MEASUREMENT AND ANALYSIS OF MUSICAL SOUND LEVEL FROM A MOBILE PHONE

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OAMEN JUDE EROMOSELE,

PSC1607900

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CERTIFICATION

We the undersigned, certify that this work done by OAMEN JUDE EROMOSELE, with matriculation number PSC1607998 in the department of physics, faculty of physical sciences, university of Benin, Benin City, Nigeria. In partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc) physics is adequate in scope and in quality.

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Prof. O.D. Osahon **Date**

Project Supervisor

____________________ _______________

Prof. M.O. Alile **Date**

Head of Department Date

____________________ __________________

External Supervisor **Date**

DEDICATION

This project is dedicated to myself.

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ACKNOWLEDGEMENT

I acknowledge Prof. O.D. Osahon for his guidance and love during the process of carrying out this research work.

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ABSTRACTS

Global statistics estimated that at the end of 2018, there were 9.3 billion mobile phone subscriptions, today virtually everyone has a cell phone. Should these phones constitute a health hazard it would be a global pandemic. Sound is part of our daily life and sounds produced from phones are closest to us. This study was undertaken to measure the frequency spectra of the sound produced by three phones commonly used in Nigeria to determine if sound level exposures from these phones should warrant the inclusion of a hearing protection programme. Data was collected and evaluated to ascertain the impact of sound from three different types of phones: GSM mobile phone made by Nokia (Nokia 1280), an android phone made by Infinix (Infinix Note 8) and an Iphone made by Apple (iPhone X), using a UT353 BT Mini Sound Meter (Bluetooth Version). The results showed that the total sound pressure levels for Nokia 1280 was 109.63*dB* and average of 98.83*dB*. This value exceeds the NIOSH allowable noise exposure levels of 85*dB* thus there is a cause for concern in using Nokia 1280 to play music for a long time. While the total sound pressure levels for Infinix Note 8 was 96.79*dB* which was slightly higher than the NIOSH allowable noise exposure levels of 95*dB* for 1 hour but on average it was found to be in line with the allowable noise exposure levels of 85*dB*. A similar lower sound level was observed in the Iphone X, an average of 77.25*dB* and a total of 88.05*dB* was recorded within an hour period. This is very safe

according to the NIOSH Recommendations which stipulates that only over a 4-hour period of continues sound can this value become a potential health risk. It was concluded that phones produced more recently takes into consideration the sound pressure levels and are current design following the NIOSH Recommendations, while older phone may pose a health risk as they had higher values of sound pressure levels. It was therefore recommended that more research need be carried out on the sound level measurement of different phones as this will inform buyers and producers of these devices on the health ramifications in using these phones.

CHAPTER ONE

GENERAL INTRODUCTION

1.0. Background of study

Sound can be defined as the form of energy that is produced when things vibrate. It propagates as an acoustic wave through solid, liquid and gaseous states. Any study of sound should begin with the properties of sound waves. There are two basic types of wave, transverse and longitudinal, differentiated by the way in which the wave is propagated. In a transverse wave, such as the wave generated in a stretched rope when one end is wiggled back and forth, the motion that constitutes the wave is perpendicular, or transverse, to the direction (along the rope) in which the wave is moving. An important family of transverse waves is generated by electromagnetic sources such as light, radio, in which the electric and magnetic fields constituting the wave oscillate perpendicular to the direction of propagation. Sound waves are longitudinal as it travels parallel to the direction of the wave.

Mobile phones play an important role in providing the fastest means of communication amongst populations globally, yet its usage is also associated with potential public health hazards. It transmit and receive signers through radio wave, and this signal is converted to sound wave which we hear from the speakers of the phone. At high and continues dosage these sound waves can constitute a health concern.

1.1. Introduction

Sound is all around us, it is a common part of everyday life[1]. Sound is a form of energy, just like electricity and light. A sound is made when air molecules vibrate and move in a pattern called waves, or sound waves or pressure waves[2]. This vibrations set particles in the surrounding medium (gases, liquids and solids as well as in more complex fluids like e.g. organisms and tissues.) in vibrational motion, thus transporting energy through the medium[3,4]. Since the particles are moving in parallel direction to the wave movement, the sound wave is referred to as a longitudinal wave[2]. The result of longitudinal waves is the creation of compressions and rarefactions within the medium figure 1.1.

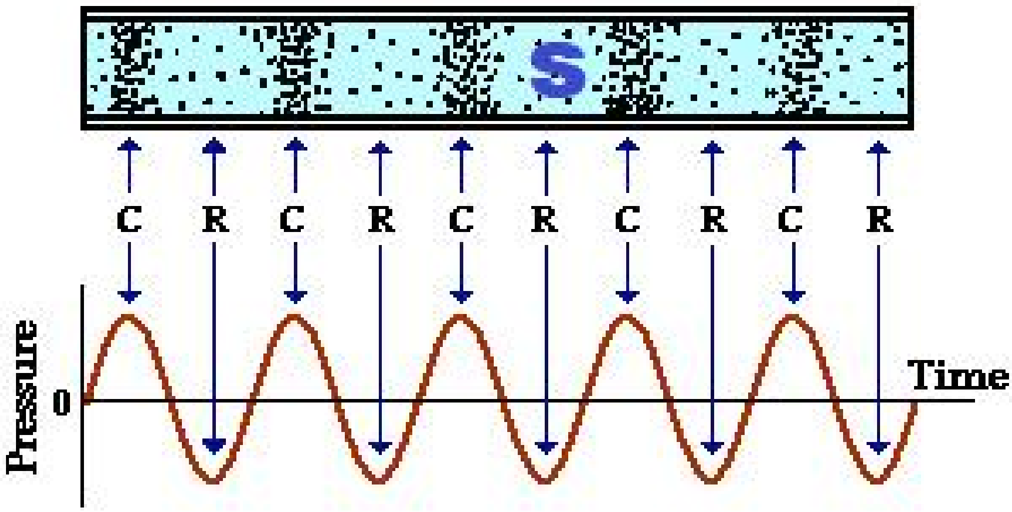

Figure 1.1: Wave form of sound, showing Sound wave movement in a medium [S] Compression [C] and Rarefactions [R]. Source:[5]

Sound should have Wavelength, Amplitude and Frequency for it to be said to have occurred.

1.2. Wavelength

When a wave is created, the distance between one compression and the next compression is called the wavelength (figure 1.2). The faster the sound waves pass a given point, the shorter the wavelength and the higher the frequency[6]. Sounds of all frequencies travel at the same rate in the same medium. (Sound in dry air at 0 C travels at the rate of 1200 kilometers per hour, or 331.6 MPS; in a solid medium the sound waves travel faster.)[5].

1.3. Amplitude

The vibrations can "squeeze" the air molecules together very hard or very gently. This squeezing is called "amplitude". The amplitude of a sound can also be viewed as the amount of work done to generate the energy that sets the particles in motion, it is reflected in the degree of displacement[6] figure 1.2. The more we push an object to make it vibrate, the larger the vibrations and the louder the sound, or the greater the amplitude. Sound waves with the same frequency can have different amplitudes.

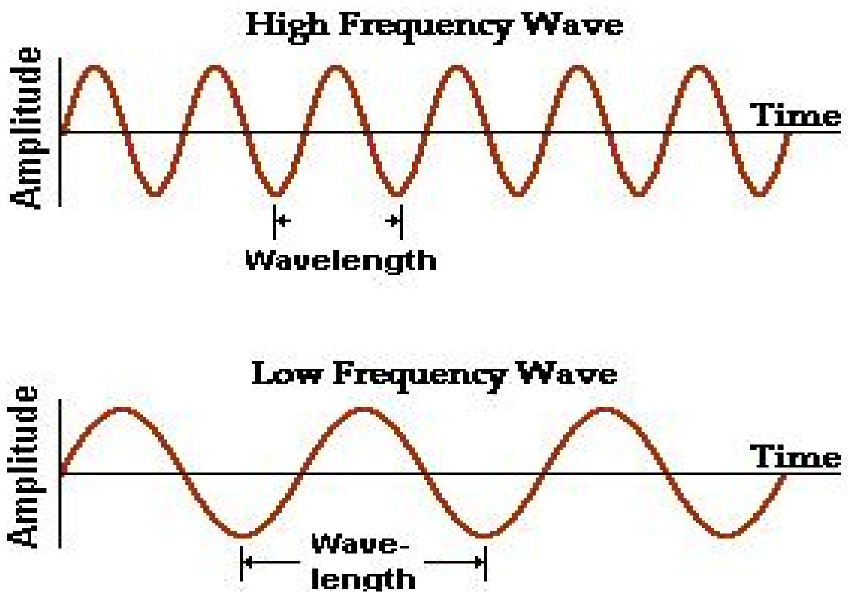

Figure 1.2: Sound wave showing wave length, Amplitude and frequency of wave.

Source:[1]

1.4. Frequency

Every sound has a range from a high to a low pitch. The pitch of a sound depends on upon the frequency of the vibrations that cause it[6]. The frequency (f) of a sound is the number of complete waves or vibrations that go past a particular place each second. It can also be measured as the number of complete back-and-forth vibrations of a particle of the medium per unit of time. The more vibrations per second, the higher the frequency and sound pitch (figure 1.2). The fewer vibrations per second, the lower the frequency and sound pitch[7]. For example, a sound with a frequency of 880 Hz is an octave higher than one with a frequency of 440 Hz.

