Ethiopian Institute of Architecture, Building Construction and City Development

IDENTIFING AND MEASURING NON-IONIZING ELECTROMAGNETIC HOTSPOTS AND VULNERABLE AREAS FOR BUILDINGS IN ADDIS ABABA, ETHIOPIA

By

Binyam Derbe Mulugeta

A Thesis

Submitted to the school of graduate studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architectural Engineering.

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Abstract

A connection between non-ionizing EMF and human health has been stipulated by an increasing number of studies and symptoms characterized as Electro-hyper-sensitivity (EHS) are frequently reported. When a building is exposed to such kind of EMF radiations it can be referred as a sick building. This research aims to identify and measure EMF hot spots and vulnerable buildings in Addis Ababa. Data for the intensity of the EMF radiation was taken using HF 59B analyzer for higher frequency and 3951A M/E analyzer for Electric field and magnetic field around EMF sources, and ArcMap 10.3 GIS is used to model and analyze the data, the analyzed result has shown that, from the total area which is 54000ha of Addis Ababa 31.25% (16235ha) of the land is in hot radiation zone which is designated as extreme exposure; 30.5%(15843ha) of the area is severely exposed; 21%(10906ha) of the area is slightly exposed and the remaining 17% (8967.99ha) of the area have a negligible amount of exposure. Buildings with in these hot EMF radiation zones have to use measures to decrease the intensity of radiation and keep the user safe and healthy.

Key words: Non-Ionizing EMF, EMF hotspot, Vulnerable building

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Acronyms

AA	Addis Ababa
BS	Base Station
EF	Electric Field
ELF	Extremely Low Frequency
EME	Electro Magnetic Energy
EMF	Electromagnetic Field
EMR	Electromagnetic Radiation
HF	High Frequency
HVTL	High voltage transmission line
IARC	International agency for research on cancer
IEEE	Institute of Electrical and Electronics Engineers.
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MF	Magnetic field
MT	Mobile Telephone
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety and Hazzard Authority
RF	Radio Frequency
SS	Substation
WHO	World Health Organization

CHAPTER ONE
INTRODUCTION

1.1 Background

Energy can be transferred from one body to the other through waves in the form of particle vibrations these waves can be an Electromagnetic waves generated by the Electromagnetic Field (EMF) where energy is transferred through the vibration of electric and magnetic fields (Science Learning Hub – Pokapū Akoranga Pūtaiao, 2021).

Electromagnetic energies are the backbone for the complex technological advancement in the current human civilization but they are also associated with negative and harmful impact to the surrounding natural environment. The consequence of living in close to these type of energies will result a negative health impact on the users (Balmori, 2014).

EMFs can be classified into two, natural EMF and the manmade EMF. According to Panagopoulos & Chrousos(2019), the natural non ionizing electromagnetic energy is the most essential type of energy it's a pace maker for human/animal biological rhythms. The human made EMF can be caused by cellphone towers, high-power transmission lines, transformers and from domestic electrical devices.

The international agency for research on cancer (IARC) under World Health Organization has listed non-ionizing RF radiation as possibly carcinogenic to humans based on an increased risk for glioma, a malignant type of brain cancer, associated with wireless phone use. 78,000 malignant and non-malignant brain tumors are recorded per year only in Unites States.

Exposure of people to the totally polarized EMFs of the human technology, especially Radio Frequency (RF) or microwave and ELF EMFs from Mobile Telephony (MT) antennas, and ELF 50–60 Hz electric and magnetic fields from power lines has increased to unprecedented levels in order to satisfy the increasing demands of technological applications used by the modern society (Sangeetha et al., 2014 , Panagopoulos and Chrousos, 2019).

A connection between EMF and human health has been indicated by an increasing number of studies such as (Babatsikou, 2011; Busby & Fucic, 2006; Rifai & Hakami, 2014; Saim et al., 2010) and Electro-hyper-sensitivity (EHS) causes symptoms which are frequently reported in urban environments (Panagopoulos, 2011).

According to Carpenter, (2014)

> *"Electro hypersensitivity (EHS) is a syndrome that consists of some combination of excessive fatigue, headache, weakness, memory impairment, tinnitus, dizziness, irritability, sleep disturbances, loss of appetite and a general feeling of ill health that occurs in some individuals and is attributed to electromagnetic fields, most commonly to radiofrequency (RF) EMFs."*

Through the evolution of the human being towards the current sophisticated civilization, there happened a wide use of electromagnetic devices to ease the lives of humans. If devices that emit electromagnetic radiation surpass the restricted limit then the emitted radiation can alter the DNA of a cell which leads to the emergence of carcinogenic diseases (Vasile et al., 2014).

Recently the city of Addis Ababa has upgraded the quality of the signal by positioning several cellphone towers either on top of buildings or using towers in the middle of the neighborhoods. But these towers do also have a negative impact because they release harmful radio frequency to the surrounding area, High voltage transmission lines do also radiate EMF energy to the surrounding area, the higher the energy of the transmission lines, the higher the impact they cause (Saim et al., 2010).

When a building is exposed to such kind of EMF radiations for a longer period of time causes illness to the users, such kind of a building can be referred as a sick building (Babatsikou, 2011). Sick building syndrome can also be caused by the natural earth forces that are determinantal to human health.

Buildings enclose spaces for the user to perform the necessary functions. These buildings should be built or located away from radiation hot spots to keep the user from any health hazards. Buildings with in the high electromagnetic radiation zone have to be identified, designed and constructed to protect the users from the negative health impacts caused by the radiation.

1.2 Problem statement

The city of Addis Ababa is subjected to non-ionizing EMF radiations mainly caused by cellphone towers, high power transmission lines, and substations as shown in Figure 11-Figure 12. Many people knowingly or unknowingly are living in a very close distance to such sources facing an electric shock from the electric field and feeling ill due to the presence of the magnetic field.

These sources cause an active radiation zone which is harmful to the health of human beings. Living for a long period of time within these radiated areas will cause an illness, which is called Electro hypersensitivity syndrome.

The government is not responding to this hot and contemporary issue by setting guidelines as that of the developed countries, this will create an atmosphere where there is an extreme radiation due to uncontrolled multiple sources.

Buildings have to limit the Electro-smog from the outdoor environment so that people living with in these buildings should live, work and accomplish their task without feeling any harmful effect. Buildings located within the active radiation source have to be identified to mitigate the effects caused by them and to adopt and integrate new techniques that will help reduce the level of exposure.

Previously Such kind of study was not performed on the city of Addis Ababa or in Ethiopia in general, and this study tries to address the knowledge gap in the local context.

1.3 Objective

General Objective:

To identify EMF hot spots and vulnerable buildings in Addis Ababa, Ethiopia.

Specific Objectives:

1. To map out potential non-Ionizing EMF sources in Addis Ababa
2. To detect and measure the intensity of radiation from the source
3. To identify vulnerable areas for buildings based on the intensity of radiation

1.4 Research Question

Main question:

Where are non-Ionizing EMF hotspots and vulnerable/endangered buildings in the city of Addis Ababa, Ethiopia?

Specific question:

1. Where are the potential EMF inducing sources in the city of Addis Ababa?
2. What is the intensity of EMF radiation from the source?
3. Which areas are exposed to EMF that can make a building vulnerable in Addis Ababa?

1.5 Scope of the study

Thematically, the research was focused on non-ionizing EMF radiation, especially on the relation between these radiations and vulnerable buildings. Spatially the research was limited to the current jurisdiction boundary of Addis Ababa city. Moreover, temporally the research was conducted for 20 months from September 2019 to May 2021.

1.6 Significance of the study

The ultimate aim of the study is to give awareness to the people living in Addis Ababa about the carcinogenic EMF emissions caused by the growing telecom and electricity infrastructure, and reduce the effect of sick buildings by creating a mechanism to shield the user from the harmful radiation.

The study does also give an insight for city planners, especially on the relation between public infrastructures and housing dwellings. For architects it will give an

insight about the effect of EMF radiation and enhancement of buildings quality in terms of protecting the user from the negative impact of EMF radiation

The other significance of the study is it guides the government to use it as a tool for setting policy regarding buffer zones and radiation limits since a new directorate has been established under the Ethiopian radiation protection authority (ERPA) for non-ionizing EMF radiations, this study will be a good input for standardization. According to ERPA Ethiopia currently doesn't have a radiation limit for non-ionizing EMF radiations.

1.7 Limitation of the study

Basically, the limitations while doing this research includes, absence of previously done research on Non-Ionizing EMF radiation in Ethiopia and lack of collaboration from Ethio-Telecom.

The study is also limited to cellphone towers, transformers, HVTL and substations which are Non ionizing EMF sources, only horizontal direction EMF intensity was considered during the study with a fixed height of 1.5m and the effect of vegetation and building shadow on the internal building EMF value was not considered.

CHAPTER TWO
LITERATURE REVIEW

2.1 Theoretical review

2.1.1 EMF and Its types

Electromagnetic radiation as the name implies is a type of radiation where the radiation contains both electric and magnetic fields, it can be associated with natural EMF like lightning and man-made electrical appliances. EMF radiation contains both horizontal and vertical wave motions at right angle with each other in a single propagation (physicsabout.com, December 14,2020).

Electromagnetic radiation (EMR) can be categorized into two based on their ability of ionization, Non-ionizing EMR, and Ionizing EMR (Saim et al., 2010). Non-Ionizing EMF radiation- Forces with low-frequency range mostly radiated from cell phones, high voltage power lines, radio frequency microwaves, and visual light (Zerek et al., 2019). Ionizing EMF radiations are radiations with a very high frequency, they are known for their capacity to change the human DNA (Busby & Fucic, 2006).

2.1.2 Non-Ionizing EMF sources

I. Cellular phone towers

Base stations are central stations in cellular communication systems. Base stations consist of three main portions; the antenna, the apparatus shield, and the tower. The base stations conveying antennas are placed on high poles or rooftops. Radio signals are fed to the antenna through cables. There are two types of base stations: macro-cellular base stations and the micro-cellular base station (Doğanay, 2015).

The radio signals fed in terms of power is radiated in cone like fan-shaped beams as shown in Figure 1 below, which are oriented towards the horizon with a slight downward tilt. Most of the energy is scattered in space (Pachuau & Pachuau, 2014).

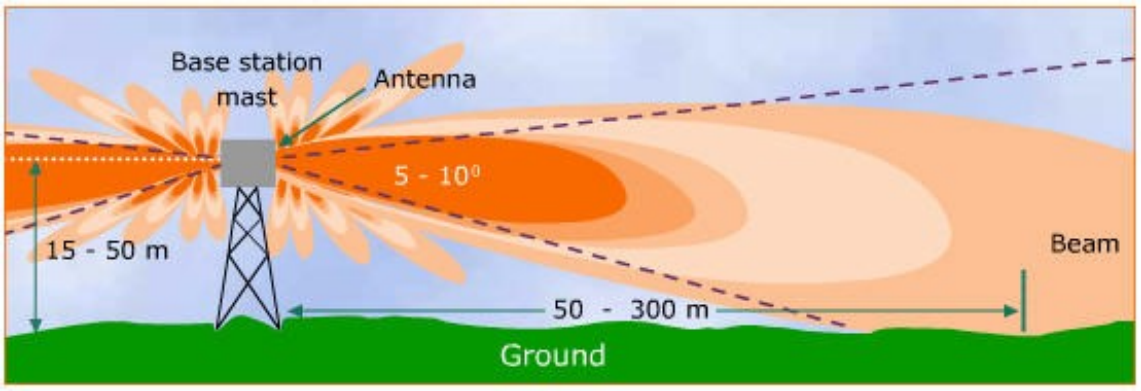
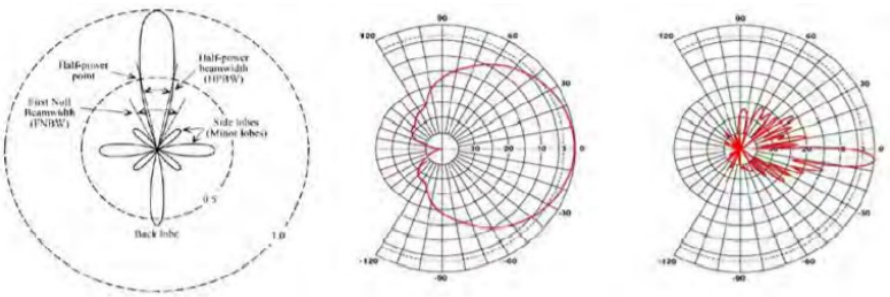


Figure 1: *Power radiated from an antenna (Source: Pachuau & Pachuau, 2014)*

Antenna Radiation Pattern Properties

The radiation attribute of antennas is showing the antenna radiation figure which graphically represents radiation strength as a space function. Radiation patterns are usually depicted in a three-dimensional (3D) graph or using a horizontal or vertical pattern (Awad & Habeeballah, 2014). Figure 2 below shows (a) different radiation lobes, (b) horizontal pattern, and (c) vertical pattern.



(a) (b) (c)

Figure 2 : *Example of an antenna radiation pattern Different radiation lobes (b) Horizontal pattern (c) Vertical pattern (Source: Awad & Habeeballah, 2014).*

II. High voltage transmission lines

High voltage transmission lines are an electrical energy transmission line that carries more than 66 Kv. These lines transfer electrical energy from source to distribution substation. When an electric current head through a conducting medium it causes an electromagnetic field around the medium. When the power of the current goes high so does the electromagnetic field increase around the medium. While it's easy to shield a building against the electric field produced by nearby powerlines, it's hard to shield against the magnetic field generated (Zamanian & Hardiman, 2005).

The high voltage transmission lines and for the distribution of low voltage electricity inside a building create a basic so-called background magnetic radiation, known as the magnetic flux density of the environment. The average value of background induction reaches 200nT in residential and commercial buildings. 5 μT to 20 μT magnetic flux densities have been measured below high voltage power lines, but at distance from 50m to 100m this quickly reduces to the atmospheric value of the magnetic flux density (Vladimir Sinik & Zeljko V.Despotovic, 2012).

III. Transformers

A transformer facilitates the distribution of electric current with efficient quality and reliability to neighborhoods (Temtim, 2017). The electrical energy generated in power plants is apportioned to consumer areas via high voltage powerlines like 110kv and 400kv. The voltage is reduced by transformers for household expenditure. A transformer can radiate energy up to 25m to the south as wide as 20m as shown in Figure 3 below, which can make it dangerous for people living in that direction.

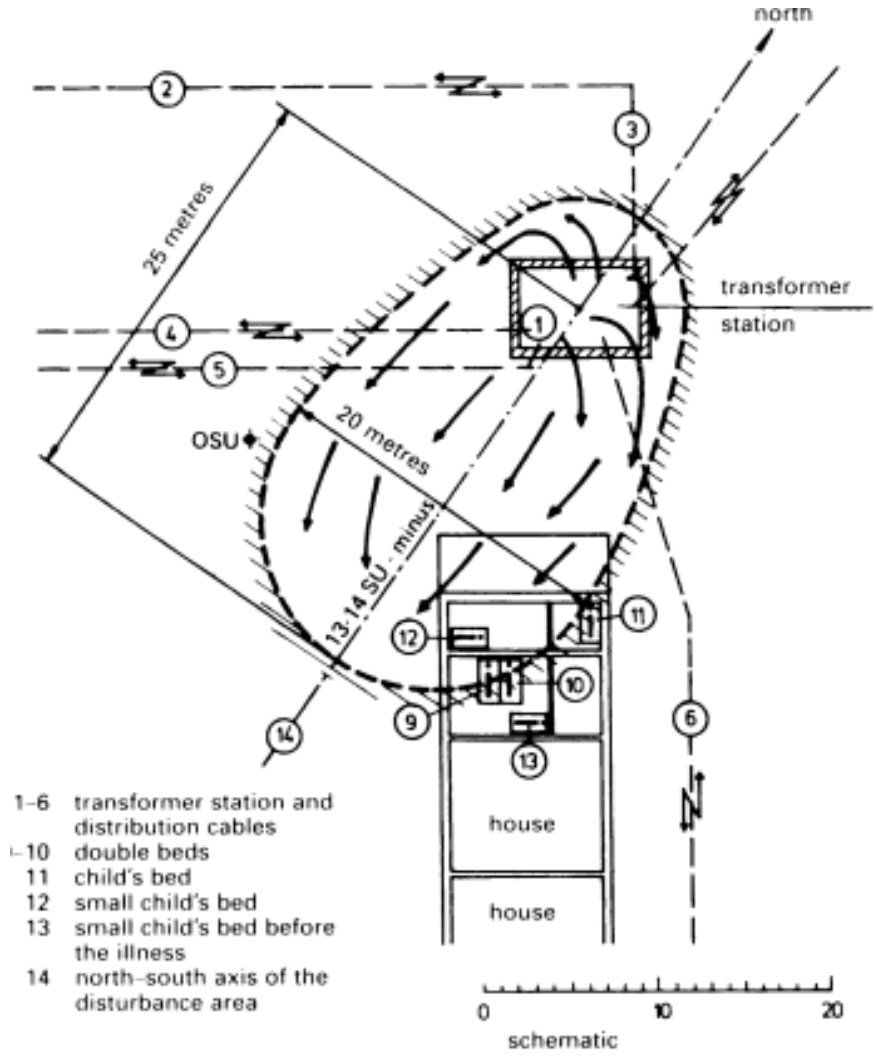


Figure 3- *Transformer EMF radiation range (source K.E. Lotz, nd)*

2.1.3 EMR and Human health

First cases of electromagnetic health issues were first noticed by medical doctors Dr. Palm and Dr. Hartmann, they have identified psychologically disturbing effects especially when people feel sick after settling at a certain place repeatedly over time. According to a research forum for geobiology conducted by Dr. Hartman and Dr. Palm the world is covered by a so-called global net consisting of stationary waves. When these waves intersect with each other they will create a strong resonance creating a negative health effect on the user if the user stays at that place for a longer period (Neufert, n.d.; Ramesh Sorate et al., 2014).

People living within 10's of meters from a base station tower will receive 10,000 to 10,000,000 times stronger signal than required for mobile communication (Kumar, 2010).

According to Eger H (2004) in Germany found that a newly developing cancer case was significantly higher among patients living within a 400-meter distance from the transmission tower. A research conducted in Spain by Oberfeld (2004) people living within 50-150m of the cellphone tower experience depression, fatigue and sleeping disorder. The cellphone tower has a power density of 0.11 $\mu W/cm^2$.

Researches concerning the effect of emf radiation on human health vary but most independent scholars agree on the effect of EMF radiation. Health problems caused by EMF radiation is studied by (Abdul Latif et al., 2016; Ameen, n.d.; Clark, 1985; Djalel, 2014; Doganay, 2015; EVE, 1957; India & Telecommunications, n.d.; Mitra et al., 2014; Neufert, n.d.; Odemer & Odemer, 2019; Pachuau & Pachuau, 2014; Panagopoulos & Chrousos, 2019; Rahman, n.d.; Rifai & Hakami, 2014;

Saim et al., 2010; Singh, 2013; Spurny & Dachev, 2009; Vasile et al., 2014; Vladimir Sinik & Zeljko V.Despotovic, 2012; Zamanian & Hardiman, 2005).

Health risks associated with microwave radiations caused by cellphone towers are believed to cause health risks if stayed for a long period at such polluted places (Abdul Latif et al., 2016; India & Telecommunications, n.d.; Mitra et al., 2014; Odemer & Odemer, 2019; Pachuau & Pachuau, 2014; R.Arrosan et al., 2012; Rahman, n.d.). High power transmission lines do also have the same health effects on the users living in very close proximity to the power lines (Djalel, 2014; Rifai & Hakami, 2014). Radio frequency does also have the same impact on the health of people living near the emitting tower (Ahmad et al., 2011; Clark, 1985).

The power density values given in Table **1** below are for a single carrier and a single operator. If multiple carriers are being used and multiple operators are present on the same rooftop or tower, then the above values will increase manifold (Kumar, 2010). According to the table for a single transmitter at a distance of 50m is equal to 0.0318W/m^2= 31800 µW/m^2 has caused cancer for several people in a duration of 2 to 3 years.

Table 1: *power density for a single carrier operator (source GK-cell-tower-rad-report-DOT-Dec2010)*

Distance R (m)	**Power density (P_d) in W/m^2**	**Power density (P_d) in µW/m^2**
1	9.6	79600000
3	8.84	8840000
5	3.18	3180000
10	0.796	796000
50	0.0318	31800
100	0.008	7920
500	0.000318	318

2.1.4 Vulnerable buildings

Buildings can be vulnerable to radiation causing occupants acute health problems with a variety of symptoms triggered when the user enters the building this situation is called the sick building syndrome which is first noticed in the 1970s. the symptoms mostly are resolved when the user leaves such vulnerable buildings (Babatsikou, 2011).

Building biology is a field of building science which studies the indoor living environment to create a healthy, restful, and stress-free environment for occupants. Non-Ionizing EMF radiations are one of the factors that play a role in making a building sick.

A building can be exposed to indoor and outdoor electromagnetic radiation. Indoor radiations can be reduced by decreasing the number of electrical equipment's from a building or using appliances that emit a negligible amount of EMF radiation whereas the outdoor radiations are very hard to avoid since they come from a public infrastructure such as high voltage powerlines and cell phone tower masts.

2.1.5 The Building Biology Evaluation Guideline

The Building Biology Evaluation Guidelines are based on the precautionary principle, to reduce the effect of long term EMF exposure especially in areas where people spend most of their time like sleeping areas and office working areas have to be in a safe exposure level to allow the biological and metabolic process at normal rate (SBM-2008C, 2008).

The Institute for building biology (SBM-2008C, 2008) has set the following guidelines;

a. <0.1 μW/m^2 (0.00001 μW/cm^2) - No Concern, It reflects the unexposed natural conditions or the common and nearly inevitable background level of our modern living environment.

b. 0.1 - 10 μW/m^2 (0.00001 to 0.001 μW/cm^2) -Slight Concern, as a precaution and especially concerning sensitive and ill people, Proper treatment should be carried out whenever it is possible.

c. 10 - 1000 μW/m^2 (0.001 to 0.1 μW/cm^2) -Severe Concern, Values in this category are not acceptable, Remediation should be carried out soon. Scientific studies indicate biological effects and health problems within this reference range.

d. >1000 μW/m^2 (> 0.1 μW/cm) - Extreme Concern These values call for immediate and rigorous action. In this category international guidelines and recommendations for public and occupational exposures may be reached or even exceeded.

These guidelines are summarized in Table **2** below.

Table 2: *Building Biology evaluation guideline (source: SBM-2008C, 2008)*

Building Biology Evaluation Guidelines (SBM-2015)						
Anomaly			**No**	**Slight**	**Severe**	**Extreme**
High frequency	HF	μW/m^2	<0.1	0.1-10	10-1000	>1000
	M	nT	<20	20-100	100-500	>500
Low Frequency	E	With grounding cable V/m	<1	1-5	5-50	>50
		Potential-free V/m	<0.3	0.3-1.5	1.5-10	>10

2.1.6 Architectural shielding techniques

EMF shielding strategies are increasingly combined in the construction of buildings and are retrofitted in existing constructions to reduce radiation intensity in living or working spaces. These strategies are:

A. Selection of building material

National Institute of Standards and Technology (NIST) in U.S tested eight different concrete mixes, each at three different thicknesses. The concrete was solid and without any reinforcement. The key findings were:

• With higher frequencies higher shielding capacity

• The amount of shielding differed little between the eight mixes

• The attenuation depends directly on the thickness of the concrete, If a concrete wall that shields (attenuates) by 12 dB is doubled in thickness, the wall will then attenuate by 2 x 12 dB = 24 db.

Building materials have different shielding capacity as shown in Table **3** below. Reinforced concrete with rebar has higher attenuation level compared to normal block work. As shown in Table **3** as the thickness of the material increases from 203mm block to 609mm the shielding capacity increased as well.

Table 3: *Building materials and their shielding capacity*

Material	**500MHz**	**1GHz**	**2GHz**	**5GHz**	**8GHz**
Reinforced concrete with rebar 140mm OC	23	27	35	55	73
Reinforced concrete with rebar 70mm OC	23	27	31	53	68
Concrete blocks 203mm	8	12	11	15	18
Concrete blocks 609mm	26	28	30	39	39
Dry Lumber 38mm	2	3	3.3	4	4
Dry Lumber 152mm	4.5	6	8.5	20	25
Bricks 89mm	0	3.5	5.5	15	16
Bricks 267mm (3 bricks)	4	7	10.5	32	27
Glass panels 6mm	0	0.8	1.4	1	1.5
Glass panels 13mm	1.2	2.2	3.4	0	1.6
Dry wall 6mm	0.1	0.3	0.6	0	0.4
Dry wall 13mm	0.1	0.3	0.6	0	0.4

(Source: The U.S. National Institute of Standards and Technology (NIST))

And according to Hakgudener (2007), Brick faced concrete walls and brick faced masonry block show good shielding performance as shown in Table **4** to keep safe EMF level internally specially in residential spaces like sleeping areas and baby's room.

Table 4: *Building materials average maximum transmission field percentages*

Building material	**Thickness (mm)**	**Average maximum transmission field (0.5-2.0GHz) %**	**Average maximum transmission field (3.0-8.0GHz) %**
Brick	271	76%	13%
Brick faced concrete wall	271	19%	0.1%
Brick faced masonry block	284.4	38.5%	4%
Plain concrete	203	15%	4%
Drywall	9.5	98%	100%
Glass	12.5	87%	86%
Lumber(dry)	113	76%	34%
Lumber(wet)	113	75%	32.5%
Plywood(dry)	11.8	97%	98%
Plywood (wet)	11.8	86%	76%
Reinforced concrete	203	52%	0.3%
Rebar grid	19 (70*70mm2 grid)	64%	88%

(Source Hakgudener, 2007)

B. Conductive shielding paints

This paint is a solution which can be easily implemented for both interior and exterior shielding. It consists of carbon particles suspended in a high-quality acrylic binder. The paints contain no metallic components and thus are highly resistant to corrosion.

As shown in Figure **4** these paints can be used for shielding of walls, ceilings and floors. These RF shielding paints are electro-conductive coatings for the shielding against high-frequency (HF) radiation and/or low-frequency (LF) electric fields.

Typical areas of application are laboratories, work spaces, living areas, or general architectural shielding of buildings (www.lbagroup.com).

Figure 4: *EMF shielding paints (b)- Yshield electromagnetic shielding paint (source: www.radiansa.com)*

These paints can be applied in

a) Industry: to prevent data interception in areas such as conference rooms

b) Laboratories: shielding EMF- sensitive equipment's

c) Living areas: Protection against cellphone towers HF-radiation, TV and radio broadcasting antenna and protection against low-frequency electric fields from powerlines.

C. Architectural shielding meshes and fleeces

For high-efficiency interior shielding, for example, where sensitive scientific or medical equipment needs to be isolated from the high-frequency electromagnetic signal, or in the construction of Faraday cages, metalized nylon fleeces or metalized polymer nettings with high shielding effectiveness, up to 100dB at 1 GHz, are generally used these shields are shown in the Figure **5** (a) and (b) below.

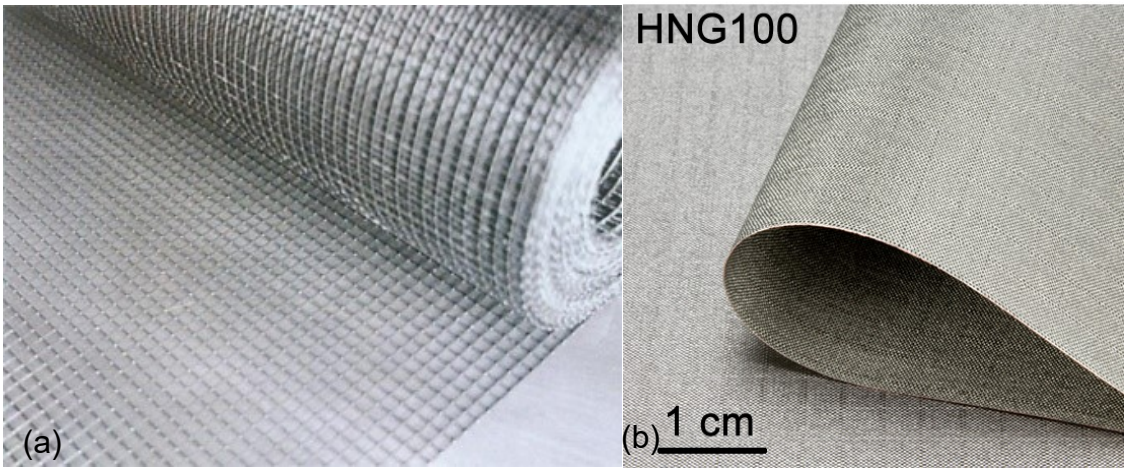


Figure 5: *(a)EMF shielding meshes and (b)fleeces (source: www.radiansa.com,September 16,2020)*

D. Shielding textiles

fabrics are made from polyester or cotton filaments woven with micro-fine silver/copper threads as shown in Figure **6** below; thus, the material has no surface conductivity. Often the simplest method reduces the intensity of electromagnetic radiation entering a building through the windows, open or shut, is to install net curtains made of specially produced shielding fabric. This fabric has a 38db attenuation and weighs 70g/m^2.

Figure 6**:** *Swiss shield fabric for shielding EMF radiation (source: www.radiansa.com,September 16,2020)*

E. Window films

Windows can also be shielded using transparent, conductive self-adhesive films. The films are available in various grades, optimized for light transmission or shielding efficiency as shown in Figure 7.

