0.115$, $p = .354$). Vision problems showed a near-zero, non-significant correlation ($r = 0.049$, $p = .693$).

3.4: Families with Cancer Patients:

Families with Cancer patient

		Frequency	Percent
Valid	No	31	46.3
	Yes	36	53.7
	Total	67	100.0

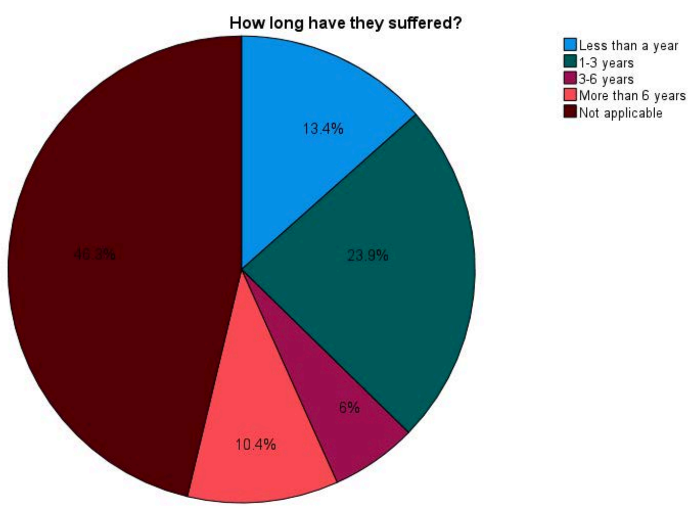


Figure 99: Number of families with cancer patients and the duration of the disease

Among the 67 participating households, 36 families (53.7%) reported the presence of a cancer patient, while 31families (46.3%) reported none. The majority of affected families reported illness duration of 1–3 years (23.9%), followed by less than 1 year (13.4%) and more than 5 years (10.4%).

3.5: Device-based symptoms:

3.5.1. Health Effects from Phone

Crosstab

Count

		Health Effects from Phone		
		no	Yes	Total
Age	Less than 15	0	1	1
	15-30 years	7	19	26
	30-45 years	6	18	24
	More than 45	3	13	16
Total		16	51	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.694[a]	3	.875
Likelihood Ratio	.936	3	.817
Linear-by-Linear Association	.159	1	.690
N of Valid Cases	67		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .24.

Figure 100: Health effects from Phones and its correlation with various age groups

A majority of participants, that is 51 out of 67, making up 76.1%, reported health complaints attributed to mobile phone use, while only 16 respondents (23.9%) denied any effects.
Crosstabulation with age revealed that younger participants aged from 15-45 years accounted for most of the reported health issues (37 respondents), whereas only a small number of older participants (>45 years) reported similar complaints (13 respondents).
Despite these differences, the Chi-square test showed that the relationship between age group and phone-related health effects was not statistically significant ($\chi^2(3) = 0.694$, $p = .875$).

3.5.2. Health Effects from Laptop

Crosstab

Count

		Health effects from laptop: No	Health effects from laptop: yes	Total
Age	Less than 15	1	0	1
	15-30 years	12	14	26
	30-45 years	17	7	24
	More than 45	10	6	16
Total		40	27	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.947[a]	3	.267
Likelihood Ratio	4.309	3	.230
Linear-by-Linear Association	.935	1	.334
N of Valid Cases	67		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .40.

Figure 101: Health effects from Laptops and its correlation with various age groups

A cross-tabulation was performed to examine the distribution of laptop-related health effects across different age groups. Among 26 participants aged 15-30 years, 12 (46.2%) reported no health effects, and 14 (53.8%) reported health effects. In the 30–45-year age group, 17 (70.8%) reported no health issues, while 7 (29.2%) reported health effects. For those aged more than 45 years, 10 (62.5%) reported no health issues, while 6 (37.5%) reported health effects. Only one participant fell into the less than 15 years group, who reported no health effects.

A Chi-square test showed that the relationship between age group and health effects from laptop use was not statistically significant. This indicates that age was not significantly associated with the reporting of health issues related to laptop use.

3.5.3. Health Effects from TV

Crosstab

Count

		Health effect from TV: No	Health effect from TV: Yes	Total
Age	Less than 15	1	0	1
	15-30 years	23	3	26
	30-45 years	22	2	24
	More than 45	15	1	16
Total		61	6	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.466[a]	3	.926
Likelihood Ratio	.555	3	.907
Linear-by-Linear Association	.236	1	.627
N of Valid Cases	67		

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .09.

Figure 102: Health effects from TVs and its correlation with various age groups

Among the 26 respondents in the 15–30 years group, 23 (88.5%) reported no health effects, and 3 (11.5%) reported health issues. For the 30–45-year-old group, 22 (91.7%) reported no health problems, while 2 (8.3%) reported health effects. Among the more than 45-year-olds with 16 participants, 15 (93.8%) reported no health effects, and 1 (6.2%) reported issues. The group under 15 years again reported no effects.

The Chi-square test showed no significant relationship between age group and health effects from TV use ($\chi^2(3, N = 67) = 0.466, p = .926$). This suggests that age did not have a significant impact on whether participants reported health issues on TV.

3.5.4. Health Effects of AC

Crosstab

Count

		Health effect from AC: No	Health effect from AC: Yes	Total
Age	Less than 15	1	0	1
	15-30 years	12	14	26
	30-45 years	17	7	24
	More than 45	11	5	16
Total		41	26	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.435[a]	3	.218
Likelihood Ratio	4.756	3	.191
Linear-by-Linear Association	1.785	1	.182
N of Valid Cases	67		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .39.

Figure 103: Health effects from ACs and its correlation with various age groups

Out of 67 participants, 26 respondents (38.8%) reported health effects associated with air conditioner (AC) use, while 41 (61.2%) reported no such effects. Crosstabulation across age groups revealed that complaints were most commonly observed among the 15–30-year (14 participants) and 30–45-year (7 participants) groups, whereas older participants (>45 years) reported fewer effects (5 participants).

However, Chi-square analysis demonstrated that the association between age group and AC-related health effects was not statistically significant ($\chi^2(3) = 4.435, p = .218$), indicating that age did not play a major role in self-reported symptoms from AC use.

3.6: Mental health problems in the respondents:

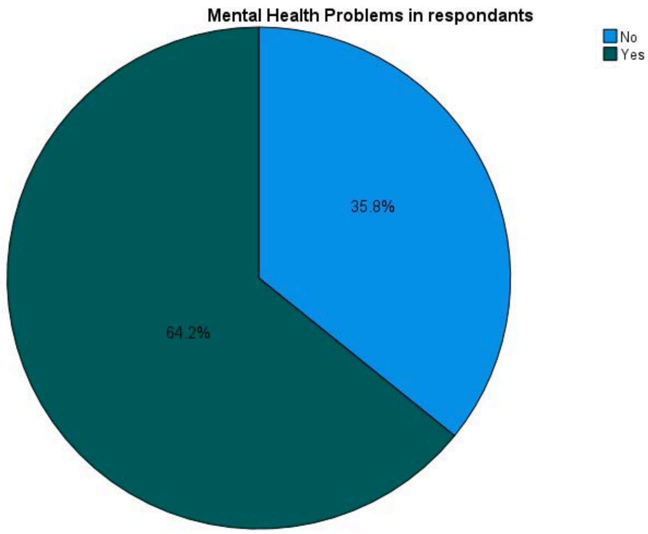


Figure 104: Mental health problems in respondents

Among the 67 participants, alarmingly, 43 respondents (64.2%) reported experiencing mental health problems, while 24 respondents (35.8%) did not.