1 Hertz = 1 vibration/second

f = 1/Time

Depending on the medium, sound travels at some speed c which defines the wavelength l: l = c/f

1.5. Measurement of sound

The measurement of sound makes it possible to detect the level of sound that could be detrimental to humans and the environment[8]. The softest audible sound modulates the air pressure by around 10^{-6} Pascal (Pa) or 20000 Hz, while the loudest audible sound which can inflict pain is10^{2} Pa or 20 Hz. Because of this wide range it is convenient to measure sound amplitude on a logarithmic scale in Decibel [*dB*]. Decibel is not a physical unit - it expresses only a ratio for comparing the intensity of two sounds: 10 log10 (I/Io) where I and Io are two intensity/power levels ($I \sim P^2$, P is sound pressure)[6]

dB of sound pressure level (dB SPL) is defined as $dB = 10\log\left(\frac{p}{p_o}\right)^2 = 20\log\left(\frac{p}{p_o}\right)$

Since sound is a form of energy, it can be changed from one form to another. Other forms of energy can be transformed into sound[9]. Sound energy can be changed into electrical energy. Sound waves that are changed into electricity can be seen on an oscilloscope and mobile phones.

Sound travels quickly in air at nearly 340 meters per second but can travel through steel at about 5,200 meters per second. 770 MPH, is the speed of sound, When you go to a rock concert, you may have to cover your ears because the sound is so loud[10]. This loudness is called intensity. Intensity is also measured in *dB*. The threshold of sound is 0*dB*. A rock concert has an intensity of 120 decibels. Sounds of 120 decibels or greater can cause people pain and ear damage[10].

1.6. Noise

Depending on whether we like it or not, the sound is broadly classified into noise and music. Music is what pleases our sense of hearing[8]. It depends on numerous factors and varies from person to person. On the other hand, the definition of noise is hazy. The boundaries that separate musical sound from noise is blurry. What is music to someone, can be noise to somebody else[3].

Musical sounds generally have certain features; they are periodic and somewhat regular. They are pleasing to our ears and minds, and they constitute one of the greatest forms of expression since the beginning of time. Noise on the other hand is unpleasant sound. It is more irregular. When looking at the waveform, a visual representation of sound, music has more patterns and gradual variances in volume, but noise is jagged and sporadic[9].

The level of annoyance of noise depends on the quality of the sound and our attitude towards it. The sound at high volume can damage materials and cause harm to the auditory system of humans resulting in Noise-induced hearing loss (NIHL). This can affect the ability to communicate effectively and also the social, emotional, cognitive and behavior of an individual[4].

High level of sounds which can cause ear problems constitute what is known as Noise pollution. Which are mainly caused by machines and transportation systems, vehicles, aircraft, and trains.

1.7. Sound Level Instrument

The measurement of sound makes it possible to detect the level of sound that could be detrimental to humans and the environment and is a useful tool in noise reduction and management[3]. Sound measurements also permit precise, scientific analysis of sounds[8]. However, due to the physiological and psychological differences between individuals, sound cannot be scientifically measured accurately for a given person.

Sound levels are generally measured in decibels (dB). A sound level meter is a measuring instrument used to assess noise or sound levels by measuring sound pressure[8]. Often referred to as a sound pressure level (SPL) meter, decibel (dB) meter, noise meter or noise dosimeter; a sound level meter is commonly a hand-held instrument with a microphone used to capture sound[11]. The sound is then evaluated within the device and acoustic (sound that travels through air) measurement values are displayed[9] Figure 1.3.

Generally, the diaphragm of the microphone in a typical sound level meter responds to changes in air pressure caused by sound waves. This movement of the diaphragm, that is the sound pressure deviation (pascal Pa), is converted into an electrical signal (volts V)[2]. A microphone is distinguishable by the voltage value produced when a known, constant sound pressure is applied. This is known as microphone sensitivity[2]. The instrument needs to know the sensitivity of the particular microphone being used. Using this information, the instrument is able to accurately convert the electrical signal back to sound pressure, and display the resulting sound pressure level (decibels dB SPL).

Figure 1.3: A typical Sound Level Meter

Sound level meters are commonly used in noise pollution studies for the quantification of different kinds of noise, and music, especially for industrial, environmental, mining and aircraft noise. The current international standard that specifies sound level meter functionality and performances is the IEC 61672-1:2013[3,5,10,11].

An important attribute to consider when searching for a suitable sound level meter is its type or class[8]. The type or class of a decibel meter defines the device's accuracy as per American National Standards Institute (ANSI) or International Electrotechnical Commission (IEC) guidelines[5]. Typically, "type" is the grade according to the ANSI S1.4 standard, whereas "class" is the grade according to the IEC 61672 standard. There are two types or classes assigned to decibel meters: type 1 / class 1 or type 2 / class 2. For assessing noise in basic industrial, commercial, educational, recreational or residential applications, a type 2 / class 2 decibel meter usually will suffice[5]. For precision-grade assessments often made in a laboratory, a type 1 / class 1 sound level meter primarily is used. For the purpose of this study the type 1/class 1 sound level meter will be employed in assessing the sound levels of musical instruments[6].

1.8. Mobile phones

Mobile telephones have been available since 1983. Their usage has spread widely and rapidly[12]. In 2005, it was estimated that there were more than 2.14 billion mobile phone users in the world, with an expected rise of 90% to 6 billion people by 2010. Currently over 9 million people use phones worldwide. Mobile phones transmit and receive signals using electromagnetic fields in the radiofrequency band. The Global System for Mobile Communications (GSM) is currently the most widely used digital mobile phone service operating at 900 to 1,800 MHz frequency bands[12]. Although the electromagnetic radiation emitted is within the accepted range, data on its long-term effect is sadly lacking. The possibility that the EMR have an accumulative effect and subsequently preclude to cellular damage is a sobering thought. The ear, especially the inner ear, not only being the closest to the mobile phone, is the direct recipient of the EMR thus making it the most likely affected organ[13]. The delicate hair cells in the organ of Corti does not have regenerative properties, thus damages are often permanent with little chance of recovery in advanced stages. Hair cells are known to be sensitive to chronic exposure to loud noise. Therefore, the ear is at risk of exposure to noise from the mobile phone as well as the electromagnetic radiation waves emitted by the phone[13].

Since Martin Cooper made the first mobile telephone call in 1973, the use of the technology has assumed various dimensions. Great innovation in mobile phone development over the years has made the cell phone evolved into more than just a device used for making voice calls[11]. In addition to telephony, smartphones, mobile phones with more advanced computing ability through the use of native software applications, have features such as Global Positioning System (GPS) navigation; music playback, bluetooth, video camera[9]. and internet access. These features enable them support a wide variety of services such as text messaging, multimedia messaging service (MMS), WhatsApp, viber, email, business applications, gaming, photography, and video.

1.9. Types of mobile Phones

A smartphone is a mobile phone with more advanced computing capability and connectivity than a feature phone which has a limited functionality. The first smartphones combined the functions of a personal digital assistant (PDA) with a mobile phone. Later models added the functionality of portable media players, low-end compact digital cameras, pocket video cameras, and GPS navigation units to form one multi-use device[13]. Many modern smartphones also include high-resolution touch screens and web browsers that display standard web pages as well as mobile-optimised sites. Another defining aspect of a smartphone is its ability to multitask between applications and operations. Fair phones are types of smartphones which are designed and developed with ecological and ethical issues foremost in mind[14]. They are made from recycled, recyclable and responsibly sourced goods with minimal packaging such that if one component breaks down or the user wants to update it, only that particular component is replaced.

Feature phones are low-end mobile phones that do not have the computing power of smartphones[16]. They are generally limited in capabilities and typically provide voice calling and text messaging functionality with basic multimedia and internet capabilities. Feature phones predominantly run on a proprietary Java Micro Edition platform and can only run basic applications. It should be noted that the capability gap between smartphones and feature phones is rapidly becoming narrower everyday as feature phones are becoming more advanced. Thus, the smartphone phone of today may become a feature phone years to come.

1.10. **Summary**

Sound is the result of oscillations, variations in atmospheric pressure. An ideal audible sound ranges from 20 Hz and 20 kHz. The sound level meter provides measurements of sound pressure level and displays it in units of *dB*. Sound measurements allows for the determination of the level of the sound which may cause damage, or point to a fault, and is a useful tool in noise reduction[13]. Noise-induced hearing loss (NIHL) is caused by exposure to hazardous noise levels. In the United States, over 22 million civilian workers are exposed to hazardous levels of noise[11]. In the military, the most common injuries to service members are caused by excessive noise exposure. Safety measures need to be implemented when harmful sounds are observed and they are initiated based on available data, this data is gotten from research, hence this study intends to isolate and identify the sound level from different phones.

1.11. Aim and Objectives of this work

The aim of this project is to measure and analysis musical sound level from a mobile phones and determine its impact on human health.