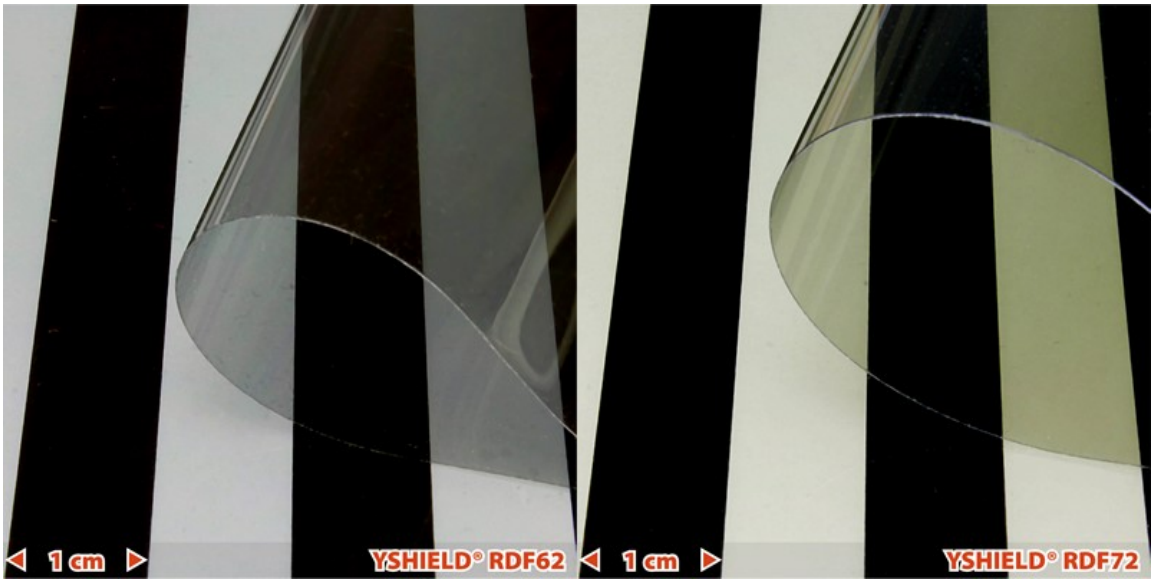


Figure 7: Adhesive films for shielding window (source: www.radiansa.com,September 16,2020)

The relevance of using Architectural shielding techniques is to understand building materials and their shielding capacity is important to determine the level of indoor radiation caused by external EMF sources. From Table **3** and Table **4** its clear that building materials have better shielding capacity if they are 2 to 3 times thick. Overlaying different building materials is also another means like applying brick on concrete wall or on a masonry block.

Sometimes changing the building material for a vulnerable building can be expensive, rather than changing the materials used retrofitting can be a recommendable alternative. Abuilding can be retrofitted using specially made conductive paints, fabrics and transparent films.

2.1.7 International standards

There's an international organization that deals with non-ionizing radiation it's called International Commission on Non-Ionizing Radiation Protection (ICNIRP). The institute of electrical and electronics engineers (IEEE)-USA does also have its standards regarding EMF exposure limits. ICNIRP has guidelines concerning EMR ranging up to 300 GHz frequency. the general public exposure guidelines are basic restrictions to limit emf radiation in the telecom industry and are shown in Table 5 here below.

Table 5: *ICNIRP guideline for the general public exposure*

Type of exposure	**Frequency range**	**Electric Field Strength (V/m**	**Magnetic Fiel Strength (A/m**	**Power density (W/m) 400-2000**
Frequency				
General Public	400-2000 MHz	1.375f ½	0.0037f ½	f/200
	2-300 GHz	61	0.16	10

(Source: www.icnirp.org, November 25,2019)

According to a report from the inter-ministerial committee for emf radiation in India, the ICNIRP restrictions are not sufficient to protect the public health and needs reconsideration. The standards set by ICNIRP and IEEE are believed to be insufficient to counter environmental and psychological impacts because of this many developed countries have set their standards 10^{th} or 100^{th} times smaller than what ICNIRP and IEEE have set as a standard as shown in Table **6** below.

Table 6: *International exposure limits for RF fields*

	International Exposure limits for RF fields (1800 MHz)
12 W/m^2	USA, Canada and Japan 9.2
9.2 W/m^2	ICNIRP and EU recommendation 1998 – Adopted in India
9 W/m^2	Exposure limit in Australia
2.4 W/m^2	Exposure limit in Belgium
1.0 W/m^2	Exposure limit in Italy, Israel
0.5 W/m^2	Exposure limit in Auckland, New Zealand
0.45 W/m^2	Exposure limit in Luxembourg 0.4
0.4 W/m^2	Exposure limit in China
0.2 W/m^2	Exposure limit in Russia (since 1970), Bulgaria
0.1 W/m^2	Exposure limit in Poland, Paris, Hungary
0.1 W/m^2	Exposure limit in Italy in sensitive areas
0.095 W/m^2	Exposure limit in Switzerland, Italy
0.09 W/m^2	ECOLOG 1998 (Germany) Precaution recommendation only
0.001 W/m^2	Exposure limit in Austria

The 2009 published Bio-initiative report recommends 1000 μW/m^2 for outdoor cumulative RF exposure and power density limit up to 50 μWatt/m^2 with an upper limit as 100 μWatt/m^2.· There are reports for a safe distance from power lines from these reports OSHA report is one of them as shown in Table **7** below here the report has set minimum approach distance standards at different power voltage transmission lines.

Table 7: *OSHA Minimum Approach Distance*

Powerline voltage(kv)	**Minimum approach distance(m)**
0 – 50	3
Over 50 kV to 200	4.5
Over 200 kV to 350	6
Over 350 kV to 500	8
Over 500 kV to 750	11.5

(Source: OSHA 1926.1408)

Many countries have their own standard when it comes to non-ionizing EMF radiation due to the assumption that ICNIRP guidelines are at the highest range, India used to follow this guideline but based on their study they have decreased the safe level by a hundred times from that of the international standard. Countries like Italy have two different sets of guidelines one for the general public and the other for very sensitive areas.

2.2 Contextual review

2.2.1 History of Telephone and Electric line in Ethiopia.

According to Ethio-telecom, Telecommunication services was introduced in Ethiopia by Emperor Menelik II in 1894 when the construction of the telephone line from Harar to the capital city, Addis Ababa, was commenced. Then the interurban network continued to expand satisfactorily in all other directions from the capital. Many important centers in the Empire were interconnected by lines, thus facilitating long distance communication with the assistants or operators at intermediate stations frequently acting as verbal human repeaters between the distant calling parties.

Ethio-telecom further states that there are about 6000 base stations which are available in Ethio telecom GSM, WCDMA, CDMA, and LTE networks. The basic architecture and configurations of selected BS sites are: The BTS model is Huawei distributed BS (DBS)3900 with configuration of baseband unit (BBU)3900 and remote radio unit (RRU)3929, RRU3936 and RRU3826 models. Base stations are clustered in to different zones. There is different layer of Cells (1, 2 or 3 layers) (GSM, WCDMA and LTE).

according to Ethiopian electric utility (EEU) there are around 8000transformers and three major high-power transmission lines which are 230kv.132kv and 45kv can be found in Addis Ababa

2.2.2 Electric Power supply in Addis Ababa

The Ethiopian electric power authority handles the responsibility to produce and transmit power to the customers while the Ethiopian electric utility (EEU) is responsible for the distribution of the produced electricity. The main source of electricity is the Hydropower system generating up to 1978mw. The other sources

of electricity are the diesel power, geothermal power and wind power. The existing maximum transmission capacity is 400Kv next to the 400 Kv, 230Kv,66Kv and 45Kv are in use covering a total of 12652.65km.

According to the Addis Ababa Distribution Masterplan Project (**AADMP**)there are 29 substations in and around Addis Ababa. It consists of Bulk Power Points 22 substations with the highest voltage over 132kV and primary substations 7 substations with the highest voltage as 45kV or 33kV. The main transmission network of Addis Ababa Capital Region is as shown in

Figure 8 The transmission line is configured in a ring shape so as to surround the center of the city. However, Addis Center substation, Addis West substation Addis East substation, etc., which are the important feeding points for power demand are supplied as a radial line from 132kV ring network.

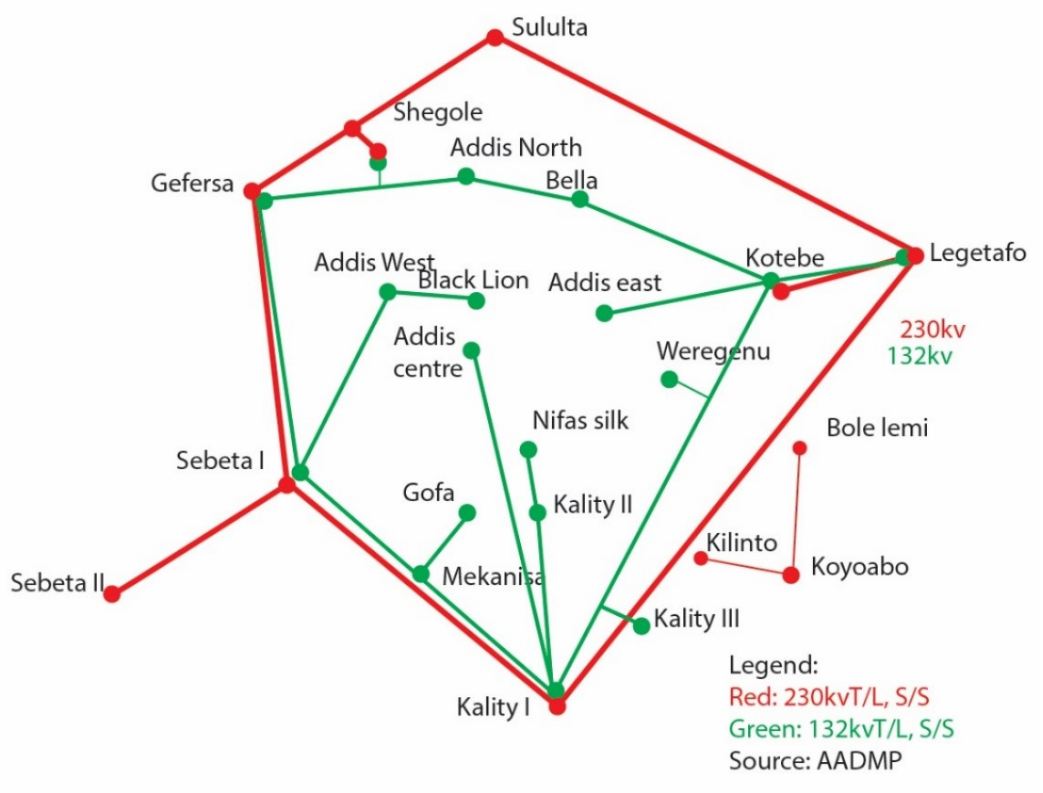


Figure 8: *Ring shape configuration of power lines around AA*

As shown in the Figure 9 below, most of Addis Ababa's power transmission lines are found along the boundary of the city specially to the south west area.

Figure 9: *High power transmission lines in Kality I substation*

Akaki I substation which is found around the Gelan condominium receives 230kv,132kv and 45 kv powerlines from nearby substation and redistribute them to the city. Figure 10 below shows kality I substation and the surrounding neighborhood.

Figure 10: *Aerial view of Kality I substation*

according to Ethiopian electric utility (EEU) there are around 8000 transformers and three major high-power transmission lines, which are 230kv.132kv and 45kv are can be found in Addis Ababa.

2.2.3 Addis Ababa exposure to EMF radiation

I. Cellphone tower radiation in Addis Ababa

Addis Ababa's cell phone network have been updated recently due to the increase in the number of users and the fact that some physical structures were blocking the network, in order to address this state-of-the-art cell phone masts were introduced which are power full relative to the older ones. The increase in the number of cell phone towers have eased the necessity for a good quality of a communication medium but all this comes with a negative consequence.

Currently in some neighborhoods space shortage for the towers appears as a problem. To solve this high-rise building roofs are used to carry the network transmission and receiving antennas. This allows the radiation to make an immediate effect on the user. Cell phone towers are erected among neighborhoods using either cellphone towers or on the roof of buildings as shown in Figure **11**(a) and (b).

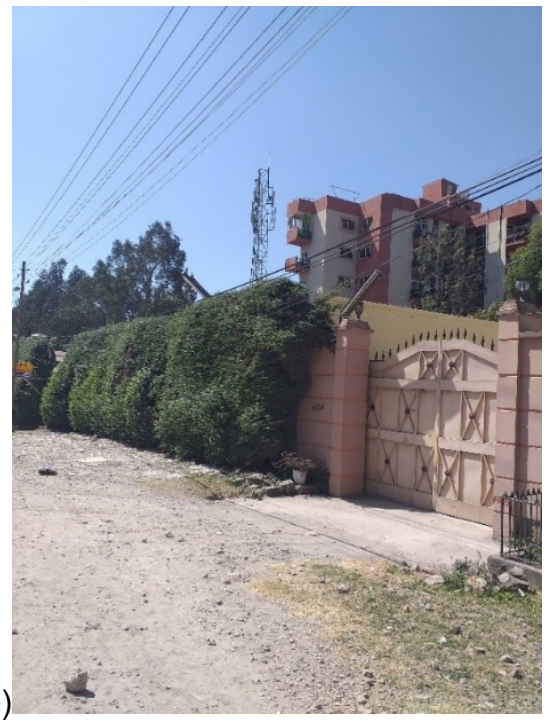
(a)  (b) 

Figure 11: *a) Cellphone tower in the middle of neighborhood and b) on the roof of a building Transformer positions in the neighborhood*

Many transformers in Addis Ababa are planted following the street powerlines where they end up being too close to a property line. As shown in the Figure 12(a)-(g) below transformers can be found too close to buildings which is very dangerous not only because it's a source for EMF radiation but also it can cause a very serious electric shock in case of failure.

(a)  (b) 

(c)  (D) 

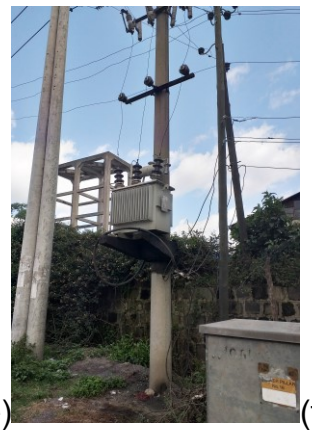
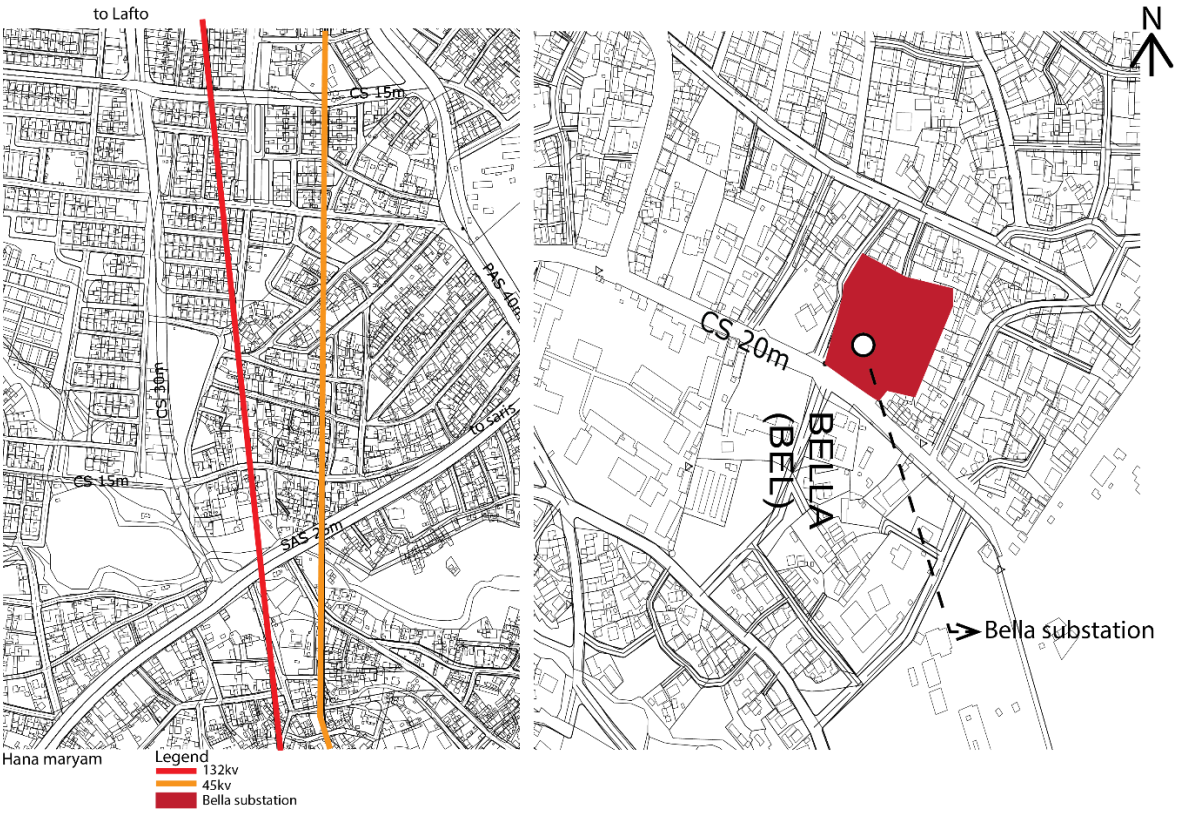
(e)  (f)  (g) 

Figure 12: *(a)-(g) Transformer and building relation in Addis Ababa at different places (a) around 22, (b) Hana Dildiy, (c) Dufa Dufa, (d) & (f) Kadisco, (e) Maseltegna, & (g) Haile Garment.*

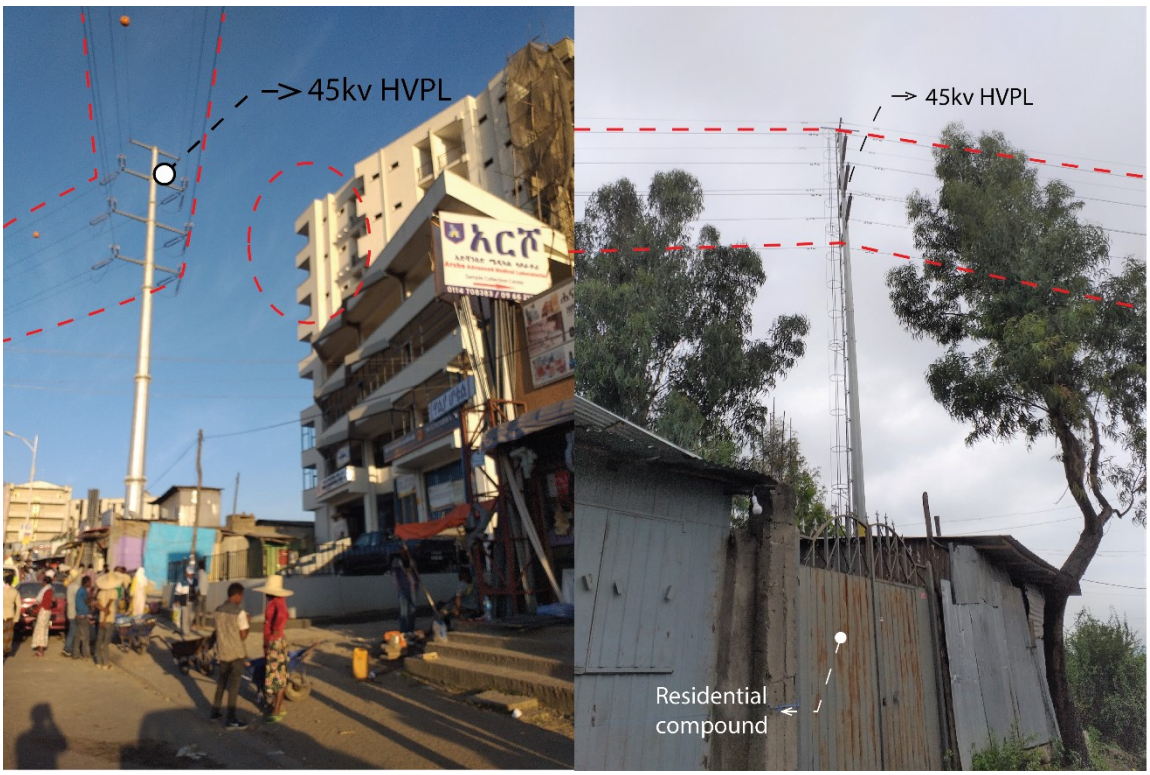
II. Substation and power line

Due to the rapid population growth once, the substations were thought to be outside of the city but know they are all caught and surrounded with residences and people are living around them. The high-power lines carrying huge currents of electricity pass overhead through buildings where many of them are residential areas as shown in Figure 13.



(a) (b)

Figure 13: *(a) HVTL and (b) base station relationship with the surrounding buildings*



(a) (b)

Figure 14: *(a) and (b) 45kv transmission line relationship with the surrounding buildings*

Ethiopian radiation authority has a very strong regulations and guide lines for Ionizing EMF radiation but regarding non-Ionizing radiation limited work is done. Currently a new directorate is established for non-Ionizing EMF radiations under the main authority to deal with problems arising from the radiation.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Description of the study area

This research was conducted in Addis Ababa, the Capital city of Ethiopia. It is geographically found between 8° 58' 50.1708" Northing and 38° 45' 27.9396" Easting as shown in figure 15 below. covering an area of 527sqkm. the population density is estimated 5165 per square kilometer.

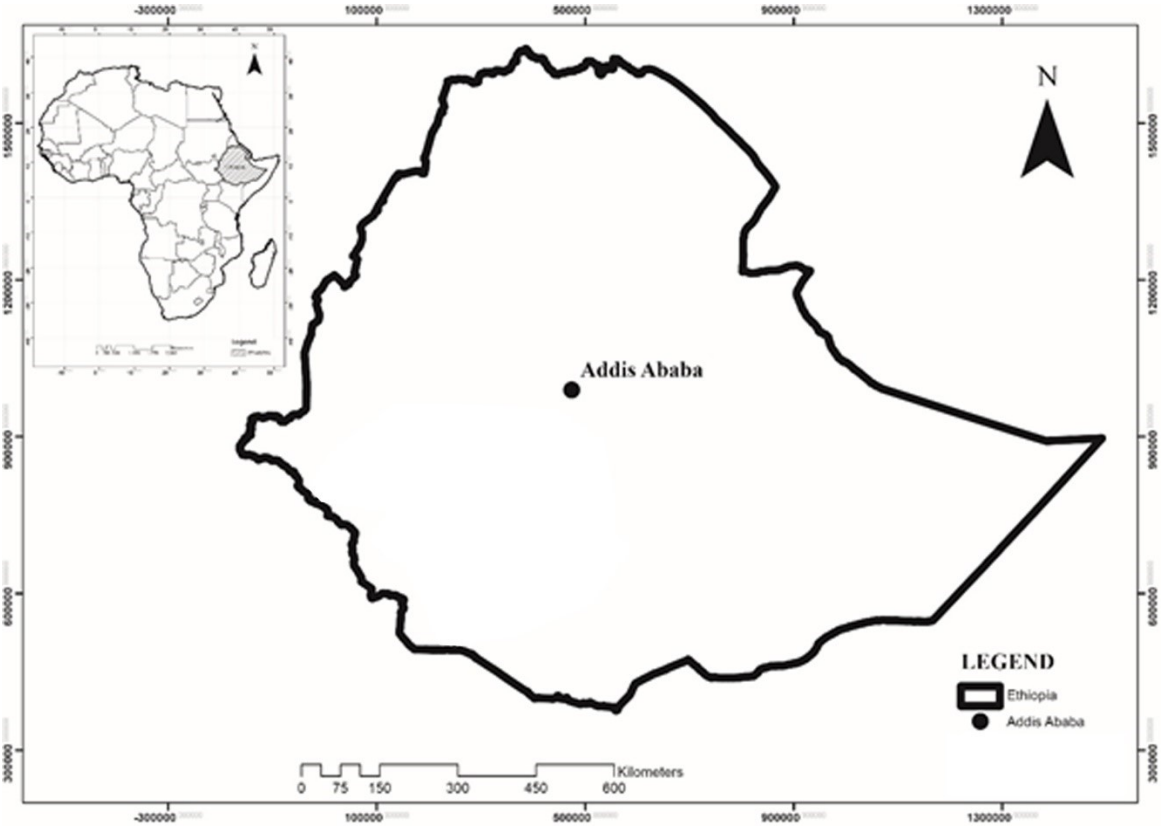


Figure 15*: The study area- Addis Ababa city*

3.2 Data source and type

I.Data Source

A. Primary Data

On the primary data gathering power density, Electric filed and magnetic field is collected through field survey taking measurements around EMF sources like high voltage powerlines transformers substations and cellphone towers.

B. Secondary Data

The secondary data is collected from Ethiopian Electric Utility (EEU), Ethio Telecom data base, books, reports and journals. The general method of data collection is summarized at Table 8 .

II. Data type

Quantitative data is utilized for this study, the qualitative data regarding location of EMF sources and their intensity of radiation is classified in to four major groups like extreme, severe, slight and no radiation. Along with the quantitative data the intensity of EMF sources at different horizontal distance is collected and analyzed.

3.3 Sample size and sampling technique

Purposive data sampling technique is used, by this technique all major powerlines (45Kv, 132Kv and 230Kv) crossing the city of Addis Ababa with UMTS 3G telecom base station is chosen for the study and from transformers with the capacity of 630kv,315kv, 200kv and 100kv are chosen.

3.4 Data Collection

The measurements were taken from EMF sources. These sources are high voltage transmission lines, transformers, cellphone tower and substations. And measurements were taken at various horizontal distances for each EMF sources as shown below:

- High Voltage Transmission Lines: - measurements were done for 230 Kv, 132Kv and 45Kv HVTL which are pass through the city. EMF effect is measured at ≤1 m; 5 m; 10 m; 50 m, 100 m; 200 m and 300 m horizontal distance from the cable the direction of measurement is illustrated in Annex 1, 2 and 3 of this paper.
- Transformers: - the measurement of were done for four types of transforms which has electric and magnetic field strength of 100KV, 200Kv, 315Kv and 630Kv. For transformers, it was at ≤1 m; 5 m; 10 m; 15 m, 20 m; 25 m and 30 m horizontal distance. And the measurement was taken in three directions as shown in Annex 4, 5, 6 and 7 of this paper.
- Cell Phone Tower: - The study considers 642 base station (BS) sites which are found in Addis Ababa. These base stations are mapped from Ethio-telecom database, the location of selected BSs is shown below in Annex 9 of this paper. BSs of UMTS B1 (2100) is chosen because of the high number of UMTS 3G towers in the study area. The measurement was taken at ≤10 m; 20 m; 30 m; 40 m, 50 m; 60 m; 90 m; 120 m; 150 m; 210 m; 240 m; 310 m; 460 m; 500 m along the antennae direction. The height of the measurements is taken at the human heart level (1.50m). The measurement was taken for mobile phone tower that are located in an open area to as to decrease the absorption and reflection of surrounding buildings and for the ease of measurement.

- Substations: - Kality II substation which is found around Gelan condominium is chosen due to the presence of 3 high voltage power lines (230Kc, 132Kv, 45Kv) which goes to this station from different part of the country and the area is next to a farm kand which makes it easier to measure the intensity of radiation at different horizontal distance. Direction of measurement is illustrated in Annex 8 of this paper.

3.5 Data analysis and interpretation

ArcMap 10.3 GiS software is used to analyze the collected measured readings from the sampled sources. Using the input data as an input the software generated maps showing extreme, severe, slight and no influence areas based on the building biology evaluation guidelines.

3.6 Instruments

I. HF 59B HF analyzer

HF 59B HF analyzer is used for power density measurement at different distance from the source. The unit used for power density is in milliwatt per meter square (mW/m^2) or micro watt per meter square ($\mu W/m^2$). The instrument is shown in Figure 16(a) below.

II.ME 3951A M/E Analyzer

ME 3951A M/E Analyzer is used as shown inf Figure 16(b) for power frequencies coming from transformers and high-power transmission lines the magnetic field is measured in nano Tesla unit and the electric field is measured in V/m.

III.UBB27 HF analyzer

For internal building measurement of EMF in buildings UBB27 HF analyzer is used to measure radiations inside buildings which is shown in Figure 16(d). The unit used for power density is in milliwatt per meter square (mW/m^2) or micro watt per meter square ($\mu W/m^2$).

IV.eDG20_G10 high frequency attenuator

This attenuator increases the upper field strength measurement range of the HF-Analyzers by a factor of 100 i.e. (Decreases the signal strength 100 times).

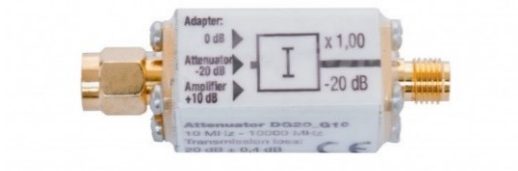
V.High pass filter HP700_G3

This preamplifier shown in Figure 16(c) increases the lower field strength measurement range of the HF Analyzer by a factor of 10

Figure 16 below shows the instruments used for this study

(a)

(b)



(c)

(d)

Figure 16: *Instruments used for the study (a) HF 59B HF analyzer (b) ME 3951A M/E Analyzer (c) eDG20_G10 high frequency attenuator (d) UBB27 HF analyzer.*

3.7 Summary of methods and materials

Table 8: Summarized methods and materials

Objective	Data type/unit/ instrument	Data source	Analysis
❖ To map out potential EMF inducing point and non-point sources in Addis Ababa.	power density is in (mW/m^2) or micro watt per meter square ($\mu W/m^2$). magnetic field is measured in nT and the electric field is measured in V/m. GIS, GPS software's will be used	Direct measurement using EMF analyzers Secondary source data Ethiopian Electric Utility Ethio-Telecom Database	By locating EMF sources within the vicinity of Addis Ababa By using Data from EEU and Telecom companies
❖ To detect and measure the intensity of radiation at different distance from the source	For radio and micro waves power density measurement in mW/m^2 or $\mu W/m^2$. For power lines and transformers millitesla (mT) and v/m unit will be used	Direct measurement on sample sites Modeling the measurement on GIS	Using high frequency EMF meters for the measurement of the radiation levels on the site.
❖ To identify vulnerable areas for buildings.	Through analyzing affected settlements and locating buildings with in these zones.	Analyzing the output from GIS and identifying buildings which lay on the EMF hot spot.	Selecting areas within the radiation hotspot and measuring the intensity internal and external value of a building.

3.8 Research Design

The research is designed in a way that the recorded from the field survey is thoroughly analyzed. The analytical procedure designed is shown in Figure 17.