Crosstab

Count

		Mental health Problems in respondants		
		No	Yes	Total
Age	Less than 15	0	1	1
	15-30 years	5	21	26
	30-45 years	13	11	24
	More than 45	6	10	16
Total		24	43	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.204[a]	3	.066
Likelihood Ratio	7.688	3	.053
Linear-by-Linear Association	2.743	1	.098
N of Valid Cases	67		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .36.

Figure 105: Mental health problems and their correlation with various age groups

Age-wise distribution showed that mental health problems were most prevalent among respondents aged 15–30 years, with 21 out of 26 (80.8%) participants, followed by 10 of 16 participants above 45 years (62.5%). In contrast, the 30–45 years group reported comparatively fewer mental health issues (45.8%). The single respondent aged below 15 years reported having mental health issues.

A Chi-square test revealed no statistically significant association between age and reported mental health problems ($\chi^2(3)=7.204$, $p=0.066$). Although not significant at the 0.05 level, the p-value was close to significance, suggesting a possible trend indicating that younger adults may experience mental health problems more frequently.

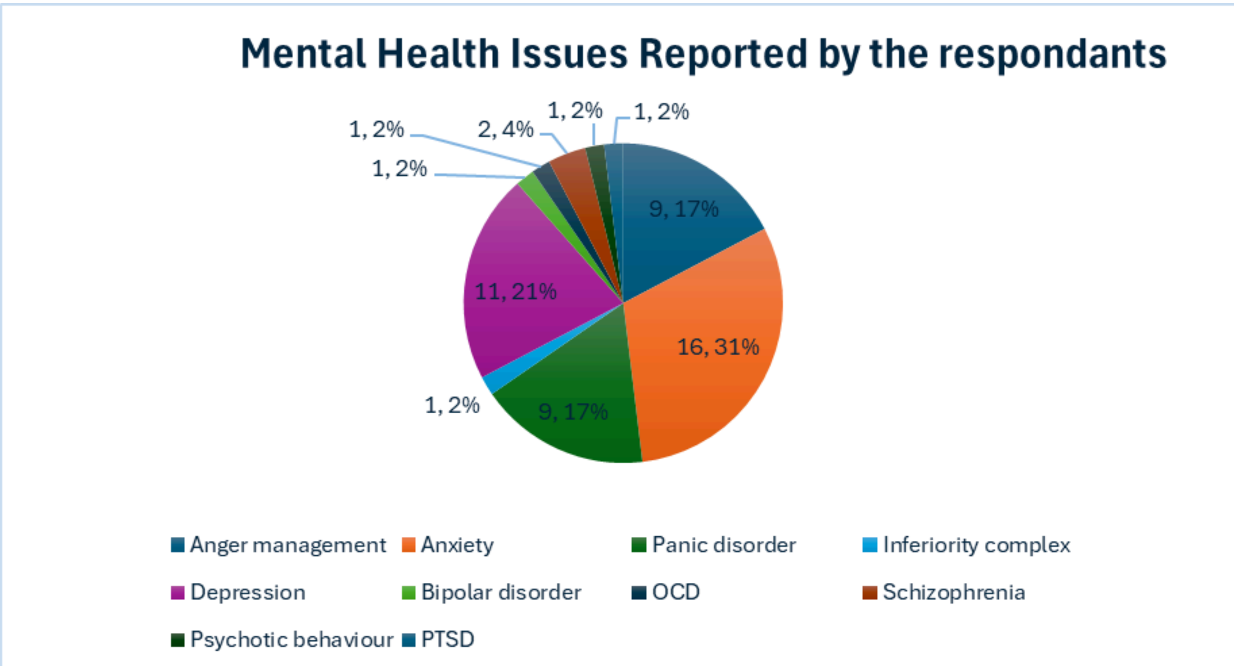


Figure 106: Mental health Problems reported by the respondents

Multiple Mental health issues were reported by each respondent. The type of mental health issues that were most common included anxiety (16.31%), depression (11.21%), anger management difficulties, panic disorder (9.17%), and a few cases of problems like Schizophrenia, inferiority complex, Bipolar Disorder, OCD, PTSD, and non-specific like Psychotic behavior.

3.7: Stress Issues in the respondents:

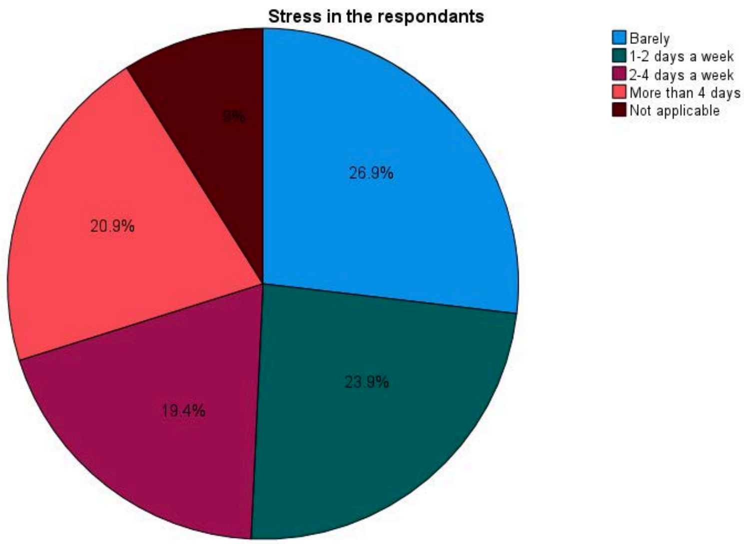


Figure 107: Levels of stress reported by the participants

Respondents were questioned about the frequency of stress in their regular lives. 61 out of 67 participants (91%) reported having some level of stress in their daily life. 26.9% reported feeling stress barely, 23.9% experienced stress 1–2 days per week, 19.4% reported stress 2–4 days per week, and 20.9% felt stress more than 4 days a week. Around 9.0% mentioned never being stressed in their regular life.

		Stress in daily life					
		Barely	1-2 days a week	2-4 days a week	More than 4 days	Not applicable	Total
Age	Less than 15	1	0	0	0	0	1
	15-30 years	6	6	3	9	2	26
	30-45 years	7	8	7	1	1	24
	More than 45	4	2	3	4	3	16
Total		18	16	13	14	6	67

Figure 108: Level of stress per age groups

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14.774[a]	12	.254
Likelihood Ratio	15.688	12	.206
Linear-by-Linear Association	.245	1	.621
N of Valid Cases	67		

a. 13 cells (65.0%) have expected count less than 5. The minimum expected count is .09.

<u>Figure 109: Stress level and its correlation with various age group</u>

Age-specific analysis showed that the 15-30 years age group reported the highest frequency of stress, with more than 70% experiencing stress at least once per week. Stress was also common among respondents aged 30–45 years and above 45 years, though slightly less frequent.

A Chi-square test showed no significant association between age and stress levels ($\chi^2(12)=14.774$, $p=0.254$). This indicates that stress was experienced across all age groups without a clear age-dependent trend.