The objectives are:

1. To measure the frequency spectra of the sound produced by the three phones.
2. To determine whether sound level from the phones should warrant the inclusion of a hearing protection programme.
3. To compare the sound pressure level measurements obtained from the phones with the Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) standards.
4. To compare the sound levels of phones from three different producers and different specifications android, GSM and iPhone.

1.12. Statement of the Research Problem

Sound measurements allows for the determination of the level of the sound which may cause damage, or indicate a fault, and is a useful tool in noise reduction.[7]

The hearing domain of sound for a young person is between approximately 20 Hz up to 20 kHz, little is known about the range of sound levels from phones especially in Nigeria.

Noise-induced hearing loss (NIHL) is a growing area of concern globally and one aspect of prevention is the education of adults and children about the potentially harmful effects on the auditory system of exposure to loud noise.

NIHL may negatively affect not only the ability to communicate effectively especially in young children and adults who use phone for so much more than just making calls but also their social, emotional, cognitive and behavioural development and academic achievement[12].

Although works are been done recently on sound levels of devices little is know about the levels of phone in Nigeria taking into cognize the Nigerian environment were the standard of liven is very poor. There is a need to ascertain the sound level impact of mobile phones on human health, more research needed especially in other to better provide safety and preventive measures when handling the phones[17].

1.13. Limitation of Study

1. poor power supply condition in Nigeria was also a limiting factor in the course of the work.
2. Another potential limitation is the brevity of some of the measured practice sessions.
3. Finial constrain was a major limiting factor in conducting this research.

CHAPTER TWO

LITERATURE REVIEW

2.1. Sound

We hear sound in everything we do and everywhere we go, it is part of life and a basic part of the human senses. Several definitions have been proposed by different authors for the definition of sound; according to [5] sound is oscillation in pressure, stress, particle displacement, particle velocity, propagated in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillation. [6] submitted that Sound is created when something vibrates and sends waves of energy (vibration) into our ears. The vibrations travel through the air or another medium (solid, liquid or gas) to the ear. The stronger the vibrations, the louder the sound. Sounds are fainter the further you get from the sound source. More so sound as succinctly put by [2], can be viewed as a wave motion in air or other media, that is, sound is a stimulus, or as an excitation of the hearing mechanism that results in the perception of sound. In this case, sound is a sensation. All this these definitions have certain things in common and these are the properties of sound which are:

- sound is a wave
- a longitudinal wave
- Sound needs a medium to travel

- Waves have an amplitude (volume) frequency (pitch), wavelength (speed).

These are the basic properties that make sound. Sound can be pleasant or unpleasant or unwanted, so called noise. In science and engineering, noise is an undesirable component that obscures a wanted signal[6]. The level of annoyance depends on the quality of the sound and our attitude towards it. At high volume and over a long-time sound can cause serious damage to our health, leading to NIHL hence the need for sound measurement.

As rightly put by [1] the mechanism of NIHL involves damage to the delicate hair cells lining the basilar membrane of the cochlea. Stereocilia, the mechano-sensing organelles of these hair cells, are deflected in a shearing motion and transform the mechanical energy of sound waves into electrical impulses for the hair cells. This results in an excitation of the auditory nerve. Excessively loud sounds can damage or destroy the stereocilia. The hearing damage can transpire in two ways. Brief exposure to extremely loud sounds can cause permanent damage, while continuous exposure to loud sounds wears out the hair cells and weakens their ability to recover, resulting in permanent hearing loss.

According to the Occupational Safety and Health Administration (OSHA)[14] excessive exposure to high-intensity sound causes damage to the outer hair cells of the organ of Corti, in the cochlea, which are responsible for the enhancement of hearing sensitivity and tuning. The outer hair cells have a motor function that amplifies soft sounds along all frequency points in the cochlea. When outer hair cells are damaged, low-level sounds are perceived as softer or not heard at all while mid and high-level sounds can be perceived as loud[14]. Outer hair cell damage also can widen cochlear auditory filters thereby leading to a loss of frequency specificity. These alterations in auditory perception can have deleterious effects on the perception of sound.

In order to understand the gravity of the problem of hearing loss globally the National Institute for Occupational Safety and Health (NIOSH)[15] in 1998 stipulated stringent criterias for the protection of the individual's hearing sensitivity in the work place and other environment, and this has been accepted to considered best "best practice"[8]. Many of the NIOSH criteria are based on standards of the International Standards Organization[15].

NIOSHA exposure regulations are based on a time-intensity relationship. The amount of time an individual can spend in a high-intensity environment depends on the sound level of that environment[15]. NIOSH criteria indicate that a Hearing Conservation Programme should be established which includes annual audiometric testing, education and training for employees in environments where they are exposed to 85 dB(A) or more over an eight-hour period[16]. The NIOSH levels are shown in Table 1.

Table 1: ***NIOSH Allowable Noise Exposure Levels***[15]

Max. Exposure level in dB(A)	NIOSH Recommendations
80	Begin conservation programme
85	8 hrs.
88	4 hrs.
90	2 hrs., 31 min., 11.4 sec.
91	2 hrs.
94	1 hr.
95	47 min., 37.2 sec.
97	30 min.
100	15 min.
103	7 min., 15 sec.
105	4 min., 43.47 sec.
106	3 min., 37.5 sec.
109	1 min., 48.75 sec.
110	1 min., 29.292 sec.
112	54.38 sec.
115	27 seconds

2.2. Sound level measurement

Sound intensity or loudness, measured as sound pressure level (SPL) in a logarithmic decibel (dB) scale, is used to indicate how we hear a specific sound. The point at which a person starts to hear sound is referred to as a dB of 0, while a whisper is equal to 30 dB. An average rock band performance can measure up to 110 dB and a firecracker up to 145 dB (Table 1). Continuous exposure to noise of 85 dB or more over a typical 8-hour workday can cause permanent hearing loss[15].

Table 2. Noise level chart and its source[14]

Loudness (dB)	Source
0	Softest sound that can be heard
10	Normal breathing
30	Whisper
50 - 65	Normal conversation
80 – 85	City traffic noise
95 - 110	Motorcycle
110	Rock band
120	Thunderclap
125	Balloon popping
145	Firecracker

The measurement of sound makes it possible to detect the level of sound that could be detrimental to humans and the environment and is a useful tool in noise reduction and management. Sound is the result of oscillations, variations in atmospheric pressure[2]. For it to be heard these pressure variations must occur at least 20 times per second. The frequency of the sound is measured using the pressure variation per second and it travels through a medium[17].

Sound levels are typically measured in decibels (dB) using a sound level meter. The human hearing response is nonlinear so an increase of 3 dB actually represents a doubling of the sound intensity[18]. Sound level meters use scales of sound as follows:

A-weighting—measuring low intensity;

B-weighting—measuring moderate intensity;

C-weighting—measuring high intensity.

These are measured and recorded as dB(A), dB(B), and dB(C), with dB(A) reflecting the human range of sound detection.

The sustained noise level that personnel are exposed to can be represented as Leq which describes the average sound level over a set period of time. Using the logarithms scale comparing the sound pressure of one sound with another becomes easier[19]. The following definition gives the level of sound pressure *p* in decibels:

$$SPL = 10\log_{10}\left(\frac{p^2}{p_{ref}^2}\right)dB$$

Where:

SPL - Sound Pressure Level in *dB*

p - sound pressure fluctuation (above or below atmospheric pressure)

Pref - 20 micropascals (2 x 10-5Pa), which is approximately the threshold of hearing[24].

Unlike Nigeria and many underdeveloped countries, in developed nations multiple noise measurements are typically presented on a map or plan of the workplace. This provides an overview of the working area and locations of the higher noise sources[20]. Measurements are compared with international standards for exposure limits relevant to the type of work environment giving consideration to the variety of tasks being conducted and the equipment being used. Control measures should be implemented to reduce noise exposure as necessary.

2.3. The sound level meter

A sound level meter (SLM) is a device commonly used to measure sound amplitude, frequency composition, and other acoustical parameters. In order to record or measure a sound, the acoustic signal must first be changed into a signal that can be quantified and manipulated. The first piece of equipment in this step is the microphone. Inside the microphone, a diaphragm vibrates as a result of the interaction with the physical sound wave. This movement creates a tiny electrical signal analogous to the sound wave[21]. This signal is too small to process and is boosted by a preamplifier. After this step, the now-amplified signal moves through a series of circuitry that processes the signal and converts it to a meaningful readout on the screen. The signal processing components for a SLM is illustrated below in Figure 1.

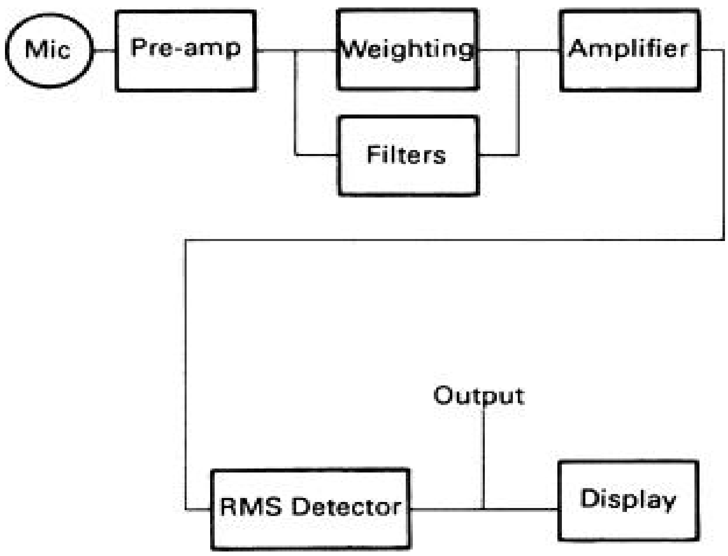

Figure 2.1. Sound level meter signal processing chain.