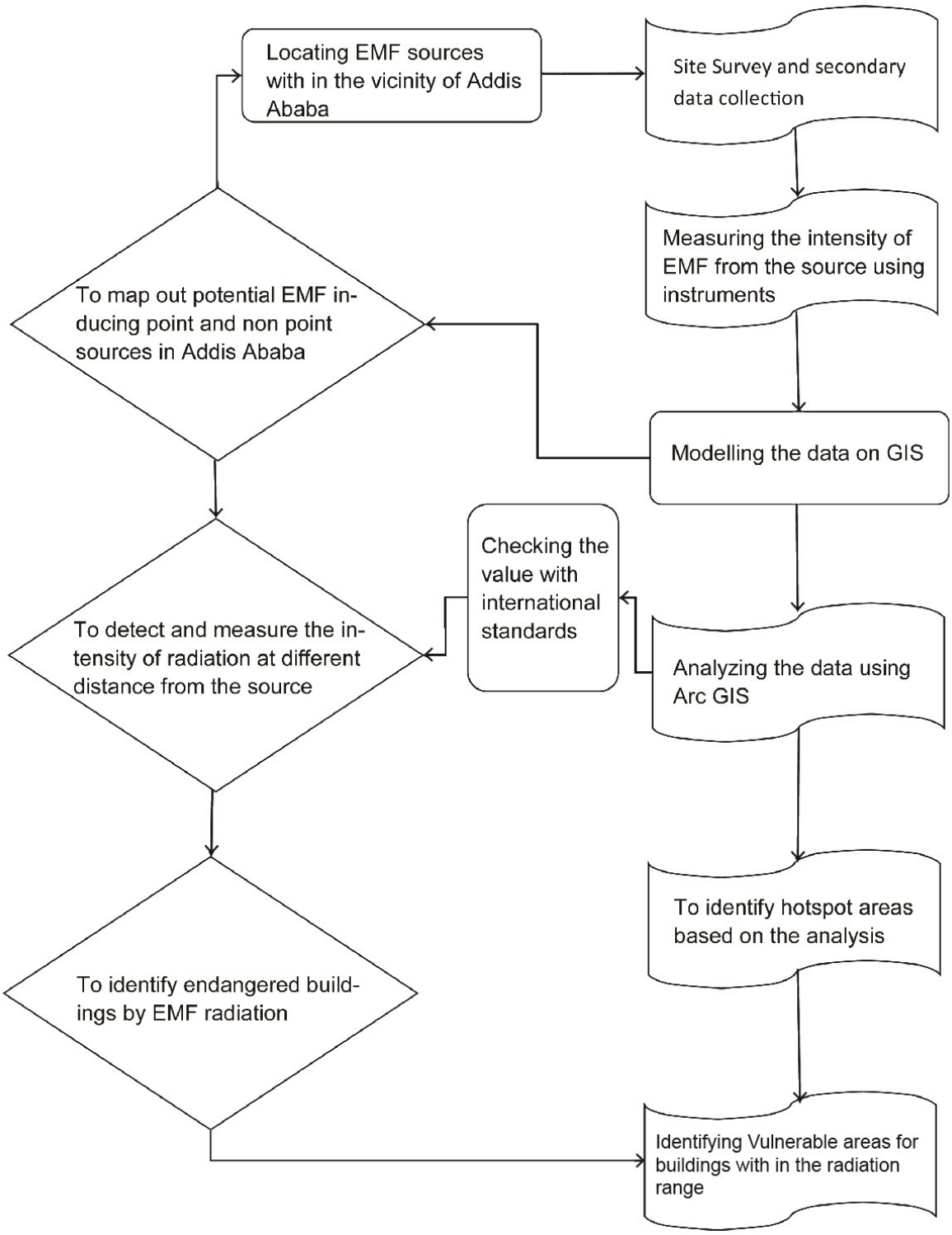


Figure 17: *Research design*

3.9 Data Analysis

3.9.1 Location and Intensity of potential EMF inducing sources

I. High voltage transmission lines

The western side of Addis Ababa have a dense concentration of HVTL as shown in Figure 18 below due to the 3 high voltage transmission lines that pass through the city of Addis Ababa, which are 230kv,132kv, and 45kv. 66Kv transmission line is found just outside the city of Addis Ababa stretching from Gefersa to Fitche in the Oromia region (North west side of Addis Ababa).

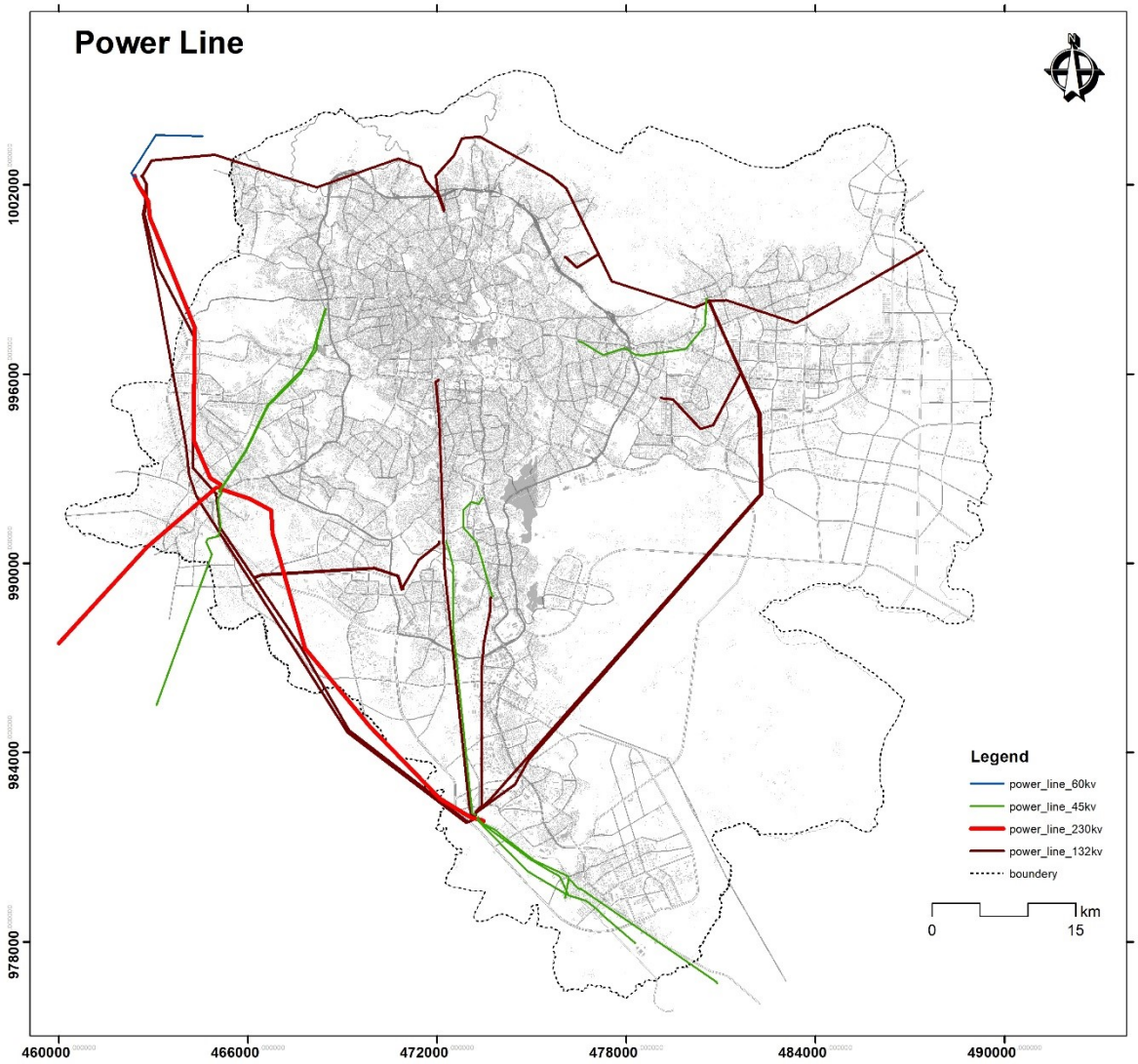


Figure 18: *High voltage transmission lines in Addis Ababa*

A. 230kv High voltage transmission line

This high voltage transmission line is found in the western part of Addis Ababa and meets Kality I substation and links to Sebeta substation. Figure 19 shows 230kv power line in the way to Kality I substation.

Figure 19**:** *230Kv high voltage powerline*

Based on the measured value comparing it with the building evaluation guideline shown in Table **2**, at a distance of 50m from the transmission line there is a radiation categorized as extreme in terms of EF with a value of 1999v/m but the magnetic field at this distance have a slight effect and goes to no effect at a distance of 250m. The relation of 230Kv transmission line with distance in terms of EF, MF and HF is described in Table 9 and Figure 20.

Table 9: *EMF reading on the right side (A) and left side (B) of 230Kv*

230Kv transmission line A & B

	Electric field v/m		Magnetic Field nT		HF µw/m2	
Distance(m)	**A**	**B**	**A**	**B**	**A**	**B**
c	1999	1999	610	525	1999	1999
1	1999	1999	560	510	1999	1999
3	1999	1760	545	460	1999	1999
5	1999	1522	440	425	1999	1999
10	1999	800	315	390	1999	1999
50	1999	413	50	70	1999	1999
100	512	102	40	61	1999	1999
200	75	40	22	12	1999	1999
250	1	1	11	5	1999	1999

As shown in Figure 20 higher magnetic field strength is observed up to a distance of 100m for 230Kv HVTL.

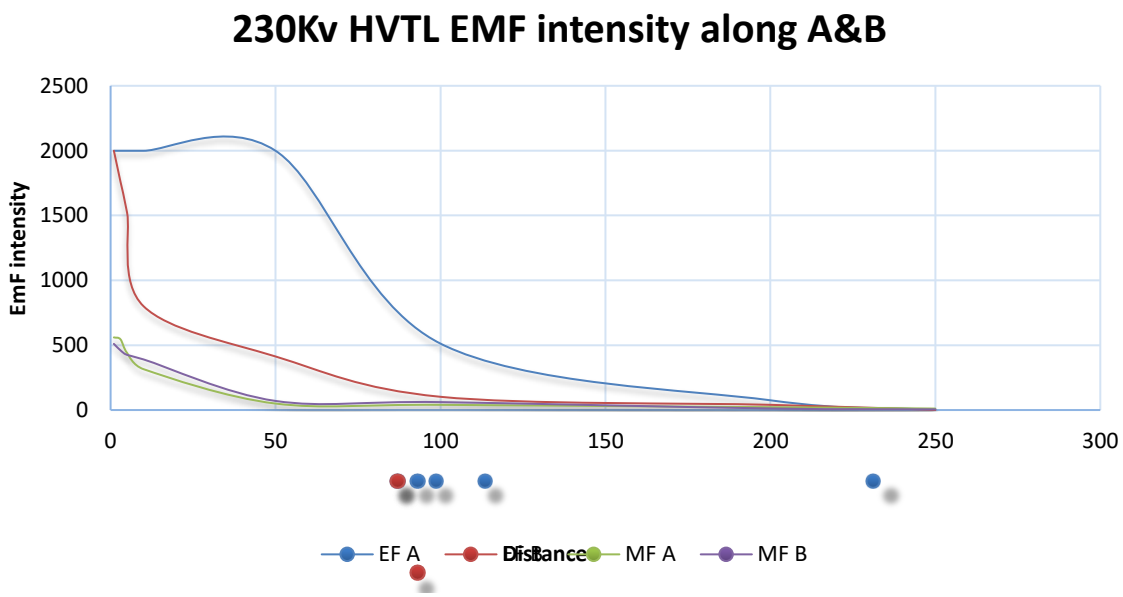


Figure 20: *230kv HVTL EMF Intensity along the transmission line*

B. 132kv High Voltage transmission line

132kv power line covers most part of the city compared to other high-power transmission lines. It is found in the western and northern parts of the city. It links most of the substations found in Addis like kality I, kality III, Sebeta, Gefersa, Addis North, Bella, Addis south, Gofa, Kotebe and Weregenu substations. Figure **21** below shows farm shade buildings very close to 132Kv HVPL around Gelan area next to Akaki I substation.

Figure 21**:** *132kv HVPL around Gelan area*

As shown in Table 10 an extreme radiation is observed up to a distance of 50m for the magnetic field with a value ranging from 1852nT- 145nT, for the electric field there is an extreme exposure up to a distance of 50m and slight exposure at a distance of 200m with a value of 5v/m.

Table 10*: EMF reading on the right side (A) of 132kv*

132kv transmission line A & B						
Distance(m)	**EF (v/m)**		**MF (nT)**		**HF**	
	A	B	A	B	A	B
c	1254	1254	1262	1262	1999	1999
10	578	610	1235	1852	1999	1858
20	222	125	1386	1387	1912	1948
30	48	68	1116	1317	1938	1519
40	57	42	447	1163	1999	430
50	53	38	136	782	1999	398
100	5	2	38	85	1999	258
200	1	1	17	20	1999	1196

Even though a higher EMF reading is observed up to 50m in EF and MF there is a much higher intensity along the B side in terms of magnetic field strength as shown in Figure **22**.

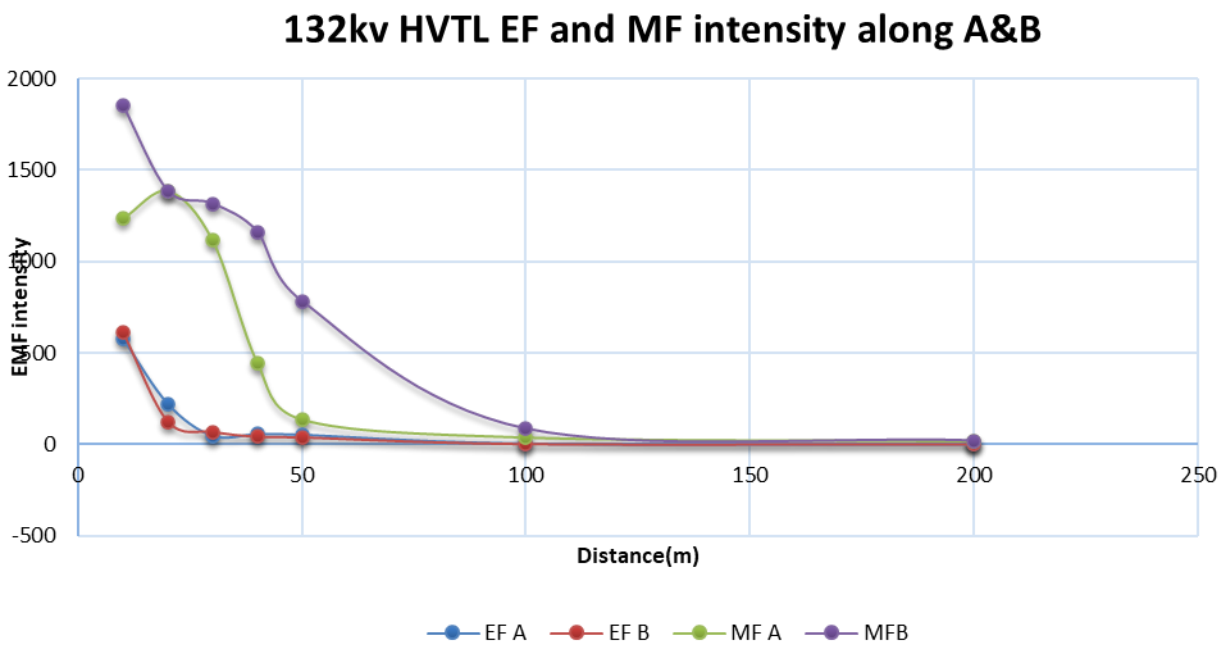


Figure 22: *132Kv HVTL MF and EF strength*

C. 45Kv High voltage transmission line

Figure **23** shows one of the 45Kv high voltage line that connects Kality I with Kality III substation and it is also found around Gelan area.

Figure 23**:** *45kv transmission line around Gelan area*

Based on the building evaluation guide line there is an extreme radiation from the center up to 30m in the value of electric field with a maximum value of EF-1589v/m and up to 50m for the magnetic field with a maximum value of MF-1432nT.The electric and magnetic field have a slight effect at a distance of 100m but at a distance less than 40m its extreme while at 40m the radiation is severe as shown in Table **11**.

Table 11**:** *EMF reading on the right side (A) and on the Left side (B) of 45kv HVTL*

45Kv transmission line A & B				
Distance(m)	**EF (v/m)**		**MF (nT)**	
	A	B	A	B
c	1589	1589	1432	1432
10	1291	705	1528	1999
20	486	225	1704	1999
30	130	71	1349	1955
40	24	47	1244	1479
50	11	39	1191	1999
100	5	20	161	140
200	1	1	19	16

As it is clearly shown in Figure **24** a higher intensity of MF and EF is observed specially in terms of magnetic field from the center of the source up to 100m.

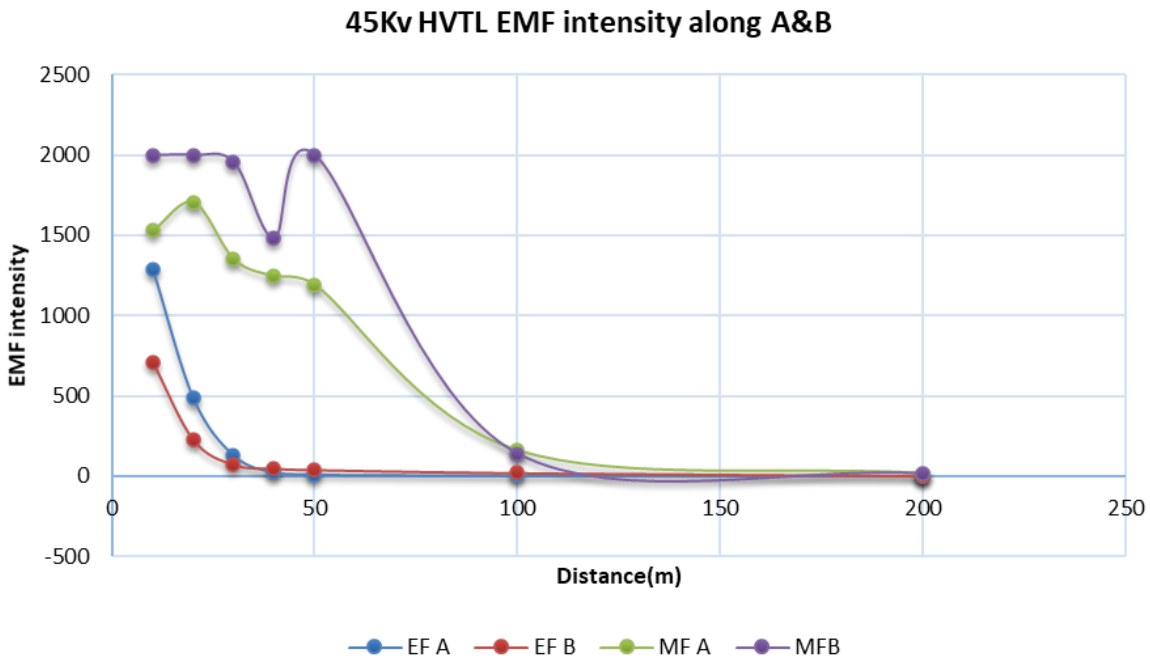


Figure 24: *45Kv HVTL EF and MF Intensity*

II. Transformers

There are around a total of 10000 transformers found in Addis Ababa and its surrounding in which 8000 are found within Addis Ababa and the rest 2000 found in the nearby cities. Figure **25** shows all the transformers found in and around Addis Ababa.

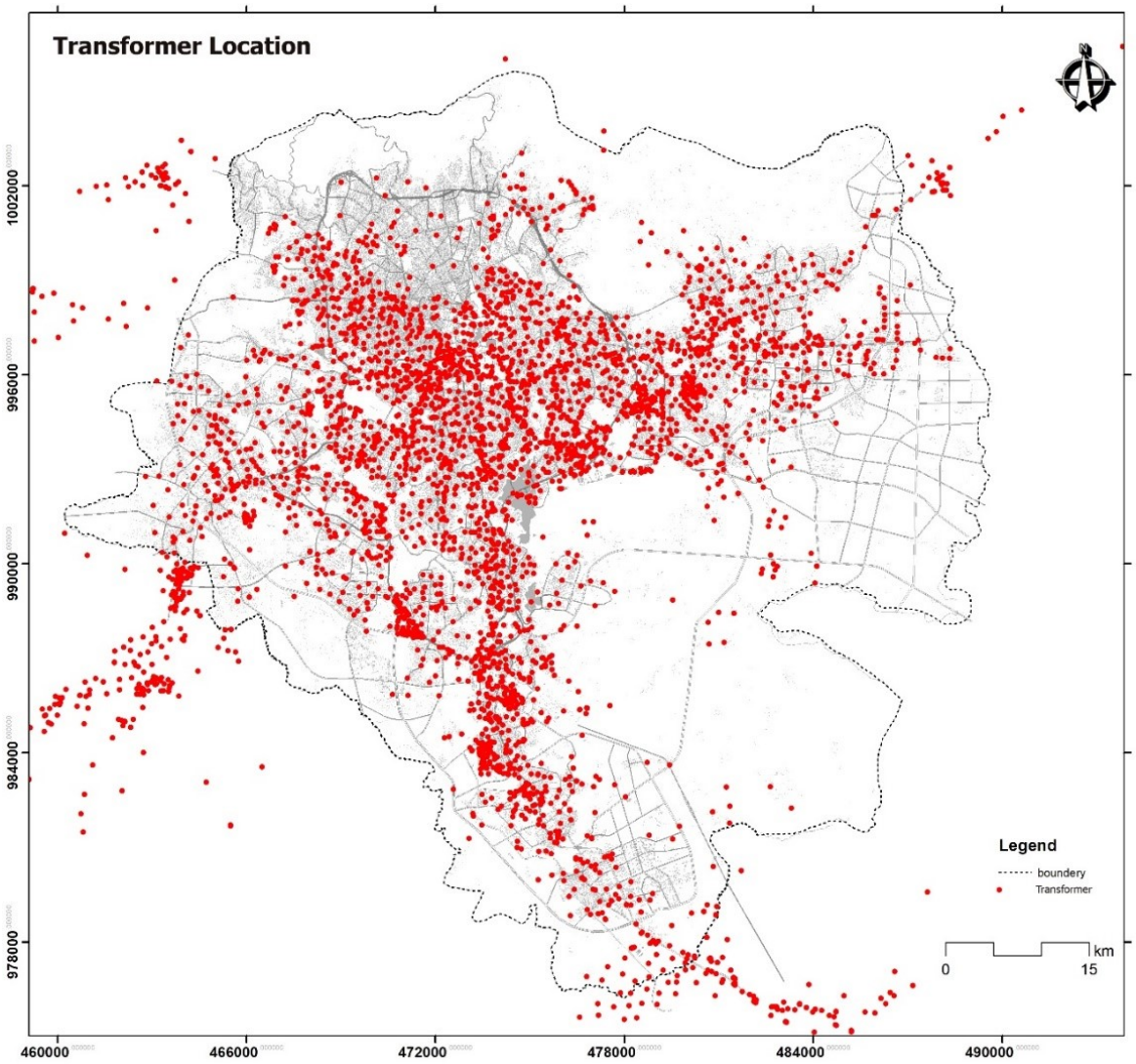


Figure 25**:** *location map of transformers in Addis Ababa*

A. Electric field strength of 100Kv, 200Kv, 315Kv, 630Kv.

I. Electric Field and Magnetic Field strength of 100kv

The measurement for 100kv is taken around Haile Garment round about which is placed at a height of 2.5m above ground at two wooden poles as shown in Figure **26**.

Figure 26**:** *100kv transformer around Haile garment round about*

A higher reading is recorded to the west side of the transformer with a value of 60v/m at one-meter distance from the source and the magnetic field strength is very high at A, C and B. The effect of radiation goes to under slight category at 20m distance from the source as shown in Table **12** and Figure **27**.

Electric and Magnetic field strength for 100Kv transformer

Table 12**:** *EF and MF reading on different directions from 100Kv transformer*

Direction	**Distance(m) vs EF and MF along 100Kv transformer**									
	1m		**5m**		**10m**		**15m**		**20m**	
	EF	MF	EF	MF	EF	MF	EF	MF	EF	MF
A	60	1999	41	1403	27	740	6	110	1	17
B	44	1999	14	1584	10	986	6	360	18	1
C	44	1999	42	1500	28	849	8	150	1	15
D	83	1326	32	1051	16	624	8	252	2	20

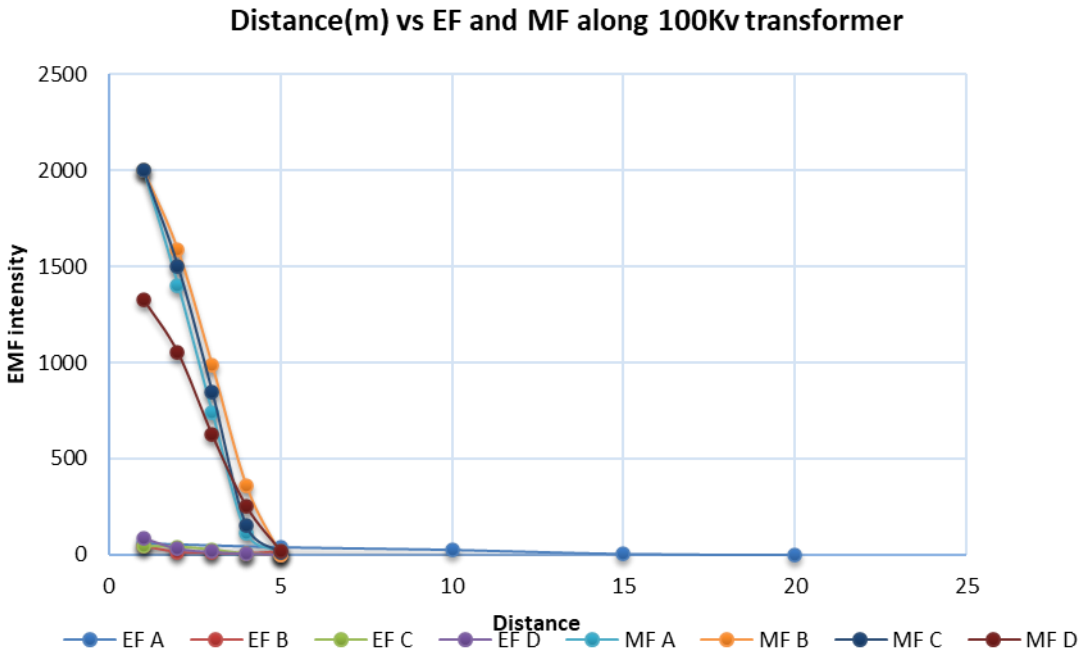


Figure 27**:** *EF and MF intensity along 100Kv transformer*

II. Electric Field and Magnetic Field strength of 200Kv

This transformer is located at Haile Garment industrial park facing a wall in the western direction as shown in Figure **28** . A 3side measurement is taken on North, east and south.

(a)  (b) 

Figure 28**:** *(a) 200Kv transformer and (b) EF and MF recording on the site*

Electric Field and Magnetic field strength for 200Kv

The value of EF and MF is higher in the southern direction which is 240v/m and the magnetic field is 1580nT. The values in Table13 shows there is extreme category magnetic radiation up to 5m from the source and slight category radiation at a distance of 20m from the source.

Table13: *EF & MF reading on different directions from 200Kv*

Direction	**Distance(m) vs EF and MF along 200Kv**									
	1		**5**		**10**		**15**		**20**	
	EF	MF	EF	MF	EF	MF	EF	MF	EF	MF
A	83	1510	122	1340	56	1020	18	153	1	18
B	70	1580	202	1304	240	542	65	144	1	11
C	13	1600	97	563	132	221	84	115	2	9

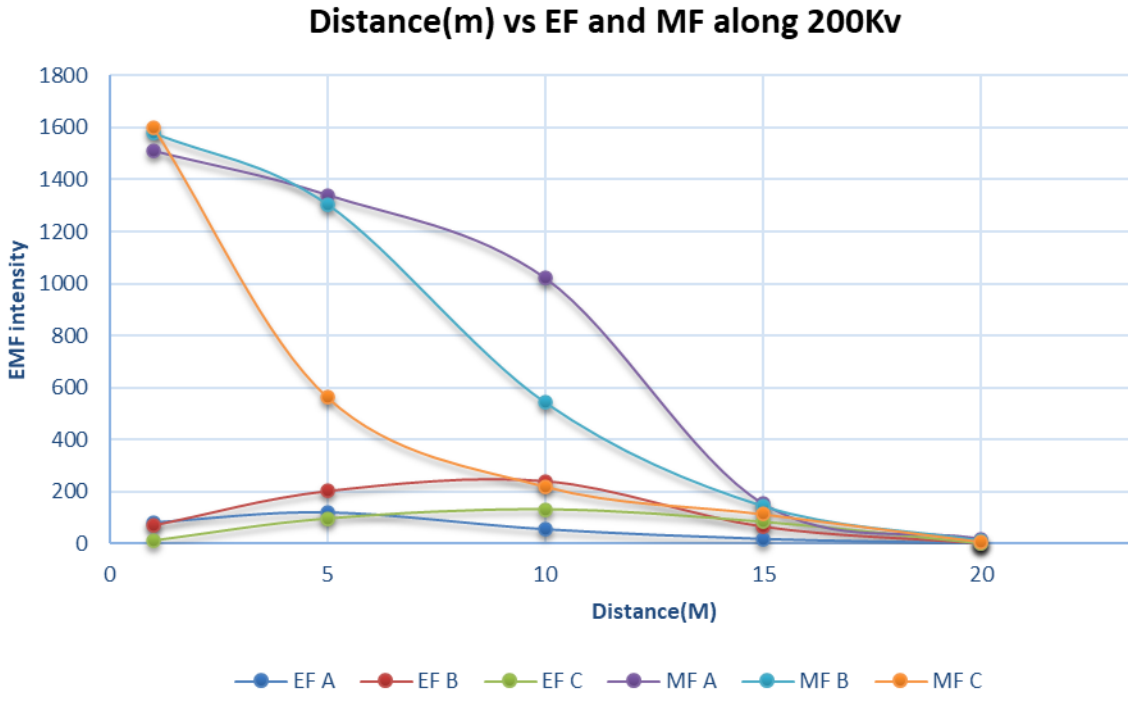


Figure 29**:** *EF and MF Intensity along 200Kv*

As its clearly indicated in Figure **29** the magnetic field strength is higher near the source and goes to no effect at a distance of 20m, whereas the electric field strength was higher at a distance of 10m from the source.

Electric Field and Magnetic Field strength of 315Kv

As shown Figure **30** in (a) and (b) MF and EF measurement was taken for 315Kv transformer next to a factory building in Haile garment industrial park.