3.8: Eye discomfort and Vision Problems in the respondents:

Crosstab

Count

		Eye discomfort or vision problem		
		No	Yes	Total
Age	Less than 15	0	1	1
	15-30 years	8	18	26
	30-45 years	8	16	24
	More than 45	3	13	16
Total		19	48	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.490[a]	3	.685
Likelihood Ratio	1.813	3	.612
Linear-by-Linear Association	.282	1	.595
N of Valid Cases	67		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .28.

<u>Figure 110: Reported Vision problems and their correlation with various age groups</u>

A majority of respondents, that is 71.6% (participants) reported experiencing eye discomfort or vision-related problems, while 28.4% mentioned having no such problems. 18 (69.2%)

respondents aged 15–30 years, 66.7% of respondents aged 30–45 years, and 81.3% of respondents aged above 45 years reported experiencing eye discomfort.
The Chi-square test indicated no significant relationship between age and eye discomfort ($\chi^2(3)=1.490$, $p=0.685$).

3.9: Cognitive problems in the respondents:

Crosstab

Count

		Cognitive effects		Total
		no	yes	
Age	Less than 15	0	1	1
	15-30 years	7	19	26
	30-45 years	12	12	24
	More than 45	3	13	16
Total		22	45	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.547[a]	3	.136
Likelihood Ratio	5.820	3	.121
Linear-by-Linear Association	.000	1	.985
N of Valid Cases	67		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .33.

Figure 111: Reported Cognitive issues and their correlation with various age groups

Cognitive-related problems such as forgetfulness, difficulty concentrating, and reduced alertness were reported in 45 or 67.2% of respondents, while 22 participants reported no issues like this. Cognitive effects were most frequently reported in the 15–30 years group (19 out of 26 of the respondents in that age group), followed by the respondents above 45 years, with 13 out of 16 mentioning such problems. In the 30–45 years group, 50% reported experiencing such effects.
The Chi-square test revealed no statistically significant association between age and cognitive effects ($\chi^2(3)=5.547$, $p=0.136$).

3.10: Issues regarding power lines, cell tower, use of cell phones:

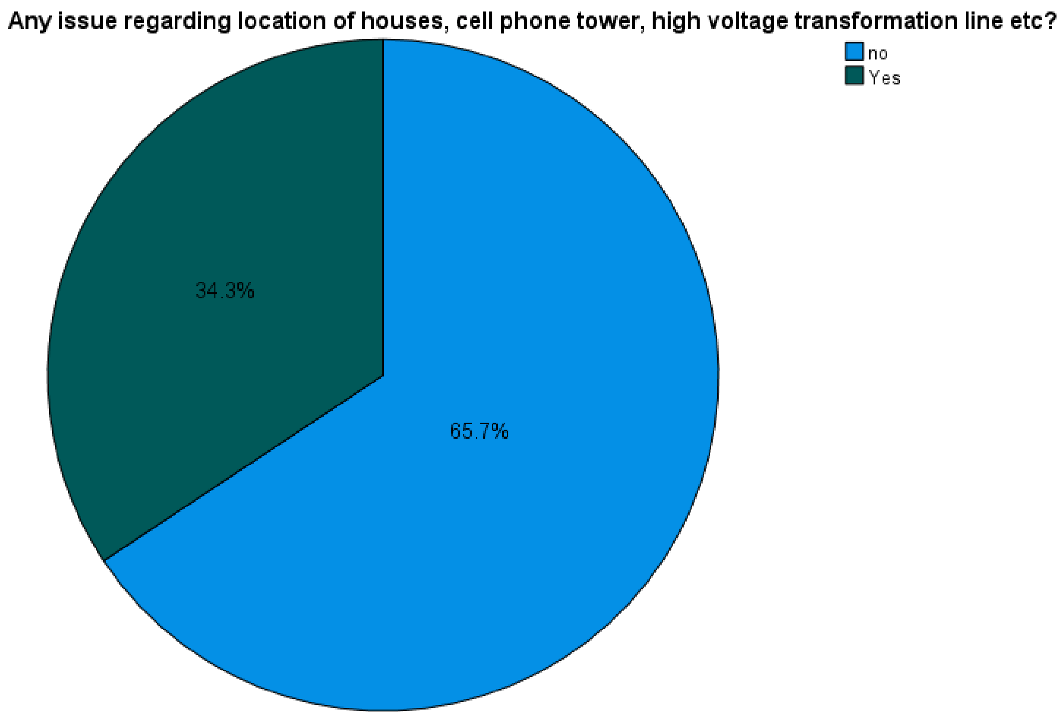


Figure 112: Problems regarding location of the house, cell tower, high voltage transformer etc.

When asked whether they experienced issues related to the location of houses, cellphone towers, or high-voltage transmission lines, about two-thirds of respondents (65.7%) reported experiencing such issues, while 34.3% reported no issues

.

Did you notice any symptom after using cell phones, high voltage power lines, etc.?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	38	56.7	56.7	56.7
	yes	8	11.9	11.9	68.7
	Not sure	21	31.3	31.3	100.0
	Total	67	100.0	100.0	

Figure 113: Symptoms from cell phone high voltage power line.

Respondents were further asked whether they noticed any symptoms after using cell phones or being near high-voltage power lines. More than half of the participants (56.7%) stated they did not experience any symptoms, while 11.9% reported symptoms, and 31.3% were unsure.

This suggests that while the majority did not directly associate health symptoms with EMF exposure, a non-negligible proportion either experienced symptoms or remained uncertain.

3.11: Symptoms observed in pets:

		Effect on your pets due to use of home appliances		
		no	yes	Total
Pet	No	55	0	55
	Yes	9	3	12
Total		64	3	67

Figure 114: Symptoms observed in pets

Out of 67 respondents, only 12 (17.9%) reported having pets like cats, birds, fish, rabbits, ducks, and hens at home. Among them, 3 respondents (25%) reported observing adverse effects on their pets due to the use of home appliances, while the remaining 9 respondents (75%) did not report any such issues. The types of effects mentioned irritated behavior leading to the killing of another bird, fish dying constantly, and birds dying soon after installing an Air conditioner.

The overall number of pet owners reporting effects was very small, which limited further statistical analysis.

3.12: Effects observed on children and older people:

		Effect on children and older people		
		no	yes	Total
Old people or children	No	16	2	18
	Yes	17	32	49
Total		33	34	67

Figure 115: Effects observed on Children and the elderly

Participants mentioned observing effects due to NIR exposure on vulnerable groups, such as children and elderly people. 34 respondents (50.7%) reported observing such effects, while 33 (49.3%) did not.

These findings highlight divided opinions, suggesting that while awareness of potential health risks is high, there is uncertainty regarding the specific impact on vulnerable populations.

Health effects reported among vulnerable groups, such as children and elderly participants, were diverse and concerning. In children, the most commonly noted complaints included irritation, behavioral problems, speech and articulation difficulties, concentration challenges, vision problems, eye irritation, and sleep deprivation. More serious developmental concerns, such as brain development issues, neural growth defects, memory decline, and addiction-related behaviors, were also reported by some families.

Among older participants, the predominant health problems included migraine, dizziness, anxiety, panic, suffocation, and sleep disturbance, as well as muscle aches, bodily cramps, and absent-mindedness. These findings suggest that both children and elderly individuals may be disproportionately sensitive to exposure from household appliances, experiencing a range of neurological, behavioral, and physiological symptoms.