The electrical signal may be processed in several ways in order to display different information on the SLM to the operator. First, the signal may be "weighted." Weighting is a way to filter a sound signal that places varying levels of importance on different frequencies that make up the signal. Common weighting networks include "A," "C," and "Z," with "A" being the most common filter used for environmental noise monitoring. A-weighting is "said to be best for the frequency response of the human ear: when a sound dosimeter is set to A-weighting, it responds to the frequency components of sound much like your ear responds"[7] With A-weighting, very low frequency components in the signal are attenuated and more emphasis is placed at frequencies where the human ear is most sensitive (around 1-4 kHz).

Another way a SLM processes sound is in terms of "response time." The SLM is programmed with a "time constant," or window in which the meter averages its readings. The time constant can be "fast," with a time constant of 125 milliseconds, or "slow," with a time constant of 1 second[8]. Typically, for continuous noise, exposure measurements are made with the meter set to "slow" response. This signal can be further analyzed by a process known as "integration" where the total sound exposure over a given period of time is accounted for and displayed as a sound exposure level (SEL)[20].

Other sound level meters have parallel filters, or use the fast Fourier transform. The results of this frequency analysis are presented on a spectrogram which shows the level of the sound in each band. The pressure variation in time is converted to level variation (dB) in frequency (Hz). The resulting signal is amplified, and the Root Mean Square (RMS) value is determined. The RMS value is important because it shows the energy quantity in the sound. The result is displayed in dB, but it can be obtained in ac or dc signal form too[12].

2.4. Factors that influence measurements from sound level meters

The IEC 60651 standard gives the specifications for sound level meters and these characteristics refer to directional characteristics, frequency weighting characteristics, time weighting, detector and indicator characteristics and sensitivity to various environments.

Connection of the sound level meter into a circuit, can influence the measured value as it can distorts the measured quantity[16].

The microphone orientation and type also distorts the sound field and influences the measurements. The used microphone should have a uniform frequency response, and should have the same sensitivity in the whole frequency range[12].

The environment also influences the measurement. Humidity, temperature, wind, vibrations, pressure can reduce the measurement accuracy. To eliminate or minimize these influences the measurement conditions must be kept constant.

2.5. Application of sound level device

Sound measurements give a clear indication of when a sound may cause damage to hearing and permit corrective measures to be taken. The degree of hearing damage can be determined by audiometry which measures a person's hearing sensitivity[18]. Thus, sound measurements are a vital part of hearing conservation programmes. Also, measurement and analysis of sound is a powerful diagnostic tool in noise reduction programmes — from airports, to factories, highways, homes and recording studios. It is a tool which can help to improve the quality of our lives.

In a nutshell sound level meters are ideal for the following applications:

- Mining
- Commercial construction (demolition and equipment)
- Road Construction
- Military
- Industrial Manufacturing: such as metal fabrication, open air automated production lines, maintenance areas
- Oil and Gas and downstream refineries – ATEX and IECEx approval
- Urban areas

With a portable decibel meter, industrial hygiene and workplace safety professionals can measure sound levels in multiple locations to ensure environmental conditions fall within recommended exposure limits (RELs).

Some sound level meter devices can be permanently installed for continuous monitoring of sound levels at a work or job site[20].

Other applications for Sound level meters are Noise at Work/Occupational Noise and Environmental and Community Noise[7]. There are also other more specialised applications such as Vehicle Noise Testing as well as basic noise measurements[4].

2.7. Mobile Phones

A mobile phone, cellular phone, cell phone, cellphone, handphone, or hand phone, sometimes shortened to simply mobile, cell or just phone, is a portable telephone that can make and receive calls over a radio frequency link while the user is moving within a telephone service area[13]. The radio frequency link establishes a connection to the switching systems of a mobile phone operator, which provides access to the public switched telephone network (PSTN). Modern mobile telephone services use a cellular network architecture and, therefore, mobile telephones are called cellular telephones or cell phones. In addition to telephony, digital mobile phones (2G) support a variety of other services, such as text messaging, MMS, email, Internet access, short-range wireless communications (infrared, Bluetooth), business applications, video games and digital photography. Mobile phones offering only those capabilities are known as feature phones; mobile phones which offer greatly advanced computing capabilities are referred to as smartphones[12].

The development of metal-oxide-semiconductor (MOS) large-scale integration (LSI) technology, information theory and cellular networking led to the development of affordable mobile communications. The first handheld mobile phone was demonstrated by John F. Mitchell and Martin Cooper of Motorola in 1973, using a handset weighing 2 kilograms (4.4 lbs). In 1979, Nippon Telegraph and Telephone (NTT) launched the world's first cellular network in Japan. In 1983, the Dyna TAC 8000x was the first commercially available handheld mobile phone. From 1983 to 2014, worldwide mobile phone subscriptions grew to over seven billion; enough to provide one for every person on Earth. In the first quarter of 2016, the top smartphone developers worldwide were Samsung, Apple and Huawei; smartphone sales represented 78 percent of total mobile phone sales. For feature phones (slang: "dumbphones") as of 2016, the top-selling brands were Samsung, Nokia and Alcatel[2].

In recent years, mobile telecommunication systems have grown significantly, to the point where more than a sixth of the world's population use mobile phones. By the end of 2004, more than a billion subscribers across more than 200 countries were estimated to be using mobile phones. The development of mobile communications has moved rapidly. In the 1980s, first generation mobile phones, using analogue technology, allowed the transmission of sound only. Digital transmission, and the global system for mobile communication, started in 1991 and includes such new developments as data and image transmission. Third generation mobile phones currently in the market offer additional services to the users (such as fax, e-mail and Internet access). The first mobile phones, as mentioned, were only used to make and receive calls, and they were so bulky it was impossible to carry them in a pocket. These phones used primitive RFID and wireless systems to carry signals from a cabled PSTN endpoint.

Later, mobile phones belonging to the Global System for Mobile Communications (GSM) network became capable of sending and receiving text messages. As these devices evolved, they became smaller and more features were added, such as multimedia messaging service (MMS), which allowed users to send and receive images. Most of these MMS-capable devices were also equipped with cameras, which allowed users to capture photos, add captions, and send them to friends and relatives who also had MMS-capable phones. Along with the texting and camera features, cell phones started to be made with a limited capability to access the Internet, known as “data services.” The earliest phone browsers were proprietary and only allowed for the use of a small subsection of the Internet, allowing users to access items like weather, news, and sports updates[13].

Eventually, phone makers started to engineer these phones to access the entire Internet, and webmasters for all sorts of businesses, government offices and other domain holders started to make web sites responsive to access by mobile phones. The trend, called “responsive design,” changed the face of the Internet, with mobile phone transactions making up a larger share of ecommerce sales and other activities. A mobile phone typically operates on a cellular network, which is composed of cell sites scattered throughout cities, country sides and even mountainous regions. If a user happens to be located in an area where there is no signal from any cell site belonging to the cellular network provider he or she is subscribed to, calls cannot be placed or received in that location. However, the cellular networks used for mobile phones, now called “smartphones” when they encompass modern design, have also evolved. At the same time, the networks used by the smart have also evolved.

First, the 4G telecommunications network pioneered an all-Internet transmission system using things like smart antenna arrays and point-to-point network “fabrics.” While still being called a “cellular network,” 4G relied on IP transmission, rather than traditional telephone circuit switching, which led to certain reception and transmission efficiencies. Now, a dominant model called 5G is being unrolled throughout the world. The 5G system uses higher frequency waves and a closer cell structure, which changes the networking style and promises greater bandwidth for users. On the device side, as companies continue to produce newer smartphones, two major operating systems have emerged. The Apple and Android operating systems are installed in the lion's share of new smartphones by various manufacturers[14].

With both of these operating system platforms, it has become routine for engineers to build hundreds of different types of functionality into modern smartphones through the design of mobile applications or “apps.” Application stores facilitate the purchase and use of these diverse applications.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY AND MATERIALS

In order to measure and analysis the musical sound level from a mobile phone and determine its impact on human health an experimental survey was done and data was collected and evaluated to ascertain the musical sound level from three types of phones.

3.1. **Materials**

Three types of phones were used in the experiment GSM mobile phone made by Nokia (Nokia 1280), an android phone made by Infinix (Infinix Note 8) and an Iphone made by Apple (iPhone X).

Nokia 1280

Figure 3.1: Nokia 1280

Nokia 1280 is an affordable ultrabasic dual band GSM mobile phone made by Nokia announced in November 2009 and released in March 2010 for developing countries. It has a classic candybar design, intended to be lightweight and durable.