(a)  (b) 

Figure 30**:** *(a) 315kv transformer and (b) EF and MF measurment for 315kv*

Electric field and Magnetic field strength for 315Kv

As shown in Table **14** and Figure **31** the highest electric field is observed at 1m from the source which is 74v/m and for the magnetic field 1429nT is recorded at the south direction which is categorized as extreme radiation.

Table 14**:** *EF and MF reading on different directions from 315Kv transformer*

Direction	**Distance(m) vs EF and MF along 315Kv**									
	1		**5**		**10**		**15**		**20**	
	EF	MF	EF	MF	EF	MF	EF	MF	EF	MF
A	74	1196	63	1102	23	446	5	130	1	17
B	30	1745	26	1414	19	640	11	140	2	20
C	38	1429	27	626	13	332	4	106	1	19

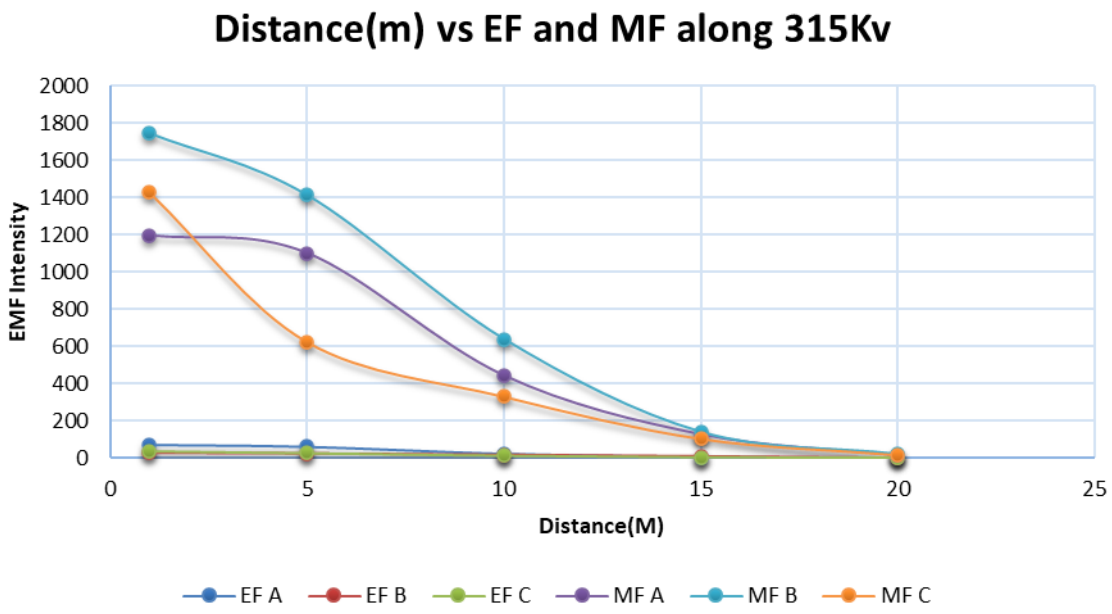


Figure 31**:** *EF and MF Intensity along 315Kv*

III. Electric Field and Magnetic Field strength of 630Kv

MF and EF measurement was taken for 630Kv transformer on the road side of Haile garment industrial park as shown in Figure **32**.

Figure 32**:** *630Kv transformer in Haile garment industry area (a) 630Kv transformer and (b) EF and MF recording on the site*

Electric Field and Magnetic Field strength for 630Kv

As shown in Table **15** and Figure **33** there is an extreme category radiation up to 15m from the source and goes slight category at a distance of 20m under extreme condition the maximum and minimum value of EF is 1698v/m and18v/m respectively. Whereas the maximum value of the magnetic field is 1698nT and minimum value 4nT.

Table 15: *EF and MF reading on different directions from 630Kv transformer*

Direction	Distance(m) vs EF and MF along 630Kv									
	1		5		10		15		20	
	EF	MF	EF	MF	EF	MF	EF	MF	EF	MF
A	1444	1135	935	1541	221	968	18	340	1	12
B	1636	1636	1198	1098	589	589	90	190	2	18
C	1254	1254	731	731	403	403	20	209	1	13

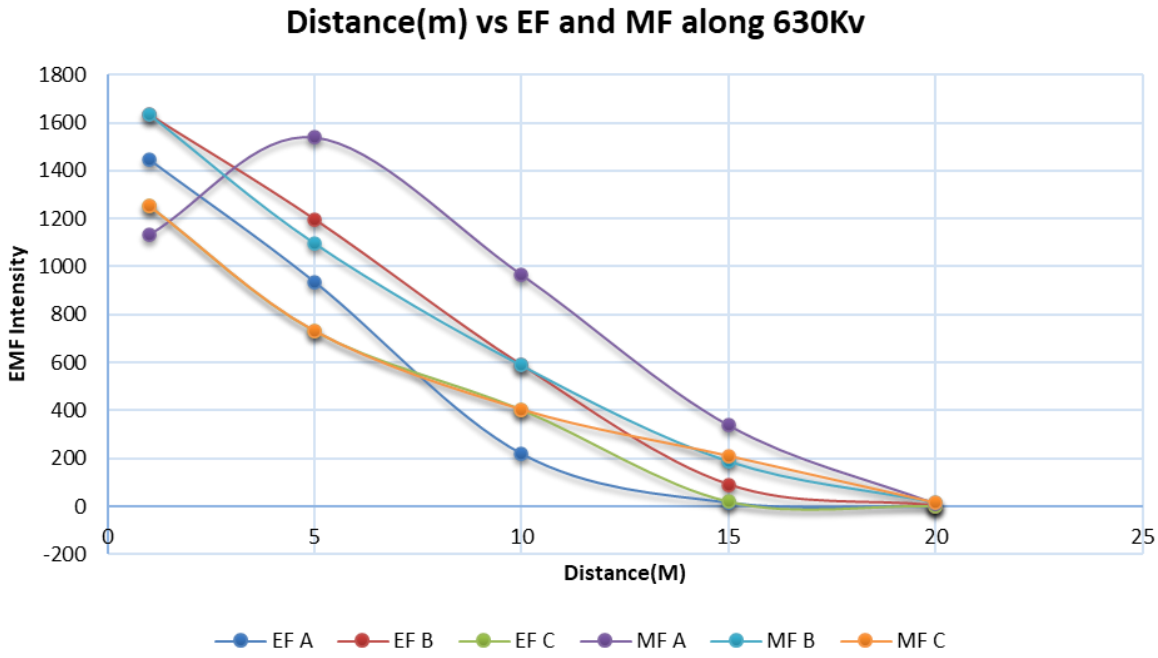


Figure 33:*EF and MF strength along a 630kv transformer*

IV. Substations

There are about 14 substations, which are found within the city of Addis Ababa, most of them are amidst neighborhoods while some of them are on the outskirt of the city but through the current dynamic transformation of the land use areas around such high-power substation are currently used as a living space. As shown

in Figure 34 below there are 4 substations on the northern and southern side of the city.

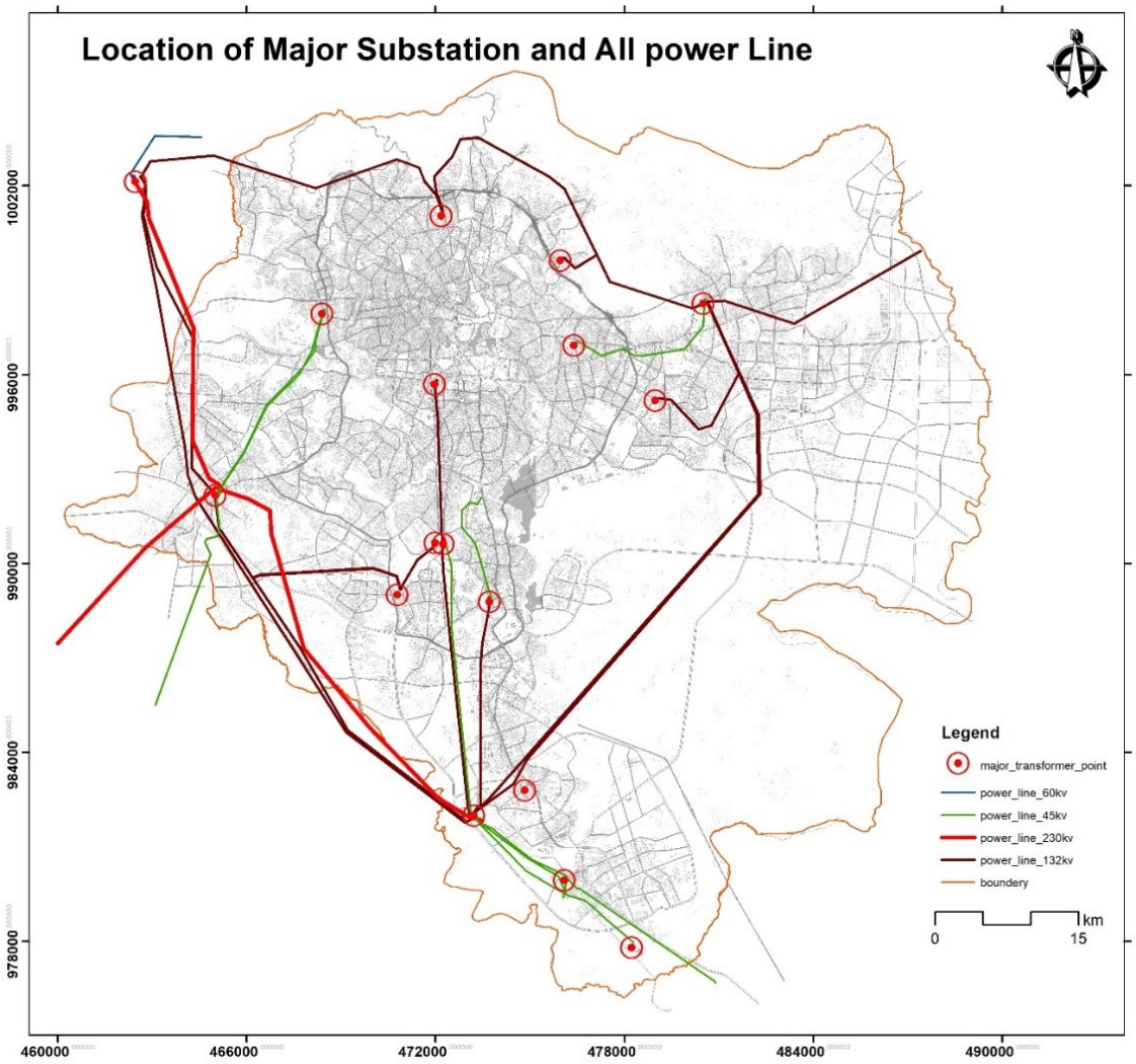


Figure 34: *location of substations in AA*

Figure 35: *Akaki I substation side view*

As shown in Table **16** the value of electric and magnetic field is higher at the southern(B) direction with an extreme category electric and magnetic field reading up to 300m from the source ranging from 1999v/m-66v/m for EF and for MF 1262nT-603nT is recorded.

Table 16**:** *EMF reading along (A), (B), (C) & (D) side of the substation*

Distance(m)	**Kality Substation (A), (B), (C) & (D)**						
	Electric field v/m				**Magnetic Field nT**		
	A	B	C	D	A	B	C
10	64	1428	1968	1999	67	1262	78
100	48	342	66	121	28	603	61
200	22	107	31	23	21	193	18
300	9	56	19	8	3	9	2
400	4	14	7	3	2	6	2
500	2	2	1	1	2	2	2

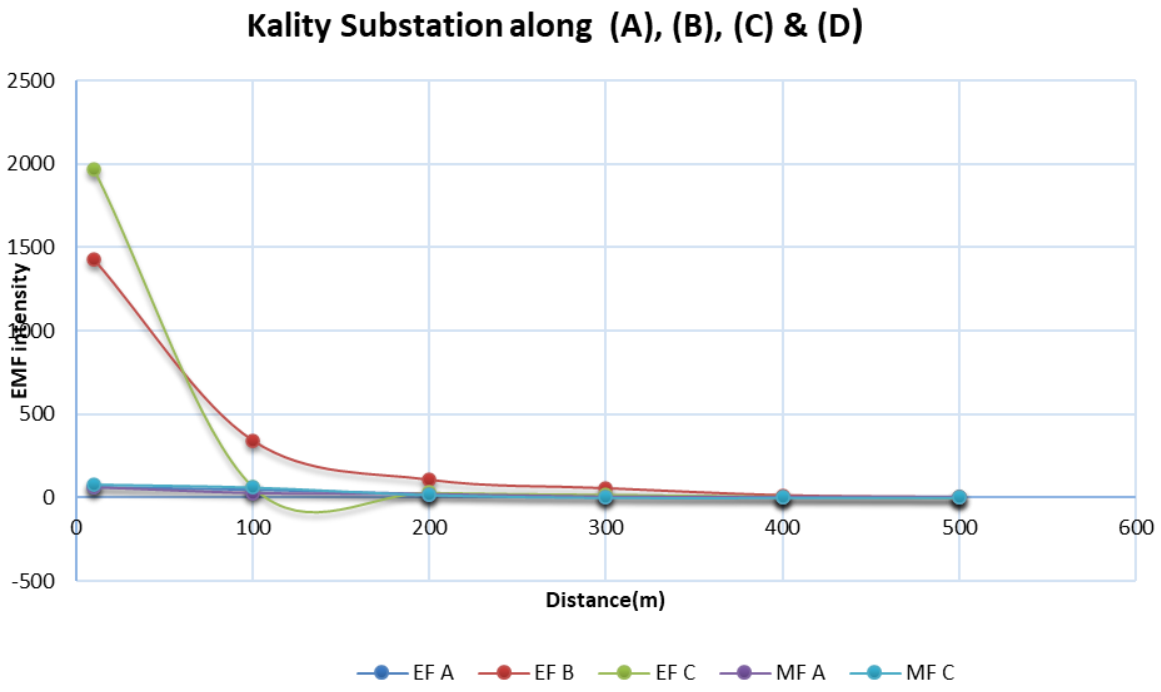


Figure 36**:** *Kality I substation EF and MF strength*

There is a general slight category radiation at a distance between 300 and 400m from the source and a safe level of radiation is recorded at a distance of 400m as shown in Figure **36**.

V. Cellphone tower

The study analyses 642 base station (BS) sites which are found in Addis Ababa. These base stations are mapped from Ethio-telecom database, the location of selected BSs is shown below in Figure 37.

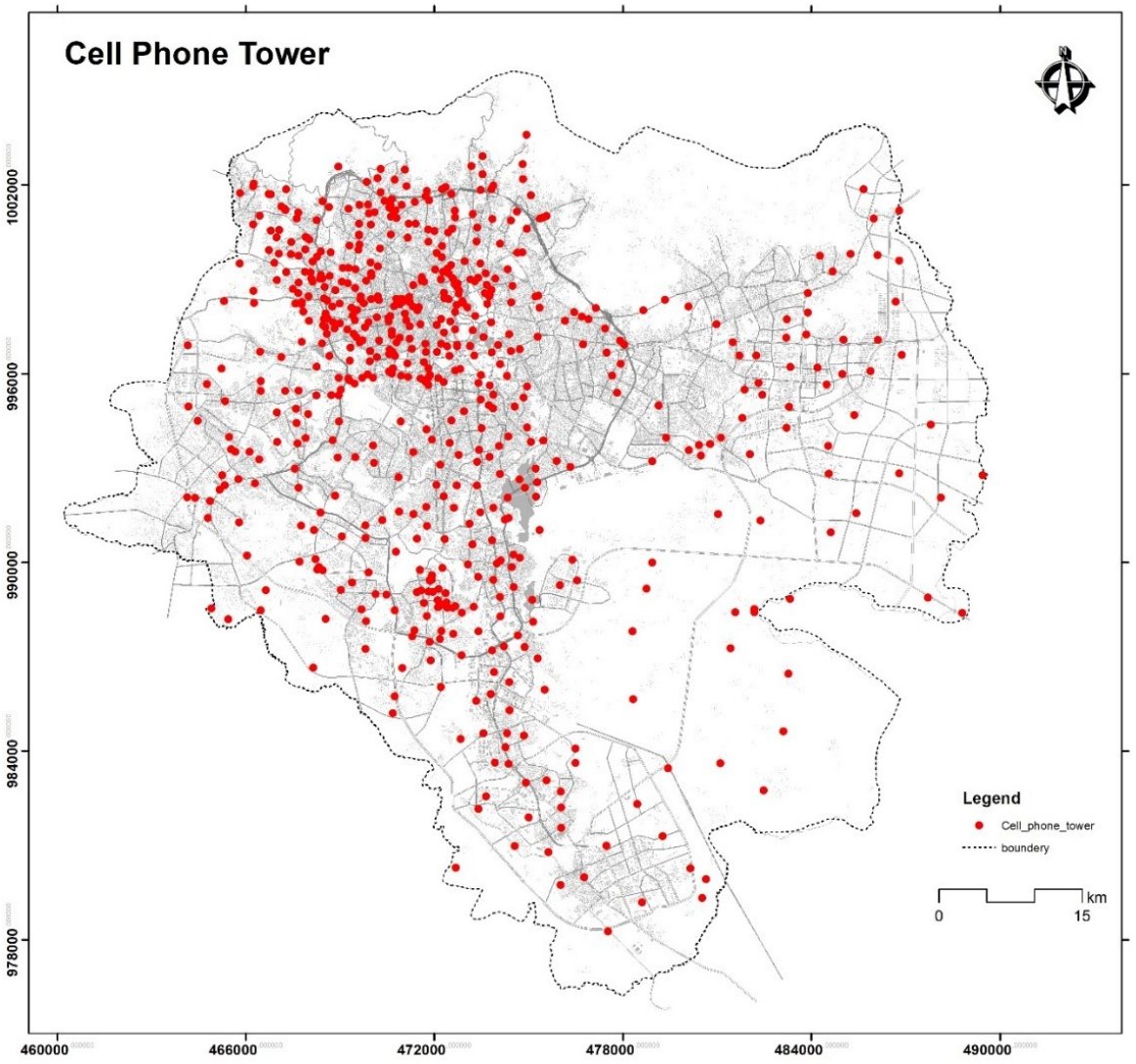


Figure 37: *location of cellphone towers with in the study area*

The effect of a cellphone tower is in this study case a 3-direction antenna tower as shown in Figure **38** with a120 degrees radiation zone each having 3 sets of antennae create an extreme radiation zone up to 240m with a value of 1220 μw/m2 and a maximum reading have been observed at the foot of the tower which is 5000μw/m2.

Figure 38**:** *3-direction 3G cellphone tower with 3 set of antennas*

A higher reading is observed at C direction as shown in Table **17** and Figure **39** below having an extreme HF intensity up to 460m.

Table 17: *measured recordings from a cell phone tower along the A, B and C direction*

Distance	**Electric field v/m**			**Magnetic Field nT**			**HF µw/m2**		
	A	B	C	A	B	C	A	B	C
c	2.5	2.5	2.5	2.9	2.9	2.9	5000	5000	5000
10	45.6	9.2	797	4	2.3	2	4800	4200	4270
20	34.6	6.5	462	4	2.7	1	4600	4400	5430
30	18	4.9	117	3	3.8	1	4200	3590	3390
40	14.4	3.5	36	3.1	4.4	2	380	1170	1290
50	20	2.4	20	2	4	1	1230	4070	1090
60	2	2	1	4.6	4.6	1	510	1040	3610
88	3.3	0.6	4	4.2	6.3	6	510	920	4330
120	2	2	2	4	4	4	235	310	970
150	1	1	1	5	5	5	235	310	1304
210	0	0	0	1	1	1	235	310	1010
240	0	0	0	0	0	0	235	310	1390
310	1	1	1	1	1	1	235	310	1280
460	1	1	1	1	1	1	235	310	1270
500	1	1	1	1	1	1	235	300	440

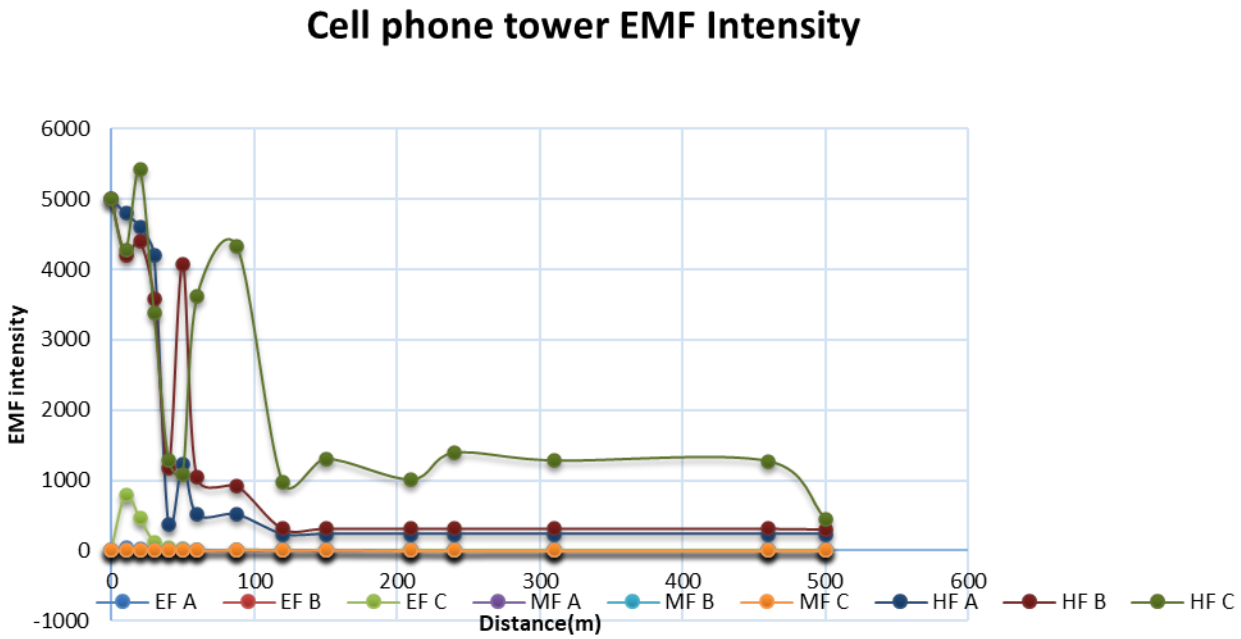


Figure 39**:** *Cellphone tower EMF intensity*

3.9.2 Internal measurement for buildings under vulnerable areas

Measurments have also been taken on buildings around a powerline and a substation. One of the building is akindergarten with in close range to Kality I substation its called salogora mebrat hail kindergarten and the second one eucalyptus wood shop which is made out of eucalyptus and metal sheet as afacade is found under a 132kv powerline.

Residential buildings, farm houses, factories, Schools for kindergartens have also been observed next to the kality I power substation which is very dangerous specially for children living in these areas where the negative health effect could be seen in children with a short period of time.

(a)  (b) 

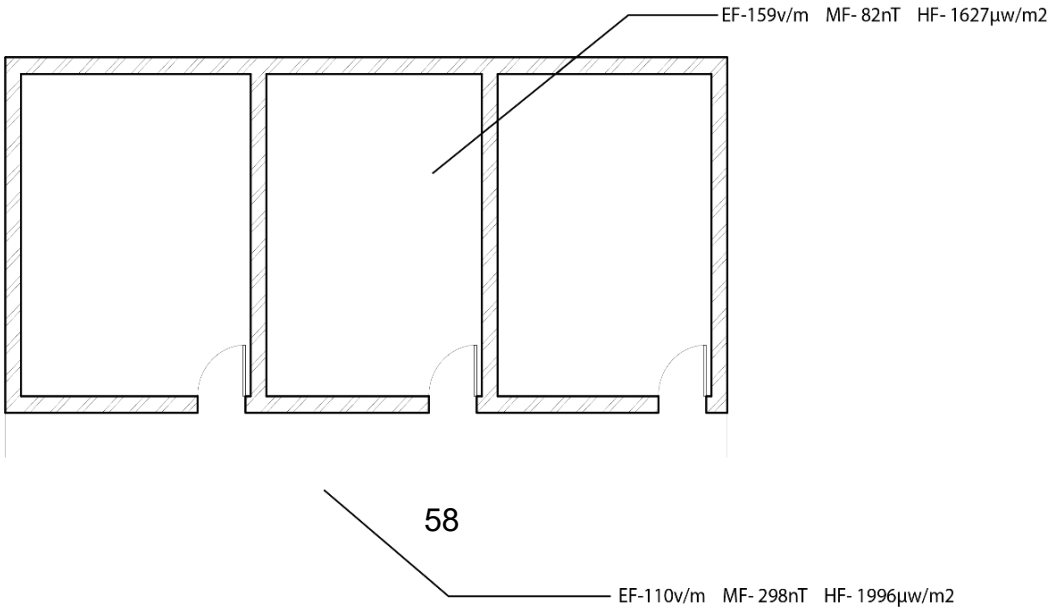
Figure 40**:** *Buildings around EMF sources (a)-Kindergarten near to a substation (b) Eucalyptus shop under 132kv*

As shown in Table **18**, The value of readings which are found in extreme radiation zone shows a 27%difference in MF between the external reading and the interior reading. the difference in value of reading between the external and internal value goes from extreme radiation level 298nT to 82nT which is severe. The value of the internal reading highly depends on the materials used for the construction of the building.

Table 18***: Internal and External value of EMF on the selected buildings***

Buildings	Internal Reading			Extenal Reading		
	EF	MF	HF	EF	MF	HF
Salo gora kindergarten	159v/m	82nT	1627µw/m2	110v/m	298nT	1996µw/m2
Eucalyptus shop	13v/m	756nT	1580µw/m2	77v/m	1190nT	1996µw/m2

(a)



(b)

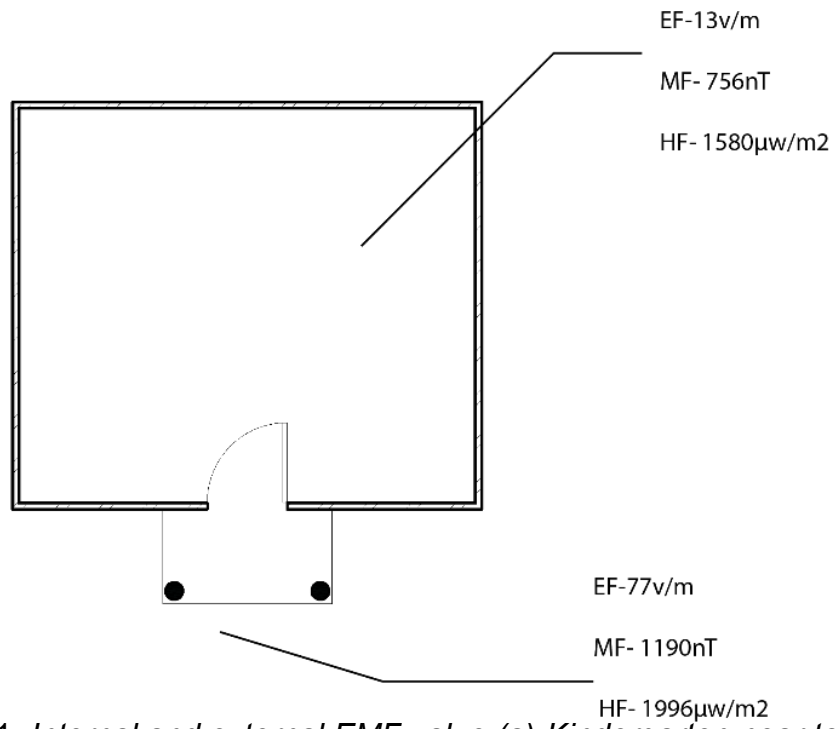


Figure 41: *Internal and external EMF value (a)-Kindergarten near to a substation (b) Eucalyptus shop under 132kv*

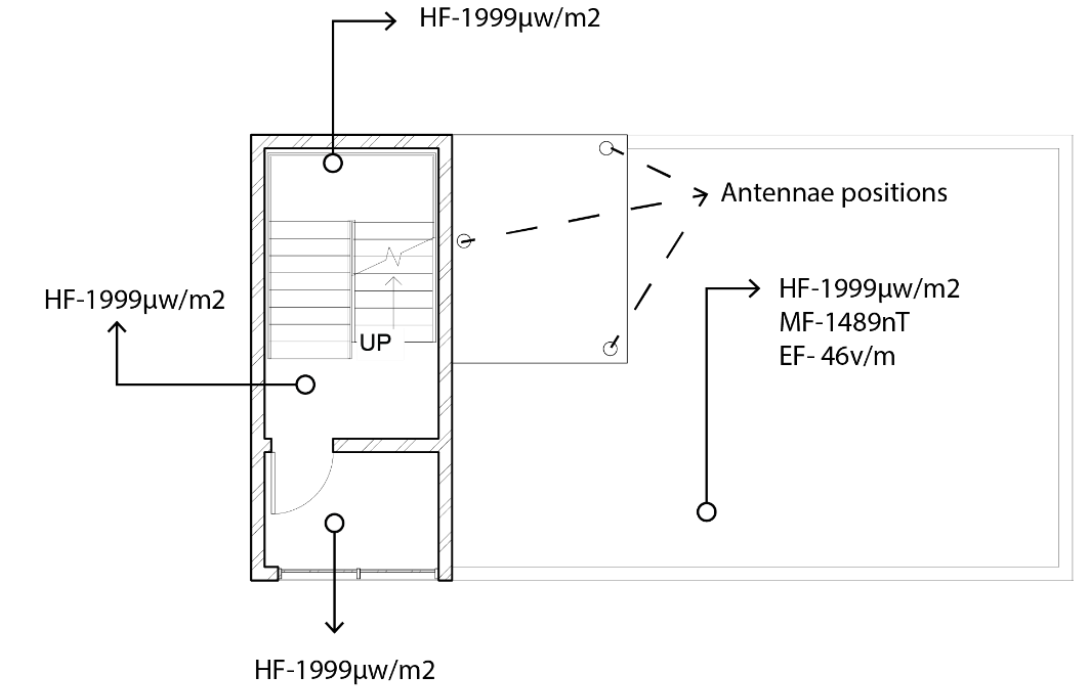
I. Building mounted cell phone tower

In a densely populated areas with limited access to a plot of land for a cell phone tower antenna are mounted on roof top of buildings to facilitate the network provision. Abuilding mounted cell phone antennae is chosen in Adey Ababa area measurements were taken inside and outside the building as shown in Figure **42** based on the measurements the roof top is in a highly extreme radiation environment with more than 1999µw/m2 value and a magnetic field of 1543nT, the electric field is comparatively low which is 46v/m.