3.13: Effect of education on Awareness in the respondents:

3.13.1. Relation between Education and level of awareness

		How informed do you feel about the potential health risk of EMF exposure from home appliances?			
		Not at all	Somewhat	Well aware	Total
Highest education level	S.S.C	1	1	1	3
	H.S.C	2	4	4	10
	Honours	1	16	17	34
	Masters	1	3	16	20
Total		5	24	38	67

Figure 116: Awareness level per highest education groups.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	12.528[a]	6	.051
Likelihood Ratio	11.386	6	.077
Linear-by-Linear Association	7.189	1	.007
N of Valid Cases	67		

a. 7 cells (58.3%) have expected count less than 5. The minimum expected count is .22.

Figure 117: Correlation between Awareness and Education Level

Respondents were also asked how informed they felt about the potential health risks of EMF exposure. Among the 67 respondents, 38 (56.7%) reported being "well aware." 24 (35.8%) reported being 'somewhat aware,' and only 5 (7.5%) stated that they were 'not at all aware.'

Educational level was associated with awareness. For example, 80% of Master's degree holders and 50% of Honours graduates reported being well aware, compared with only 33% of SSC and 40% of HSC respondents.

The chi-square test indicated a marginally significant association between education and awareness ($\chi^2 = 12.53$, df = 6, p = .051).

3.13.2. Relation between Education and knowledge of safety guidelines:

		Are you aware of the safety guidelines and regulations regarding NIR exposure from home appliances?		
		no	yes	Total
Highest education level	S.S.C	3	0	3
	H.S.C	8	2	10
	Honours	21	13	34
	Masters	7	13	20
Total		39	28	67

Figure 118: Awareness about safety guidelines per education level

About awareness of safety guidelines and regulations regarding NIR exposure from home appliances, 39 respondents (58.2%) reported being unaware, while 28 (41.8%) were aware. Awareness was especially limited among respondents with lower education: none of the SSC group and only 20% of HSC respondents reported awareness. In contrast, 38.2% of the honors degree holders and 65% of those with a Master's degree were aware of such guidelines.

This finding suggests that although many respondents recognize potential risks, fewer are knowledgeable about formal safety standards or protective measures.

3.13.3. Relation between Education and interest in more knowledge:

		Would you be interested to know more about NIR exposure and ways to reduce it?		
		no	yes	Total
Highest education level	S.S.C	1	2	3
	H.S.C	0	10	10
	Honours	2	32	34
	Masters	1	19	20
Total		4	63	67

Figure 119: Interest in knowledge about NIR per education level

A total of 63 respondents (94%) expressed interest in learning more about NIR exposure and methods to reduce it, while only 4 (6%) reported no interest. This pattern was consistent across all education levels, reflecting a strong demand for more information and public awareness initiatives.

3.13.4. Relation between Education and level of concern:

		Do you think use of these appliances can pose a threat to health?		
		no	yes	Total
Highest education level	S.S.C	1	2	3
	H.S.C	0	10	10
	Honours	1	33	34
	Masters	1	19	20
Total		3	64	67

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.509[a]	3	.089
Likelihood Ratio	3.717	3	.294
Linear-by-Linear Association	.767	1	.381
N of Valid Cases	67		

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .13.

Figure 120: Correlation between Threat Concern snd education level.

A vast majority, that is 64 respondents comprising 95.5%, reported believing that use of appliances might pose a certain level of threat to health, while only 3 (4.5%) believed otherwise. A chi-square test found no statistically significant differences across education levels ($\chi^2 = 6.51$, df = 3, p = .089), indicating that perceptions of risk were consistently high regardless of educational background.

3.13.5. Necessity for scientific studies:

		Are you aware of any scientific studies that have been conducted on the effects of NIR on human?		
		no	yes	Total
Highest education level	S.S.C	1	2	3
	H.S.C	3	7	10
	Honours	9	25	34
	Masters	8	12	20
Total		21	46	67

Figure 121: Knowledge about scientific studies per education group.

		Do you think more studies should be conducted?		
		no	yes	Total
Highest education level	S.S.C	0	3	3
	H.S.C	0	10	10
	Honours	1	33	34
	Masters	1	19	20
Total		2	65	67

Figure 122: Interest about more research per education levels

Out of the 67 participants, 46 respondents (68.7%) reported being aware of scientific studies conducted on the effects of non-ionizing radiation (NIR) on humans, whereas 21 respondents (31.3%) were not aware of any such studies. Awareness varied by educational level. Among respondents with an Honours degree, 25 participants reported awareness compared to only 1 reporting unawareness. Similarly, at the Master's level, 12 participants were aware, while 8 were not. On the other hand, participants with lower education levels (SSC and HSC) showed less awareness overall, with only 2 out of 3 SSC and 7 out of 10 HSC participants reporting awareness.

This suggests that awareness of scientific research increases with higher levels of education, with university-educated respondents (Honours and Master's) showing the highest levels of awareness.

3.13.6. Concern about Potential health effects by NIR from home appliances:

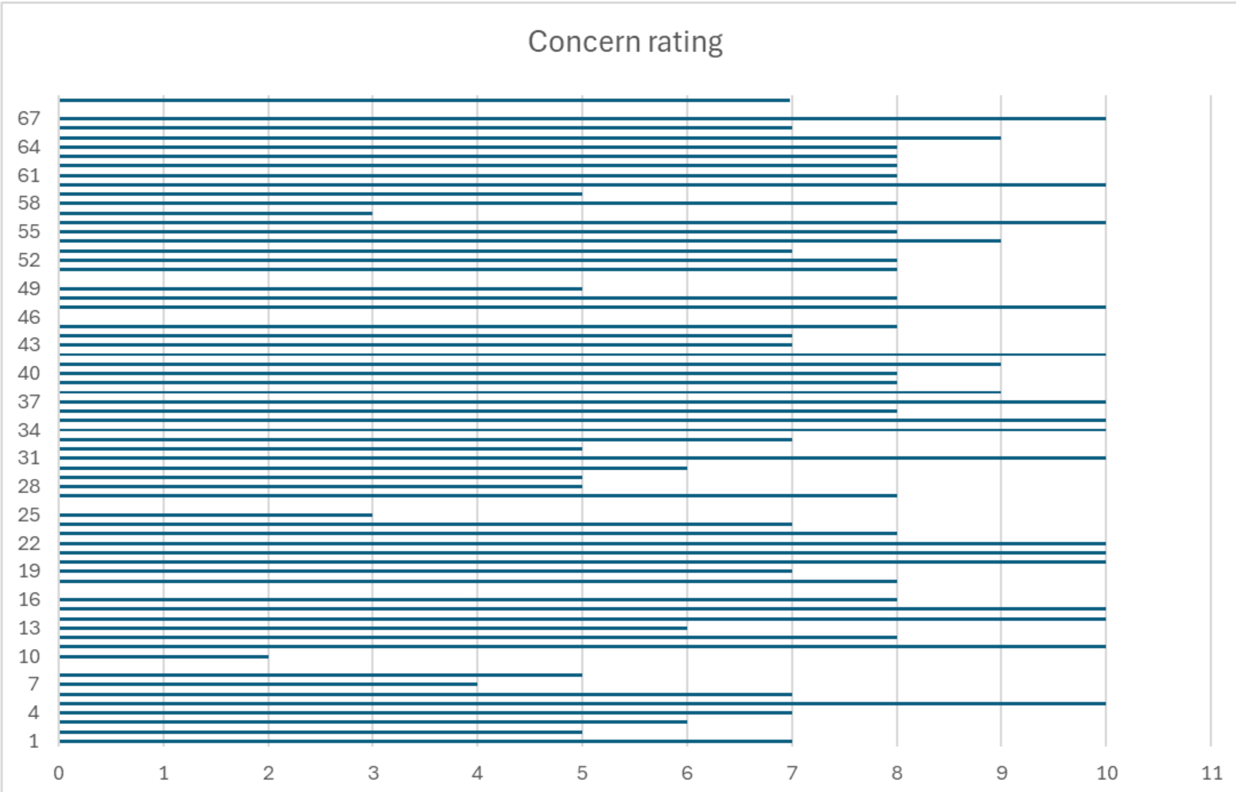


Figure 123: Concern Rating by the respondents

All 67 families were asked to rate their concern on a scale of 1 (not concerned) to 10 (extremely concerned). While the majority showed their concerns about the use of home appliances and their potential threats, some showed a lack of concern, with ratings as low as 0. The total average rating was almost 7.