Specifications

Properties	**Specifications**
Display	3.56 cm (1.4 inch)
Camera	0.3MP Rear
Battery	800 mAh Li-Ion (8.3h talk time)
Color	Black
SAR Value	1.15 W/kg
Ringtones Format	Vibration, MP3 ringtones
SIM Type	Single Sim
Operating System	Series 30
Operating Frequency	GSM - 900, 1800
Resolution	96 x 68 Pixels
Display Type	Monochrome
Ssupported Memory Card Type	No
Phone Book Memory	500
Call Log Memory	Yes
SMS Memory	Yes
Supported Networks	GSM
Audio Jack	3.5 mm
Width	45.1 mm
Height	107.2 mm
Depth	15.3 mm
Weight	81.9 g
SIM Size	Mini SIM
Keypad Type	Alphanumeric
Social Networking Phone	No

JAVA Support	No
SMS	Yes
Keypad	Yes
Predictive Text Input	Yes
Games	Yes
Other Features	Flashlight, Calendar, Speaking Alarm Clock
FM Radio	Yes

Infinix Note 8

Figure 3.2: Infinix Note 8

Infinix Note 8 is an android phone that was released in released 04/11/2020.

The specifications are giving below.

Properties		Specifications
NETWORK	Technology	GSM / HSPA / LTE
LAUNCH	Announced	2020, October 15
	Status	Available. Released 2020, November 04
	Status	Available. Released 2020, November 04
BODY	Dimensions	175.3 x 78.8 x 9 mm (6.90 x 3.10 x 0.35 in)
	SIM	Dual SIM (Nano-SIM, dual stand-by)
DISPLAY	Type	IPS LCD, 480 nits (peak)
	Size	6.95 inches, 114.7 cm2 (~83.0% screen-to-body ratio)
	Resolution	720 x 1640 pixels (~258 ppi density)
	Protection	Corning Gorilla Glass

PLATFORM	OS	Android 10, XOS v7.1
	Chipset	Mediatek Helio G80 (12 nm)
	CPU	Octa-core (2x2.0 GHz Cortex-A75 & 6x1.8 GHz Cortex-A55)
	GPU	Mali-G52 MC2
MEMORY	Card slot	microSDXC (dedicated slot)
	Internal	128GB 6GB RAM
MAIN CAMERA	Quad	64 MP, (wide), 1/1.73", 0.8µm, PDAF, 2 MP, (macro) 2 MP, (depth), 2 MP
	Features	Quad-LED flash, HDR, panorama
	Video	1440p@30fps
SELFIE CAMERA	Dual	16 MP, 2 MP, (depth)
	Features	Dual-LED flash
	Video	1080p@30fps
SOUND	Loudspeaker	Yes, with dual speakers
	3.5mm jack	Yes
COMMS	WLAN	Wi-Fi 802.11 a/b/g/n/ac, dual-band, Wi-Fi Direct, hotspot
	Bluetooth	5.0, A2DP, LE
	GPS	Yes, with A-GPS
	NFC	No
	Radio	FM radio
	USB	USB Type-C 2.0, USB On-The-Go
FEATURES	Sensors	Fingerprint, (side-mounted), accelerometer, gyro, proximity, compass

Apple (iPhone X)

Figure 3.3: iPhone X

iPhone X is an Apple phone released on November third 2017.

Properties	Specifications

NETWORK	Technology	GSM / HSPA / LTE
LAUNCH	Announced	2017, September 12
	Status	Available. Released 2017, November 03
BODY	Dimensions	143.6 x 70.9 x 7.7 mm (5.65 x 2.79 x 0.30 in)
	Weight	174 g (6.14 oz)
	Build	Glass front (Gorilla Glass), glass back (Gorilla Glass), stainless steel frame
	SIM	Nano-SIM
		IP67 dust/water resistant (up to 1m for 30 mins)
		Apple Pay (Visa, MasterCard, AMEX certified)
DISPLAY	Type	Super Retina OLED, HDR10, Dolby Vision, 625 nits (typ)
	Size	5.8 inches, 84.4 cm2 (~82.9% screen-to-body ratio)
	Resolution	1125 x 2436 pixels, 19.5:9 ratio (~458 ppi density)
	Protection	Scratch-resistant glass, oleophobic coating
		Wide color gamut, 3D Touch, True-tone
PLATFORM	OS	iOS 11.1.1, upgradable to iOS 14.6
	Chipset	Apple A11 Bionic (10 nm)
	CPU	Hexa-core 2.39 GHz (2x Monsoon + 4x Mistral)
	GPU	Apple GPU (three-core graphics)
MEMORY	Card slot	No
	Internal	64GB 3GB RAM, 256GB 3GB RAM, NVMe
MAIN CAMERA	Dual	12 MP, f/1.8, 28mm (wide), 1/3", 1.22µm, dual pixel PDAF, OIS
		12 MP, f/2.4, 52mm (telephoto), 1/3.4", 1.0µm, PDAF, OIS, 2x optical zoom
	Features	Quad-LED dual-tone flash, HDR (photo/panorama), panorama, HDR
	Video	4K@24/30/60fps, 1080p@30/60/120/240fps
SELFIE CAMERA	Dual	7 MP, f/2.2, 32mm (standard)
		SL 3D, (depth/biometrics sensor)
	Features	HDR
	Video	1080p@30fps
SOUND	Loudspeaker	Yes, with stereo speakers
	3.5mm jack	No
COMMS	WLAN	Wi-Fi 802.11 a/b/g/n/ac, dual-band, hotspot
	Bluetooth	5.0, A2DP, LE
	GPS	Yes, with A-GPS, GLONASS, GALILEO, QZSS
	NFC	Yes
	Radio	No
	USB	Lightning, USB 2.0
FEATURES	Sensors	Face ID, accelerometer, gyro, proximity, compass, barometer

		Siri natural language commands and dictation
BATTERY	Type	Li-Ion 2716 mAh, non-removable (10.35 Wh)
	Charging	Fast charging 15W, 50% in 30 min (advertised)
		USB Power Delivery 2.0, Qi wireless charging
	Talk time	Up to 21 h (3G)
	Music play	Up to 60 h
MISC	Colors	Space Gray, Silver
	Models	A1865, A1901, A1902, A1903, iPhone10,3, iPhone10,6
	SAR	1.09 W/kg (head) 1.17 W/kg (body)
TESTS	Performance	AnTuTu: 233100 (v7)
		GeekBench: 10215 (v4.4)
		GFXBench: 28fps (ES 3.1 onscreen)
	Display	Contrast ratio: Infinity (nominal), 5.013 (sunlight)
	Camera	Photo / Video
	Loudspeaker	Voice 68dB / Noise 74dB / Ring 76Db
	Audio quality	Noise -93.7dB / Crosstalk -82.8Db
	Battery life	Endurance rating 74h

3.2. **Instrument**:

The UT353 BT Mini Sound Meter (Bluetooth Version) was used. UT353 BT has Bluetooth function is a stable, safe, reliable mini sound meter, widely used in noise detection, quality control, health control, environmental noise measurement in factory, traffic, home audio and other places.

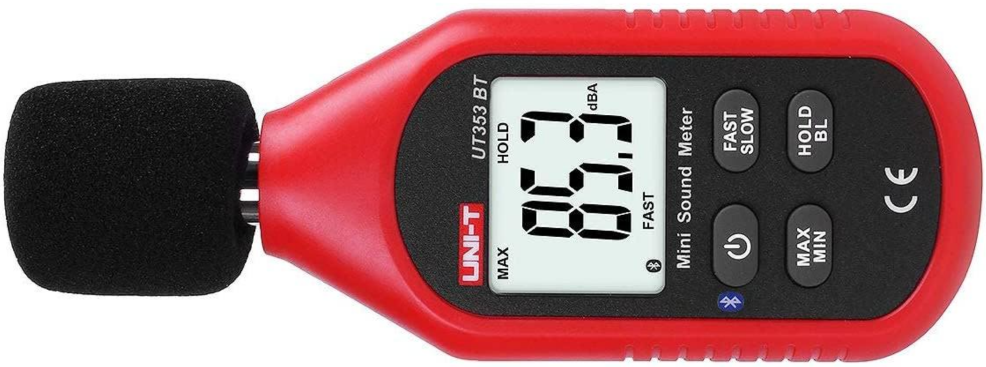

Figure 3.4: UT353 BT Mini Sound Meter (Bluetooth Version)

Product Exterior:

- Wind-proof ball
- Microphone
- Meter case
- LCD displace
- Function Keys

Bluetooth APP specification: To connect the Bluetooth, you need to install the application (iNEV APP) on the smartphone.

Compatibility: IOS 8.5 or higher version, android version 4.3 or higher version, Bluetooth 4.0 or higher version, Memory 1G or more.