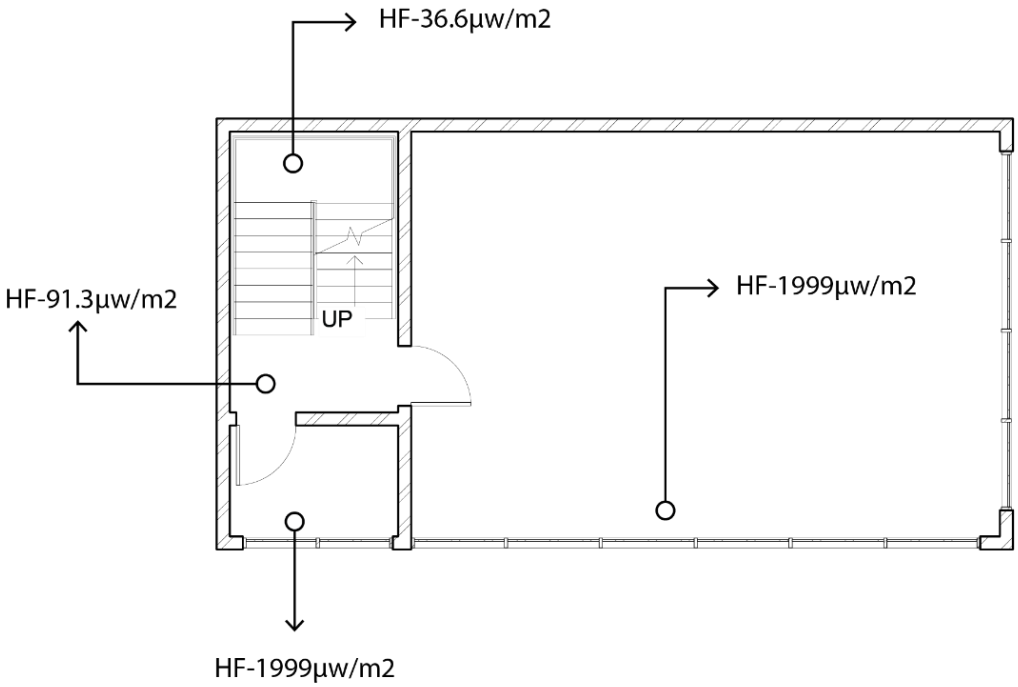
(a)  (b) 

Figure 42: *cellphone tower mounted building (a) External and (b) internal EMF measurement*

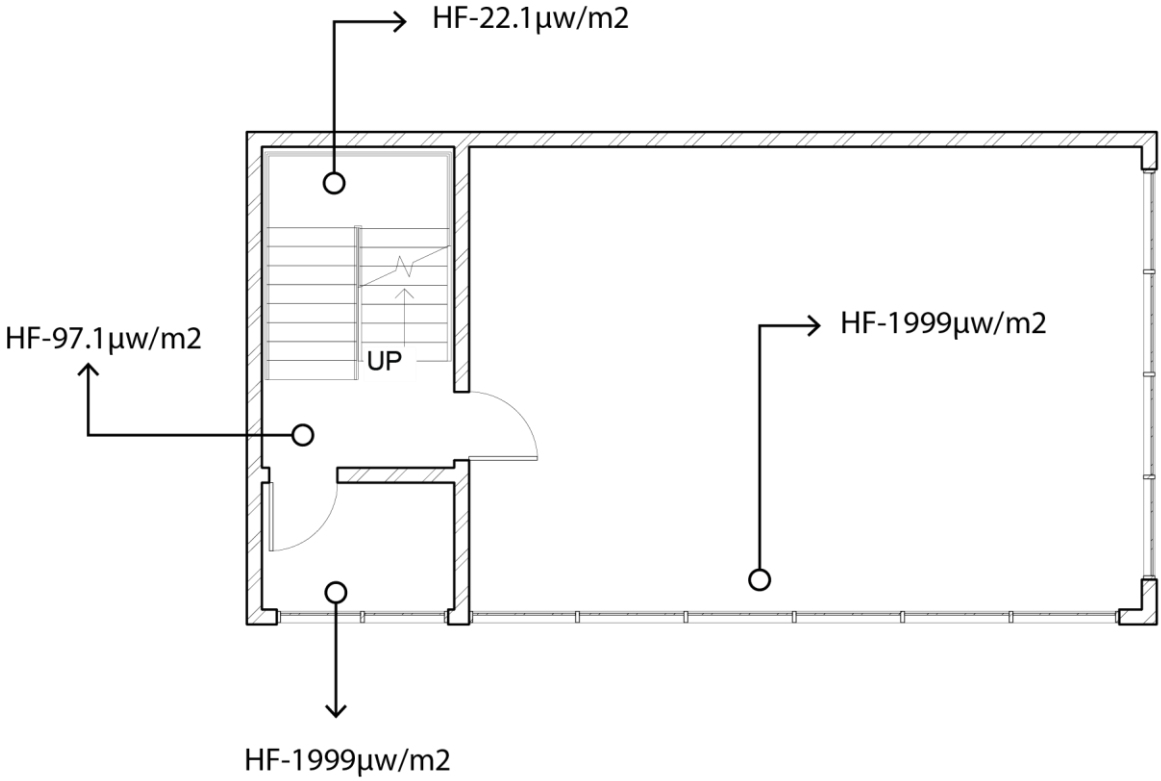
As shown in Figure 43(a) and (b) below the roof terrace have an extreme radiation environment where as on the bottom floors the radiation decreases. From the roof terrace to the 2nd floor there is a 98% difference in the intensity of the radiation around the stair case because of layers of concrete slab absorbing the emitted radiation but rooms with curtain glass windows on the lower-level floors have the same exposure as that of the roof terrace which shows the glass is completely permissible.


HF-1999µw/m2
Antennae positions
HF-1999µw/m2
MF-1489nT
EF- 46v/m
HF-1999µw/m2
UP
HF-1999µw/m2

(a)


HF-36.6µw/m2
HF-91.3µw/m2
UP
HF-1999µw/m2
HF-1999µw/m2

(b)



(c)

Figure 43*: Intensity of HF in (a) the roof terrace, (b) 3rd floor and (c) 2nd floor*

CHAPTER FOUR
RESULT

4.1 Location of potential non-Ionizing EMF inducing sources

There are more than 8000 transformers, 642 cellphone towers, 3 HVTL (230Kv, 132Kv and 45Kv) and 15 substations.in the city of Addis Ababa. Populated and dense areas of the city like Central and northern side of Addis Ababa show a dense concentration of transformers and cellphone towers but HVTL's like 230Kv, 132Kv and 45Kv HVTL are concentrated on the western and central part of Addis Ababa.

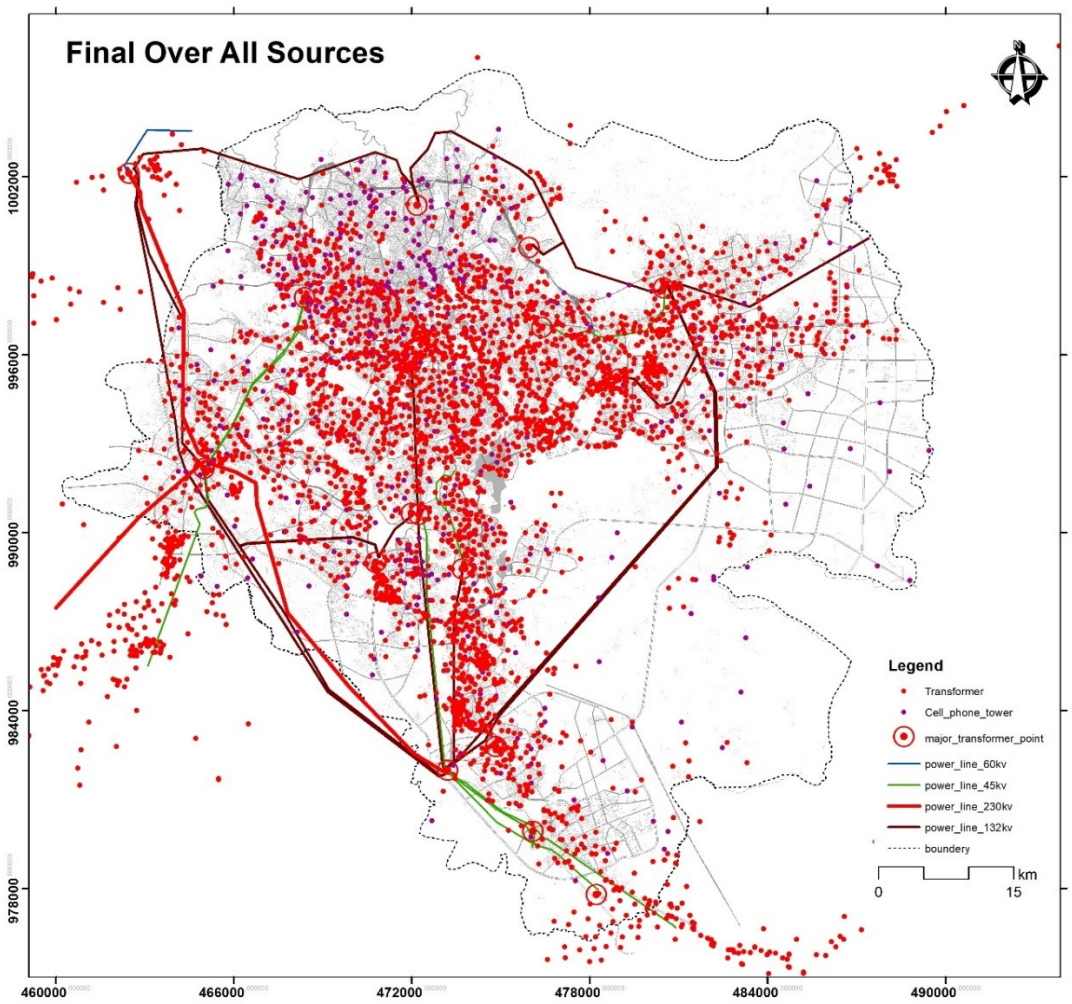


Figure 44: potential non-Ionizing EMF inducing *sources in Addis Ababa*

4.2 Intensity of non-Ionizing EMF inducing sources in Addis Ababa

630Kv,315Kv,200Kv and 100Kv generally have a higher extreme radiation reading near the source and goes to normal at 20m distance from the source. 630Kv have a higher reading at the center which is 765v/m for the electric field and 121nT for the magnetic field and the smallest reading is observed at 100Kv transformer with a value of 179v/m for the EF and 8nT for the MF. The magnitude of electric field, magnetic field and high frequency decreases as the distance increases from the source.

HVTL show an extreme category of radiation up to a distance of 50m, a higher reading is observed at this distance from 230Kv HVTL1999V/m for the electric filed and 413nT for magnetic field. The intensity goes from slight effect to no effect at a distance of 200m.

The intensity of radiation at the foot of a cell tower was 5,000μw/m^2 which is very extreme and the intensity goes to slight effect at a distance of 500m.

I. High voltage power line

High voltage transmission lines (HVPL) have a higher impact at the center of the passing cable. with a magnitude of more than 500nT for the magnetic field and >10V/m for the electric field. As shown in Table **19** from the total site 6288ha is extremely affected and 7823ha part of the city is under severe exposure zone. From the total of 6288ha extremely affected area 132Kv comprises 71% of the total which makes is very dangerous this is because 132Kv connects most of the substations in the city.

Table 19: *Impact area by 230kv, 132kv and 45kv HVPL*

Power line	Area(ha)			
	Extreme	severe	slight	no
230kv	854.6	414.89	916.91	49430.3
132kv	4515.417	5827.861	2723.08	38550.46
45kv	918.76	1581.022	1569.12	47883.09

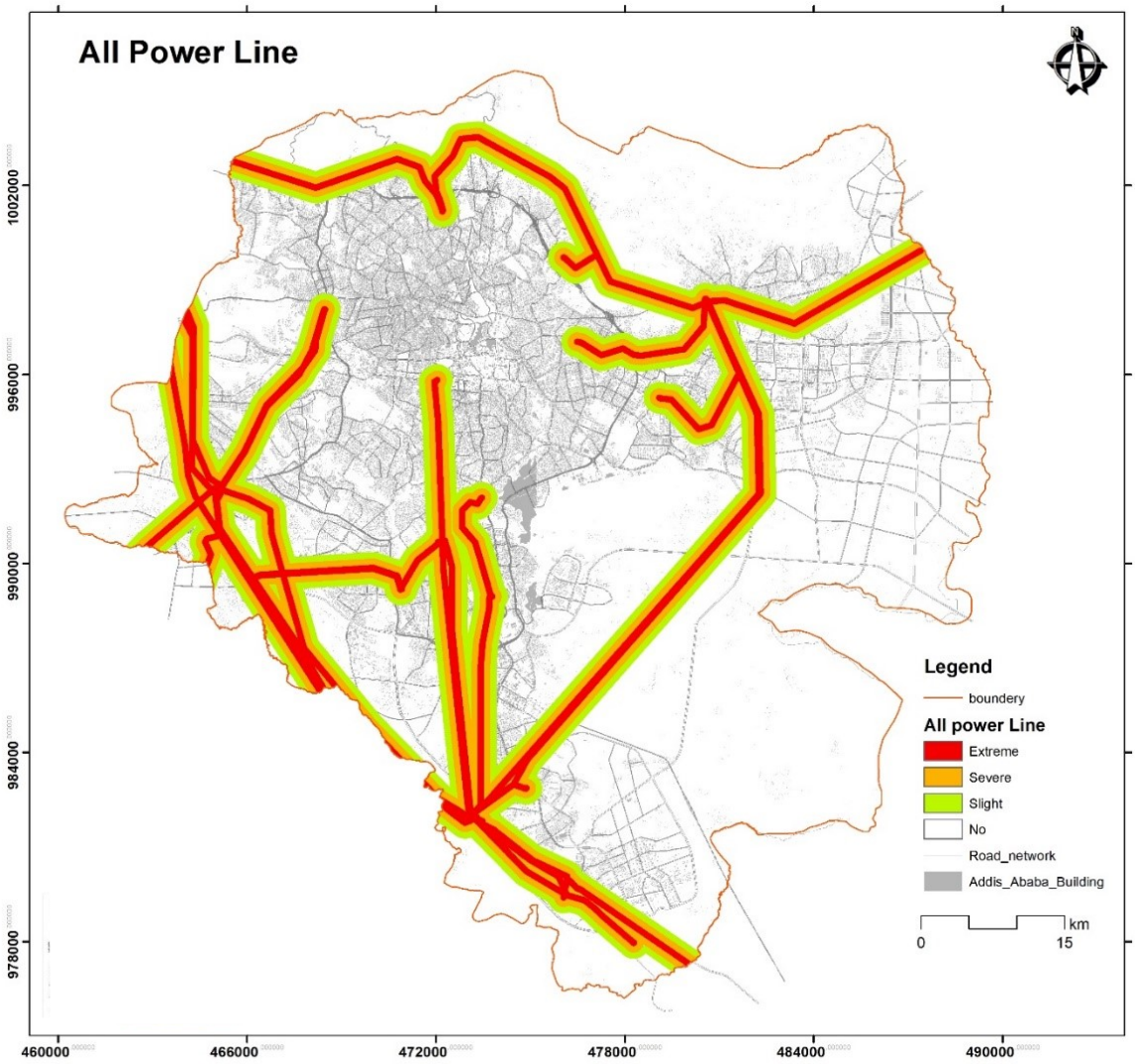


Figure 45: *The combined effect of the 3major HVPL*

As shown in Figure 45 the western and the south western area is highly affected due to the presence of these powerlines. These affected areas are slightly developed neighborhoods compared to the powerlines passing through the city center and north eastern part of the city where the powerline passes overhead

residential buildings. The combination of all these powerlines creates 15% extreme, 12% severe and 9% slight radiation zone as shown in Figure **46** below.

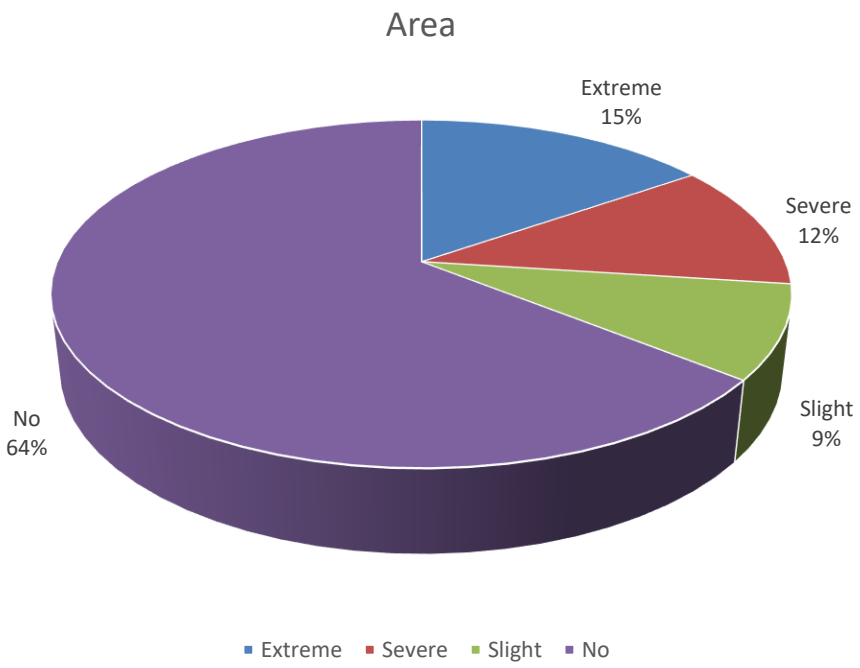


Figure 46: *Types of radiation caused by HVPL*

II. Transformers

The presence of 8000 transformers in the city creating a radiation pattern which shows how dense a settlement is in a certain area. In order to supply households with enough electricity transformers are positioned based on the population and energy demand of the area. As shown in the Figure **47** below populated areas have higher number of transformers resulting higher radiation intensity with in these areas.

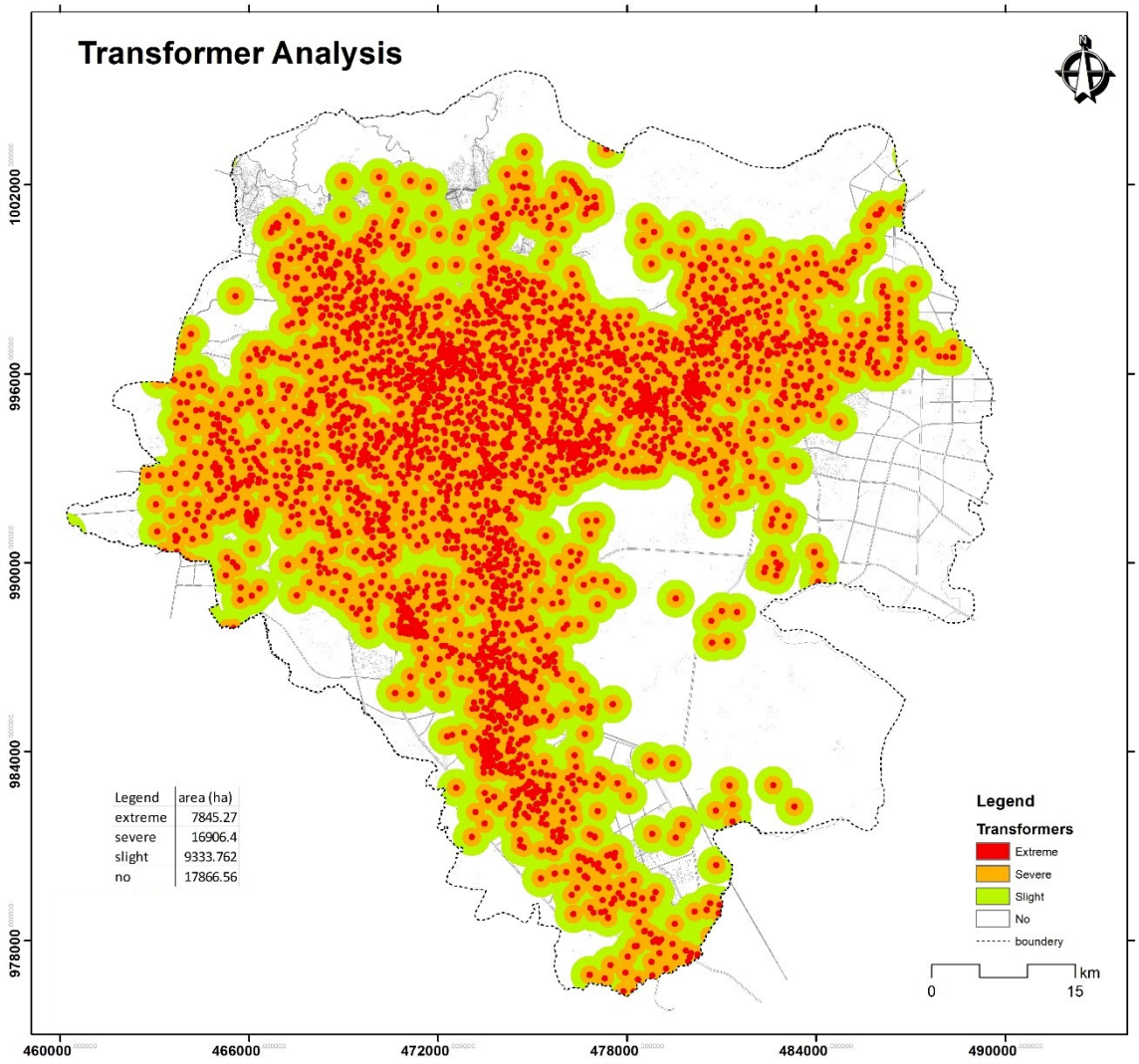


Figure 47: *The impact of transformers in terms of radiation intensity*

As described in Figure 48 due to the effect of transformers 15.1% of the city is under Extreme radiation zone, severe 32%, slight 18% and 35% of the city is free from radiation caused by transformers specially in the eastern and on the tip of the northern parts of the city.

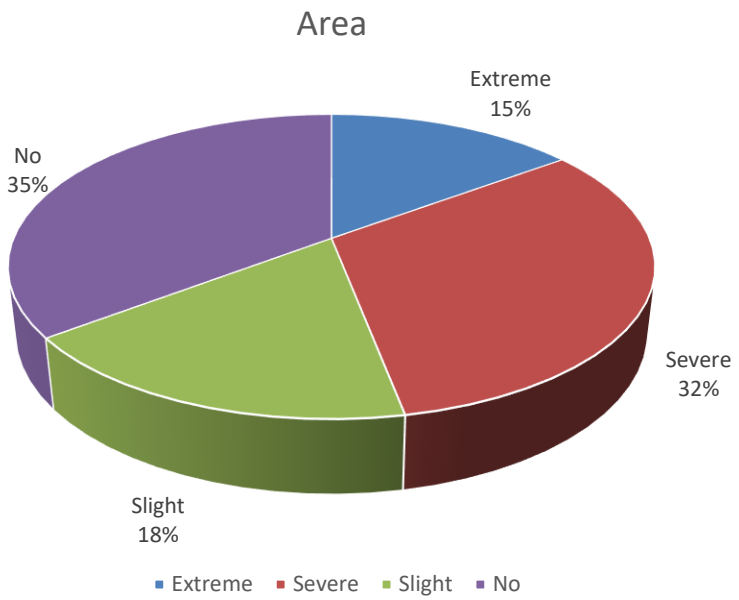


Figure 48: *Types of radiation caused by transformers*

III. Substation

Regarding Substations their total radiation effect is modelled in the fig below. Comparatively from other EMF sources they have lower coverage of area. For instance, the extreme radiation zone caused by these stations is 195ha, severe 1095.32ha and slight radiation covering 1753.6ha area of the city.

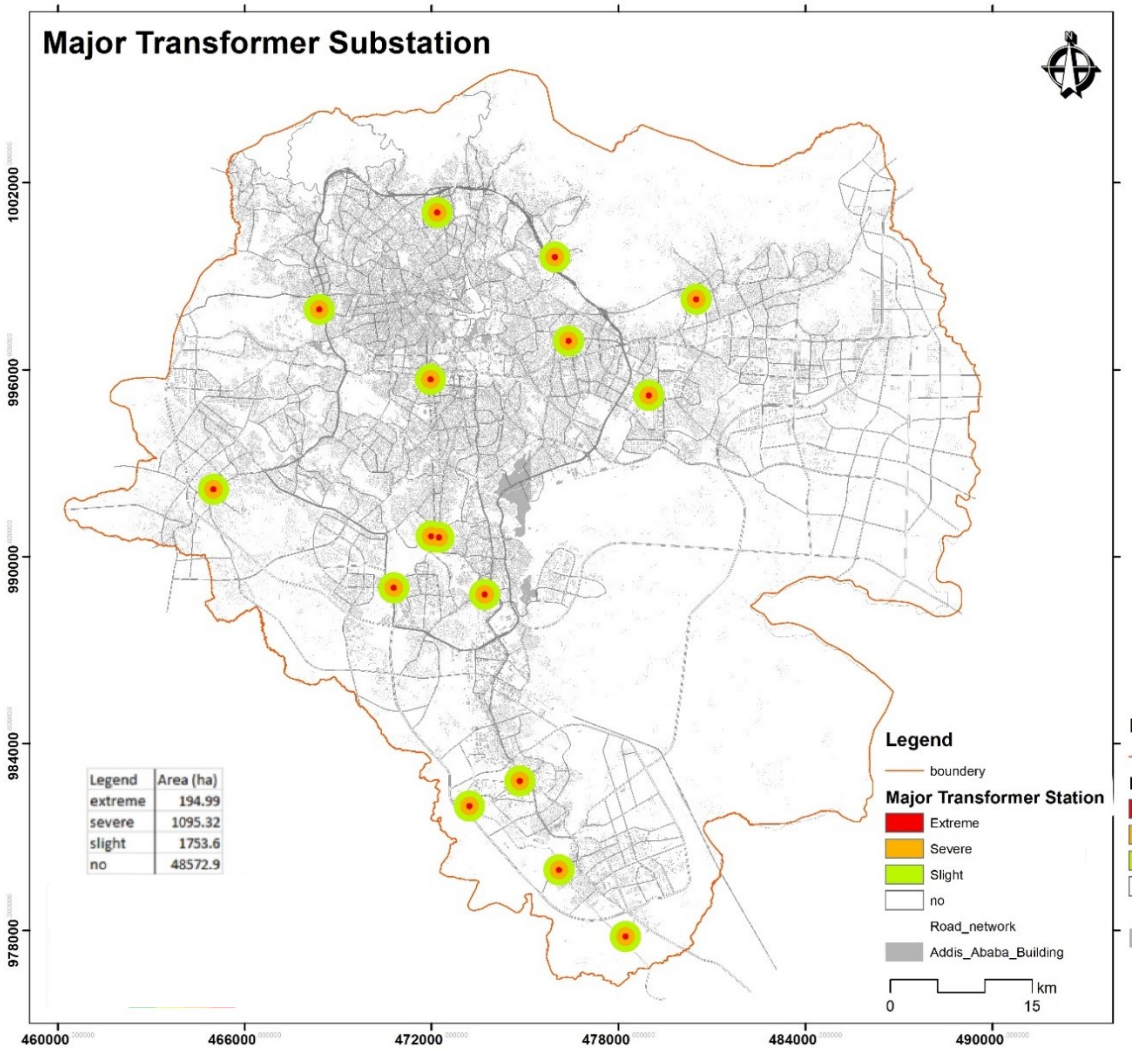


Figure 49: *The impact of Substations in terms of radiation intensity*

As described in Figure **50** 94% of the city is free from the radiation caused by substations and only 0.3% of the area is under extreme radiation zone.

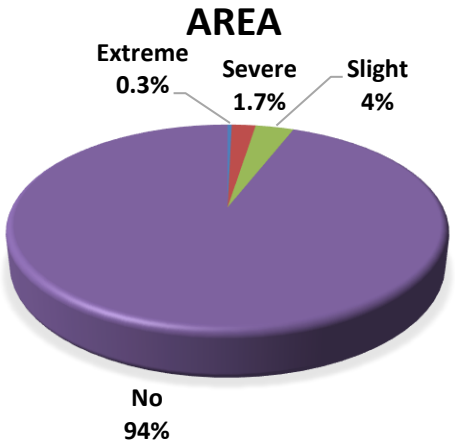


Figure 50: *Types of radiation caused by Substations*

IV. Cellphone tower

12% from the total area of the city of addis ababa is under extreme radiation zone caused by cellphone towers , 31% of the city is severly affected. Places with no effect from cellphone towers contribute only 27% covering area of 13806.79ha as showin in the Figure **51** below.