Highest education level * On a scale of 1-10, how concerned are you about the potential health risks associated with EMF from home appliances? Crosstabulation

Count

		On a scale of 1-10, how concerned are you about the potential health risks associated with EMF from home appliances?										
		0	2	3	4	5	6	7	8	9	10	Total
Highest education level	S.S.C	0	0	2	0	0	0	0	1	0	0	3
	H.S.C	0	0	0	0	2	1	2	2	0	3	10
	Honours	4	1	0	0	3	1	5	10	3	7	34
	Masters	1	0	0	1	2	1	3	5	1	6	20
Total		5	1	2	1	7	3	10	18	4	16	67

Figure 124: Concern rating per education groups.

The results indicated that the majority expressed moderate to high concern. The highest frequencies were reported at concern levels 8 (26.9%) and 10 (23.9%). Participants with a Master's degree reported the highest average concern level (mean ≈ 8.1), followed by Honours graduates (mean ≈ 7.6), H.S.C. level (mean ≈ 7.4), and S.S.C. level (mean ≈ 6.9). Overall, the average concern level was high, with most respondents clustering in the upper half of the scale. This suggests that NIR exposure from home appliances is perceived as a significant health issue by most participants.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	53.811[a]	27	.002
Likelihood Ratio	26.848	27	.472
Linear-by-Linear Association	.947	1	.331
N of Valid Cases	67		

a. 36 cells (90.0%) have expected count less than 5. The minimum expected count is .04.

Figure 125: Correlations between concern rating and level of education

A Chi-square test of independence indicated a statistically significant relationship between education level and concern rating ($\chi^2(27, N=67) = 53.81$, $p = .002$). This implies that educational background is associated with how individuals perceive health risks from EMF exposure.

Discussion:

Modern science has led to the development of numerous technologies, integrating various electronic and electrical appliances into daily life and, in the process, increasing human exposure to non-ionizing radiation. This exposure has become a growing concern, making it important to understand the associated safety thresholds. As these appliances become more pervasive, the likelihood of health effects may gradually increase.

This study examined household exposure to electromagnetic fields (EMFs) and highlighted the variation in exposure levels across different appliances, with some devices contributing more significantly than others. Reported health symptoms were also recorded, and graphical and statistical analyses were conducted to assess their significance.

The discussion section interprets and explains the significance of the results obtained in this study, relating them to the research objectives and existing literature. It highlights the implications of the findings, identifies possible limitations, and provides insights into future research. By analyzing the data collected on non-ionizing radiation exposure from household appliances, this study aims to understand its potential health impacts, compare measured values with baseline environmental levels, and evaluate patterns or trends that emerged during the investigation.

Demographics:

The majority of participants fell in the age group from 30 to 45 years, and most had completed honors as their highest level of education. Nearly half of the participants reported having children at home, and a significant portion mentioned the presence of elderly or family members with special needs. These demographic and household characteristics provide an opportunity for understanding the exposure patterns and reported health concerns.

Graphical analysis:

The graphical analysis allows for a well-comprehended understanding of the exposure levels from the household appliances. Bar charts were used for proper visualisation of the major differences in the exposure level across magnetic field, electric field, and RF strength, and also across houses and appliances. A total of 67 houses were included in the study, with 1,009 appliances measured, averaging approximately 15 appliances per house.

Iron machines and Fans were seen to have the highest level of magnetic field strength with an average of 69.2 and 50.9 mG, respectively. The lowest was observed in washing machines (1.4 mG), phones (1.9 mG), and wifi routers (1.7 mG). This pattern was also observed in the previous studies that the appliances and devices run by motors or having coils and electromagnet tend to give high magnetic field values. [106] In the case of magnetic fields, huge differences were observed in several appliances like phones, switchboards, lights, monitors, and laptops etc. The highest electric field values were observed for multiplugs (437.5 V/m) and microwaves (436.8 V/m), while the lowest were in intercoms and phones, with respectively 30.5 V/m and 13.2 V/m. In case of radio frequency (RF) strength, Wi-Fi routers and mobile phones exhibited the highest values, which aligns with their mode of operation that relies on RF signals.

These findings indicate that home appliances contribute greatly to NIR exposure. Like the findings here, studies done in the past also show home appliances being a major source of indoor EMF exposure, especially magnetic fields. [107] Heating devices dominate magnetic field and electric field exposure, whereas communication devices dominate Radiofrequency exposure. Magnetic and Electric fields exceeded the safety threshold occasionally, but RF exposures remained below the safety limit, suggesting that real-world exposure is generally within accepted limits but can vary by device. These findings remain consistent with past studies that showed the magnetic field and electric field contributes significantly to NIR exposure and beyond the safety limit. [108] Graphical analysis revealed a consistent pattern where few appliances account for disproportionate exposure, with most others remaining negligible.

Across all appliances measured, the mean values were 12.44 mG for magnetic field, 222.68 V/m for electric field, and 25553.88 $\mu W/m^2$ for radio frequency strength. When compared to the background measurements, it was seen that the household appliances have significantly higher exposure levels. The average magnetic field (MF) strength was 19.5 times higher than the background value, the electric field (EF) was 111.34 times higher, and the RF strength was 113.3 times higher in the household appliances. These findings indicate that certain household devices contribute substantially to non-ionizing radiation exposure, highlighting the importance of monitoring and managing exposure in domestic environments.

These findings are consistent with previous studies that indicate that heating appliances contribute more significantly to magnetic and electric field exposure. In contrast, communication devices like Wi-Fi routers and mobile phones give out higher radio frequency (RF) exposure.

Data Statistics:

In order to assess non-ionizing radiation (NIR) emissions from various household appliances, a one-sample t-test was performed. The null hypothesis (H_0) stated that the average exposure values of NIR would be less than or equal to the established safety threshold limits, whereas the alternative hypothesis (H_1) proposed that NIR exposure from household appliances would exceed these standard values.

Statistical analysis revealed that fans ($M = 50.9$ mG, $p < .001$) and air conditioners ($M = 10.5$ mG, $p < .001$) recorded the highest magnetic field levels confirming them as major contributors to household magnetic field exposure, while Wi-Fi routers ($M = 1.7$ mG, $p = .049$) and washing machines ($M = 1.5$ mG, $p = .002$) recorded the lowest magnetic field values. This supports earlier findings that fans and ACs generate higher magnetic fields due to their motor function, while digital devices emit little comparatively.