Performance Testing

A Technical Parameter

1. Range:30~130db
2. Resolution: 0.1dB
3. Accuracy: +1.5dB
4. Frequency Resolution:31.5Hz~8KHz
5. Ambient temperature:23oC+-5oC
6. Ambient humidity:< 80%RH
7. Temperature Coefficient: 0.1XAcuracy/oC

B. General Type:

a. LCD display: 4-bit LCD display. The maximum display is 9999.

b. Overload indication: The meter shows “UN” when under range, and shows “OL” when over range

c. Low battery indication: prompt low

d. Sampling rate: fast rate 125ms, slow rate is 1s

e. Sensor Type: ½ inch denser microphone

f. Impact strength: can withstand the impact of landing from 1meter height.

g. Power requirement:1.5V batteries (AAA)*3

h. Power consumption: More than 12 hours with Bluetooth enabled.

i. Product size:154mm*55mm*28mm

j. Spec of thread to connect the product with three tripod:m1/4

k. Weight: 116g

C. Environmental limitation

a) Indoor use

b) Maximum operating height:2000m

c) Pollution level:2

d) Working temperature and humidity: 0Oc-30OC (not greater than 80%RH), 30OC -40OC (not greater than 80%RH), 40OC-50OC(not greater than 45%RH)r

e) Storage temperature and humidity: 20OC-60OC(not greater than 80%RH)

IV. Bluetooth connection: before Bluetooth APP and product is connected, you need to open the Bluetooth at the same, and through the APP, search the Bluetooth and select the corresponding products to be connected in iENV APP.

- When in the working state, long press the power button to turn ON or OFF the Bluetooth

  - ✓ Bluetooth icon is flashing, indicating that the product is not connected with APP
  - ✓ Bluetooth icon isn't flahing, indicating that the product is connected with APP.

3.3. Instrumentation

Average sound levels were measured for an hour using a personal portable mini digital sound level meter (UNI-T UT353 BT). The meter used was set to calculate the percentages based on SJ/T 10423 recommendations. Care was taken to position the measurement instruments 1cm from the phone speakers. The experiment too place in a closed room to prevent external noise interference. The mini sound level meter calculated the runtime of the measurement, range (dB SPL), the average sound level over the 80 dB(A) criterion (Lavg), the time-weighted average (TWA) levels in dB(A), and the dose for the measured time. The TWA averages the sound over an eight-hour period. The TWA will be less than the Lavg if the measured time period is less than eight hours. The UNI-T Decibel Meter was calibrated before each use with the provided compatible acoustical calibrator.

Procedure

Measurements were taken using ISO/NIOSH standards which include a 3 dB exchange rate (reducing the allowable duration of exposure for every 3 dB increase in intensity) and slow response. Use of the slow response setting reduces the likelihood of an overestimation of sound levels. Measurements of each phone (mean length = 60 minutes) were made in closed room, which measured 3.05 x 3.66 x 2.29 metres.

The average sound level (Lavg) was computed for the total measurement time. These average levels determine whether the ISO/NIOSH maximum safe exposure level of 85dB(A) is reached. Dose is defined as the percentage of noise exposure measured over time, typically eight hours, with 100% as the maximum exposure allowed for one day. For example, 85 dB(A) for eight hours would be a 100% dose, and 88 dB(A) for eight hours would be a 200% dose. If the measured levels vary between 85 and 88 dB(A), the dose would be between 100% and 200%.

CHAPTER FOUR

RESULTS

3.1. The experiment was conducted and the result is given below:

Table 4.1: Sound Pressure levels of Nokia 1280 against Time (mins)

N/S	OFF/NOT PLAYING (dB)	ON/PLAYING (dB)	TIME (mins)
1	47.7	89.8	5
2	62.4	103.9	10
3	52.2	99.1	15
4	57.9	79.3	20
5	42.1	100.1	25
6	48.4	89.6	30
7	60.0	97.3	35
8	46.5	89.4	40
9	51.2	98.7	45
10	45.4	104.8	50
11	53.7	94.6	55
12	40.9	82.0	60

CALCULATIONS

- Sum of dB values when Phone was OFF for the 1st 30mins

Using $L=10\log_{10}\sum_{n=1}^{\infty}\left(10^{\frac{l1}{10}}+10^{\frac{l2}{10}}+10^{\frac{l3}{10}}+\dots+10^{\frac{ln}{10}}\right)$

Where L is the combined sound pressure levels

NB: all data are divided by 10 before imputing in the formula

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{47.7}{10}}+10^{\frac{62.4}{10}}+10^{\frac{52.2}{10}}+10^{\frac{57.9}{10}}+10^{\frac{42.1}{10}}+10^{\frac{48.4}{10}}\right)=$$

$$L_{OFF}= 10 \text{ x } 6.426= 64.26dB$$

- Sum of dB values when Phone was OFF for the 2nd 30mins

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{60.0}{10}}+10^{\frac{46.5}{10}}+10^{\frac{51.2}{10}}+10^{\frac{45.4}{10}}+10^{\frac{53.7}{10}}+10^{\frac{40.9}{10}}\right)=$$

$$L_{OFF}= 10 \text{ x } 6.164 = 61.64dB$$

$$L_{OFFtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{64.26}{10}}+10^{\frac{61.64}{10}}\right)$$

$$L_{OFFtotal} = 10 \text{ x } 6.616 = 66.16dB$$

- Sum of dB values when Phone was ON for the 1st 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{89.8}{10}}+10^{\frac{103.9}{10}}+10^{\frac{99.1}{10}}+10^{\frac{79.3}{10}}+10^{\frac{100.1}{10}}+10^{\frac{89.6}{10}}\right)=$$

$$L_{ON} = 10 \text{ x } 10.652 = 106.52dB$$

- Sum of dB values when machine was ON for the 2nd 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{97.3}{10}}+10^{\frac{89.4}{10}}+10^{\frac{98.7}{10}}+10^{\frac{104.8}{10}}+10^{\frac{94.6}{10}}+10^{\frac{82.0}{10}}\right)=$$

$$L_{ON} = 10 \text{ x } 10.671 = 106.71dB$$

$$L_{ONtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{106.52}{10}}+10^{\frac{106.71}{10}}\right)$$

$$L_{ONtotal} =10 \text{ x } 10.963 = 109.63dB$$

- Difference of the dB values of OFF from ON

$$L^{\hat{}}=10\log_{10}\left(10^{\frac{109.63}{10}}-10^{\frac{66.16}{10}}\right)=10\log_{10}(10.96298)=109.63dB$$

- Average dB values when machine was OFF

Using $\bar{L}_{Av}=L_{OFF}-10\log_{10}n \quad n=12, \quad logOFF=66.16dB$

$\bar{L}_{Av}=66.16-10\log_{10}12=66.16-10\times1.08=66.16-10.8=55.36dB$

- Average dB values when machine was ON

Using $\bar{L}_{Av}=L_{ON}-10\log_{10}n \quad n=12, \quad logON=109.63dB$

$\bar{L}_{Av}=109.63-10\log_{10}12=104.3-10\times1.08=109.63-10.8=98.83dB$

- Difference of the average in both ON and OFF

$\bar{L}_{Avtotal}=10\log_{10}\left(10^{9.883}+10^{5.536}\right)=10\log_{10}(7{,}638{,}357{,}835.7769)=$

$10\times9.883=98.83dB$

Table 4.2: Sound Pressure levels of Infinix Note 8 against Time (mins)

N/S	OFF/NOT PLAYING (dB)	ON/PLAYING (dB)	TIME (mins)
1	53.2	79.8	5
2	46.2	85.9	10
3	51.4	82.1	15
4	47.9	76.3	20
5	42.3	82.2	25
6	44.8	79.8	30
7	50.5	93.3	35
8	49.1	88.4	40
9	55.3	84.5	45
10	42.4	80.4	50
11	56.8	87.2	55
12	43.9	78.9	60

CALCULATIONS

- Sum of dB values when Phone was OFF for the 1st 30mins

Using $L=10\log_{10}\sum_{n=1}^{\infty}\left(10^{\frac{l1}{10}}+10^{\frac{l2}{10}}+10^{\frac{l3}{10}}+\ldots+10^{\frac{ln}{10}}\right)$

Where L is the combined sound pressure levels

NB: all data are divided by 10 before imputing in the formula

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{53.2}{10}}+10^{\frac{46.2}{10}}+10^{\frac{51.4}{10}}+10^{\frac{47.9}{10}}+10^{\frac{42.3}{10}}+10^{\frac{44.8}{10}}\right)=$$

L_{OFF}= 10 x 5.6968 = 56.97*dB*

- Sum of dB values when Phone was OFF for the 2nd 30mins

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{50.5}{10}}+10^{\frac{49.1}{10}}+10^{\frac{55.3}{10}}+10^{\frac{42.4}{10}}+10^{\frac{56.8}{10}}+10^{\frac{43.9}{10}}\right)=$$

L_{OFF}= 10 x 6.0224 = 60.22*dB*

$$L_{OFFtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{56.97}{10}}+10^{\frac{60.22}{10}}\right)$$

$L_{OFFtotal}$ = 10 x 6.1903 = 61.90*dB*

- Sum of dB values when Phone was ON for the 1st 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{79.8}{10}}+10^{\frac{85.9}{10}}+10^{\frac{82.1}{10}}+10^{\frac{76.3}{10}}+10^{\frac{82.2}{10}}+10^{\frac{79.8}{10}}\right)=$$