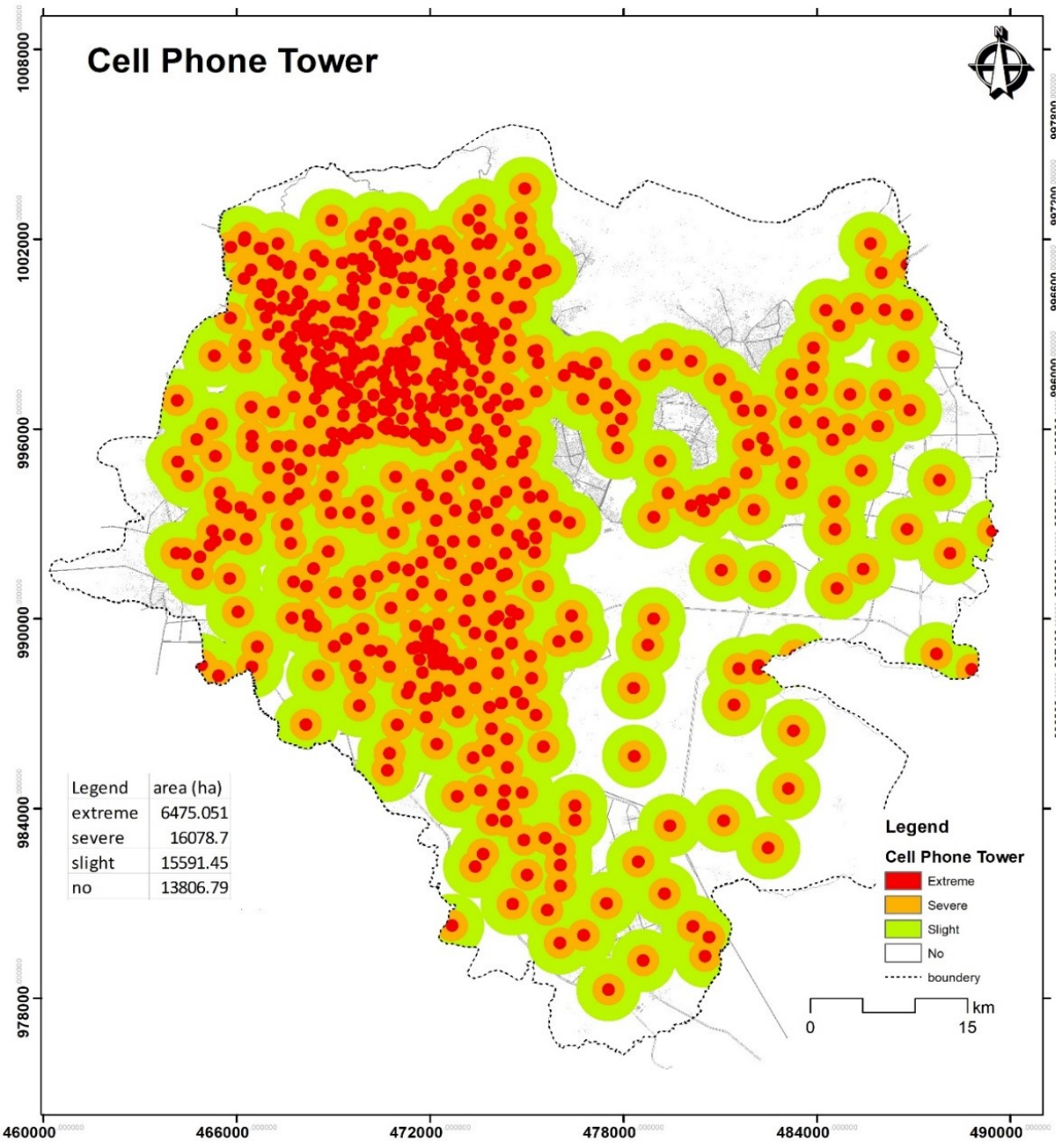


Figure 51:*The impact of Cellphone towers in terms of radiation intensity*

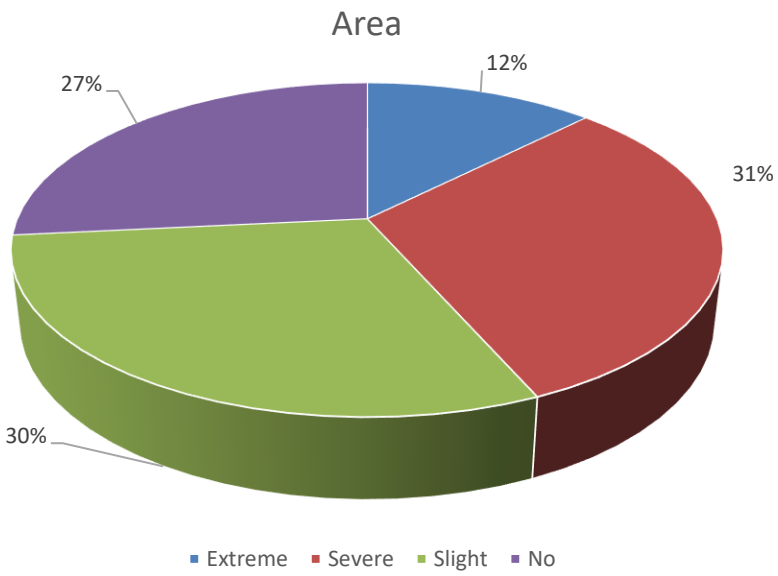


Figure 52: *Types of radiation caused by Cellphone towers*

As described in the Figure **52** above only 27% of the area is free from cellphone tower radiation.

4.3 Vulnerable areas for buildings due to the radiation

The effect of cellphone towers, substations, transformers and high power transmisstion lines are combined together with their radiation intensity as shown in Figure 53 below.

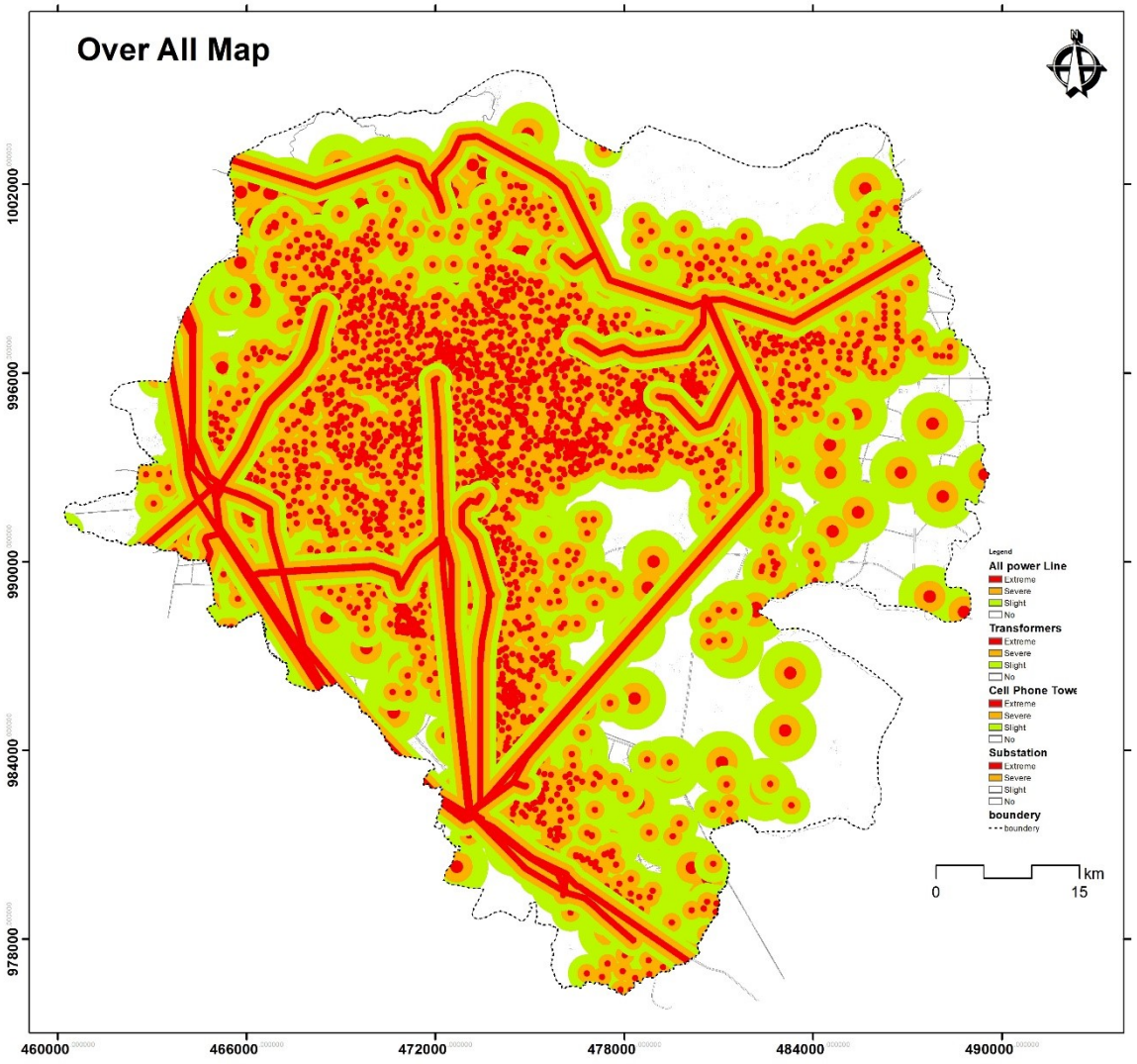


Figure 53: *Radiation pattern for existing sources in Addis Ababa*

The total effect of high powerline substation, cellphone tower and transformer are summarized in Table **20**

Table 20: *Total effect of EMF sources*

Intensity	Area (ha)
Extreme	16235
Severe	15843
Slight	10906
No	8967.992

83% of the city is exposed to EMR from minimum slight exposure to the maximum extreme exposure as shown in the Figure 54. Buildings located in these areas have to be able to deter EMF waves from getting inside functional spaces specially in areas people spend most of their time like bed rooms.

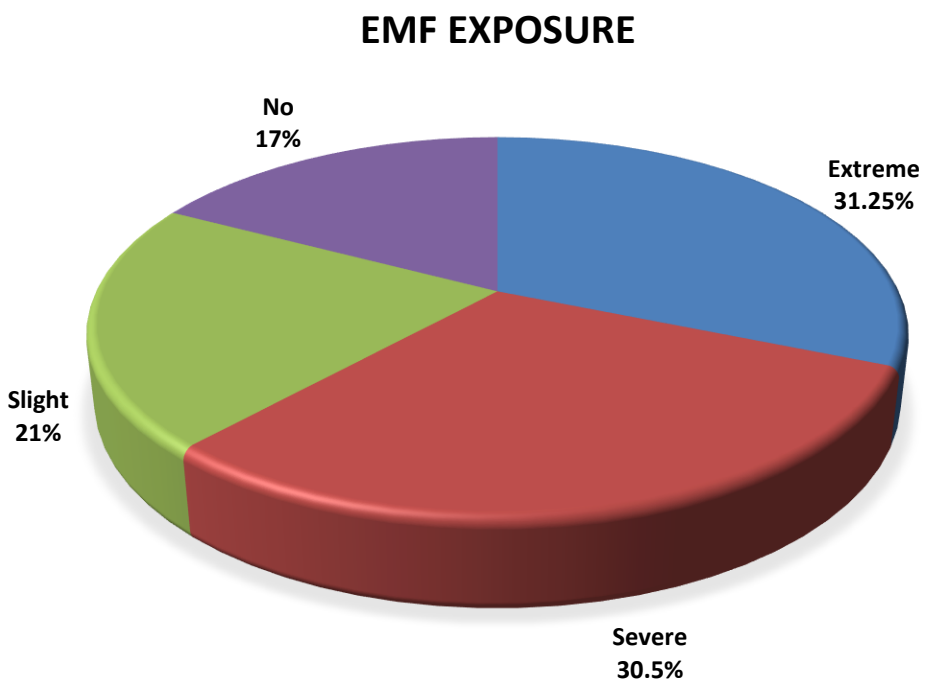


Figure 54*:Total effect of EMF sources*

CHAPTER FIVE
DISCUSSTION

5.1 Location of potential non-Ionizing EMF sources in Addis Ababa

There may be a difference in the type of the EMF source on the ground due to new demands like a small voltage transformer could get replaced by a higher one due to a new demand or advanced technological equipment's which is the case for cellphone towers where a 3G base station could get replaced by a 4G antennae, this can affect the general result of the study.

5.2 Intensity of non-Ionizing EMF sources in Addis Ababa

Transformers generally have a higher extreme radiation reading near the source and goes to normal at 20m distance from the source. The result for the intensity of transformers supports the claims of K.E. Lotz (nd) that a transformer could have an impact up to a distance of 25m, but unlike K.E. Lotz this study has observed the intensity of radiation is strong in all direction.

The result doesn't support the minimum approach distance set by OSHA (OSHA 1926.1408) for HVTL. The study suggests that a minimum of 50m should be set as a guideline for a precautionary purpose since there is a very high intensity which is extreme up to 50m. The result support the claims of (Usikalu, 2015) and (Djalel, 2014) on the intensity of HVTL from the source.

5.3 Vulnerable areas for buildings due to the radiation

The results indicate that extremely low frequency EMF and radiofrequency EMF is significant in the city of Addis Ababa having an extreme and severe EMF

exposure well over the safe level which is set by the building biology evaluation guide line.

According to The U.S. National Institute of Standards and Technology (NIST) 200mm concrete block have an attenuation capacity of 8db under 500MHz and 18db under 8GHz which makes it weak, meaning that the material has the capacity to block only 22% of the outdoor EMF value, the unblocked 78% of the outdoor EMF value will affect the user causing severe health issues. Within the context of Addis Ababa HCB concrete block is widely used and buildings under EMF exposure have very weak response to the radiation which in turn affects users spending most of their time in that building.

Next HCB concrete block single layered glass is used for openings which have 87% average maximum transmission field meaning the attenuation capacity is 13% this makes the internal space very much vulnerable to the radiation coming from a nearby source.

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Neighborhoods which are dense, urbanized and rich in infrastructure do have a higher concentration of non-Ionizing EMF sources compared to new settlement areas as shown in Figure 40. these sources are located very close to buildings due to poor planning decisions and lack of implementing guideline which are set for HVTL.

HVTL show an extreme category of radiation up to a distance of 50m, a higher reading is observed at this distance from 230Kv HVTL1999V/m for the electric filed and 413nT for magnetic field. The intensity goes from slight effect to no effect at a distance of 200m. Substations reach a safe exposure limit at a distance of 400m from the source, cellphone towers need 500m and a transformer 20m.

Based on the result 32,078ha of land which is 62% of the total area is a vulnerable area for a building to EMF. The remaining 21% is under a slight exposure level and the rest 17% is under no significant EMF exposure level. Buildings located in these areas have to be able to deter EMF waves from getting inside functional spaces specially areas where people spend most of their time like bed rooms.

Non-Ionizing EMF sources are present in most parts of the city leaving buildings under vulnerability which directly affects users causing health problems. Vulnerable buildings facing direct exposure of non-ionizing EMF can experience an extreme radiation environment if they are found in close range from the source.

Commonly used wall building material in the city is HCB block and it has a maximum transmission capacity of 78%, Whereas a window has 87% transmission level which means the outdoor exposure level is almost the same internally. This makes the building around the radiating source a sick building and needs treatment to keep the health of the user safe.

6.2 Recommendation

Ethiopia don't yet have a clear standard for non-ionizing EMF sources except high voltage transmission lines which have a buffer zone standard set by Ethiopian energy agency adopted from OSHA standard. Even though This standard works only for HVPL, the safe distance set by this standard is under the influence of non-ionizing EMF intensity, So anew standard should be in place to protect people from long term exposure.

Ethiopian radiation authority has recently opened a directorate office dedicated for non-ionizing radiation which supervises and controls devices emitting these kinds of radiation. There are multiple sources of EMF radiating devices in Addis Ababa which have to be carefully recorded and ensure the right kind of protective mechanism is used.

Special attention should be given for the location of schools, day cares and health facilities to be built away from the radiation zone. Based on the finding of the study the following recommendations are given to solve the increasing EMF radiation for a healthy natural environment and to treat buildings with a capacity to protect users from harmful radiation.

The following are recommended to have a safe indoor exposure level:

- Creating awareness about non-ionizing EMF radiation should be the priority to solve the problem without igniting fear among people
- Smart technological solutions have to be incorporated to solve the need for a better infrastructure without causing a negative impact on the human health
- Buildings which are currently found with in EMF hotspots have to be retrofitted with protective equipment's to shield the radiation.
- Some of the techniques which can be applied to vulnerable buildings include
    - Applying Architectural shielding meshes and fleeces
    - To use shielding textiles for windows, to use window shielding films and conductive shielding paints
    - Adopting tress and vegetation on the side of the EMF source
    - using the vulnerable side of the building for service functions.
    - Using Vegetation as a buffer
    - Adding a screening wall along the radiation to decrease the intensity of the radiation

In the construction design process for buildings, the preliminary design have to take Non-Ionizing EMF radiation under consideration when laying out the plan in the design stage of the building for a healthy and effective use of space . (Hakgudener, 2015) has suggested materials for safe level EMF intensity inside buildings as shown in Table **21**. For a better EMF propagation planning, the designer can incorporate these materials for effective shielding from the radiation.

Table 21: *Design guideline for effective internal EMF intensity in buildings*

Interior spaces		Power Intensity safe level	
		Below	Above
		Suggested materials to improve efficiency	Suggested materials to achieve safe levels
Residential spaces	Living rooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Dining room	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Bedrooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Bathrooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Kitchens	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Library/study	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Family/recreational rooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Laundry/sewing rooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Closets/storage areas	No action needed	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
Office spaces	General offices and multiple workstations	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Private offices	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Conference rooms	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Reception area	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
Hospitality spaces	Restaurants	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Bars	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Hotels	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
Retail spaces	Shops	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Banks	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
	Department stores	Wood, Plywood, Glass, Drywall	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film
Public Restrooms and Toilets	Restrooms and toilets	No action needed	Brick, Brick faced concrete wall, reinforced concrete, Brick faced masonry block, shielding mesh, shielding paint, shielding window film

Source: (Hakgudener, 2015)

REFERENCES

Abdul Latif, S., Karim Suhag, A., Sohail Ahmed Larik, R., Ali Mallah, G., Muhammad Ali Talpur, M., Saeed, A., Ali Larik, F., & Karim, S. (2016). AdverseEffects of Cell Phone Radiation on Human Health Article in. *International Journal of Scientific and Engineering Research*, *7*(10), 480–486. http://www.ijser.org

Ahmad, A., Ariffin, R., Mohn Noor, N., & Sagiruddin, M. A. (2011). 1.8 GHz Radio Frequency signal radiation effects on human health. *Proceedings - 2011 IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2011*, 546–550. https://doi.org/10.1109/ICCSCE.2011.6190586

Ameen, H. (n.d.). *Reduction of Cell Phone Electromagnetic Radiation Effect on Human Body*. http://www.ijsciences.com

Awad, A. H. A., & Habeeballah, T. M. (2014). *Power Density of Cellular Tower Against Distance , Direction Power Density of Cellular Tower Against Distance , Direction and Height : A Case Study*. *January*. https://doi.org/10.4197/Met

Babatsikou, F. P. (2011). The Sick Building Syndrome (SBS). In *HEALTH SCIENCE JOURNAL ® VOLUME* (Vol. 5, Issue 2). http://www.nsc.org/ehc/indoor/sbs.

Balmori, A. (2014). Electrosmog and species conservation. *Science of the Total Environment*, *496*(August 2014), 314–316. https://doi.org/10.1016/j.scitotenv.2014.07.061

Busby, C., & Fucic, A. (2006). Ionizing radiation and children's health: Conclusions. *Acta Paediatrica, International Journal of Paediatrics*, *95*(SUPPL. 453), 81–85. https://doi.org/10.1080/08035320600886547

Carpenter, D. O. (2014). *Excessive Exposure to Radiofrequency Electromagnetic Fields May Cause the*.

Clark, R. B. (1985). Fetal and neonatal effects of epidural anesthesia. *Obstetrics and Gynecology Annual*, *14*(September), 240–252.

Djalel, D. (2014). Study of the Influence High-voltage Power Lines on Environment and Human Health (Case Study: The Electromagnetic Pollution in Tebessa City, Algeria). *Journal of Electrical and Electronic Engineering*, *2*(1), 1. https://doi.org/10.11648/j.jeee.20140201.11

Doganay, G. (2015). *Electromagnetic_Radiation history*.

EVE, I. S. (1957). The effect of radiation on human heredity. *Journal of the American Medical Women's Association*, *12*(7), 199–201.

Hakgudener, S. (2007). *Future of Wlan and the Influences To the Architectural Forms and Design*. 1–131. https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=7d53ed97e31a8bd3

aa6864b0e7704416eae44e48141d7a55b82c08696ffae08b44f75cea77711c76

Hakgudener, S. (2015). Spatial Design for Healthy and Effective Electromagnetic Wave Propagation. *Procedia Engineering*, *118*, 109–119. https://doi.org/10.1016/j.proeng.2015.08.409

India, G. of, & Telecommunications, M. of C. & I. T. D. of. (n.d.). *Inter-Ministerial Committee on*.

Mitra, R., Mazumder, M., Pal, K., & Jana, S. (2014). a Study on Effect of Mobile Phone Radiation on Human Health. *Exploratory Animal and Medical Research*, *4*(2), 246–252.

Neufert. (n.d.). *Neufert_3_edition-engl.pdf*.

Odemer, R., & Odemer, F. (2019). Effects of radiofrequency electromagnetic radiation (RF-EMF) on honey bee queen development and mating success. *Science of the Total Environment*, *661*, 553–562. https://doi.org/10.1016/j.scitotenv.2019.01.154

Pachuau, L., & Pachuau, Z. (2014). Study of Cell Tower Radiation and its Health Hazards on human body. *IOSR Journal of Applied Physics*, *6*(1), 01–06. https://doi.org/10.9790/4861-06110106

Panagopoulos, D. J. (2011). *A NALYZING THE H EALTH I MPACTS OF M ODERN* (Vol. 17).

Panagopoulos, D. J., & Chrousos, G. P. (2019). Shielding methods and products against man-made Electromagnetic Fields: Protection versus risk. *Science of the Total Environment*, *667*, 255–262. https://doi.org/10.1016/j.scitotenv.2019.02.344

Pūtaiao, S. L. H. – P. A. (2021). *Waves as energy transfer*. https://www.sciencelearn.org.nz/resources/120-waves-as-energy-transfer

R.Arrosan, T.Tharshika, & Dr.Shruti Awasthi. (2012). The Effect of Mobile Phone Radiation on Human Health. *World Congress On Holistic Medicine*, *29*, 50.

Rahman, K. A. (n.d.). *Mobile_Phone_Radiation_Effects_on_Human*. Khanataur92@gmail.com

RAMESH Sorate, R., Sorate, R. R., Zode, P., Hire, H., Kharat, G., Dharmadhikari, N. P., & Pimplikar, S. S. (2014). *Geopathic Stress: A Threat to the Built Environment*. www.ijltemas.in

Rifai, A. B., & Hakami, M. A. (2014). Health Hazards of Electromagnetic Radiation. *Journal of Biosciences and Medicines*, *02*(08), 1–12. https://doi.org/10.4236/jbm.2014.28001

Saim, K., Zerrin, K., & Selçuk, S. (2010). Electromagnetic Pollution in Buildings and Its Effects on Human Health. *The International Conference on Electrical*

Engineering, *7*(7), 1–9. https://doi.org/10.21608/iceeng.2010.33047

SBM-2008C. (2008). *International Institute for Standard of Building Biology Testing Methods*. 1–12. https://hbelc.org/pdf/standards/SBM-2008C-v3.6.pdf

Singh, P. (2013). *Wireless Radiation : a Threat To*. *1*(2), 13–19.

Spurny, F., & Dachev, T. P. (2009). New results on radiation effects on human health. *Acta Geophysica*, *57*(1), 125–140. https://doi.org/10.2478/s11600-008-0070-6

Temtim, G. (2017). *Addis Ababa Institute of Technology School of Mechanical and Industrial Engineering*. *September*.

To, S., & By, P. (2010). *REPORT ON Secretary , DOT , Delhi Prepared By*. *December*, 1–50.

Usikalu, M. (2015). *Safe Distance to Extremely Low Frequency Radiation Associated with Power Transmission Lines Located in Ota , Southwest , Nigeria*. *May 2014*.

Vasile, M., Caligiuri, L. M., Lamonaca, F., Nastro, A., & Beiu, T. (2014). Nonionizing Electromagnetic Radiation (Emf) and Their Influence on the Health of Living Organisms. *Romania. All Rights Reserved ORIGINAL PAPEER Academy of Romanian Scientists Annals-Series on Biological Sciences*, *3*(2), 5–18.

Vladimir Sinik, & Zeljko V.Despotovic. (2012). ”Influence of Electromagnetic Radiation on Health of People.Limits for Exposure to EMF”. *PROCEEDINGS of the XI International Scientific Symposium INFOTEH- Jahorina 2012*, *11*(March), 417–421. http://www.infoteh.rs.ba/rad/2012/KST-4/KST-4-5.pdf

Wiedemann, P. M., Boerner, F., Claus, F., Wiedemann, P. M., Boerner, F., & Claus, F. (2016). *How far is how far enough ? Safety perception and acceptance of extra-high-voltage power lines in Germany*. *September*. https://doi.org/10.1080/13669877.2016.1220415

Zamanian, A., & Hardiman, C. (2005). *Electromagnetic Radiation and Human Health: A Review of Sources and Effects*. *July*.

Zerek, A. R., Alahimer, S., & Elfituri, M. M. M. (2019). *Investigation of EMF Radiation From GSM Base Stations and Mobile Antenna Towers in Different Locations – Libya*. *7*, 32–36.

APPENDICES

Annex 1: Publishable manuscript

Identifying and Measuring Non-Ionizing Electromagnetic Hotspots and Vulnerable Areas for Buildings in Addis Ababa, Ethiopia

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Abstract

A connection between non-ionizing EMF and human health has been stipulated by an increasing number of studies and symptoms characterized as Electro-hyper-sensitivity (EHS) are frequently reported. When a building is exposed to such kind of EMF radiations it can be referred as a sick building. This research aims to identify and measure EMF hot spots and vulnerable buildings in Addis Ababa. Data for the intensity of the EMF radiation was taken using HF 59B analyzer for higher frequency and 3951A M/E analyzer for Electric field and magnetic field around EMF sources, and ArcMap 10.3 GIS is used to model and analyze the data, the analyzed result has shown that, from the total area which is 54000ha of Addis Ababa 31.25% (16235ha) of the land is in hot radiation zone which is designated as extreme exposure; 30.5%(15843ha) of the area is severely exposed; 21%(10906ha) of the area is slightly exposed and the remaining 17% (8967.99ha) of the area have a negligible amount of exposure. Buildings with in these hot EMF radiation zones have to use measures to decrease the intensity of radiation and keep the user safe and healthy.

Key words: Non-Ionizing EMF, EMF hotspot, Vulnerable building

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1. Introduction

Energy can be transferred from one body to the other through waves in the form of particle vibrations these waves can be an Electromagnetic wave generated by the Electromagnetic Field (EMF)where energy is transferred through the vibration of electric and magnetic fields (Science Learning Hub – Pokapū Akoranga Pūtaiao, 2021)

EMFs can be classified into two natural EMF and the manmade EMF. According to Panagopoulos & Chrousos(2019) the natural non ionizing electromagnetic energy is the most essential type of energy its apace maker for human/animal biological rhythms. The human made EMF can be caused by cellphone towers, High-power transmission lines, transformers and from domestic electrical devices.

Exposure of people to the totally polarized EMFs of the human technology, especially Radio Frequency (RF) or microwave and ELF EMFs from Mobile Telephony (MT) antennas, and ELF 50–60 Hz electric and magnetic fields from power lines has increased to unprecedented levels in order to satisfy the increasing demands of technological applications used by the modern society (Sangeetha et al., 2014, Panagopoulos and Chrousos, 2019).

A connection between EMF and human health has been indicated by an increasing number of studies such as (Babatsikou, 2011; Busby & Fucic, 2006; Rifai & Hakami, 2014; Saim et al., 2010) and Symptoms characterized as Electro-hyper-sensitivity (EHS) are frequently reported especially in urban environments.

Through the evolution of the human being towards the current sophisticated civilization, there happened a wide use of electromagnetic devices to ease the lives of humans. If devices that emit electromagnetic radiation surpass the restricted limit then the emitted radiation can alter the DNA of a cell which leads to the emergence of carcinogenic diseases (Vasile et al., 2014).

When a building is exposed to such kind of EMF radiations for a longer period of time it causes illness to the users, such kind of a building can be referred as a sick building (Babatsikou, 2011). Sick building syndrome can also be caused by the natural earth forces that are determinantal to human health.

Buildings enclose spaces for the user to perform the necessary functions. These buildings should be built or located away from radiation hot spots to keep the user from any health hazards. Buildings with in the high electromagnetic radiation zone have to be identified, designed and constructed to protect the users from the negative health impacts caused by the radiation.

Recently the city of Addis Ababa has upgraded the quality of the signal by positioning several cellphone towers either on top of buildings or using towers in the middle of the neighborhoods. But these towers do also have a negative impact because they release harmful radio frequency to the surrounding area, High voltage transmission lines do also radiate EMF energy to the surrounding area. The higher the energy the higher the impact (Saim et al., 2010).

1.1. The Building Biology Evaluation Guideline

The Building Biology Evaluation Guidelines are based on the precautionary principle, with specific regard for the potential long-term exposure and risks associated with sleeping areas, and the fragile window of opportunity that sleep presents for biological and metabolic regeneration. The Institute for building biology (SBM-2008C, 2008) has set the following guidelines as shown in Table 1 below;

Table 1: Building Biology evaluation guideline (source: SBM-2008C, 2008)

Building Biology Evaluation Guidelines (SBM-2015)						
Anomaly			**No**	**Slight**	**Severe**	**Extreme**
High frequency	HF	$\mu W/m^2$	<0.1	0.1-10	10-1000	>1000
	M	nT	<20	20-100	100-500	>500
Low Frequency	E	With grounding cable V/m	<1	1-5	5-50	>50
		Potential-free V/m	<0.3	0.3-1.5	1.5-10	>10

1.2. Architectural Shielding Technique

Electromagnetic shielding strategies are increasingly incorporated in the construction of new buildings and are easily retrofitted in existing constructions to reduce radiation intensity in living or working spaces. Some of these strategies are: selection of building material, conductive shielding paints, architectural shielding meshes and fleeces, shielding textiles and window films.

2. Material and methods

This research was conducted in Addis Ababa, the Capital city of Ethiopia as shown in Figure 1. It is geographically found between 8.980603 latitude and 38.757761 longitude covering an area of 527sqkm. based on the world population review Addis Ababa's current population is estimated 4,793,699. and the population density is estimated 5165 per square kilometer.