In contrast, almost all appliances except phones ($M = 13.2$ V/m, $p = .004$) and kitchen stove hoods ($p = .237$) showed significantly higher EF levels. Microwaves ($M = 436.8$ V/m, $p < .001$) and multiplugs ($M = 437.6$ V/m, $p < .001$) showed the highest electric field exposure, indicating that large kitchen appliances and power distribution devices are consistent EF hotspots in households.

Regarding radio frequency strength, the highest exposures were observed in Wi-Fi routers (M = 274,158 $\mu W/m^2$, $p < .001$) and phones (M = 86,966 $\mu W/m^2$, $p < .001$), which were consistent with the results obtained from graphical analysis. This suggests that RF exposure from home appliances remains within global safety standards, despite being the main source of public concern. However, this does not confirm that long-term exposure has no detrimental effects on health.

These findings support the differential contributions of household appliances to magnetic, electric, and RF exposures and provide evidence for targeted monitoring of high-emission devices. These results confirm that some household devices pose higher exposure risks than others. Identifying these high-emission appliances can guide recommendations for safer use, placement, and design improvements. While certain appliances (fans, ACs, microwaves, multiplugs) consistently exceed thresholds for MF/EF, health outcomes are mostly not statistically linked to exposure levels – suggesting reported symptoms may be influenced by several other factors, like the length of exposure, or factors like the influence of other health issues.

Correlations:

Several correlation analyses were done to explore the relationship between magnetic field, electric field, radiofrequency strength, and the reported health symptoms. Mostly, the correlations observed were weak or negative. However, there were some weak positive correlations that emerged particularly between the use of the phone and certain symptoms. For example, electric field exposure from phones showed a weak positive correlation with health complaints. Similarly, radiofrequency exposure from phones exhibited a weak positive correlation with the reported symptoms.

Health issues and symptoms:

Various health issues were reported by participants. Notably, 36 families (over 50%) reported having or having had a family member with cancer, which is an alarming observation warranting further investigation. While not linked statistically to appliance exposure, this high prevalence might reflect some sort of exposure effect from long-term use of appliances. Even in previous studies association of EMF with leukemia was found. [107] This calls for long-term monitoring and lab-based tests to be done, as even international views (IARC, WHO) classified low-level EMF as 'possibly carcinogenic'.

Chi-square tests were used to explore relationships between demographics (e.g., age, education) and health complaints. Regarding phone-related symptoms, 76.1% of participants reported experiencing health effects, with the majority coming from the 15 to 30 age group. However, no statistically significant association was found between age and these reported symptoms.

In the case of mental health, 64.2% (43 out of 67) of respondents reported mental health problems, including anxiety, depression, panic disorder, bipolar disorder, and even schizophrenia, with the 15 to 30 age group showing the highest prevalence. Although not statistically significant ($\chi^2(3) = 7.204$, $p = 0.066$), the near significance suggests that there might be a trend that younger participants may be more susceptible to mental health issues due to technology use. The most commonly reported mental health problems included anxiety, depression, and difficulty managing anger. This aligns with existing literature that links EMF exposure with psychosomatic and mental health complaints, which are often caused by stress and worry as well. Stress was also reported at least once a week by 91.1% of participants. EMF exposure may be perceived as a stressor, contributing indirectly to health complaints, like mental health issues. Additionally, 71.6% reported eye discomfort, and about 67% reported forgetfulness, poor concentration, or reduced alertness, with younger respondents most affected. No statistical link with magnetic field, electric field or radiofrequency strength was found, but high prevalence might suggest EMF as potential contributors.

Health impacts were also noted in vulnerable groups, with 50% of respondents observing effects in children and elderly family members. Parents reported behavioral, developmental, and sleep problems in children, and elderly reported migraines, dizziness, cramps, and anxiety. These reflect vulnerable groups' heightened sensitivity. While causal relationships could not be established, these findings highlight the perceived vulnerability of non-adults and older adults to NIR exposure. A small number of pet owners also reported observed behavioral changes or deaths in pets associated with appliance use, suggesting potential wider biological effects that merit further study.

While causal relationships cannot be established due to reliance on self-reported data, these results highlight perceived vulnerabilities and the need for further clinical and laboratory-based studies. Younger adults may be particularly sensitive to the psychosocial effects of device use. The health outcomes demonstrate that perceived symptoms outweigh statistically proven risks, making calls for long-term monitoring of long-term exposure levels.

Awareness and education:

Almost all respondents (95.5%) believed that appliances might pose some health threat, and the average concern rating was around 7 out of 10, with most ratings around 8 and 10. Education correlated with concern levels, where more educated respondents reported a higher average concern (Master's mean is 8.1, Honours average is 7.6) compared to SSC (6.9).

This suggests that the prevalence of higher education increases the knowledge and also the concern about the electromagnetic field. Overall, this analysis indicates a positive correlation between education and awareness. This shows that education can strongly shape our perception and can make us more aware about our surroundings. Even though a few highly educated participants lacked complete knowledge about the guidelines, it was found that majority of the highly educated respondents showed higher awareness and understanding of the non-ionizing radiation safety guidelines. This also shows that education is a key determinant of awareness and concern. So, the public health campaigns and educational initiatives could definitely improve the understanding and promote safer practices of the appliances effectively.

These results call for several actions. Public health campaigns must bridge the awareness-related knowledge gap. People know about EMF but lack understanding of exposure thresholds, safety standards, and realistic risks. Also, since most participants want to learn more, the government, NGOs, and health authorities should invest in community workshops, information leaflets in local language, and media campaigns.

Concerns and suggestions:

Following the quantitative and qualitative findings on exposure levels and health symptoms, the perceptions and suggestions provided by the participants offer valuable context for understanding the real-world implications of non-ionizing radiation (NIR) exposure. During the survey, participants expressed a wide range of concerns about non-ionizing radiation exposure, reflecting both immediate health worries and long-term uncertainties.

The most important concern told by people centered around mobile phones as they are carried everywhere and are constantly used for a prolonged period of time. The participants feared this constant exposure to radiofrequency radiation and a lot were worried about the effects this is causing such as migraines, forgetfulness, difficulty in focusing, sleep deprivation, and also cognitive impairment. Psychological issues like anxiety, depression, anger management problems, and irritability were also mentioned by the respondents. Many of the people who showed their concern were mostly worried that the children wouldn't have proper brain development and they might be more vulnerable. Parents were also worried about developmental delays, behavioral changes, and long-term learning impacts. There are also some dominant fears about cancer since many respondents reported family histories and there were also extended concerns about potential genetic mutation suggesting that radiation exposure might harm their future generation as well. There were also reports about body aches, eye strain, fatigue, and stress in everyday life which highlights that the constant exposure to the appliances might be in the initial stage of taking effect.

Apart from these, people also showed huge concern about the knowledge gap. Many participants expressed their frustration about the fact that the guidelines and the risks are not properly reaching the general public. They said that they have absolutely no idea about the fact that they are daily exposed to non-ionizing radiation and its safe limits. The respondents also highlighted that there is also a lack of transparency from the manufacturers, which limits the access of general people to simple and reliable information.