L_{ON} = 10 x 8.978 = 89.78*dB*

- Sum of dB values when machine was ON for the 2nd 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{93.3}{10}}+10^{\frac{88.4}{10}}+10^{\frac{84.5}{10}}+10^{\frac{80.4}{10}}+10^{\frac{87.2}{10}}+10^{\frac{78.9}{10}}\right)=$$

$$L_{ON} = 10 \text{ x } 9.5825 = 95.83dB$$

$$L_{ONtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{89.78}{10}}+10^{\frac{95.83}{10}}\right)$$

$$L_{ONtotal} = 10 \text{ x } 9.679 = 96.79dB$$

- Difference of the dB values of OFF from ON

$$L^{\hat{}}=10\log_{10}\left(10^{\frac{96.79}{10}}-10^{\frac{61.90}{10}}\right)=10\log_{10}(9.679)=96.79dB$$

- Average dB values when machine was OFF

Using $\bar{L}_{Av}=L_{OFF}-10\log_{10}n \qquad n=12, \quad logOFF=61.90dB$

$\bar{L}_{Av}=61.90-10\log_{10}12=61.90-10\times1.08=61.90-10.8=51.10dB$

- Average dB values when machine was ON

Using $\bar{L}_{Av}=L_{ON}-10\log_{10}n \qquad n=12, \quad logON=96.79dB$

$\bar{L}_{Av}=96.79-10\log_{10}12=96.79-10\times1.08=96.79-10.8=85.99dB$

- Difference of the average in both ON and OFF

$\bar{L}_{Avtotal}=10\log_{10}\left(10^{8.599}+10^{5.110}\right)=10\log_{10}(397{,}320{,}374.424)=$

$10\times8.599=85.99dB$

Table 4.3: Sound Pressure levels of iPhone X against Time (mins)

N/S	OFF/NOT PLAYING (dB)	ON/PLAYING (dB)	TIME (mins)
1	41.5	69.7	5
2	45.7	73.7	10
3	40.4	64.8	15
4	53.9	74.0	20
5	46.4	76.4	25
6	54.1	68.5	30
7	52.3	83.3	35
8	43.5	78.5	40
9	52.4	82.8	45
10	45.1	66.3	50
11	46.8	74.7	55
12	49.0	72.3	60

CALCULATIONS

- Sum of dB values when Phone was OFF for the 1st 30mins

Using $L=10\log_{10}\sum_{n=1}^{\infty}\left(10^{\frac{l1}{10}}+10^{\frac{l2}{10}}+10^{\frac{l3}{10}}+\ldots+10^{\frac{ln}{10}}\right)$

Where L is the combined sound pressure levels

NB: all data are divided by 10 before imputing in the formula

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{41.5}{10}}+10^{\frac{45.7}{10}}+10^{\frac{40.4}{10}}+10^{\frac{53.9}{10}}+10^{\frac{46.4}{10}}+10^{\frac{54.1}{10}}\right)=$$

L_{OFF}= 10 x 5.7842 = 57.84dB

- Sum of dB values when Phone was OFF for the 2nd 30mins

$$L_{OFF}=10\log_{10}\sum_{n=6}^{l}\left(10^{\frac{52.3}{10}}+10^{\frac{43.5}{10}}+10^{\frac{52.4}{10}}+10^{\frac{45.1}{10}}+10^{\frac{46.8}{10}}+10^{\frac{49.0}{10}}\right)=$$

L_{OFF}= 10 x 5.7207 = 57.21dB

$$L_{OFFtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{57.84}{10}}+10^{\frac{57.21}{10}}\right)$$

$L_{OFFtotal} = 10 \times 6.055 = 60.55dB$

- Sum of dB values when Phone was ON for the 1st 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{69.7}{10}}+10^{\frac{73.7}{10}}+10^{\frac{64.8}{10}}+10^{\frac{74.0}{10}}+10^{\frac{76.4}{10}}+10^{\frac{68.5}{10}}\right)=$$

$$L_{ON} = 10 \times 8.049 = 80.49dB$$

- Sum of dB values when machine was ON for the 2nd 30mins

$$L_{ON}=10\sum_{n=6}^{l}\left(10^{\frac{83.3}{10}}+10^{\frac{78.5}{10}}+10^{\frac{82.8}{10}}+10^{\frac{66.3}{10}}+10^{\frac{74.7}{10}}+10^{\frac{72.3}{10}}\right)=$$

$$L_{ON} = 10 \times 8.721 = 87.21dB$$

$$L_{ONtotal}=10\log_{10}\sum_{n=12}^{l}\left(10^{\frac{80.49}{10}}+10^{\frac{87.21}{10}}\right)$$

$$L_{ONtotal} = 10 \times 8.805 = 88.05dB$$

- Difference of the dB values of OFF from ON

$$L^{\wedge}=10\log_{10}\left(10^{\frac{88.05}{10}}-10^{\frac{60.55}{10}}\right)=10\log_{10}(8.8042)=88.04dB$$

- Average dB values when machine was OFF

Using $\bar{L}_{Av}=L_{OFF}-10\log_{10} n \qquad n=12, \quad logOFF=60.55dB$

$\bar{L}_{Av}=60.55-10\log_{10}12=61.90-10\times1.08=60.55-10.8=49.75dB$

- Average dB values when machine was ON

Using $\bar{L}_{Av} = L_{ON} - 10\log_{10} n \qquad n = 12, \quad logON = 88.05dB$

$\bar{L}_{Av} = 88.05 - 10\log_{10} 12 = 88.05 - 10 \times 1.08 = 88.05 - 10.8 = 77.25dB$

- Difference of the average in both ON and OFF

$\bar{L}_{Avtotal} = 10\log_{10}\left(10^{7.725} + 10^{4.975}\right) = 10\log_{10}(3{,}182{,}850.5107) =$

$10 \times 7.726 = 77.26dB$

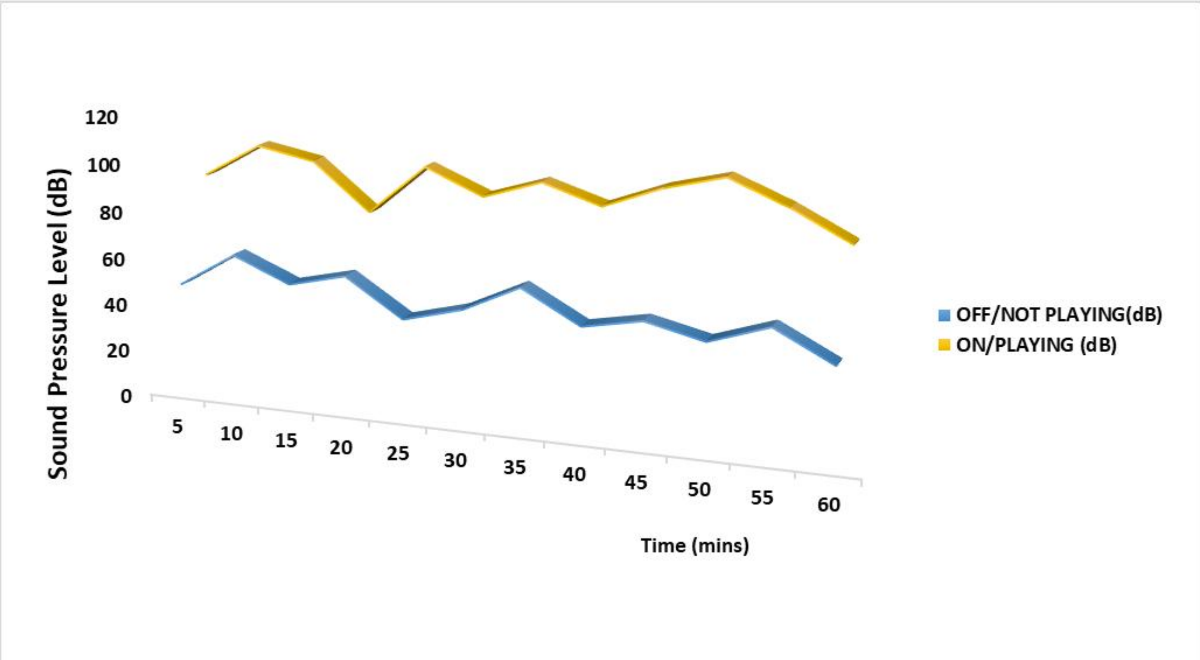

Figure 4.1: Plot of Sound Pressure levels of Nokia 1280 against Time (mins)