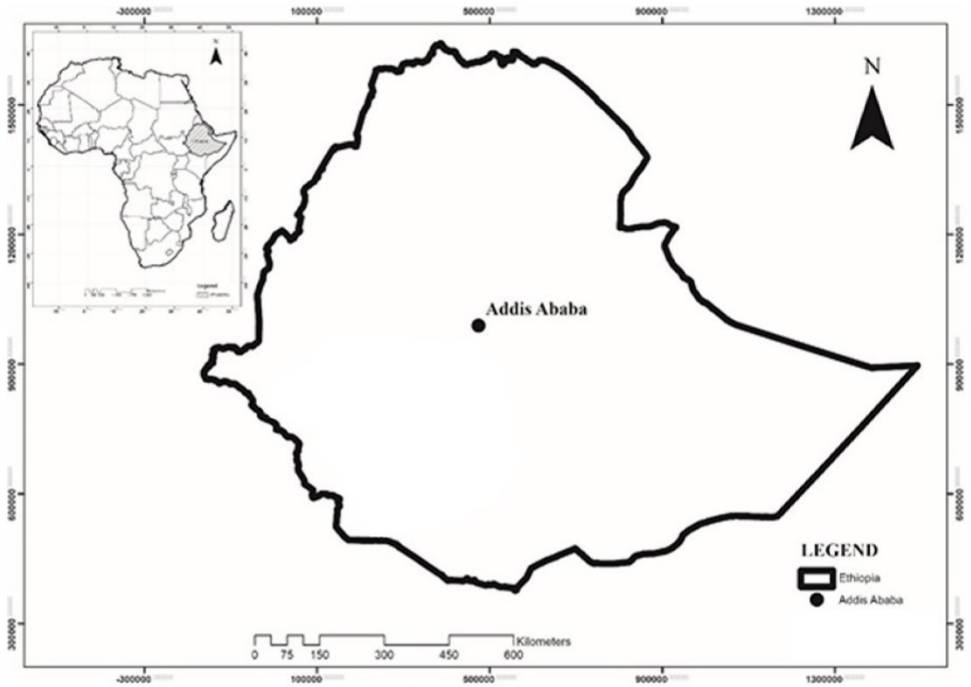


Figure 1: The study area

Primary data is collected through field survey taking measurements around EMF sources like high voltage powerlines transformers substations and cellphone towers. The secondary data is collected from Ethiopian Electric Utility (EEU), Ethio Telecom data base, books, reports and journals.
The intensity of radiation is classified in to four major groups like extreme, severe, slight and no radiation. EMF sources at different horizontal distance is collected and analyzed.

The measurements were taken at various horizontal distances with a height of 1.5m from the natural ground level: For cell phone tower ≤10 m; 20 m; 30 m; 40 m, 50 m; 60 m; 90 m;120 m;150 m ;210 m; 240 m; 310 m; 460 m; 500 m along the antennae direction.
For high voltage transmission line, the measurements were taken at ≤1 m; 5 m; 10 m; 50 m, 100 m; 200 m and 300 m horizontal distance from the cable and For transformers ≤1 m; 5 m; 10 m; 15 m, 20 m; 25 m and 30 m horizontal distance was used.

ArcMap 10.3 GiS software is used to analyze the collected measured readings from the sampled sources. Using the input data as an input the software generated maps showing extreme, severe, slight and no influence areas based on the building biology evaluation guidelines.

As shown in Figure 2, HF 59B HF analyzer, ME 3951A M/E Analyzer, eDG20_G10high frequency attenuator UBB27 HF analyzer was used to measure the intensity of EMF.

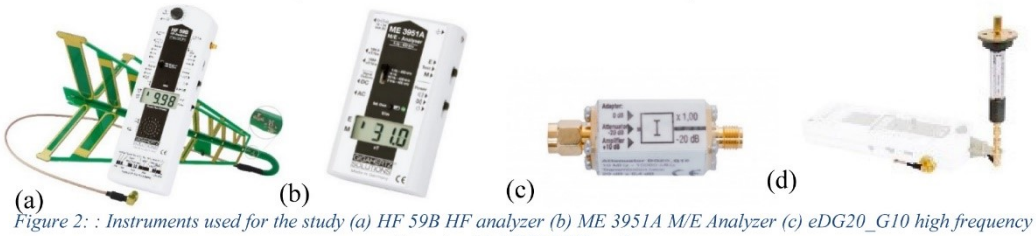


Figure 2: : Instruments used for the study (a) HF 59B HF analyzer (b) ME 3951A M/E Analyzer (c) eDG20_G10 high frequency attenuator (d) UBB27 HF analyzer.

3. Results

I. High voltage power line

High voltage transmission lines (HVPL) have a higher impact at the center of the passing cable. with a magnitude of more than 500nT for the magnetic field and >10V/m for the electric field. As shown in Table 20 from the total site 6288ha is extremely affected and 7823ha part of the city is under severe exposure zone. From the total of 6288ha extremely affected area 132Kv comprises 71% of the total which makes is very dangerous this is because 132Kv connects most of the substations in the city.

Table 2: Impact area by 230kv, 132kv and 45kv HVPL

Power line	Area(ha)			
	Extreme	severe	slight	no
230kv	854.6	414.89	916.91	49430.3
132kv	4515.417	5827.861	2723.08	38550.46
45kv	918.76	1581.022	1569.12	47883.09

Figure 3 (a) and (b) below the western and the south western area is highly affected due to the presence of these powerlines. These affected areas are slightly developed neighborhoods compared to the powerlines passing through the city center and north eastern part of the city where the powerline passes overhead residential areas. The combination of all these powerlines creates 15% extreme, 12% severe and 9% slight radiation zone.

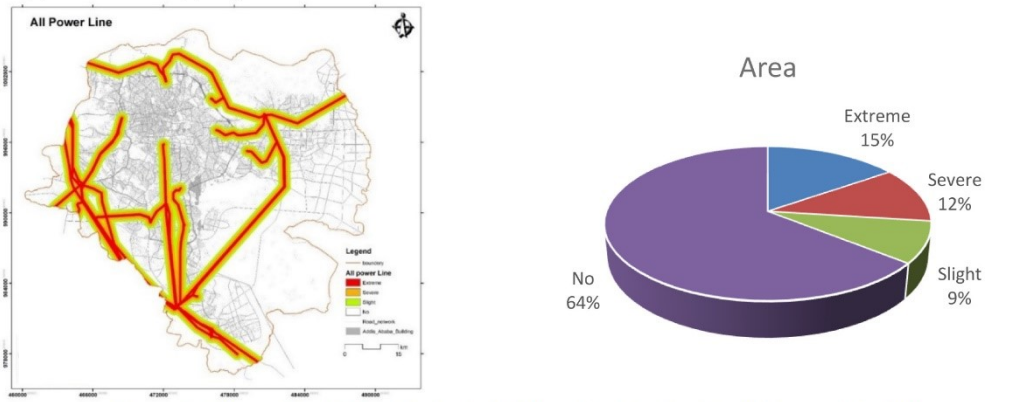


Figure 3 (a) The combined effect of the 3major HVPL and (b) Intensities of radiation caused by HVPL

(a) (b)

II. Transformers

630Kv,315Kv,200Kv and 100Kv generally have a higher extreme radiation reading near the source and goes to normal at 20m distance from the source. 630Kv have a higher reading at the center which is 765v/m for the electric field and 121nT for the magnetic field and the smallest reading is observed at 100Kv transformer with a value of 179v/m for the EF and 8nT for the MF. The magnitude of electric field, magnetic field and high frequency decreases as the distance increases from the source.

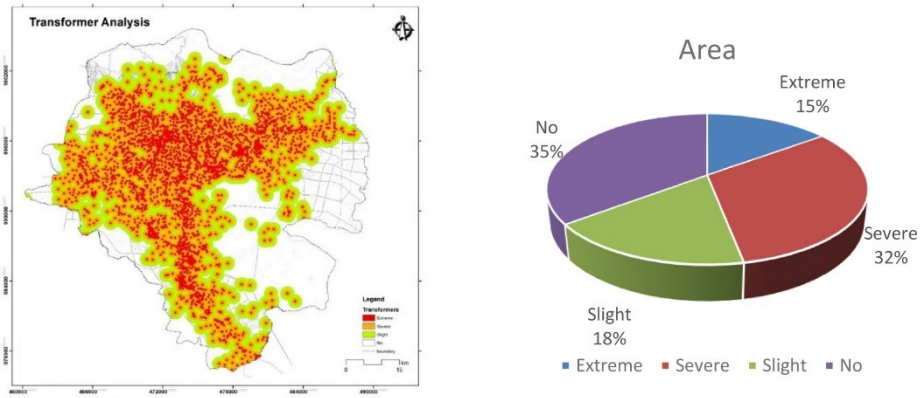


Figure 4: (a) The impact of transformers in terms of radiation intensity and (b) Intensity of radiation caused by transformers

(a) (b)

The presence of 8000transformers in the city creating a radiation pattern which shows how dense a settlement is in a certain area. In order to supply households with enough electricity transformers are positioned based on the population and energy demand of the area. As shown in the Figure 4(a) above populated areas have higher number of transformers resulting higher radiation intensity with in these areas.

As described in Figure 4(b) due to the effect of transformers 15.1% of the city is under Extreme

radiation zone, severe 32%, slight 18% and 35% of the city is free from radiation caused by transformers specially in the eastern and on the tip of the northern parts of the city.

III. Substation

Regarding Substations their total radiation effect is modelled in Figure 5(a) below. Comparatively from other EMF sources they have lower coverage of area. For instance, the extreme radiation zone caused by these stations is 195ha, severe 1095.32ha and slight radiation covering 1753.6ha area of the city. As described in Figure 5(b) - 94% of the city is free from the radiation caused by substations and only 0.3% of the area is under extreme radiation zone

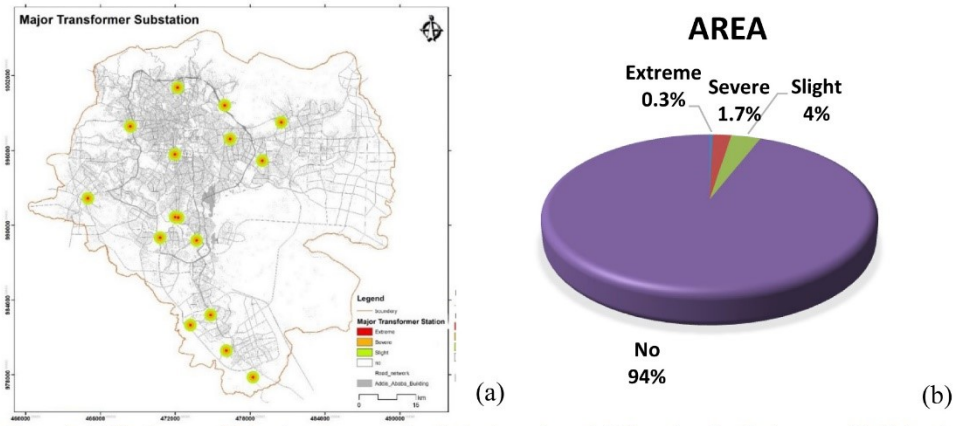


Figure 5: (a) The impact of Substations in terms of radiation intensity and (b) Intensity of radiation caused by Substations

IV. Cellphone tower

12% from the total area of the city of Addis Ababa is under extreme radiation zone caused by cellphone towers, 31% of the city is severely affected. Places with no effect from cellphone towers contribute only 27% covering area of 13806.79ha and only 27% of the area is free from cellphone tower radiation as shown in Figure 6 (a) and (b) below.

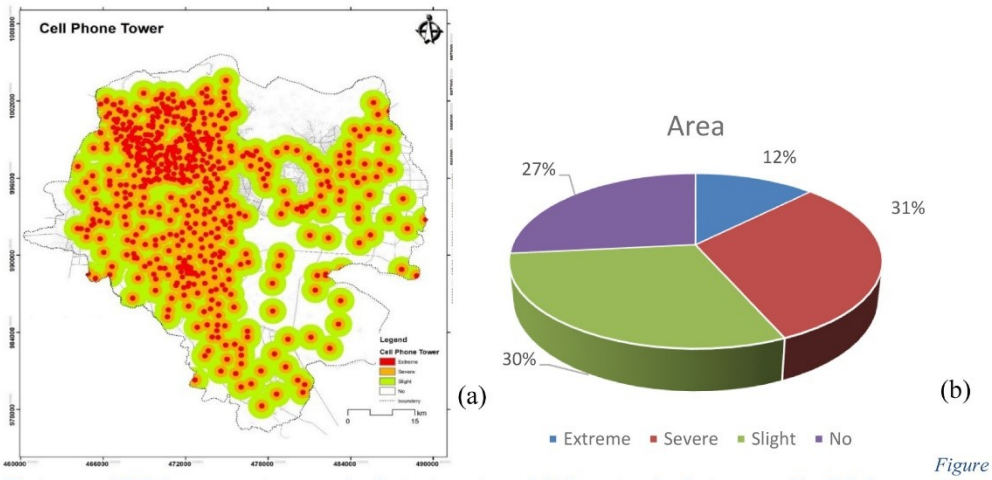


Figure 6: (a) The impact of Cellphone towers in terms of radiation intensity and (b) Intensity of radiation caused by Cellphone towers

V. Overall impact of sources

The effect of cellphone towers, substations, transformers and high-power transmission lines are combined together with their radiation intensity as shown in Figure 7 (a)and(b) below.

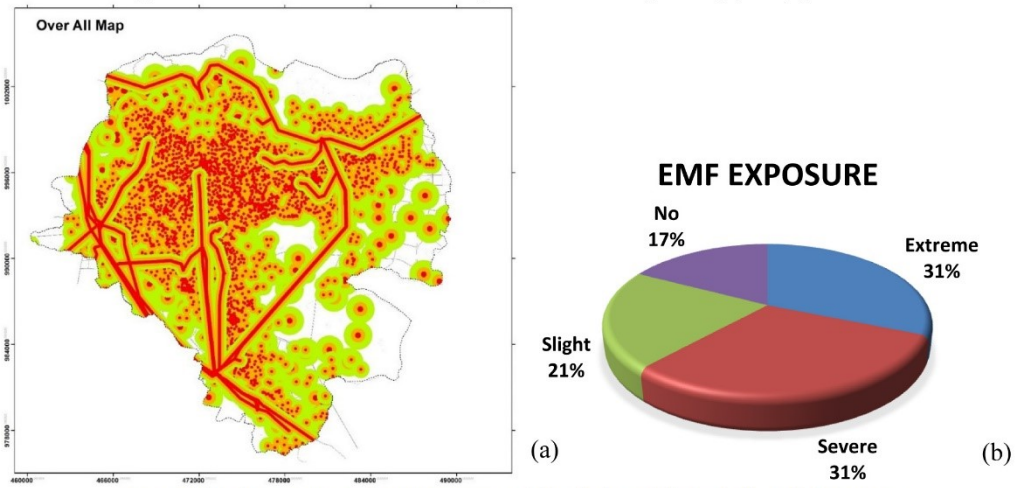


Figure 7(a) Radiation pattern of existing sources in Addis Ababa and (b) Total effect of EMF sources

The total effect of high powerline substation, cellphone tower and transformer are summarized in Table 3.

Table 3: Total effect of EMF sources

Intensity	Area (ha)
Extreme	16235
Severe	15843
Slight	10906
No	8967.992

83% of the city is exposed to EMR from minimum slight exposure to the maximum extreme exposure as shown in Table 3 above. Buildings located in these areas have to be able to deter EMF waves from getting inside functional spaces especially in areas people spend most of their time like bed rooms.

Buildings with in the EMF hotspot areas

Measurements have also been taken on buildings around a powerline and a substation. One of the building is a kindergarten with in close range to Kality I substation it's called salo gora mebrat hail kindergarten and the second one eucalyptus wood shop which is made out of eucalyptus and metal sheet as a facade is found under a 132kv powerline.

Residential buildings, farm houses, factories, Schools for kindergartens have also been observed next to the kality I power substation which is very dangerous specially for children living in these areas where the negative health effect could be seen in children with a short period of time.

4. Discussion

There may be a difference in the type of the EMF source on the ground due to new demands like a small voltage transformer could get replaced by a higher one due to a new demand or advanced technological equipment's which is the case for cellphone towers where a 3G base station could get

replaced by a 4G antennae, this can affect the general result of the study.

Transformers generally have a higher extreme radiation reading near the source and goes to normal at 20m distance from the source. The result for the intensity of transformers supports the claims of K.E. Lotz (nd) that a transformer could have an impact up to a distance of 25m, but unlike K.E. Lotz this study has observed the intensity of radiation is strong in all direction.

The result doesn't support the minimum approach distance set by OSHA (OSHA 1926.1408) for HVTL. The study suggests that a minimum of 50m should be set as a guideline for a precautionary purpose since there is a very high intensity which is extreme up to 50m. The result support the claims of (Usikalu, 2015) and (Djalel, 2014) on the intensity of HVTL from the source.

The results indicate that extremely low frequency EMF and radiofrequency EMF is significant in the city of Addis Ababa having an extreme and severe EMF exposure well over the safe level which is set by the building biology evaluation guide line.

According to The U.S. National Institute of Standards and Technology (NIST) 200mm concrete block have an attenuation capacity of 8db under 500MHz and 18db under 8GHz which makes it weak, meaning that the material has the capacity to block only 22% of the outdoor EMF value, the unblocked 78% of the outdoor EMF value will affect the user causing severe health issues. Within the context of Addis Ababa HCB concrete block is widely used and buildings under EMF exposure have very weak response to the radiation which in turn affects users spending most of their time in that building. Next HCB concrete block single layered glass is used for openings which have 87% average maximum transmission field meaning the attenuation capacity is 13% this makes the internal space very much vulnerable to the radiation coming from a nearby source.

5. Conclusions

Neighborhoods which are dense, urbanized and rich in infrastructure do have a higher concentration of non-Ionizing EMF sources compared to new settlement areas as shown in Figure 40. these sources are located very close to buildings due to poor planning decisions and lack of implementing guideline which are set for HVTL. HVTL show an extreme category of radiation up to a distance of 50m, a higher reading is observed at this distance from 230Kv HVTL1999V/m for the electric filed and 413nT for magnetic field. The intensity goes from slight effect to no effect at a distance of 200m. Substations reach a safe exposure limit at a distance of 400m from the source, cellphone towers need 500m and a transformer 20m.

Based on the result 32,078ha of land which is 62% of the total area is a vulnerable area for a building to EMF. The remaining 21% is under a slight exposure level and the rest 17% is under no significant EMF exposure level. Buildings located in these areas have to be able to deter EMF waves from getting inside functional spaces specially areas where people spend most of their time like bed rooms.

Non-Ionizing EMF sources are present in most parts of the city leaving buildings under vulnerability which directly affects users causing health problems. Vulnerable buildings facing direct exposure of non-ionizing EMF can experience an extreme radiation environment if they are found in close range from the source.

Commonly used wall building material in the city is HCB block and it has a maximum transmission capacity of 78%, Whereas a window has 87% transmission level which means the outdoor exposure level is almost the same internally. This makes the building around the radiating source a sick building and needs treatment to keep the health of the user safe.

6. Recommendation

Ethiopia as a country don't yet have a clear standard for non-ionizing EMF sources except high voltage transmission lines which have a buffer zone standard set by Ethiopian energy agency adopted from OSHA standard. Even though This standard works only for HVPL, the safe distance set by this standard is under the influence of non-ionizing EMF influence so anew standard should be in place to protect people from long term exposure.

Ethiopian radiation authority has recently opened a directorate office dedicated for non- ionizing radiation which supervises and controls devices emitting these kinds of radiation. There are multiple sources of EMF radiating devices in Addis Ababa which have to be carefully recorded and ensure the right kind of protective mechanism is used.

Special attention should be given for the location of schools, day cares and health facilities to be built away from the radiation zone. Based on the finding of the study the following recommendations are given to solve the increasing EMF radiation for a healthy natural environment and to treat buildings with a capacity to protect users from harmful radiation

- Ethiopia as a country should set a standard or adopt the best international practice which limits the level of EMF radiation in all places specially in sensitive area like ecologically significant sites, schools.
- Creating awareness about non-ionizing EMF radiation should be the priority to solve the problem without igniting fear among people
- Smart technological solutions have to be incorporated to solve the need for a better infrastructure without causing a negative impact on the human health
- Buildings which are currently found with in EMF hotspots have to be retrofitted with protective equipment's to shield the radiation.
- Some of the techniques which can be applied to vulnerable buildings include
    - To use conductive shielding paints
    - Applying Architectural shielding meshes and fleeces
    - To use shielding textiles for windows and to use window shielding films
    - Adopting tress and vegetation on the side of the EMF source
    - using the vulnerable side of the building for service functions.

7. Reference

Abdul Latif, S., Karim Suhag, A., Sohail Ahmed Larik, R., Ali Mallah, G., Muhammad Ali Talpur, M., Saeed, A., Ali Larik, F., & Karim, S. (2016). AdverseEffects of Cell Phone Radiation on Human Health Article in. *International Journal of Scientific and Engineering Research*, *7*(10), 480–486. http://www.ijser.org

Ahmad, A., Ariffin, R., Mohn Noor, N., & Sagiruddin, M. A. (2011). 1.8 GHz Radio Frequency signal radiation effects on human health. *Proceedings - 2011 IEEE International Conference on Control System, Computing and Engineering, ICCSCE 2011*, 546–550. https://doi.org/10.1109/ICCSCE.2011.6190586

Ameen, H. (n.d.). *Reduction of Cell Phone Electromagnetic Radiation Effect on Human Body*. http://www.ijsciences.com

Babatsikou, F. P. (2011). The Sick Building Syndrome (SBS). In *HEALTH SCIENCE JOURNAL ® VOLUME* (Vol. 5, Issue 2). http://www.nsc.org/ehc/indoor/sbs.

Busby, C., & Fucic, A. (2006). Ionizing radiation and children's health: Conclusions. *Acta Paediatrica, International Journal of Paediatrics*, *95*(SUPPL. 453), 81–85. https://doi.org/10.1080/08035320600886547

Clark, R. B. (1985). Fetal and neonatal effects of epidural anesthesia. *Obstetrics and Gynecology Annual*, *14*(September), 240–252.

Djalel, D. (2014). Study of the Influence High-voltage Power Lines on Environment and Human Health (Case Study: The Electromagnetic Pollution in Tebessa City, Algeria). *Journal of Electrical and Electronic Engineering*, *2*(1), 1. https://doi.org/10.11648/j.jeee.20140201.11

Doganay, G. (2015). *Electromagnetic_Radiation history*.

EVE, I. S. (1957). The effect of radiation on human heredity. *Journal of the American Medical Women's Association*, *12*(7), 199–201.

India, G. of, & Telecommunications, M. of C. & I. T. D. of. (n.d.). *Inter-Ministerial Committee on*.

Mitra, R., Mazumder, M., Pal, K., & Jana, S. (2014). a Study on Effect of Mobile Phone Radiation on Human Health. *Exploratory Animal and Medical Research*, *4*(2), 246–252.

Neufert. (n.d.). *Neufert_3_edition-engl.pdf*.

Odemer, R., & Odemer, F. (2019). Effects of radiofrequency electromagnetic radiation (RF-EMF) on honey bee queen development and mating success. *Science of the Total Environment*, *661*, 553–562. https://doi.org/10.1016/j.scitotenv.2019.01.154

Pachuau, L., & Pachuau, Z. (2014). Study of Cell Tower Radiation and its Health Hazards on human body. *IOSR Journal of Applied Physics*, *6*(1), 01–06. https://doi.org/10.9790/4861-06110106

Panagopoulos, D. J., & Chrousos, G. P. (2019). Shielding methods and products against man-made Electromagnetic Fields: Protection versus risk. *Science of the Total Environment*, *667*, 255–262. https://doi.org/10.1016/j.scitotenv.2019.02.344

Pūtaiao, S. L. H. – P. A. (2021). *Waves as energy transfer*. https://www.sciencelearn.org.nz/resources/120-waves-as-energy-transfer

Rahman, K. A. (n.d.). *Mobile_Phone_Radiation_Effects_on_Human*. Khanataur92@gmail.com

Rifai, A. B., & Hakami, M. A. (2014). Health Hazards of Electromagnetic Radiation. *Journal of Biosciences and Medicines*, *02*(08), 1–12. https://doi.org/10.4236/jbm.2014.28001

Saim, K., Zerrin, K., & Selçuk, S. (2010). Electromagnetic Pollution in Buildings and Its Effects on Human Health. *The International Conference on Electrical Engineering*, *7*(7), 1–9. https://doi.org/10.21608/iceeng.2010.33047

Singh, P. (2013). *Wireless Radiation : a Threat To*. *1*(2), 13–19.

Spurny, F., & Dachev, T. P. (2009). New results on radiation effects on human health. *Acta Geophysica*, *57*(1), 125–140. https://doi.org/10.2478/s11600-008-0070-6

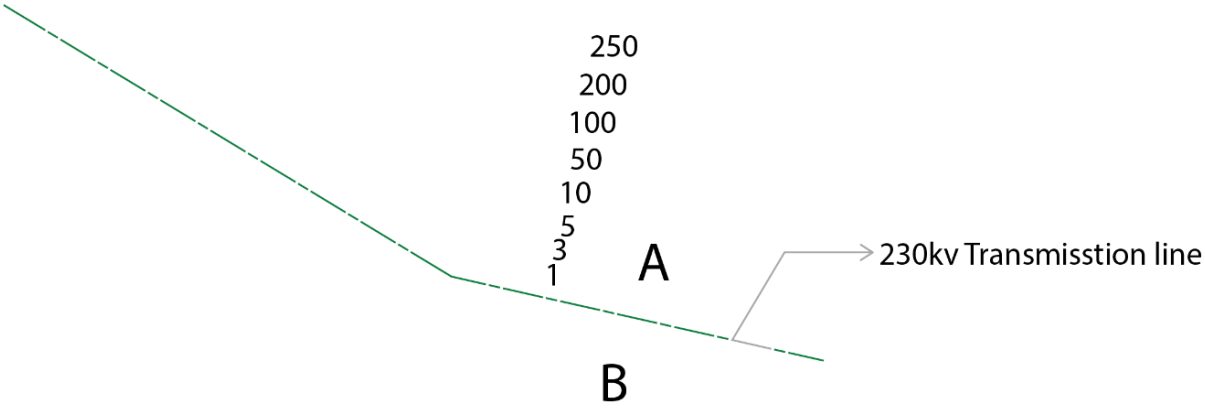
Vasile, M., Caligiuri, L. M., Lamonaca, F., Nastro, A., & Beiu, T. (2014). Nonionizing Electromagnetic Radiation (Emf) and Their Influence on the Health of Living Organisms. *Romania. All Rights Reserved ORIGINAL PAPEER Academy of Romanian Scientists Annals-Series on Biological Sciences*, *3*(2), 5–18.

Vladimir Sinik, & Zeljko V.Despotovic. (2012). "Influence of Electromagnetic Radiation on Health of People.Limits for Exposure to EMF". *PROCEEDINGS of the XI International Scientific Symposium INFOTEH- Jahorina 2012*, *11*(March), 417–421. http://www.infoteh.rs.ba/rad/2012/KST-4/KST-4-5.pdf

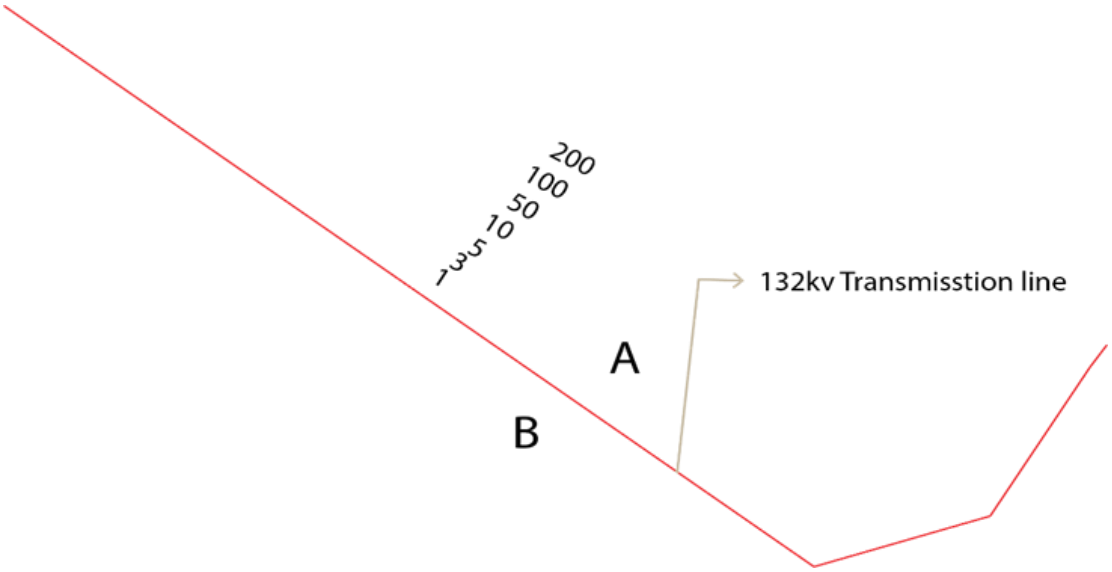
Zamanian, A., & Hardiman, C. (2005). *Electromagnetic Radiation and Human Health: A Review of Sources and Effects*. *July*.

Zerek, A. R., Alahimer, S., & Elfituri, M. M. M. (2019). *Investigation of EMF Radiation From GSM Base Stations and Mobile Antenna Towers in Different Locations – Libya*. *7*, 32–36.