Participants offered several suggestions aimed at mitigating these risks and improving public awareness, such as:

- Public Awareness and Education: Spreading clear and practical information about the electromagnetic field exposure and safety threshold is extremely important. People should be taught about making conscious decisions and informed choices about using household appliances. The participants expressed opinions about needing campaigns to educate the citizens about the safe use of appliances, exposure limits, and also practical strategies to lower the health effects.
- Government regulations: People called out to enforce strict safety rules, regular monitoring, and also clear leveling of devices with the thresholds.
- Technological development: A few respondents suggested that research should be done in order to introduce devices and appliances that cause reduced emission of non-ionizing radiation. Appliances can also be introduced instead of high EMF gadgets.
- Affordability and Accessibility: Reducing the electronic tax was also suggested by some people so that people can purchase higher quality and safer appliances. Some even suggested making EMF meters widely available at low cost so that it is readily available for everyone.
- Practical Solutions: The participants suggested that there is a need for real-life solutions and not just research. For example, appliances should be available in the market with warning signs, thresholds, and user guidelines so that people can make choices. Apart from this, since many studies have been done, the results of these studies should be conveyed to people so that they can better understand it.

These responses and suggestions highlight the desire and will of the participants, that is, the general public, for knowledge solutions and stricter regulations by incorporating public awareness campaigns and initiatives for proper education. Scientific research can be complemented, and all of this can contribute to a safer household or domestic environment.

Limitations:

While this study provides valuable insights into household exposure to non-ionizing radiation (NIR) and associated health perceptions, several limitations must be acknowledged:

- Sample Size and Population: The study included a small sample size of only 67 households with 1,009 appliances in total. This limited sample size, along with the narrow demographic range of participants, restricts the generalization of the findings. There was also an uneven distribution in the case of selecting houses from various places in Dhaka city. For example, the appliances of more than 10 houses were measured in one part of the city, and in another, only 1 or 2 houses were taken into account.

- Uneven Demographics: The participant pool was not evenly distributed in terms of age, gender, education, or household composition. This unevenness could introduce bias in reporting exposure to perceptions and health outcomes. Demographics were uneven (majority women, mostly aged 30–45, with higher education levels). This narrow sample reduces generalizability to the broader population.

- Measurement Constraints: Appliances were not always measured during active use, potentially underestimating real exposure levels. For example, a microwave in standby mode emits differently compared to when in full operation. When the majority of appliances were plugged in but not in active use, measurements may have underestimated actual exposure. The proximity of multiple appliances sometimes interfered with accurate readings of the magnetic field, electric field, and radio frequency strength. There were many appliances connected to the power outlet in a congested way. Apart from this, sometimes the appliances like fans, lights, and ACs were out of reach due to the high ceiling and couldn't be measured for EMF properly.

- Time constraints: The lack of time limits the number of measurements that can be done repeatedly and does not allow and leave a chance for continuous or long-term monitoring. The limited study duration also restricted the amount of data collection and shortened the process. This prevented the longitudinal observation and detailed investigation of health effects from constant and collective exposure of NIR over time. An extended monitoring period is necessary to capture more accurate exposure levels and potential long-term health impacts.

- Reliance on Self-Reported Data: Health symptoms were collected by the direct report of the participants. So the data might be influenced by their awareness, perception, or concern. Apart from this, since no laboratory based or clinical tests were conducted, it was not possible to establish causation between NIR exposure and health outcomes.

- Participant Hesitation: Some respondents were reluctant or hesitant to answer survey questions properly, which might have resulted in untrue or biased data. For example, in the case of answering about mental health or about disability, participants weren't completely willing. Apart from this, many hesitated to let the appliances at their homes be measured for potential EMF exposure. This restricted the measurement process a lot, impacting data collection.

- External Factors: Some participants were not aware of outdoor sources of NIR exposure, like nearby cell phone towers. This might have influenced the actual measurements of the home appliances.

These limitations are essential to be considered while interpreting the results. Even when the findings are important, they represent only a preliminary insight, not a definitive conclusion. Hence, more rigorous experiment designs, larger samples, continuous monitoring, and lab-based tests are needed to confirm and give validity to these results.

Future prospects:

This study gives important early insights into household non-ionizing radiation (NIR) exposure, but it also shows that more work is needed. The limitations we found, along with the concerns and suggestions from participants, point to the need for bigger, more thorough studies that bring together different fields. In the future, research should not only improve methods and include more households but also be used to guide practical actions, create better policies, and raise public awareness.

Apart from all that, a greater number of households and appliances, particularly of different demographics, is needed; it will make both the present study representative and future investigations more generalized. Furthermore, more accurate and calibrated instruments should be used; this will make the magnetic, electric, and radio frequency field measurements more accurate. Additionally, the investigations should not only last for a long time but for a sufficient time of appliances' active work; the exposure levels should indeed reflect real-life exposure. Laboratorial experiments and clinical observations are also mandatory; these will permit etiological conclusions to be made instead of being based on symptoms only. Long-term studies and research also should be conducted. That type of study will allow for the accumulation effect assessments and possible chronic effects evaluation. Longitudinal studies can aid in tracking the changes of exposure and health developments across time.

Collaboration, especially in interdisciplinary fields, is often very successful in research. Cross-disciplinary including physics, biomedical sciences, environmental studies, and public health views, will offer a better and broader insight on NIR exposure and its implications.

In addition to enhancing experiment design, and well-established equipment, regulation and policy development are required. The study highlights a lack of updated NIR safety guidelines and policies in the home. These findings could be used by regulatory agencies to develop even stronger standards and recommendations for safer appliance design and use.

Improved Household Designs and Technological Innovations. Designing appliances with lower NIR emissions or adding shielding technologies can help reduce exposure. Research can look at these innovations for safety and efficiency. Medical and health professionals can take an active role in monitoring, advising, and guiding households about potential health risks from NIR exposure, especially for vulnerable populations.

Studies in the future can focus on the environmental impacts and also pets and animals to examine potential effects of household Non-ionizine radiation on domestic animals. This can provide a broader perspective and ecological insight. More comprehensive focus needs to also be given on Vulnerable and Sensitive Groups of the society, like children, the elderly, disabled or special need people, pregnant women, and individuals with pre-existing health conditions, as these groups may be more susceptible to health issues due to EMF exposure.

Public awareness campaigns can be used to teach people on safe use of appliances. Health professionals can also play an important role in educating the people. Government policy makers can play the most important role here by guaranteeing public awareness and making sure that the safety guidelines are being followed properly.

By focusing in such areas, future studies can offer more accurate findings in case of exposure of household non-ionizing radiation and its effect on people. It can also help in enhancing the public health, people's safety, and also making policies, creating advanced technologies, and also with educational strategies for preventing possible health hazards from non-ionizing radiation.

Conclusion:

The main objective of this study was to find the levels of non-ionizing radiation that are emitted from common household appliances in Dhaka city and also to assess the potential health effects of the residents who are constantly exposed to non-ionizing radiation every day. There are two sections of this study. First is field measurement of magnetic field, electric field, and radio frequency strength from various appliances such as television, light, refrigerator, microwave, blenders, and also devices like laptops, phones, Wi-Fi routers, etc. The second one is to use a structured questionnaire survey for analyzing and understanding the demographic differences in detail, the household composition, the health outcomes, and also the awareness level regarding EMF.

Since Dhaka is a densely populated country focused on urbanization in Bangladesh, this city was chosen to address an important knowledge gap. International studies have been constantly conducting research and examinations on occupational and environmental EMS exposure levels. However, there is very little research done on home appliances and even fewer in Bangladesh despite its growing dependence on electronic appliances. Hence, this study was done that provided several important insights.