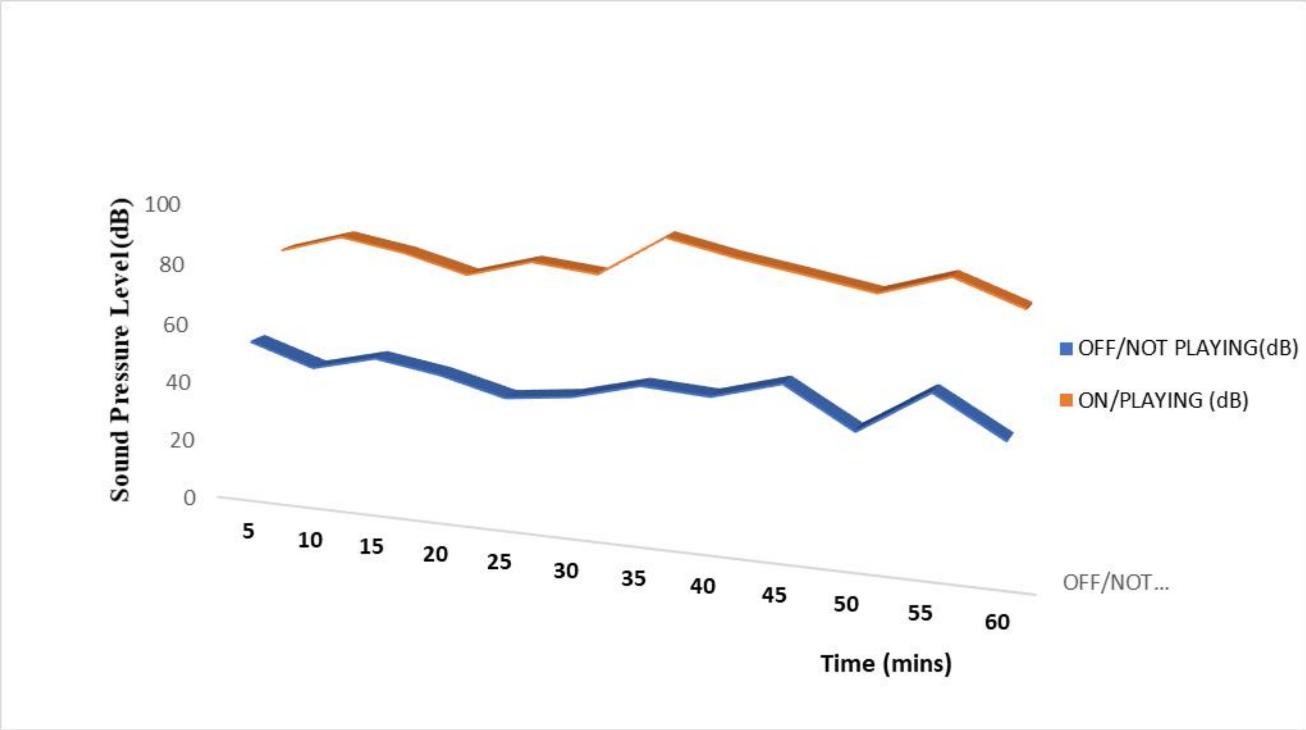

Figure 4.2: Plot of Sound Pressure levels of Infinix Note 8 against Time (mins)

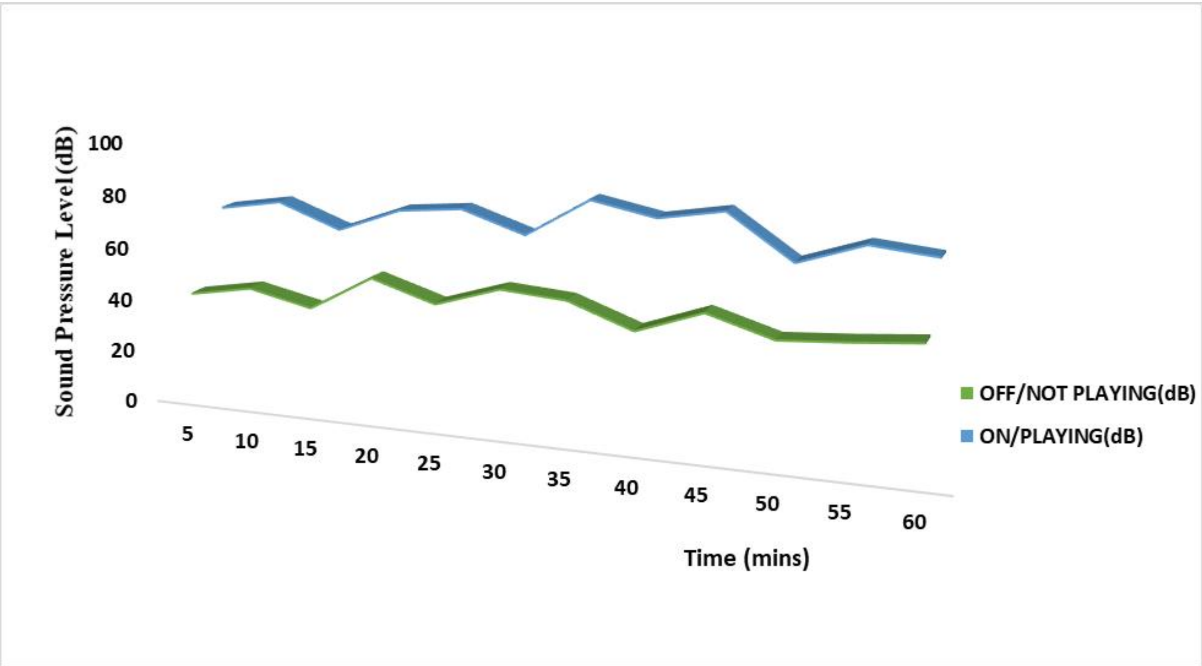

Figure 4.3: Plot of Sound Pressure levels of iPhone X against Time (mins)

CHAPTER FOUR

5.0 DISCUSSION

Global statistics estimated that at the end of 2018, there were 9.3 billion mobile phone subscriptions, today virtually every one has a cell phone[14]. Should these phones constitute a health hazard it would be a global pandemic. Sound is part of our daily life and sounds produced from phones are closest to us[15]. This study was undertaken to measure the frequency spectra of the sound produced by three phones commonly used in Nigeria to determine if sound level exposures from these phones should warrant the inclusion of a hearing protection programme[16]. The results in Table 4.1 showed that the total sound pressure levels for Nokia 1280 was 109.63*dB* and average of 98.83*dB*. This value exceeds the NIOSH[8] allowable noise exposure levels of 85*dB* thus there is a cause for concern in using Nokia 1280 to play music for a long time. Figure 4.1 shows the graph of the sound level pressure over a one hour period. The values were quit high as many of the values while the device was playing music (ON) where around and above 95*dB*. This suggestive a health hazard as the NIOSH[8] Recommended time for 95*dB* is 47 min., 37.2 sec. This is in line with the findings of [11] they observed that mean sound levels (Leq) for instrument groups in their study were 87-95 dB(A), which clearly suggests the need for attention to hearing health.

Table 4.2 shows that the total sound pressure levels for Infinix Note 8 was 96.79dB and average of 85.99dB, this value are slightly higher than the NIOSH[8] allowable noise exposure levels of 95dB for 1 hour but at an average it is in line with this allowable noise exposure levels of 85dB. The use of Infinix Note 8 and many recently made android phone are relatively safe as the sound level considerations were adopted when producing these devices unlike previous phones. From the graph in figure 4.2 it can be deduced that Sound Pressure levels of Infinix Note 8 against time, maintained values of 85dB this according to NIOSH is safe and would not require hearing conservation program.

A similar lower sound level was observed in the Iphone X as seen in table 4.3, an average of 77.25dB and a total of 88.05dB was recorded within an hour period. This is very safe according to the NIOSH Recommendations which stipulates that only over a 4-hour period of continues sound can this value become a potential health risk. Iphones were made by Apple company using the most advanced technology serious concerns for the sound levels were implemented during production. The sound specification has already been calculated and made safe from production unlike other phone and especially older phones in which sound pressure measurement were not noted. Figure 4.3 shows a marginal difference between the environmental sound and the sound from an Iphone X playing music. This suggests that of all the phones studied Iphones are the safest.

It is noteworthy to state that little to no work has been done on the sound pressure levels of phones and this leads to lack of knowledge on the detrimental effect of these phones and also limits informed choices when a person wants to purchase a phone.

5.2. CONCLUSION

The generation of the sound pressure level depends on: The type of the noise source, the nature of the working environment, and the distance from the source to the receiver. It's also depends on the part of the total electrical or mechanical energy which is transformed into sound energy. Phones produce sound that are relatively very close to our ears when they are made, thus caution must be exercised when using these devices to avoid hearing loss. In the 21 century NIHL is increasing with the various sources of noise pollution resulting industrialization and the invention of loud sound producing machines, phones and ear plugs hence, there is a need for education on the impart of these devices on the human health and better design of acoustic materials to produce safe sound. The good news with the latest phones being produced now takes into consideration the sound pressure levels and are current design following the NIOSH Recommendations.

5.3 RECOMMENDATIONS

1. Limited works have been done on the sound pressures levels of phones. A more robust study over a longer period and different times of the day is thereby recommended
2. The generation of the sound pressure level depends on: The type of the noise source, the nature of the working environment, and the distance from the source to the receiver. It's also depends on the part of the total electrical or mechanical energy which is transformed into sound energy. The important factors in protecting hearing are: The length of time exposer to the sound and the distance from the source of the sound. A best rule to avoid noise that are: too close, too long, or too loud.
3. Due to the potential for damage to the auditory system and the obvious benefits of instruction in hearing health, hearing conservation programmes are suggested for older phones but its relatively safer many Android and iPhones.
4. Older phones should be removed from the market if found not to meet the recommended standard.
5. It is crucial that software should be designed to further help control the sound pressure levels from phones.

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