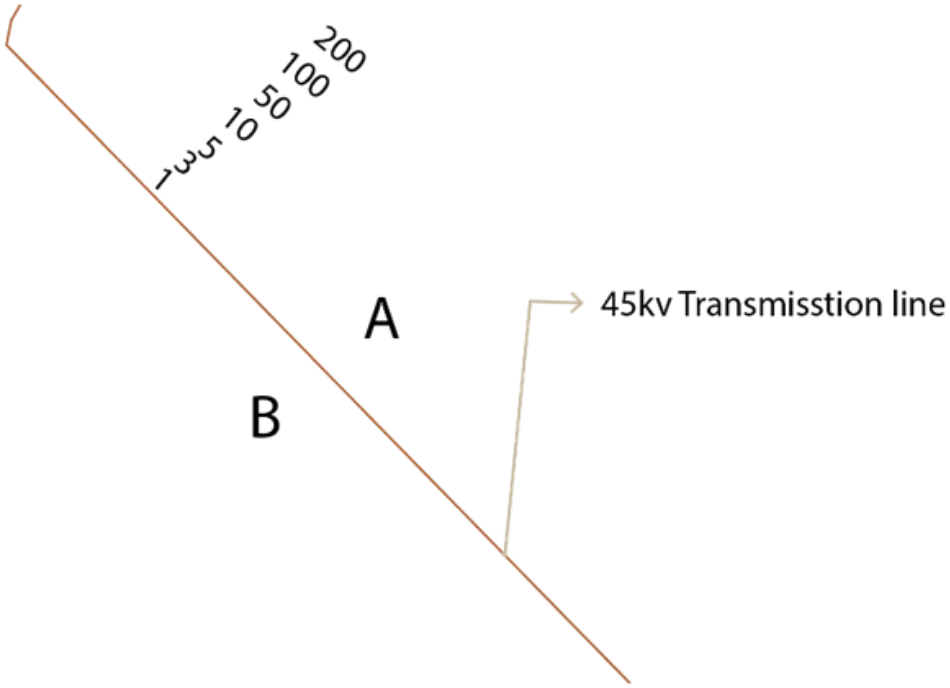
Annex 2: *230Kv HVTL measured sides A and B*



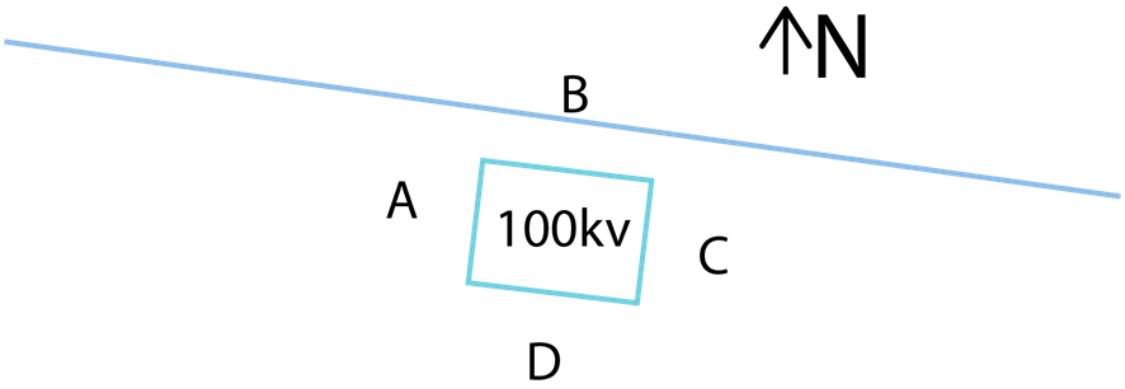
Annex 3*: 32Kv HVPL measured sides A and B*



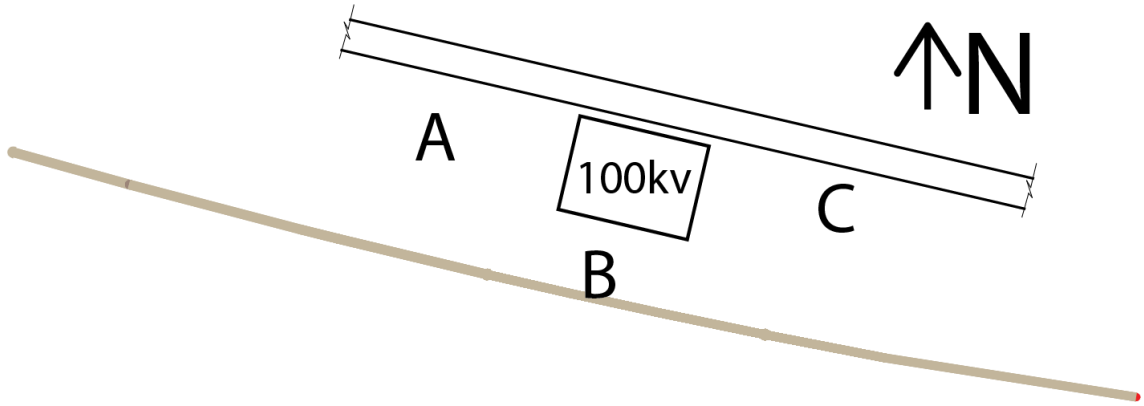
Annex 4: *45Kv HVPL measured sides A and B*



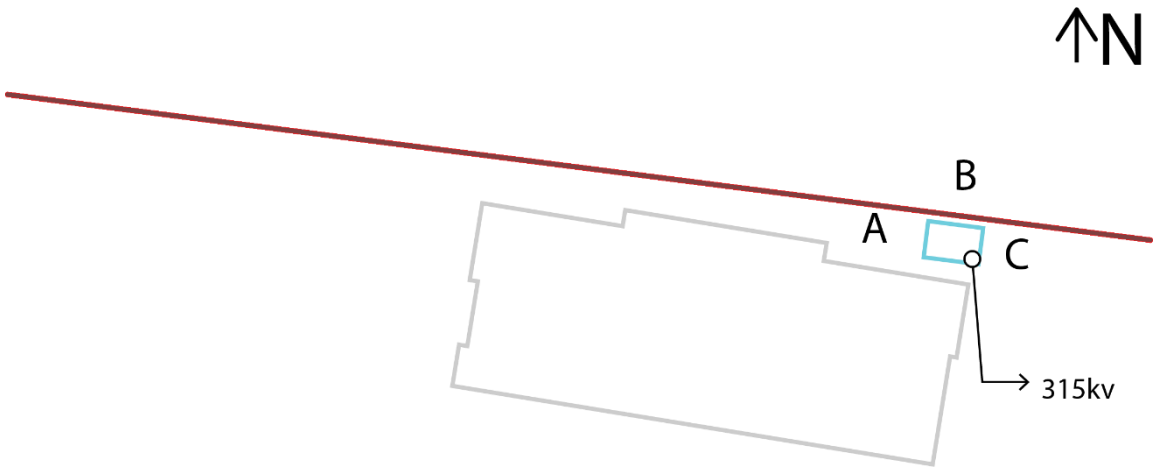
Annex 5: 100Kv transformer measured at A, B, C and D side



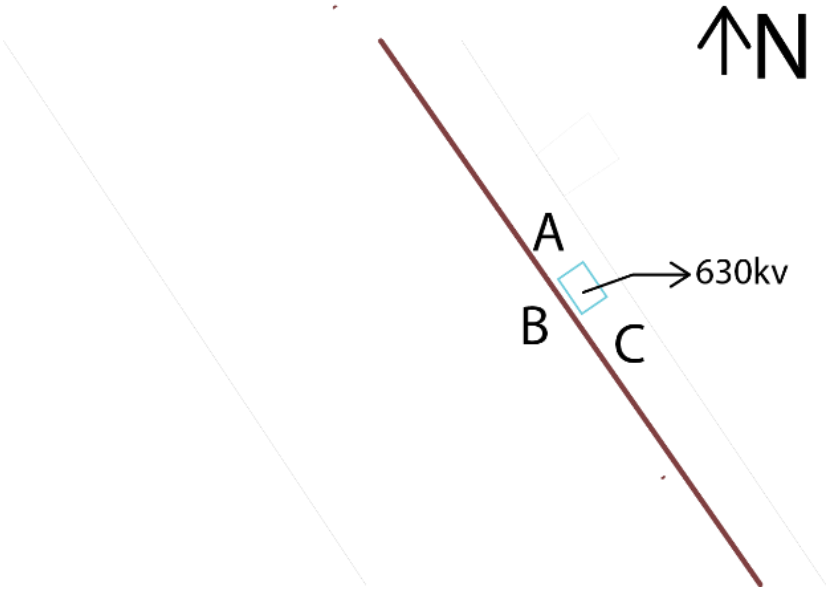
Annex 6: *100Kv transformer measured sides A, B and C side*



Annex 7: *315Kv transformer measured in A, B and C side*

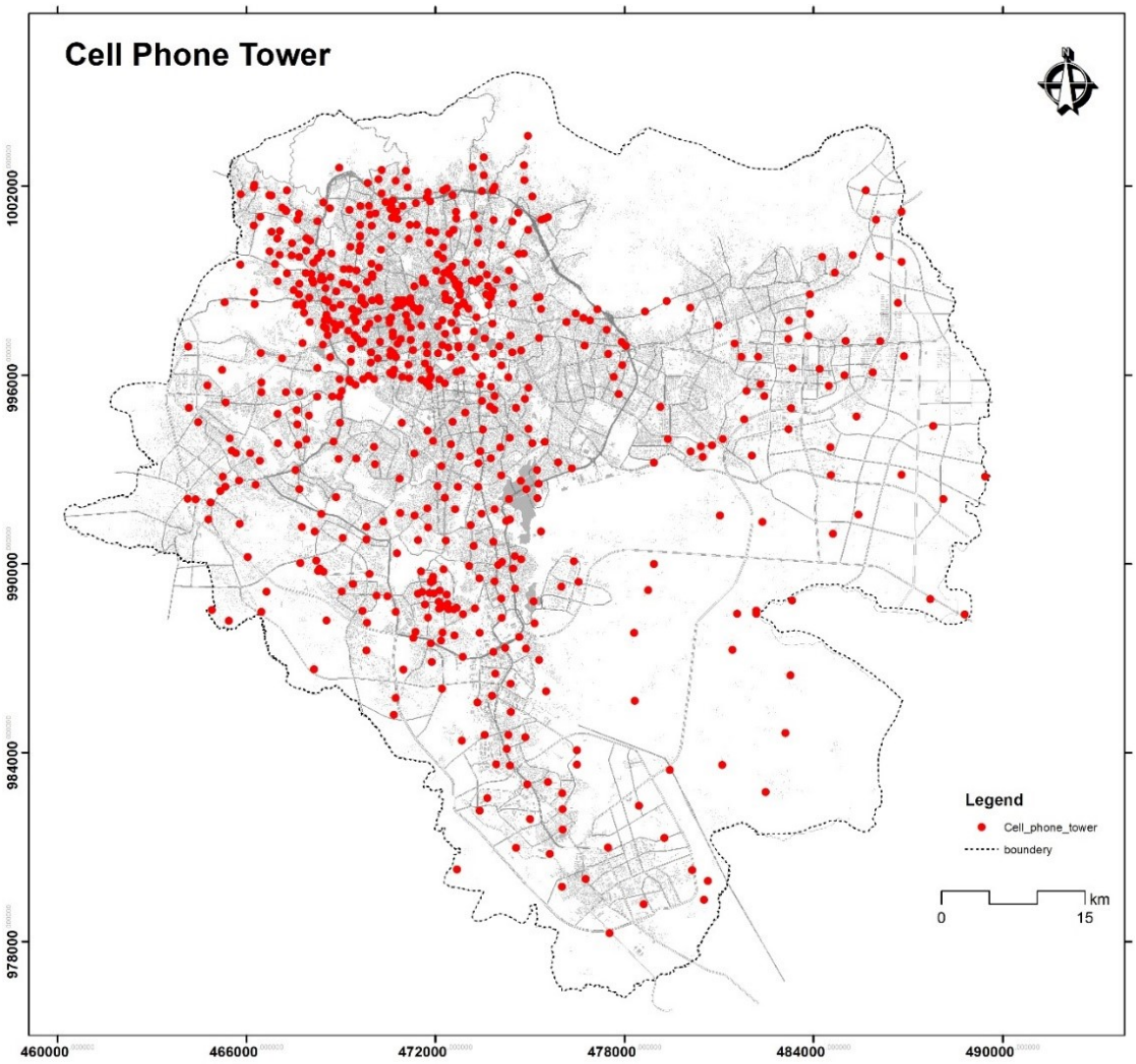


Annex 8: *315Kv transformer measured in A, B and C side*

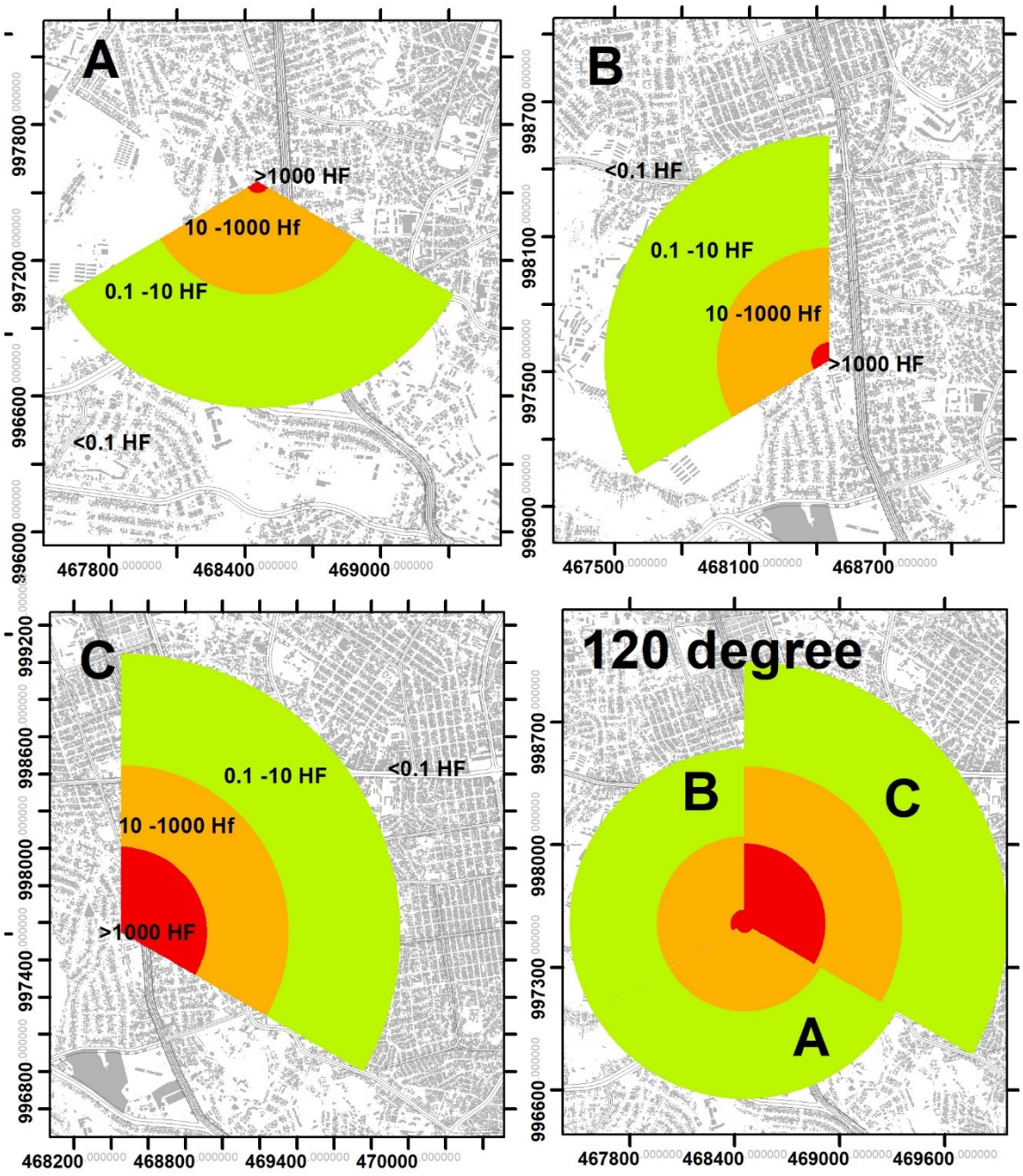


Annex 9: *Akaki I substation measured sides of the substation*

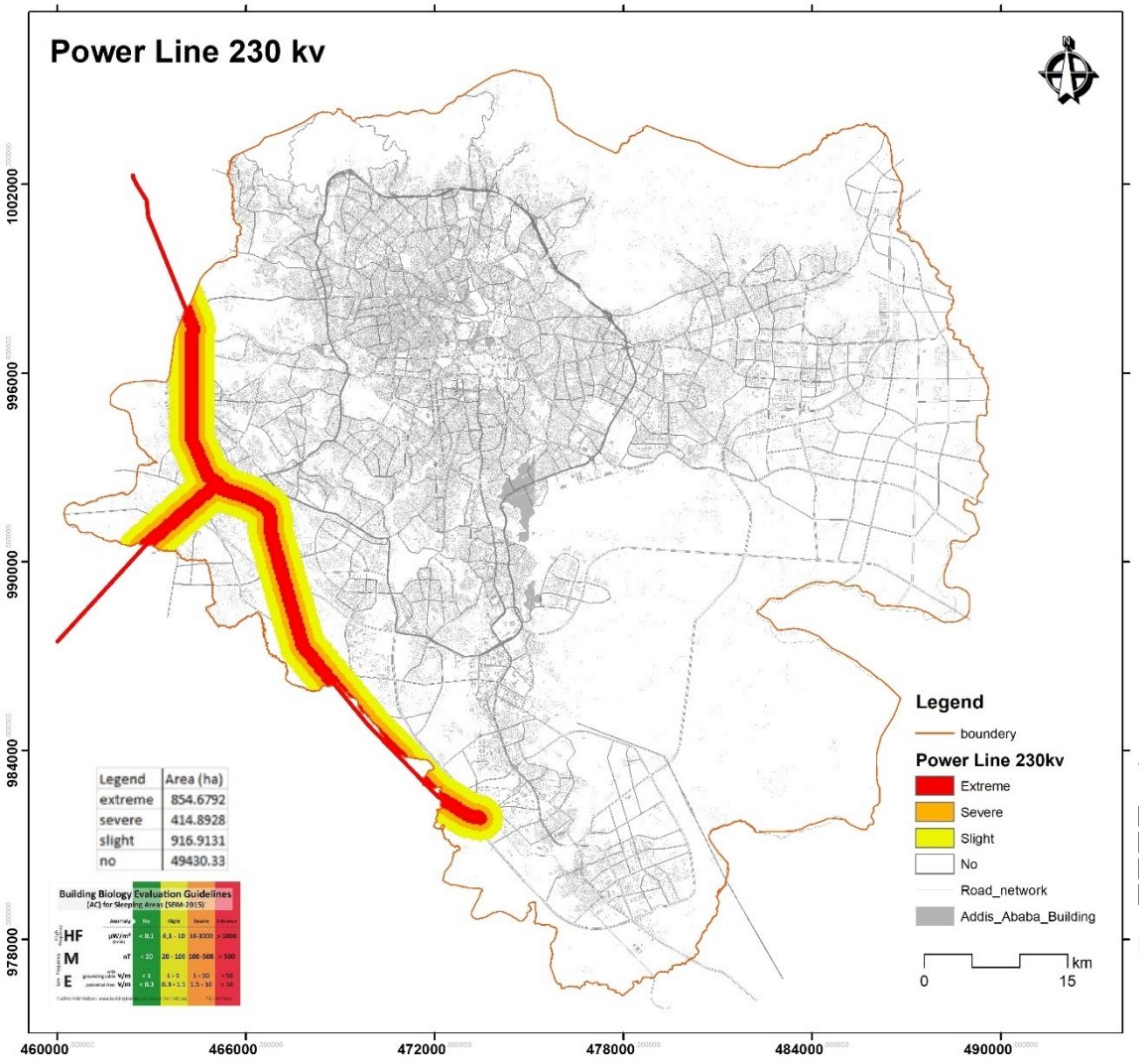
Annex 10: *Location of cellphone towers with in the study area*



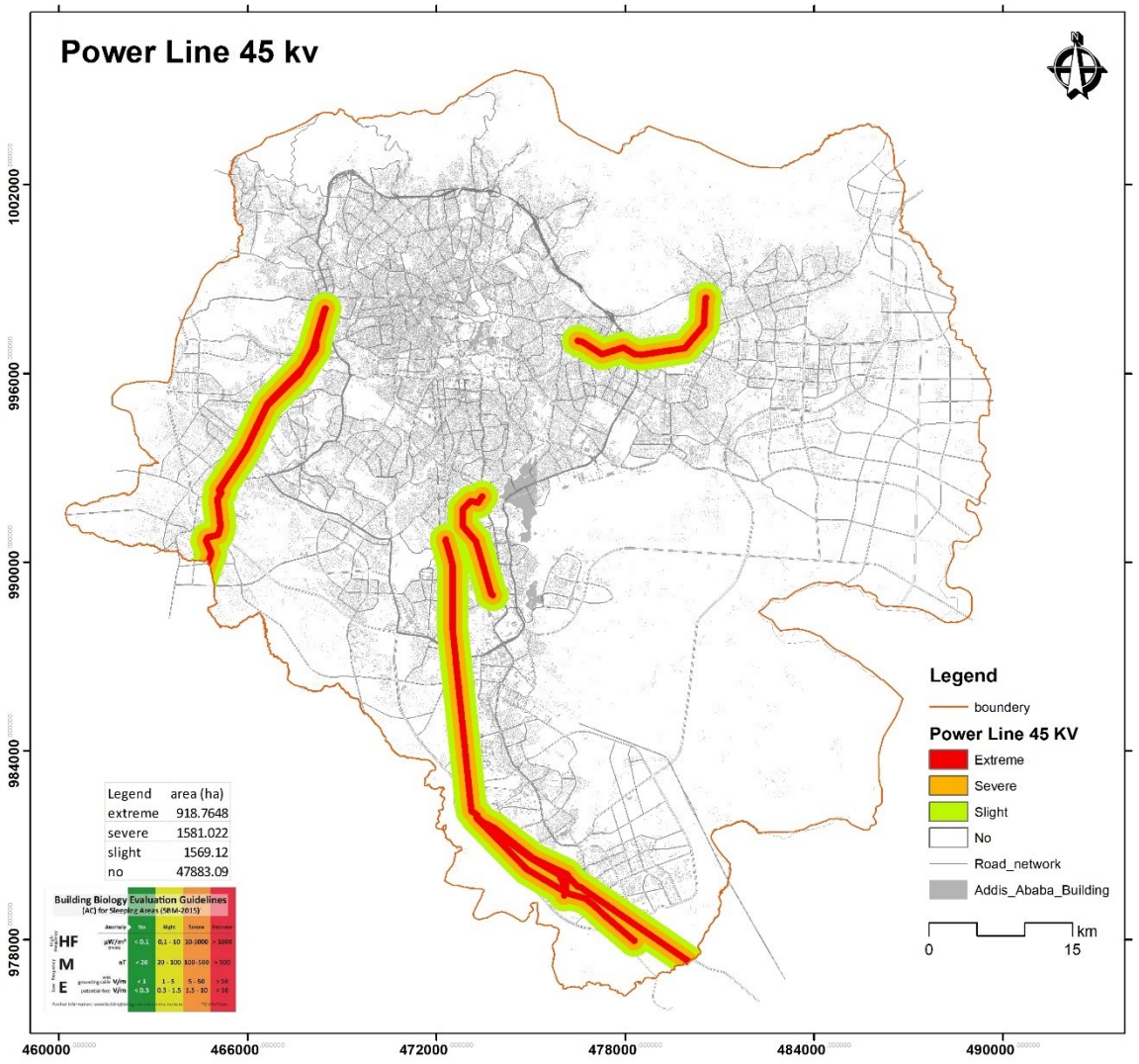
Annex 11: *Intensity of micro waves along the direction of the antenna*



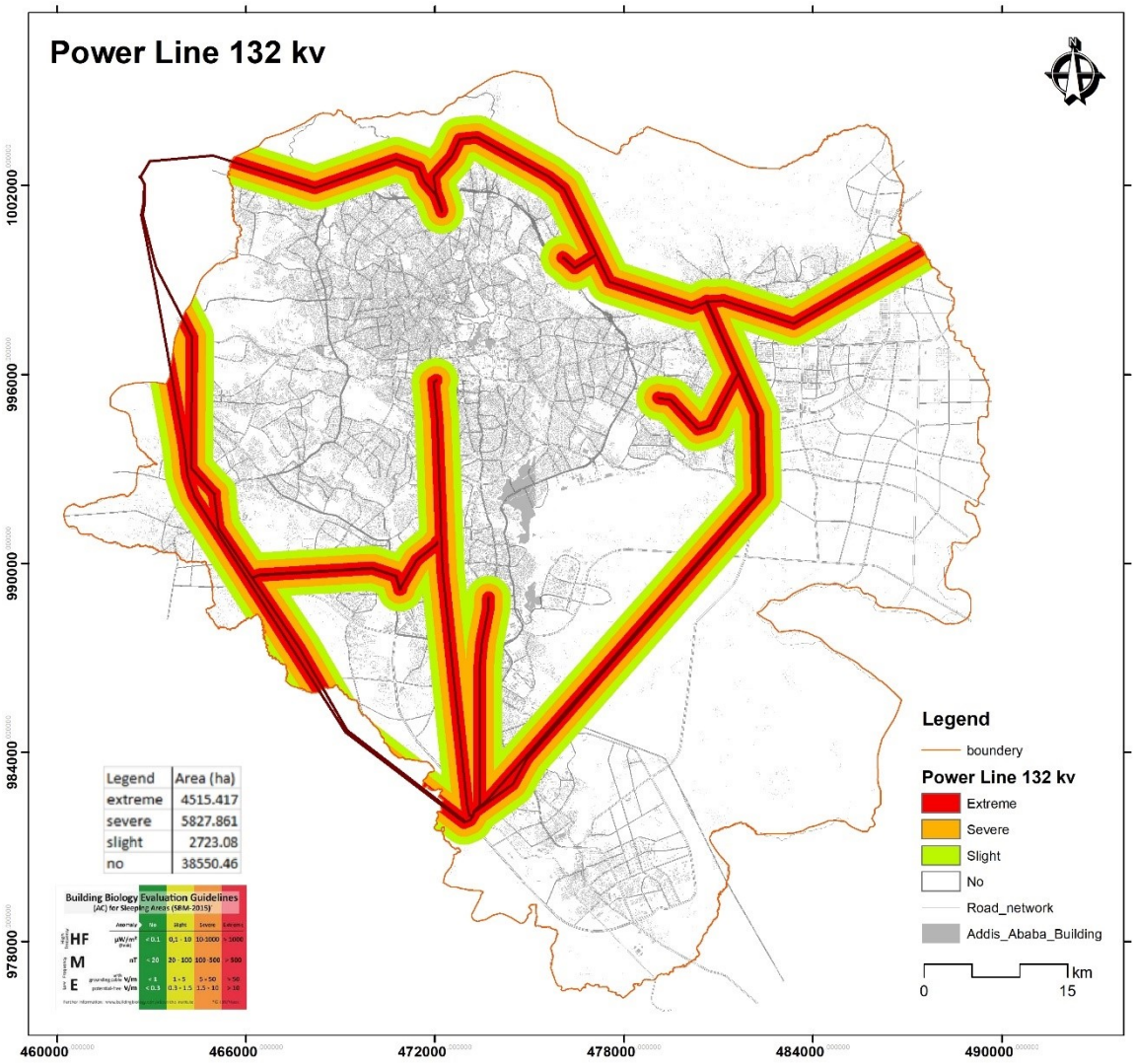
Annex 12: *The intensity of radiation along 230Kv HVTL*



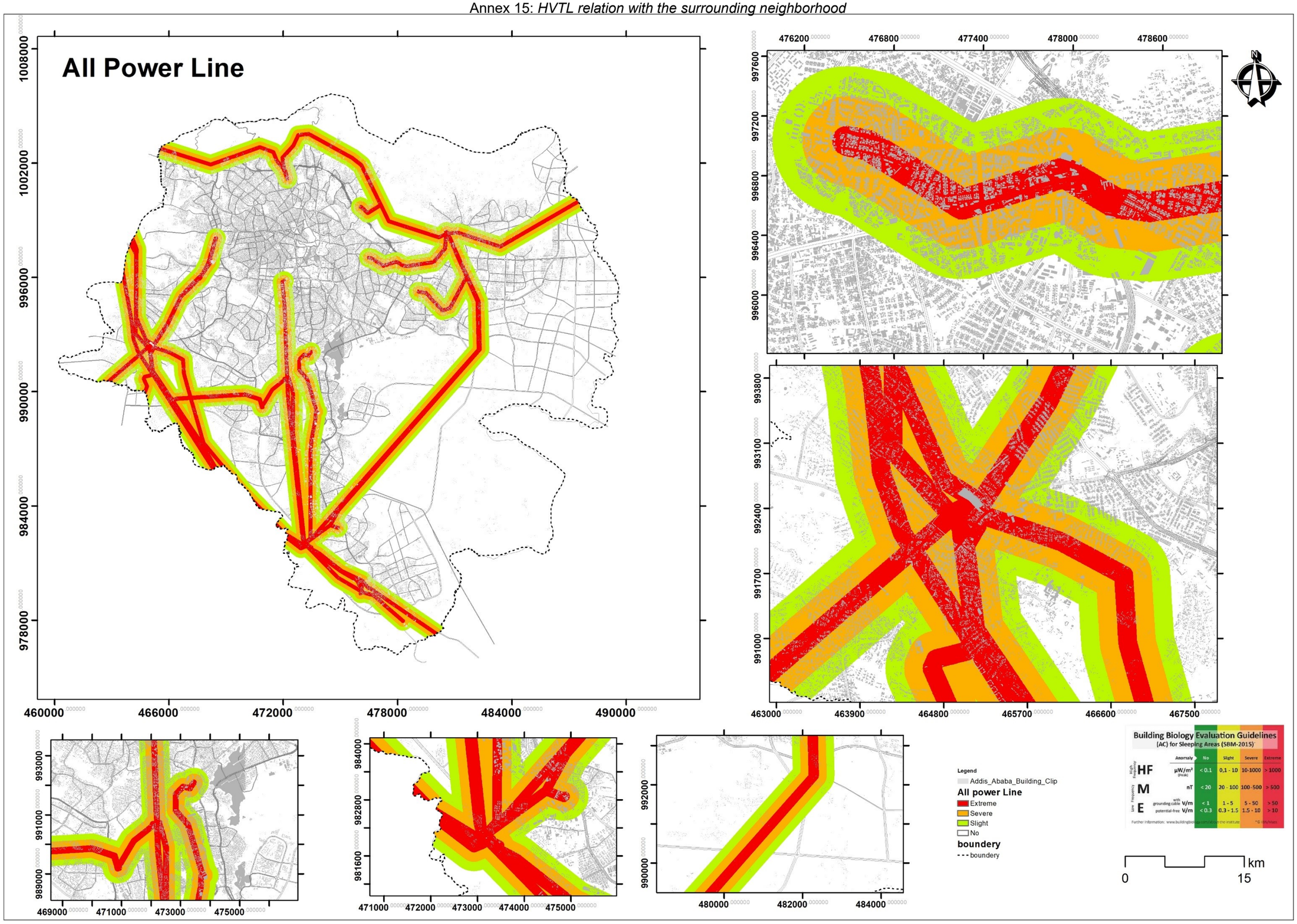
Annex 13: *The intensity of radiation along 45Kv HVTL*



Annex 14: *The intensity of radiation along 132Kv HVTL*



Annex 15: *HVTL relation with the surrounding neighborhood*



Annex 16: *Transformer relation with the surrounding neighborhood*