From the study, we find that several appliances like fans, iron machines, and some refrigerators showed EMF magnetic field values that are well above the international safety threshold. For example, fans recorded a magnetic field value of 800.69 mG on average in some cases, while iron machines reached as high as, beyond 300 mg. From these results, we can understand that motor-driven and heating devices are potentially the strongest source of magnetic field exposure. Electric fields were constantly high across all the appliances. However, multiplugs, microwaves, refrigerators, and televisions produced the highest amount of electric field value. This finding suggests that electric field exposure in homes may be considerably more widespread than magnetic field exposure. This could be due to internal wiring. Radio frequency strength emission was found near Wi-Fi routers, mobile phones, and laptops, which makes sense as the devices were intentionally designed to transmit signals. Even though radio frequency levels remained within the safety threshold, constant and long-term exposure can still cause great harm to the human body.

The exposure level of households in Dhaka city overall demonstrated higher levels than natural electromagnetic field readings. For example, when the background level magnetic field value is 0.64 mG, the household magnetic field levels were 12.44 mG on average. Electric field levels were also a lot higher. It was 222.68 V/m compared to 2 Vm in the baseline. Apart from this, even in case of radio frequency, significant variability existed. A huge difference was also seen between households in case of electric field, magnetic field, and radio frequency strength, which could possibly be influenced due to several factors such as the type of appliances, the usage pattern, the age and design of the devices, etc. Also, it was observed that larger and motorized appliances contributed more to elevated electric field levels. For example, devices such as air conditioners, microwaves, refrigerators, washing machines, etc., while other smaller gadgets like phones and laptops contributed way less to the electric field. However, these gadgets and devices contributed considerably to the case of radio frequency strength exposure.

A huge portion of the participants reported several symptoms such as fatigue, sleep disturbance, headaches, difficulty concentrating, and, even in some cases, psychological stress. These symptoms align perfectly with electromagnetic hypersensitivity, which has been reported previously in other studies. Apart from this, the households that have vulnerable members like people with children, the elderly, or disabilities seem to be more concerned, even when their knowledge about safety thresholds and regulatory guidelines seems to be limited. It was also observed that there is a lack of public health communication and various erroneous campaigns led by the government. People were not completely aware of the international safety standards either. So, it is very important that these research findings hold important emphasis and implications for stakeholders, policymakers, healthcare professionals, manufacturers, and the general public.

The high level of magnetic field and electro field levels recorded from various appliances were commonly found in household appliances like iron machines, etc. This suggests that the residents are constantly exposed to electromagnetic field levels that are significantly higher than the natural background level. Even though all exposure did not exceed the international standard, the proximity to the appliances or devices and also the frequency of exposure are very important factors that can lead to various potential biological effects. Particularly, the households that have children and elderly people or other vulnerable members may face heightened risk because of their sensitivity.

In Bangladesh, there is an absence of a nationally enforced standard for non-ionizing radiation exposure, which creates a huge regulatory gap. Currently, it is completely dependent on the international guidelines, which are insufficient because it primarily focus on the thermal effects. This may not fully account for long-term, low-level non-thermal biological effects. The data presented in this study reinforces this immediate need for our country to establish proper, specific guidelines, a regulatory framework, and a monitoring system for domestic EMF exposure.

From our survey, it is found that public awareness is comparatively low about non-ionizing radiation, and most households are not aware of safety precautions like maintaining distance from appliances during operation or limiting the time of exposure. So, this is a huge problem in our country. For this reason, several awareness campaigns labeling appliances and devices with proper integration of electromagnetic field safety in health education are extremely important to educate the people and also minimize the risk of getting affected.

There is a huge debate globally that discusses non-ionizing radiation and whether it causes serious health risks. This conundrum and debate remain unsolved till now. This study adds to the growing body of evidence that suggests that long-term exposure to non-ionizing radiation, even below the safety threshold, may have subtle but very important and risky health consequences, even when the casualties and the effects cannot be firmly confirmed. The patterns observed in the households of Dhaka city align with international findings, which reinforces the call for continued research into both thermal and most importantly, non-thermal biological effects of non-ionizing radiation.

Like every other study, there are several limitations in our research as well. Even though the sample size is very small, with only 67 households across various areas of Dhaka city, it is not at all perfect compared to the huge population in this city. Also, the study focuses on certain socio-economic households; rural or semi-urban households were not included at all, which might provide different results. This study also captures the exposure level and health outcomes only at one point. But for this kind of study, long-term monitoring and long-term study and multiple measurements are extremely necessary to understand the exposure level and health effects from it completely. Health outcomes were also based on only self-reports. There was no lab-based test done to confirm the association of the symptoms with the non-ionizing radiation. There were also appliances, for example, microwaves, that were measured while plugged in, but not in operation, which might have affected the peak emission level. Lastly, even when the comparisons were made against international safety thresholds, these thresholds are questionable and do not exactly reflect the proper estimates of health outcomes.

Depending on this finding, many recommendations, like establishing national guidelines in Bangladesh for electromagnetic field exposure, which is both tailored based on NIRP guidelines and also the emerging evidence of non-thermal effects, can be proposed. Many regulatory framework bodies can also be created to ensure compliance and regulation. Also, funding should be given in long-term epidemiological studies to assess the appropriate health outcomes. Healthcare professionals can incorporate electromagnetic field-related health awareness in routine check-ups, specifically when patients come with unexplained neurological or cognitive complaints. Research collaboration between the medical and engineering communities can also be encouraged for further understanding of the NIR impacts. The general public can adopt various measures as precautions, for example, maintaining safe distances from appliances and devices, limiting the use, and switching off appliances when not in use. The proper placement of Wi-Fi routers and avoiding prolonged use of mobile phones should be prioritized. Apart from this, awareness should be spread among households, especially with children, elderly people, or people with disabilities or special needs. The researchers can conduct longitudinal studies with larger sample sizes and can explore the biological mechanisms of the thermal and non-thermal impacts of non-ionizing radiation in both in vivo and in vitro studies. Long-term studies to assess the combined effect of multiple appliance exposures can also be done to understand real-life scenarios

Based on these findings and limitations of the study, future research needs to expand the scope to include the rural households along with the urban ones, where the patterns of appliances may differ and might yield different results. Lab-based tests like biomarker studies for oxidative stress markers, hormone changes, DNA damage assays, etc., can be done to complement and confirm the self-reported health outcome. The impact of emerging technologies like 5G networks or smart appliances in Bangladesh can be examined as well for non-ionizing radiation. It is important to collaborate internationally to develop harmonized and evidence-based safety protocols and standards that will reflect and focus on all the kinds of risks related to non-ionizing radiation. In conclusion, this study shows that the domestic household environment in Dhaka city is associated with significant levels of non-ionizing electromagnetic fields compared to the natural background levels, even when the exposures do not always exceed the international safety threshold.

This finding highlights the immediate need for regulations, monitoring, awareness, and continued research. Even though non-ionizing radiation has made modern technologies convenient, it is of utmost importance to manage it properly for our own safety and health. This means not only providing guidelines or making policies, but also promoting awareness and public education campaigns, and funding the long-term health monitoring systems. Ultimately, this study contributes to the global input about electromagnetic field radiation, and also a call for policymakers, researchers, and the general public in Bangladesh to be aware and responsible in their own place, because with responsibility and informed choices, awareness can be attained, and the modern appliances can be enjoyed to the fullest.

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